MySQL 5.5 Reference Manual

Including MySQL NDB Cluster 7.2 Reference Guide

Abstract

This is the MySQL™ Reference Manual. It documents MySQL 5.5 through 5.5.60, as well as NDB Cluster releases based on version 7.2 of NDBCLUSTER through 5.5.58-ndb-7.2.32.

MySQL 5.5 features. This manual describes features that are not included in every edition of MySQL 5.5; such features may not be included in the edition of MySQL 5.5 licensed to you. If you have any questions about the features included in your edition of MySQL 5.5, refer to your MySQL 5.5 license agreement or contact your Oracle sales representative.

For notes detailing the changes in each release, see the MySQL 5.5 Release Notes.

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For help with using MySQL, please visit either the MySQL Forums or MySQL Mailing Lists, where you can discuss your issues with other MySQL users.

For additional documentation on MySQL products, including translations of the documentation into other languages, and downloadable versions in variety of formats, including HTML and PDF formats, see the MySQL Documentation Library.

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Table of Contents

Preface and Legal Notices xxiii
1 General Information 1
1.1 About This Manual 2
1.2 Typographical and Syntax Conventions 2
1.3 Overview of the MySQL Database Management System 4
1.3.1 What is MySQL? 4
1.3.2 The Main Features of MySQL 5
1.3.3 History of MySQL 8
1.4 What Is New in MySQL 5.5 9
1.5 MySQL Information Sources 17
1.5.1 MySQL Web Sites 17
1.5.2 MySQL Mailing Lists 17
1.5.3 MySQL Community Support at the MySQL Forums 19
1.5.4 MySQL Community Support on Internet Relay Chat (IRC) 20
1.5.5 MySQL Enterprise 20
1.6 How to Report Bugs or Problems 20
1.7 MySQL Standards Compliance 24
1.7.1 MySQL Extensions to Standard SQL 26
1.7.2 MySQL Differences from Standard SQL 28
1.7.3 How MySQL Deals with Constraints 30
1.8 Credits 33
1.8.1 Contributors to MySQL 33
1.8.2 Documenters and translators 38
1.8.3 Packages that support MySQL 39
1.8.4 Tools that were used to create MySQL 40
1.8.5 Supporters of MySQL 40
2 Installing and Upgrading MySQL 41
2.1 General Installation Guidance 43
2.1.1 Which MySQL Version and Distribution to Install 43
2.1.2 How to Get MySQL 45
2.1.3 Verifying Package Integrity Using MD5 Checksums or GnuPG 45
2.1.4 Installation Layouts 59
2.1.5 Compiler-Specific Build Characteristics 59
2.2 Installing MySQL on Unix/Linux Using Generic Binaries 59
2.3 Installing MySQL on Microsoft Windows 62
2.3.1 MySQL Installation Layout on Microsoft Windows 65
2.3.2 Choosing an Installation Package 65
2.3.3 MySQL Installer for Windows 66
2.3.4 MySQL Notifier 84
2.3.5 Installing MySQL on Microsoft Windows Using an MSI Package 95
2.3.6 MySQL Server Instance Configuration Wizard 101
2.3.7 Installing MySQL on Microsoft Windows Using a `noinstall` ZIP Archive 115
2.3.8 Troubleshooting a Microsoft Windows MySQL Server Installation 123
2.3.9 Windows Postinstallation Procedures 124
2.3.10 Upgrading MySQL on Windows 126
2.4 Installing MySQL on OS X 128
2.4.1 General Notes on Installing MySQL on OS X 128
2.4.2 Installing MySQL on OS X Using Native Packages 129
2.4.3 Installing a MySQL Launch Daemon 133
2.4.4 Installing and Using the MySQL Preference Pane 136
2.5 Installing MySQL on Linux 140
2.5.1 Installing MySQL on Linux Using RPM Packages 141
2.5.2 Installing MySQL on Linux Using Debian Packages 146
2.5.3 Deploying MySQL on Linux with Docker 146
2.5.4 Installing MySQL on Linux Using Native Package Managers 153

2.6 Installing MySQL Using Unbreakable Linux Network (ULN) 156
2.7 Installing MySQL on Solaris 157
2.7.1 Installing MySQL on Solaris Using a Solaris PKG 158
2.8 Installing MySQL on FreeBSD 159
2.9 Installing MySQL from Source 159
2.9.1 MySQL Layout for Source Installation 161
2.9.2 Installing MySQL Using a Standard Source Distribution 161
2.9.3 Installing MySQL Using a Development Source Tree 166
2.9.4 MySQL Source-Configuration Options 167
2.9.5 Dealing with Problems Compiling MySQL 179
2.9.6 MySQL Configuration and Third-Party Tools 181
2.10 Postinstallation Setup and Testing 181
2.10.1 Initializing the Data Directory 182
2.10.2 Starting the Server 185
2.10.3 Testing the Server 188
2.10.4 Securing the Initial MySQL Accounts 190
2.10.5 Starting and Stopping MySQL Automatically 194
2.11 Upgrading or Downgrading MySQL 195
2.11.1 Upgrading MySQL 195
2.11.2 Downgrading MySQL 205
2.11.3 Rebuilding or Repairing Tables or Indexes 210
2.11.4 Copying MySQL Databases to Another Machine 211
2.12 Perl Installation Notes 212
2.12.1 Installing Perl on Unix 212
2.12.2 Installing ActiveState Perl on Windows 213
2.12.3 Problems Using the Perl DBI/DBD Interface 214
3 Tutorial 217
3.1 Connecting to and Disconnecting from the Server 217
3.2 Entering Queries 218
3.3 Creating and Using a Database 221
3.3.1 Creating and Selecting a Database 222
3.3.2 Creating a Table 223
3.3.3 Loading Data into a Table 224
3.3.4 Retrieving Information from a Table 225
3.4 Getting Information About Databases and Tables 238
3.5 Using mysql in Batch Mode 239
3.6 Examples of Common Queries 241
3.6.1 The Maximum Value for a Column 241
3.6.2 The Row Holding the Maximum of a Certain Column 241
3.6.3 Maximum of Column per Group 242
3.6.4 The Rows Holding the Group-wise Maximum of a Certain Column 242
3.6.5 Using User-Defined Variables 243
3.6.6 Using Foreign Keys 243
3.6.7 Searching on Two Keys 245
3.6.8 Calculating Visits Per Day 245
3.6.9 Using AUTO_INCREMENT 246
3.7 Using MySQL with Apache 248
4 MySQL Programs 249
4.1 Overview of MySQL Programs 250
4.2 Using MySQL Programs 254
4.2.1 Invoking MySQL Programs 254
4.2.2 Connecting to the MySQL Server 255
4.2.3 Specifying Program Options 258
4.2.4 Using Options on the Command Line 259
4.2.5 Program Option Modifiers 261
4.2.6 Using Option Files 261
4.2.7 Command-Line Options that Affect Option-File Handling 266
4.2.8 Using Options to Set Program Variables 267

4.2.9 Option Defaults, Options Expecting Values, and the = Sign 268
4.2.10 Setting Environment Variables 271
4.3 MySQL Server and Server-Startup Programs 272
4.3.1 mysqld — The MySQL Server 272
4.3.2 mysqld_safe — MySQL Server Startup Script 273
4.3.3 mysql.server — MySQL Server Startup Script 278
4.3.4 mysqld_multi — Manage Multiple MySQL Servers 280
4.4 MySQL Installation-Related Programs 283
4.4.1 comp_err — Compile MySQL Error Message File 283
4.4.2 mysqlbug — Generate Bug Report 284
4.4.3 mysql_install_db — Initialize MySQL Data Directory 285
4.4.4 mysql_plugin — Configure MySQL Server Plugins 287
4.4.5 mysql_secure_installation — Improve MySQL Installation Security 289
4.4.6 mysql_tzinfo_to_sql — Load the Time Zone Tables 289
4.4.7 mysql_upgrade — Check and Upgrade MySQL Tables 290
4.5 MySQL Client Programs 295
4.5.1 mysql — The MySQL Command-Line Tool 295
4.5.2 mysqladmin — Client for Administering a MySQL Server 317
4.5.3 mysqlcheck — A Table Maintenance Program 324
4.5.4 mysqldump — A Database Backup Program 331
4.5.5 mysqlimport — A Data Import Program 350
4.5.6 mysqlshow — Display Database, Table, and Column Information 355
4.5.7 mysqlslap — Load Emulation Client 359
4.6 MySQL Administrative and Utility Programs 367
4.6.1 innochecksum — Offline InnoDB File Checksum Utility 367
4.6.2 myisam_ftdump — Display Full-Text Index information 367
4.6.3 myisamchk — MyISAM Table-Maintenance Utility 369
4.6.4 myisamlog — Display MyISAM Log File Contents 385
4.6.5 myisampack — Generate Compressed, Read-Only MyISAM Tables 386
4.6.6 mysqlaccess — Client for Checking Access Privileges 392
4.6.7 mysqlbinlog — Utility for Processing Binary Log Files 394
4.6.8 mysqldumpslow — Summarize Slow Query Log Files 409
4.6.9 mysqlhotcopy — A Database Backup Program 411
4.6.10 mysql_convert_table_format — Convert Tables to Use a Given Storage Engine 414
4.6.11 mysql_find_rows — Extract SQL Statements from Files 415
4.6.12 mysql_fix_extensions — Normalize Table File Name Extensions 415
4.6.13 mysql_setpermission — Interactively Set Permissions in Grant Tables 416
4.6.14 mysql_waitpid — Kill Process and Wait for Its Termination 416
4.6.15 mysql_zap — Kill Processes That Match a Pattern 417
4.7 MySQL Program Development Utilities 417
4.7.1 msql2mysql — Convert mSQL Programs for Use with MySQL 418
4.7.2 mysql_config — Display Options for Compiling Clients 418
4.7.3 my_print_defaults — Display Options from Option Files 419
4.7.4 resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols 420
4.8 Miscellaneous Programs 421
4.8.1 perror — Explain Error Codes 421
4.8.2 replace — A String-Replacement Utility 422
4.8.3 resolveip — Resolve Host name to IP Address or Vice Versa 422
4.9 MySQL Program Environment Variables 423
5 MySQL Server Administration 425
5.1 The MySQL Server 425
5.1.1 Configuring the Server 426
5.1.2 Server Configuration Defaults 428
5.1.3 Server Option and Variable Reference 428
5.1.4 Server Command Options 456
5.1.5 Server System Variables 487
5.1.6 Using System Variables 584

5.1.7 Server Status Variables 597
5.1.8 Server SQL Modes 622
5.1.9 IPv6 Support 630
5.1.10 Server-Side Help 634
5.1.11 Server Response to Signals 635
5.1.12 The Server Shutdown Process 635
5.2 The MySQL Data Directory 637
5.3 The mysql System Database 637
5.4 MySQL Server Logs 639
5.4.1 Selecting General Query and Slow Query Log Output Destinations 640
5.4.2 The Error Log 642
5.4.3 The General Query Log 644
5.4.4 The Binary Log 645
5.4.5 The Slow Query Log 657
5.4.6 The DDL Log 659
5.4.7 Server Log Maintenance 659
5.5 MySQL Server Plugins 661
5.5.1 Installing and Uninstalling Plugins 661
5.5.2 Obtaining Server Plugin Information 664
5.5.3 MySQL Enterprise Thread Pool 665
5.6 Running Multiple MySQL Instances on One Machine 671
5.6.1 Setting Up Multiple Data Directories 673
5.6.2 Running Multiple MySQL Instances on Windows 674
5.6.3 Running Multiple MySQL Instances on Unix 677
5.6.4 Using Client Programs in a Multiple-Server Environment 678
5.7 Tracing mysqld Using DTrace 678
5.7.1 mysqld DTrace Probe Reference 679
6 Security 697
6.1 General Security Issues 698
6.1.1 Security Guidelines 698
6.1.2 Keeping Passwords Secure 699
6.1.3 Making MySQL Secure Against Attackers 707
6.1.4 Security-Related mysqld Options and Variables 709
6.1.5 How to Run MySQL as a Normal User 709
6.1.6 Security Issues with LOAD DATA LOCAL 710
6.1.7 Client Programming Security Guidelines 712
6.2 The MySQL Access Privilege System 713
6.2.1 Privileges Provided by MySQL 714
6.2.2 Grant Tables 718
6.2.3 Specifying Account Names 724
6.2.4 Access Control, Stage 1: Connection Verification 726
6.2.5 Access Control, Stage 2: Request Verification 728
6.2.6 When Privilege Changes Take Effect 730
6.2.7 Troubleshooting Problems Connecting to MySQL 731
6.3 MySQL User Account Management 736
6.3.1 User Names and Passwords 736
6.3.2 Adding User Accounts 738
6.3.3 Removing User Accounts 739
6.3.4 Setting Account Resource Limits 739
6.3.5 Assigning Account Passwords 741
6.3.6 Pluggable Authentication 743
6.3.7 Proxy Users 745
6.3.8 SQL-Based MySQL Account Activity Auditing 750
6.4 Using Encrypted Connections 751
6.4.1 Configuring MySQL to Use Encrypted Connections 752
6.4.2 Command Options for Encrypted Connections 754
6.4.3 Creating SSL Certificates and Keys Using openssl 757
6.4.4 OpenSSL Versus yaSSL 762

6.4.5 Building MySQL with Support for Encrypted Connections 762
6.4.6 Encrypted Connection Protocols and Ciphers 763
6.4.7 Connecting to MySQL Remotely from Windows with SSH 765
6.5 Security Plugins 765
6.5.1 Authentication Plugins 765
6.5.2 MySQL Enterprise Audit 784
7 Backup and Recovery 805
7.1 Backup and Recovery Types 806
7.2 Database Backup Methods 809
7.3 Example Backup and Recovery Strategy 811
7.3.1 Establishing a Backup Policy 811
7.3.2 Using Backups for Recovery 813
7.3.3 Backup Strategy Summary 814
7.4 Using mysqldump for Backups 814
7.4.1 Dumping Data in SQL Format with mysqldump 814
7.4.2 Reloading SQL-Format Backups 815
7.4.3 Dumping Data in Delimited-Text Format with mysqldump 816
7.4.4 Reloading Delimited-Text Format Backups 817
7.4.5 mysqldump Tips 818
7.5 Point-in-Time (Incremental) Recovery Using the Binary Log 820
7.5.1 Point-in-Time Recovery Using Event Times 821
7.5.2 Point-in-Time Recovery Using Event Positions 822
7.6 MyISAM Table Maintenance and Crash Recovery 822
7.6.1 Using myisamchk for Crash Recovery 823
7.6.2 How to Check MyISAM Tables for Errors 824
7.6.3 How to Repair MyISAM Tables 824
7.6.4 MyISAM Table Optimization 827
7.6.5 Setting Up a MyISAM Table Maintenance Schedule 827
8 Optimization 829
8.1 Optimization Overview 830
8.2 Optimizing SQL Statements 832
8.2.1 Optimizing SELECT Statements 832
8.2.2 Subquery Optimization 866
8.2.3 Optimizing INFORMATION_SCHEMA Queries 870
8.2.4 Optimizing Data Change Statements 875
8.2.5 Optimizing Database Privileges 876
8.2.6 Other Optimization Tips 876
8.3 Optimization and Indexes 877
8.3.1 How MySQL Uses Indexes 877
8.3.2 Primary Key Optimization 878
8.3.3 Foreign Key Optimization 879
8.3.4 Column Indexes 879
8.3.5 Multiple-Column Indexes 880
8.3.6 Verifying Index Usage 881
8.3.7 InnoDB and MyISAM Index Statistics Collection 882
8.3.8 Comparison of B-Tree and Hash Indexes 883
8.4 Optimizing Database Structure 884
8.4.1 Optimizing Data Size 885
8.4.2 Optimizing MySQL Data Types 886
8.4.3 Optimizing for Many Tables 888
8.4.4 Internal Temporary Table Use in MySQL 890
8.5 Optimizing for InnoDB Tables 891
8.5.1 Optimizing Storage Layout for InnoDB Tables 891
8.5.2 Optimizing InnoDB Transaction Management 892
8.5.3 Optimizing InnoDB Redo Logging 893
8.5.4 Bulk Data Loading for InnoDB Tables 893
8.5.5 Optimizing InnoDB Queries 894
8.5.6 Optimizing InnoDB DDL Operations 894

8.5.7 Optimizing InnoDB Disk I/O 895
8.5.8 Optimizing InnoDB Configuration Variables 897
8.5.9 Optimizing InnoDB for Systems with Many Tables 898
8.6 Optimizing for MyISAM Tables 898
8.6.1 Optimizing MyISAM Queries 898
8.6.2 Bulk Data Loading for MyISAM Tables 900
8.6.3 Optimizing REPAIR TABLE Statements 901
8.7 Optimizing for MEMORY Tables 902
8.8 Understanding the Query Execution Plan 903
8.8.1 Optimizing Queries with EXPLAIN 903
8.8.2 EXPLAIN Output Format 903
8.8.3 Extended EXPLAIN Output Format 914
8.8.4 Estimating Query Performance 916
8.9 Controlling the Query Optimizer 916
8.9.1 Controlling Query Plan Evaluation 916
8.9.2 Switchable Optimizations 917
8.9.3 Index Hints 918
8.10 Buffering and Caching 921
8.10.1 InnoDB Buffer Pool Optimization 921
8.10.2 The MyISAM Key Cache 921
8.10.3 The MySQL Query Cache 925
8.11 Optimizing Locking Operations 932
8.11.1 Internal Locking Methods 932
8.11.2 Table Locking Issues 934
8.11.3 Concurrent Inserts 936
8.11.4 Metadata Locking 936
8.11.5 External Locking 937
8.12 Optimizing the MySQL Server 938
8.12.1 System Factors 938
8.12.2 Optimizing Disk I/O 939
8.12.3 Using Symbolic Links 940
8.12.4 Optimizing Memory Use 943
8.12.5 Optimizing Network Use 947
8.13 Measuring Performance (Benchmarking) 949
8.13.1 Measuring the Speed of Expressions and Functions 949
8.13.2 The MySQL Benchmark Suite 949
8.13.3 Using Your Own Benchmarks 950
8.13.4 Measuring Performance with performance_schema 951
8.14 Examining Thread Information 951
8.14.1 Thread Command Values 951
8.14.2 General Thread States 953
8.14.3 Delayed-Insert Thread States 959
8.14.4 Query Cache Thread States 960
8.14.5 Replication Master Thread States 961
8.14.6 Replication Slave I/O Thread States 961
8.14.7 Replication Slave SQL Thread States 962
8.14.8 Replication Slave Connection Thread States 963
8.14.9 NDB Cluster Thread States 963
8.14.10 Event Scheduler Thread States 964
9 Language Structure 965
9.1 Literal Values 965
9.1.1 String Literals 965
9.1.2 Numeric Literals 968
9.1.3 Date and Time Literals 968
9.1.4 Hexadecimal Literals 970
9.1.5 Bit-Value Literals 972
9.1.6 Boolean Literals 973
9.1.7 NULL Values 974

9.2 Schema Object Names 974
9.2.1 Identifier Qualifiers 976
9.2.2 Identifier Case Sensitivity 978
9.2.3 Mapping of Identifiers to File Names 980
9.2.4 Function Name Parsing and Resolution 982
9.3 Keywords and Reserved Words 986
9.4 User-Defined Variables 1006
9.5 Expression Syntax 1009
9.6 Comment Syntax 1011
10 Globalization 1013
10.1 Character Set Support 1013
10.1.1 Character Sets and Collations in General 1014
10.1.2 Character Sets and Collations in MySQL 1015
10.1.3 Specifying Character Sets and Collations 1019
10.1.4 Connection Character Sets and Collations 1029
10.1.5 Configuring Application Character Set and Collation 1031
10.1.6 Error Message Character Set 1033
10.1.7 Column Character Set Conversion 1034
10.1.8 Collation Issues 1035
10.1.9 Unicode Support 1043
10.1.10 Supported Character Sets and Collations 1049
10.2 Setting the Error Message Language 1061
10.3 Adding a Character Set 1062
10.3.1 Character Definition Arrays 1064
10.3.2 String Collating Support for Complex Character Sets 1065
10.3.3 Multi-Byte Character Support for Complex Character Sets 1065
10.4 Adding a Collation to a Character Set 1066
10.4.1 Collation Implementation Types 1067
10.4.2 Choosing a Collation ID 1068
10.4.3 Adding a Simple Collation to an 8-Bit Character Set 1069
10.4.4 Adding a UCA Collation to a Unicode Character Set 1070
10.5 Character Set Configuration 1073
10.6 MySQL Server Time Zone Support 1074
10.6.1 Staying Current with Time Zone Changes 1077
10.6.2 Time Zone Leap Second Support 1078
10.7 MySQL Server Locale Support 1079
11 Data Types 1083
11.1 Data Type Overview 1084
11.1.1 Numeric Type Overview 1084
11.1.2 Date and Time Type Overview 1087
11.1.3 String Type Overview 1088
11.2 Numeric Types 1092
11.2.1 Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT 1092
11.2.2 Fixed-Point Types (Exact Value) - DECIMAL, NUMERIC 1092
11.2.3 Floating-Point Types (Approximate Value) - FLOAT, DOUBLE 1093
11.2.4 Bit-Value Type - BIT 1093
11.2.5 Numeric Type Attributes 1094
11.2.6 Out-of-Range and Overflow Handling 1095
11.3 Date and Time Types 1096
11.3.1 The DATE, DATETIME, and TIMESTAMP Types 1097
11.3.2 The TIME Type 1099
11.3.3 The YEAR Type 1099
11.3.4 YEAR(2) Limitations and Migrating to YEAR(4) 1100
11.3.5 Automatic Initialization and Updating for TIMESTAMP 1101
11.3.6 Fractional Seconds in Time Values 1104
11.3.7 Conversion Between Date and Time Types 1105
11.3.8 Two-Digit Years in Dates 1105

11.4 String Types 1106
11.4.1 The CHAR and VARCHAR Types 1106
11.4.2 The BINARY and VARBINARY Types 1108
11.4.3 The BLOB and TEXT Types 1109
11.4.4 The ENUM Type 1110
11.4.5 The SET Type 1113
11.5 Spatial Data Types 1115
11.5.1 Spatial Data Types 1117
11.5.2 The OpenGIS Geometry Model 1118
11.5.3 Supported Spatial Data Formats 1123
11.5.4 Creating Spatial Columns 1126
11.5.5 Populating Spatial Columns 1126
11.5.6 Fetching Spatial Data 1127
11.5.7 Optimizing Spatial Analysis 1128
11.5.8 Creating Spatial Indexes 1128
11.5.9 Using Spatial Indexes 1129
11.6 Data Type Default Values 1131
11.7 Data Type Storage Requirements 1132
11.8 Choosing the Right Type for a Column 1136
11.9 Using Data Types from Other Database Engines 1136
12 Functions and Operators 1139
12.1 Function and Operator Reference 1140
12.2 Type Conversion in Expression Evaluation 1149
12.3 Operators 1151
12.3.1 Operator Precedence 1152
12.3.2 Comparison Functions and Operators 1153
12.3.3 Logical Operators 1159
12.3.4 Assignment Operators 1160
12.4 Control Flow Functions 1162
12.5 String Functions 1164
12.5.1 String Comparison Functions 1175
12.5.2 Regular Expressions 1179
12.5.3 Character Set and Collation of Function Results 1184
12.6 Numeric Functions and Operators 1185
12.6.1 Arithmetic Operators 1186
12.6.2 Mathematical Functions 1188
12.7 Date and Time Functions 1197
12.8 What Calendar Is Used By MySQL? 1218
12.9 Full-Text Search Functions 1219
12.9.1 Natural Language Full-Text Searches 1220
12.9.2 Boolean Full-Text Searches 1223
12.9.3 Full-Text Searches with Query Expansion 1226
12.9.4 Full-Text Stopwords 1226
12.9.5 Full-Text Restrictions 1229
12.9.6 Fine-Tuning MySQL Full-Text Search 1230
12.9.7 Adding a Collation for Full-Text Indexing 1232
12.10 Cast Functions and Operators 1233
12.11 XML Functions 1239
12.12 Bit Functions and Operators 1250
12.13 Encryption and Compression Functions 1252
12.14 Information Functions 1258
12.15 Spatial Analysis Functions 1267
12.15.1 Spatial Function Reference 1268
12.15.2 Argument Handling by Spatial Functions 1269
12.15.3 Functions That Create Geometry Values from WKT Values 1270
12.15.4 Functions That Create Geometry Values from WKB Values 1270
12.15.5 MySQL-Specific Functions That Create Geometry Values 1271
12.15.6 Geometry Format Conversion Functions 1272

12.15.7 Geometry Property Functions 1272
12.15.8 Spatial Operator Functions 1278
12.15.9 Functions That Test Spatial Relations Between Geometry Objects 1278
12.16 Aggregate (GROUP BY) Functions 1280
12.16.1 Aggregate (GROUP BY) Function Descriptions 1280
12.16.2 GROUP BY Modifiers 1284
12.16.3 MySQL Handling of GROUP BY 1287
12.17 Miscellaneous Functions 1289
12.18 Precision Math 1294
12.18.1 Types of Numeric Values 1295
12.18.2 DECIMAL Data Type Characteristics 1295
12.18.3 Expression Handling 1296
12.18.4 Rounding Behavior 1297
12.18.5 Precision Math Examples 1298
13 SQL Statement Syntax 1303
13.1 Data Definition Statements 1304
13.1.1 ALTER DATABASE Syntax 1304
13.1.2 ALTER EVENT Syntax 1305
13.1.3 ALTER FUNCTION Syntax 1307
13.1.4 ALTER LOGFILE GROUP Syntax 1307
13.1.5 ALTER PROCEDURE Syntax 1308
13.1.6 ALTER SERVER Syntax 1309
13.1.7 ALTER TABLE Syntax 1309
13.1.8 ALTER TABLESPACE Syntax 1330
13.1.9 ALTER VIEW Syntax 1331
13.1.10 CREATE DATABASE Syntax 1331
13.1.11 CREATE EVENT Syntax 1332
13.1.12 CREATE FUNCTION Syntax 1336
13.1.13 CREATE INDEX Syntax 1337
13.1.14 CREATE LOGFILE GROUP Syntax 1341
13.1.15 CREATE PROCEDURE and CREATE FUNCTION Syntax 1342
13.1.16 CREATE SERVER Syntax 1348
13.1.17 CREATE TABLE Syntax 1349
13.1.18 CREATE TABLESPACE Syntax 1379
13.1.19 CREATE TRIGGER Syntax 1381
13.1.20 CREATE VIEW Syntax 1383
13.1.21 DROP DATABASE Syntax 1387
13.1.22 DROP EVENT Syntax 1388
13.1.23 DROP FUNCTION Syntax 1388
13.1.24 DROP INDEX Syntax 1388
13.1.25 DROP LOGFILE GROUP Syntax 1389
13.1.26 DROP PROCEDURE and DROP FUNCTION Syntax 1389
13.1.27 DROP SERVER Syntax 1390
13.1.28 DROP TABLE Syntax 1390
13.1.29 DROP TABLESPACE Syntax 1391
13.1.30 DROP TRIGGER Syntax 1391
13.1.31 DROP VIEW Syntax 1391
13.1.32 RENAME TABLE Syntax 1392
13.1.33 TRUNCATE TABLE Syntax 1393
13.2 Data Manipulation Statements 1394
13.2.1 CALL Syntax 1394
13.2.2 DELETE Syntax 1395
13.2.3 DO Syntax 1398
13.2.4 HANDLER Syntax 1399
13.2.5 INSERT Syntax 1400
13.2.6 LOAD DATA INFILE Syntax 1409
13.2.7 LOAD XML Syntax 1418
13.2.8 REPLACE Syntax 1426

13.2.9 SELECT Syntax 1428
13.2.10 Subquery Syntax 1443
13.2.11 UPDATE Syntax 1455
13.3 Transactional and Locking Statements 1458
13.3.1 START TRANSACTION, COMMIT, and ROLLBACK Syntax 1458
13.3.2 Statements That Cannot Be Rolled Back 1460
13.3.3 Statements That Cause an Implicit Commit 1460
13.3.4 SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Syntax 1461
13.3.5 LOCK TABLES and UNLOCK TABLES Syntax 1462
13.3.6 SET TRANSACTION Syntax 1468
13.3.7 XA Transactions 1469
13.4 Replication Statements 1472
13.4.1 SQL Statements for Controlling Master Servers 1472
13.4.2 SQL Statements for Controlling Slave Servers 1475
13.5 Prepared SQL Statement Syntax 1481
13.5.1 PREPARE Syntax 1484
13.5.2 EXECUTE Syntax 1485
13.5.3 DEALLOCATE PREPARE Syntax 1485
13.5.4 Automatic Prepared Statement Repreparation 1486
13.6 Compound-Statement Syntax 1486
13.6.1 BEGIN ... END Compound-Statement Syntax 1486
13.6.2 Statement Label Syntax 1487
13.6.3 DECLARE Syntax 1487
13.6.4 Variables in Stored Programs 1488
13.6.5 Flow Control Statements 1489
13.6.6 Cursors 1494
13.6.7 Condition Handling 1495
13.7 Database Administration Statements 1510
13.7.1 Account Management Statements 1510
13.7.2 Table Maintenance Statements 1527
13.7.3 Plugin and User-Defined Function Statements 1536
13.7.4 SET Syntax 1539
13.7.5 SHOW Syntax 1543
13.7.6 Other Administrative Statements 1585
13.8 Utility Statements 1593
13.8.1 DESCRIBE Syntax 1593
13.8.2 EXPLAIN Syntax 1593
13.8.3 HELP Syntax 1594
13.8.4 USE Syntax 1596
14 The InnoDB Storage Engine 1599
14.1 Introduction to InnoDB 1600
14.1.1 Benefits of Using InnoDB Tables 1602
14.1.2 Best Practices for InnoDB Tables 1603
14.1.3 Checking InnoDB Availability 1603
14.1.4 Upward and Downward Compatibility 1604
14.1.5 Testing and Benchmarking with InnoDB 1604
14.1.6 Turning Off InnoDB 1605
14.1.7 Third-Party Software Contributions 1605
14.2 Installing the InnoDB Storage Engine 1607
14.3 Upgrading the InnoDB Storage Engine 1608
14.4 Downgrading the InnoDB Storage Engine 1608
14.5 InnoDB and the ACID Model 1608
14.6 InnoDB Multi-Versioning 1609
14.7 InnoDB Architecture 1610
14.7.1 Buffer Pool 1610
14.7.2 Change Buffer 1611
14.7.3 Adaptive Hash Index 1612

14.7.4 Redo Log Buffer 1613
14.7.5 System Tablespace 1613
14.7.6 InnoDB Data Dictionary 1613
14.7.7 Doublewrite Buffer 1614
14.7.8 Undo Logs 1614
14.7.9 File-Per-Table Tablespaces 1614
14.7.10 Redo Log 1614
14.8 InnoDB Locking and Transaction Model 1615
14.8.1 InnoDB Locking 1615
14.8.2 InnoDB Transaction Model 1619
14.8.3 Locks Set by Different SQL Statements in InnoDB 1627
14.8.4 Phantom Rows 1630
14.8.5 Deadlocks in InnoDB 1630
14.9 InnoDB Configuration 1633
14.9.1 InnoDB Startup Configuration 1634
14.9.2 InnoDB Buffer Pool Configuration 1638
14.9.3 Configuring the Memory Allocator for InnoDB 1646
14.9.4 Configuring InnoDB Change Buffering 1647
14.9.5 Configuring Thread Concurrency for InnoDB 1648
14.9.6 Configuring the Number of Background InnoDB I/O Threads 1649
14.9.7 Using Asynchronous I/O on Linux 1650
14.9.8 Configuring the InnoDB Master Thread I/O Rate 1651
14.9.9 Configuring Spin Lock Polling 1651
14.9.10 Configuring InnoDB Purge Scheduling 1651
14.9.11 Configuring Optimizer Statistics for InnoDB 1652
14.10 InnoDB Tablespaces 1653
14.10.1 Resizing the InnoDB System Tablespace 1653
14.10.2 Changing the Number or Size of InnoDB Redo Log Files 1654
14.10.3 Using Raw Disk Partitions for the System Tablespace 1654
14.10.4 InnoDB File-Per-Table Tablespaces 1656
14.11 InnoDB Tables and Indexes 1659
14.11.1 InnoDB Tables 1660
14.11.2 InnoDB Indexes 1680
14.12 InnoDB Table Compression 1681
14.12.1 Overview of Table Compression 1681
14.12.2 Enabling Compression for a Table 1681
14.12.3 Tuning Compression for InnoDB Tables 1682
14.12.4 Monitoring InnoDB Table Compression at Runtime 1685
14.12.5 How Compression Works for InnoDB Tables 1686
14.12.6 SQL Compression Syntax Warnings and Errors 1689
14.13 InnoDB File-Format Management 1691
14.13.1 Enabling File Formats 1692
14.13.2 Verifying File Format Compatibility 1692
14.13.3 Identifying the File Format in Use 1695
14.13.4 Downgrading the File Format 1695
14.14 InnoDB Row Storage and Row Formats 1696
14.14.1 Overview of InnoDB Row Storage 1696
14.14.2 Specifying the Row Format for a Table 1696
14.14.3 DYNAMIC and COMPRESSED Row Formats 1696
14.14.4 COMPACT and REDUNDANT Row Formats 1697
14.15 InnoDB Disk I/O and File Space Management 1697
14.15.1 InnoDB Disk I/O 1698
14.15.2 File Space Management 1698
14.15.3 InnoDB Checkpoints 1700
14.15.4 Defragmenting a Table 1700
14.15.5 Reclaiming Disk Space with TRUNCATE TABLE 1701
14.16 InnoDB Fast Index Creation 1701
14.16.1 Overview of Fast Index Creation 1701

14.16.2 Examples of Fast Index Creation 1701
14.16.3 Implementation Details of Fast Index Creation 1702
14.16.4 Concurrency Considerations for Fast Index Creation 1702
14.16.5 How Crash Recovery Works with Fast Index Creation 1703
14.16.6 Limitations of Fast Index Creation 1703
14.17 InnoDB Startup Options and System Variables 1704
14.18 InnoDB INFORMATION_SCHEMA Tables 1742
14.18.1 InnoDB INFORMATION_SCHEMA Tables about Compression 1742
14.18.2 InnoDB INFORMATION_SCHEMA Transaction and Locking Information 1743
14.18.3 InnoDB INFORMATION_SCHEMA Buffer Pool Tables 1749
14.19 InnoDB Integration with MySQL Performance Schema 1753
14.19.1 Monitoring InnoDB Mutex Waits Using Performance Schema 1755
14.20 InnoDB Monitors 1757
14.20.1 InnoDB Monitor Types 1757
14.20.2 Enabling InnoDB Monitors 1758
14.20.3 InnoDB Standard Monitor and Lock Monitor Output 1760
14.20.4 InnoDB Tablespace Monitor Output 1765
14.20.5 InnoDB Table Monitor Output 1767
14.21 InnoDB Backup and Recovery 1770
14.21.1 InnoDB Backup 1770
14.21.2 InnoDB Recovery 1771
14.22 InnoDB and MySQL Replication 1773
14.23 InnoDB Troubleshooting 1775
14.23.1 Troubleshooting InnoDB I/O Problems 1775
14.23.2 Forcing InnoDB Recovery 1776
14.23.3 Troubleshooting InnoDB Data Dictionary Operations 1777
14.23.4 InnoDB Error Handling 1779
15 Alternative Storage Engines 1781
15.1 Setting the Storage Engine 1784
15.2 Overview of MySQL Storage Engine Architecture 1785
15.2.1 Pluggable Storage Engine Architecture 1786
15.2.2 The Common Database Server Layer 1786
15.3 The MyISAM Storage Engine 1787
15.3.1 MyISAM Startup Options 1789
15.3.2 Space Needed for Keys 1791
15.3.3 MyISAM Table Storage Formats 1791
15.3.4 MyISAM Table Problems 1794
15.4 The MEMORY Storage Engine 1795
15.5 The CSV Storage Engine 1799
15.5.1 Repairing and Checking CSV Tables 1800
15.5.2 CSV Limitations 1801
15.6 The ARCHIVE Storage Engine 1801
15.7 The BLACKHOLE Storage Engine 1802
15.8 The MERGE Storage Engine 1805
15.8.1 MERGE Table Advantages and Disadvantages 1807
15.8.2 MERGE Table Problems 1808
15.9 The FEDERATED Storage Engine 1810
15.9.1 FEDERATED Storage Engine Overview 1810
15.9.2 How to Create FEDERATED Tables 1811
15.9.3 FEDERATED Storage Engine Notes and Tips 1813
15.9.4 FEDERATED Storage Engine Resources 1815
15.10 The EXAMPLE Storage Engine 1815
15.11 Other Storage Engines 1815
16 High Availability and Scalability 1817
16.1 Using ZFS Replication 1819
16.1.1 Using ZFS for File System Replication 1820
16.1.2 Configuring MySQL for ZFS Replication 1821
16.1.3 Handling MySQL Recovery with ZFS 1822

16.2 Using MySQL with memcached 1822
16.2.1 Installing memcached 1823
16.2.2 Using memcached 1825
16.2.3 Developing a memcached Application 1843
16.2.4 Getting memcached Statistics 1868
16.2.5 memcached FAQ 1876
17 Replication 1881
17.1 Replication Configuration 1882
17.1.1 How to Set Up Replication 1883
17.1.2 Replication Formats 1892
17.1.3 Replication and Binary Logging Options and Variables 1899
17.1.4 Common Replication Administration Tasks 1948
17.2 Replication Implementation 1951
17.2.1 Replication Implementation Details 1951
17.2.2 Replication Relay and Status Logs 1953
17.2.3 How Servers Evaluate Replication Filtering Rules 1955
17.3 Replication Solutions 1962
17.3.1 Using Replication for Backups 1963
17.3.2 Using Replication with Different Master and Slave Storage Engines 1966
17.3.3 Using Replication for Scale-Out 1967
17.3.4 Replicating Different Databases to Different Slaves 1968
17.3.5 Improving Replication Performance 1970
17.3.6 Switching Masters During Failover 1971
17.3.7 Setting Up Replication to Use Encrypted Connections 1973
17.3.8 Semisynchronous Replication 1974
17.4 Replication Notes and Tips 1979
17.4.1 Replication Features and Issues 1979
17.4.2 Replication Compatibility Between MySQL Versions 2004
17.4.3 Upgrading a Replication Setup 2005
17.4.4 Troubleshooting Replication 2006
17.4.5 How to Report Replication Bugs or Problems 2007
18 MySQL NDB Cluster 7.2 2009
18.1 NDB Cluster Overview 2012
18.1.1 NDB Cluster Core Concepts 2014
18.1.2 NDB Cluster Nodes, Node Groups, Replicas, and Partitions 2016
18.1.3 NDB Cluster Hardware, Software, and Networking Requirements 2019
18.1.4 What is New in MySQL NDB Cluster 7.2 2020
18.1.5 MySQL Server Using InnoDB Compared with NDB Cluster 2023
18.1.6 Known Limitations of NDB Cluster 2026
18.2 NDB Cluster Installation 2038
18.2.1 Installing NDB Cluster on Linux 2040
18.2.2 Installing NDB Cluster on Windows 2046
18.2.3 Initial Configuration of NDB Cluster 2055
18.2.4 Initial Startup of NDB Cluster 2057
18.2.5 NDB Cluster Example with Tables and Data 2058
18.2.6 Safe Shutdown and Restart of NDB Cluster 2061
18.2.7 Upgrading and Downgrading NDB Cluster 2062
18.3 Configuration of NDB Cluster 2064
18.3.1 Quick Test Setup of NDB Cluster 2064
18.3.2 Overview of NDB Cluster Configuration Parameters, Options, and Variables 2066
18.3.3 NDB Cluster Configuration Files 2108
18.3.4 Using High-Speed Interconnects with NDB Cluster 2232
18.4 NDB Cluster Programs 2232
18.4.1 ndbd — The NDB Cluster Data Node Daemon 2232
18.4.2 ndbinfo_select_all — Select From ndbinfo Tables 2239
18.4.3 ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded) 2240
18.4.4 ndb_mgmd — The NDB Cluster Management Server Daemon 2241
18.4.5 ndb_mgm — The NDB Cluster Management Client 2249

18.4.6 ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables ... 2250
18.4.7 ndb_config — Extract NDB Cluster Configuration Information ... 2253
18.4.8 ndb_cpcd — Automate Testing for NDB Development ... 2260
18.4.9 ndb_delete_all — Delete All Rows from an NDB Table ... 2260
18.4.10 ndb_desc — Describe NDB Tables ... 2261
18.4.11 ndb_drop_index — Drop Index from an NDB Table ... 2265
18.4.12 ndb_drop_table — Drop an NDB Table ... 2266
18.4.13 ndb_error_reporter — NDB Error-Reporting Utility ... 2267
18.4.14 ndb_index_stat — NDB Index Statistics Utility ... 2268
18.4.15 ndb_move_data — NDB Data Copy Utility ... 2273
18.4.16 ndb_print_backup_file — Print NDB Backup File Contents ... 2276
18.4.17 ndb_print_file — Print NDB Disk Data File Contents ... 2276
18.4.18 ndb_print_schema_file — Print NDB Schema File Contents ... 2277
18.4.19 ndb_print_sys_file — Print NDB System File Contents ... 2277
18.4.20 ndb_redo_log_reader — Check and Print Content of Cluster Redo Log ... 2277
18.4.21 ndb_restore — Restore an NDB Cluster Backup ... 2280
18.4.22 ndb_select_all — Print Rows from an NDB Table ... 2299
18.4.23 ndb_select_count — Print Row Counts for NDB Tables ... 2302
18.4.24 ndb_show_tables — Display List of NDB Tables ... 2303
18.4.25 ndb_size.pl — NDBCLUSTER Size Requirement Estimator ... 2304
18.4.26 ndb_waiter — Wait for NDB Cluster to Reach a Given Status ... 2307
18.4.27 Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs ... 2309
18.5 Management of NDB Cluster ... 2313
18.5.1 Summary of NDB Cluster Start Phases ... 2313
18.5.2 Commands in the NDB Cluster Management Client ... 2315
18.5.3 Online Backup of NDB Cluster ... 2319
18.5.4 MySQL Server Usage for NDB Cluster ... 2324
18.5.5 Performing a Rolling Restart of an NDB Cluster ... 2325
18.5.6 Event Reports Generated in NDB Cluster ... 2327
18.5.7 NDB Cluster Log Messages ... 2337
18.5.8 NDB Cluster Single User Mode ... 2351
18.5.9 Quick Reference: NDB Cluster SQL Statements ... 2352
18.5.10 ndbinfo: The NDB Cluster Information Database ... 2355
18.5.11 NDB Cluster Security Issues ... 2376
18.5.12 NDB Cluster Disk Data Tables ... 2383
18.5.13 Adding NDB Cluster Data Nodes Online ... 2390
18.5.14 Distributed MySQL Privileges for NDB Cluster ... 2401
18.5.15 NDB API Statistics Counters and Variables ... 2404
18.6 NDB Cluster Replication ... 2416
18.6.1 NDB Cluster Replication: Abbreviations and Symbols ... 2417
18.6.2 General Requirements for NDB Cluster Replication ... 2417
18.6.3 Known Issues in NDB Cluster Replication ... 2419
18.6.4 NDB Cluster Replication Schema and Tables ... 2425
18.6.5 Preparing the NDB Cluster for Replication ... 2428
18.6.6 Starting NDB Cluster Replication (Single Replication Channel) ... 2429
18.6.7 Using Two Replication Channels for NDB Cluster Replication ... 2431
18.6.8 Implementing Failover with NDB Cluster Replication ... 2432
18.6.9 NDB Cluster Backups With NDB Cluster Replication ... 2434
18.6.10 NDB Cluster Replication: Multi-Master and Circular Replication ... 2440
18.6.11 NDB Cluster Replication Conflict Resolution ... 2444
18.7 NDB Cluster Release Notes ... 2453
19 Partitioning ... 2455
19.1 Overview of Partitioning in MySQL ... 2457
19.2 Partitioning Types ... 2460
19.2.1 RANGE Partitioning ... 2462
19.2.2 LIST Partitioning ... 2466

19.2.3 COLUMNS Partitioning 2468
19.2.4 HASH Partitioning 2475
19.2.5 KEY Partitioning 2478
19.2.6 Subpartitioning 2480
19.2.7 How MySQL Partitioning Handles NULL 2483
19.3 Partition Management 2487
19.3.1 Management of RANGE and LIST Partitions 2488
19.3.2 Management of HASH and KEY Partitions 2494
19.3.3 Maintenance of Partitions 2495
19.3.4 Obtaining Information About Partitions 2496
19.4 Partition Pruning 2498
19.5 Restrictions and Limitations on Partitioning 2502
19.5.1 Partitioning Keys, Primary Keys, and Unique Keys 2508
19.5.2 Partitioning Limitations Relating to Storage Engines 2511
19.5.3 Partitioning Limitations Relating to Functions 2512
19.5.4 Partitioning and Table-Level Locking 2513
20 Stored Programs and Views 2515
20.1 Defining Stored Programs 2516
20.2 Using Stored Routines (Procedures and Functions) 2517
20.2.1 Stored Routine Syntax 2517
20.2.2 Stored Routines and MySQL Privileges 2518
20.2.3 Stored Routine Metadata 2518
20.2.4 Stored Procedures, Functions, Triggers, and LAST_INSERT_ID() 2519
20.3 Using Triggers 2519
20.3.1 Trigger Syntax and Examples 2520
20.3.2 Trigger Metadata 2523
20.4 Using the Event Scheduler 2523
20.4.1 Event Scheduler Overview 2524
20.4.2 Event Scheduler Configuration 2525
20.4.3 Event Syntax 2527
20.4.4 Event Metadata 2527
20.4.5 Event Scheduler Status 2528
20.4.6 The Event Scheduler and MySQL Privileges 2528
20.5 Using Views 2531
20.5.1 View Syntax 2531
20.5.2 View Processing Algorithms 2532
20.5.3 Updatable and Insertable Views 2533
20.5.4 The View WITH CHECK OPTION Clause 2535
20.5.5 View Metadata 2535
20.6 Access Control for Stored Programs and Views 2536
20.7 Binary Logging of Stored Programs 2537
21 INFORMATION_SCHEMA Tables 2545
21.1 The INFORMATION_SCHEMA CHARACTER_SETS Table 2548
21.2 The INFORMATION_SCHEMA COLLATIONS Table 2549
21.3 The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table 2549
21.4 The INFORMATION_SCHEMA COLUMNS Table 2550
21.5 The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table 2550
21.6 The INFORMATION_SCHEMA ENGINES Table 2551
21.7 The INFORMATION_SCHEMA EVENTS Table 2551
21.8 The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables 2555
21.9 The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables 2555
21.10 The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table 2555
21.11 The INFORMATION_SCHEMA PARAMETERS Table 2556
21.12 The INFORMATION_SCHEMA PARTITIONS Table 2557
21.13 The INFORMATION_SCHEMA PLUGINS Table 2560
21.14 The INFORMATION_SCHEMA PROCESSLIST Table 2561

21.15 The INFORMATION_SCHEMA PROFILING Table 2562
21.16 The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table 2563
21.17 The INFORMATION_SCHEMA ROUTINES Table 2563
21.18 The INFORMATION_SCHEMA SCHEMATA Table 2565
21.19 The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table 2565
21.20 The INFORMATION_SCHEMA STATISTICS Table 2566
21.21 The INFORMATION_SCHEMA TABLES Table 2566
21.22 The INFORMATION_SCHEMA TABLESPACES Table 2568
21.23 The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table 2568
21.24 The INFORMATION_SCHEMA TABLE_PRIVILEGES Table 2569
21.25 The INFORMATION_SCHEMA TRIGGERS Table 2569
21.26 The INFORMATION_SCHEMA USER_PRIVILEGES Table 2571
21.27 The INFORMATION_SCHEMA VIEWS Table 2571
21.28 InnoDB INFORMATION_SCHEMA Tables 2573
21.28.1 The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table 2573
21.28.2 The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table 2575
21.28.3 The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table 2577
21.28.4 The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables 2579
21.28.5 The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables 2580
21.28.6 The INFORMATION_SCHEMA INNODB_LOCKS Table 2581
21.28.7 The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table 2582
21.28.8 The INFORMATION_SCHEMA INNODB_TRX Table 2583
21.29 NDB Cluster INFORMATION_SCHEMA Tables 2585
21.29.1 The INFORMATION_SCHEMA FILES Table 2586
21.29.2 The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table 2591
21.30 Thread Pool INFORMATION_SCHEMA Tables 2592
21.30.1 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table 2592
21.30.2 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table 2594
21.30.3 The INFORMATION_SCHEMA TP_THREAD_STATE Table 2596
21.31 Extensions to SHOW Statements 2596
22 MySQL Performance Schema 2599
22.1 Performance Schema Quick Start 2600
22.2 Performance Schema Build Configuration 2605
22.3 Performance Schema Startup Configuration 2606
22.4 Performance Schema Runtime Configuration 2607
22.4.1 Performance Schema Event Timing 2608
22.4.2 Performance Schema Event Filtering 2611
22.4.3 Event Pre-Filtering 2612
22.4.4 Naming Instruments or Consumers for Filtering Operations 2613
22.4.5 Determining What Is Instrumented 2614
22.5 Performance Schema Queries 2615
22.6 Performance Schema Instrument Naming Conventions 2615
22.7 Performance Schema Status Monitoring 2616
22.8 Performance Schema General Table Characteristics 2619
22.9 Performance Schema Table Descriptions 2620
22.9.1 Performance Schema Table Index 2620
22.9.2 Performance Schema Setup Tables 2621
22.9.3 Performance Schema Instance Tables 2623
22.9.4 Performance Schema Wait Event Tables 2626
22.9.5 Performance Schema Summary Tables 2630
22.9.6 Performance Schema Miscellaneous Tables 2632
22.10 Performance Schema Option and Variable Reference 2634
22.11 Performance Schema System Variables 2635
22.12 Performance Schema Status Variables 2640
22.13 Performance Schema and Plugins 2641
22.14 Using the Performance Schema to Diagnose Problems 2641

23 Connectors and APIs 2643
23.1 MySQL Connector/C 2646
23.2 MySQL Connector/C++ 2646
23.3 MySQL Connector/J 2646
23.4 MySQL Connector/Net 2647
23.5 MySQL Connector/ODBC 2647
23.6 MySQL Connector/Python 2647
23.7 libmysqld, the Embedded MySQL Server Library 2647
23.7.1 Compiling Programs with libmysqld 2648
23.7.2 Restrictions When Using the Embedded MySQL Server 2648
23.7.3 Options with the Embedded Server 2649
23.7.4 Embedded Server Examples 2649
23.8 MySQL C API 2652
23.8.1 MySQL C API Implementations 2653
23.8.2 Simultaneous MySQL Server and Connector/C Installations 2654
23.8.3 Example C API Client Programs 2655
23.8.4 Building and Running C API Client Programs 2655
23.8.5 C API Data Structures 2659
23.8.6 C API Function Overview 2664
23.8.7 C API Function Descriptions 2669
23.8.8 C API Prepared Statements 2718
23.8.9 C API Prepared Statement Data Structures 2718
23.8.10 C API Prepared Statement Function Overview 2724
23.8.11 C API Prepared Statement Function Descriptions 2727
23.8.12 C API Threaded Function Descriptions 2750
23.8.13 C API Embedded Server Function Descriptions 2751
23.8.14 C API Client Plugin Functions 2752
23.8.15 C API Encrypted Connection Support 2755
23.8.16 C API Multiple Statement Execution Support 2757
23.8.17 C API Prepared Statement Handling of Date and Time Values 2759
23.8.18 C API Prepared CALL Statement Support 2760
23.8.19 C API Prepared Statement Problems 2763
23.8.20 C API Automatic Reconnection Control 2764
23.8.21 C API Common Issues 2765
23.9 MySQL PHP API 2766
23.10 MySQL Perl API 2766
23.11 MySQL Python API 2767
23.12 MySQL Ruby APIs 2767
23.12.1 The MySQL/Ruby API 2768
23.12.2 The Ruby/MySQL API 2768
23.13 MySQL Tcl API 2768
23.14 MySQL Eiffel Wrapper 2768
24 Extending MySQL 2769
24.1 MySQL Internals 2769
24.1.1 MySQL Threads 2769
24.1.2 The MySQL Test Suite 2770
24.2 The MySQL Plugin API 2771
24.2.1 Types of Plugins 2771
24.2.2 Plugin API Characteristics 2774
24.2.3 Plugin API Components 2775
24.2.4 Writing Plugins 2776
24.3 MySQL Services for Plugins 2816
24.4 Adding New Functions to MySQL 2817
24.4.1 Features of the User-Defined Function Interface 2818
24.4.2 Adding a New User-Defined Function 2818
24.4.3 Adding a New Native Function 2827
24.5 Debugging and Porting MySQL 2829
24.5.1 Debugging a MySQL Server 2829

24.5.2 Debugging a MySQL Client 2837
24.5.3 The DBUG Package 2837
25 MySQL Enterprise Edition 2841
25.1 MySQL Enterprise Monitor Overview 2841
25.2 MySQL Enterprise Backup Overview 2842
25.3 MySQL Enterprise Security Overview 2842
25.4 MySQL Enterprise Encryption Overview 2843
25.5 MySQL Enterprise Audit Overview 2843
25.6 MySQL Enterprise Firewall Overview 2843
25.7 MySQL Enterprise Thread Pool Overview 2844
26 MySQL Workbench 2845
A MySQL 5.5 Frequently Asked Questions 2847
A.1 MySQL 5.5 FAQ: General 2847
A.2 MySQL 5.5 FAQ: Storage Engines 2849
A.3 MySQL 5.5 FAQ: Server SQL Mode 2849
A.4 MySQL 5.5 FAQ: Stored Procedures and Functions 2850
A.5 MySQL 5.5 FAQ: Triggers 2853
A.6 MySQL 5.5 FAQ: Views 2856
A.7 MySQL 5.5 FAQ: INFORMATION_SCHEMA 2856
A.8 MySQL 5.5 FAQ: Migration 2857
A.9 MySQL 5.5 FAQ: Security 2857
A.10 MySQL FAQ: MySQL 5.5 and NDB Cluster 2858
A.11 MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets 2871
A.12 MySQL 5.5 FAQ: Connectors & APIs 2883
A.13 MySQL 5.5 FAQ: Replication 2883
A.14 MySQL 5.5 FAQ: MySQL Enterprise Thread Pool 2887
A.15 MySQL 5.5 FAQ: InnoDB Change Buffer 2888
A.16 MySQL 5.5 FAQ: Virtualization Support 2890
B Errors, Error Codes, and Common Problems 2891
B.1 Sources of Error Information 2891
B.2 Types of Error Values 2891
B.3 Server Error Codes and Messages 2892
B.4 Client Error Codes and Messages 2944
B.5 Problems and Common Errors 2948
B.5.1 How to Determine What Is Causing a Problem 2948
B.5.2 Common Errors When Using MySQL Programs 2949
B.5.3 Administration-Related Issues 2962
B.5.4 Query-Related Issues 2969
B.5.5 Optimizer-Related Issues 2977
B.5.6 Table Definition-Related Issues 2977
B.5.7 Known Issues in MySQL 2978
C Restrictions and Limits 2983
C.1 Restrictions on Stored Programs 2983
C.2 Restrictions on Condition Handling 2987
C.3 Restrictions on Server-Side Cursors 2987
C.4 Restrictions on Subqueries 2987
C.5 Restrictions on Views 2989
C.6 Restrictions on XA Transactions 2990
C.7 Restrictions on Character Sets 2991
C.8 Restrictions on Performance Schema 2991
C.9 Restrictions on Pluggable Authentication 2992
C.10 Limits in MySQL 2993
C.10.1 Limits on Joins 2993
C.10.2 Limits on Number of Databases and Tables 2993
C.10.3 Limits on Table Size 2994
C.10.4 Limits on Table Column Count and Row Size 2995
C.10.5 Limits Imposed by .frm File Structure 2998
C.10.6 Windows Platform Limitations 2998

D Indexes 3001
MySQL Glossary 3515

Preface and Legal Notices

This is the Reference Manual for the MySQL Database System, version 5.5, through release 5.5.60. Differences between minor versions of MySQL 5.5 are noted in the present text with reference to release numbers (5.5.*x*). For license information, see the Legal Notices.

This manual is not intended for use with older versions of the MySQL software due to the many functional and other differences between MySQL 5.5 and previous versions. If you are using an earlier release of the MySQL software, please refer to the appropriate manual. For example, *MySQL 5.1 Reference Manual* covers the 5.1 series of MySQL software releases.

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Chapter 1 General Information

Table of Contents

1.1 About This Manual 2
1.2 Typographical and Syntax Conventions 2
1.3 Overview of the MySQL Database Management System 4
    1.3.1 What is MySQL? 4
    1.3.2 The Main Features of MySQL 5
    1.3.3 History of MySQL 8
1.4 What Is New in MySQL 5.5 9
1.5 MySQL Information Sources 17
    1.5.1 MySQL Web Sites 17
    1.5.2 MySQL Mailing Lists 17
    1.5.3 MySQL Community Support at the MySQL Forums 19
    1.5.4 MySQL Community Support on Internet Relay Chat (IRC) 20
    1.5.5 MySQL Enterprise 20
1.6 How to Report Bugs or Problems 20
1.7 MySQL Standards Compliance 24
    1.7.1 MySQL Extensions to Standard SQL 26
    1.7.2 MySQL Differences from Standard SQL 28
    1.7.3 How MySQL Deals with Constraints 30
1.8 Credits 33
    1.8.1 Contributors to MySQL 33
    1.8.2 Documenters and translators 38
    1.8.3 Packages that support MySQL 39
    1.8.4 Tools that were used to create MySQL 40
    1.8.5 Supporters of MySQL 40

The MySQL™ software delivers a very fast, multi-threaded, multi-user, and robust SQL (Structured Query Language) database server. MySQL Server is intended for mission-critical, heavy-load production systems as well as for embedding into mass-deployed software. Oracle is a registered trademark of Oracle Corporation and/or its affiliates. MySQL is a trademark of Oracle Corporation and/or its affiliates, and shall not be used by Customer without Oracle's express written authorization. Other names may be trademarks of their respective owners.

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The following list describes some sections of particular interest in this manual:

- For a discussion of MySQL Database Server capabilities, see Section 1.3.2, “The Main Features of MySQL”.
- For an overview of new MySQL features, see Section 1.4, “What Is New in MySQL 5.5”. For information about the changes in each version, see the Release Notes.
- For installation instructions, see Chapter 2, *Installing and Upgrading MySQL*. For information about upgrading MySQL, see Section 2.11.1, “Upgrading MySQL”.
- For a tutorial introduction to the MySQL Database Server, see Chapter 3, *Tutorial*.
- For information about configuring and administering MySQL Server, see Chapter 5, *MySQL Server Administration*.
- For information about security in MySQL, see Chapter 6, *Security*.

- For information about setting up replication servers, see Chapter 17, *Replication*.
- For information about MySQL Enterprise, the commercial MySQL release with advanced features and management tools, see Chapter 25, *MySQL Enterprise Edition*.
- For answers to a number of questions that are often asked concerning the MySQL Database Server and its capabilities, see Appendix A, *MySQL 5.5 Frequently Asked Questions*.
- For a history of new features and bug fixes, see the Release Notes.

Important

To report problems or bugs, please use the instructions at Section 1.6, "How to Report Bugs or Problems". If you find a sensitive security bug in MySQL Server, please let us know immediately by sending an email message to `<secalert_us@oracle.com>`. Exception: Support customers should report all problems, including security bugs, to Oracle Support.

1.1 About This Manual

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If you are using MySQL 5.6, please refer to the *MySQL 5.6 Reference Manual*.

Because this manual serves as a reference, it does not provide general instruction on SQL or relational database concepts. It also does not teach you how to use your operating system or command-line interpreter.

The MySQL Database Software is under constant development, and the Reference Manual is updated frequently as well. The most recent version of the manual is available online in searchable form at http://dev.mysql.com/doc/. Other formats also are available there, including HTML, PDF, and EPUB versions.

The Reference Manual source files are written in DocBook XML format. The HTML version and other formats are produced automatically, primarily using the DocBook XSL stylesheets. For information about DocBook, see http://docbook.org/

If you have questions about using MySQL, you can ask them using our mailing lists or forums. See Section 1.5.2, "MySQL Mailing Lists", and Section 1.5.3, "MySQL Community Support at the MySQL Forums". If you have suggestions concerning additions or corrections to the manual itself, please send them to the http://www.mysql.com/company/contact/.

This manual was originally written by David Axmark and Michael "Monty" Widenius. It is maintained by the MySQL Documentation Team, consisting of Chris Cole, Paul DuBois, Edward Gilmore, Stefan Hinz, David Moss, Philip Olson, Daniel Price, Daniel So, and Jon Stephens.

1.2 Typographical and Syntax Conventions

This manual uses certain typographical conventions:

- `Text in this style` is used for SQL statements; database, table, and column names; program listings and source code; and environment variables. Example: "To reload the grant tables, use the `FLUSH PRIVILEGES` statement."

- **`Text in this style`** indicates input that you type in examples.
- `Text in this style` indicates the names of executable programs and scripts, examples being `mysql` (the MySQL command-line client program) and `mysqld` (the MySQL server executable).
- *`Text in this style`* is used for variable input for which you should substitute a value of your own choosing.
- *Text in this style* is used for emphasis.
- **Text in this style** is used in table headings and to convey especially strong emphasis.
- `Text in this style` is used to indicate a program option that affects how the program is executed, or that supplies information that is needed for the program to function in a certain way. *Example*: "The `--host` option (short form `-h`) tells the `mysql` client program the hostname or IP address of the MySQL server that it should connect to".
- File names and directory names are written like this: "The global `my.cnf` file is located in the `/etc` directory."
- Character sequences are written like this: "To specify a wildcard, use the '`%`' character."

When commands are shown that are meant to be executed from within a particular program, the prompt shown preceding the command indicates which command to use. For example, `shell>` indicates a command that you execute from your login shell, `root-shell>` is similar but should be executed as `root`, and `mysql>` indicates a statement that you execute from the `mysql` client program:

```
shell> type a shell command here
root-shell> type a shell command as root here
mysql> type a mysql statement here
```

In some areas different systems may be distinguished from each other to show that commands should be executed in two different environments. For example, while working with replication the commands might be prefixed with `master` and `slave`:

```
master> type a mysql command on the replication master here
slave> type a mysql command on the replication slave here
```

The "shell" is your command interpreter. On Unix, this is typically a program such as `sh`, `csh`, or `bash`. On Windows, the equivalent program is `command.com` or `cmd.exe`, typically run in a console window.

When you enter a command or statement shown in an example, do not type the prompt shown in the example.

Database, table, and column names must often be substituted into statements. To indicate that such substitution is necessary, this manual uses *`db_name`*, *`tbl_name`*, and *`col_name`*. For example, you might see a statement like this:

```
mysql> SELECT col_name FROM db_name.tbl_name;
```

This means that if you were to enter a similar statement, you would supply your own database, table, and column names, perhaps like this:

```
mysql> SELECT author_name FROM biblio_db.author_list;
```

SQL keywords are not case sensitive and may be written in any lettercase. This manual uses uppercase.

In syntax descriptions, square brackets ("`[`" and "`]`") indicate optional words or clauses. For example, in the following statement, `IF EXISTS` is optional:

```
DROP TABLE [IF EXISTS] tbl_name
```

When a syntax element consists of a number of alternatives, the alternatives are separated by vertical bars (“|”). When one member from a set of choices *may* be chosen, the alternatives are listed within square brackets (“[” and “]”):

```
TRIM([[BOTH | LEADING | TRAILING] [remstr] FROM] str)
```

When one member from a set of choices *must* be chosen, the alternatives are listed within braces (“{” and “}”):

```
{DESCRIBE | DESC} tbl_name [col_name | wild]
```

An ellipsis (`...`) indicates the omission of a section of a statement, typically to provide a shorter version of more complex syntax. For example, `SELECT ... INTO OUTFILE` is shorthand for the form of `SELECT` statement that has an `INTO OUTFILE` clause following other parts of the statement.

An ellipsis can also indicate that the preceding syntax element of a statement may be repeated. In the following example, multiple *`reset_option`* values may be given, with each of those after the first preceded by commas:

```
RESET reset_option [,reset_option] ...
```

Commands for setting shell variables are shown using Bourne shell syntax. For example, the sequence to set the `CC` environment variable and run the `configure` command looks like this in Bourne shell syntax:

```
shell> CC=gcc ./configure
```

If you are using `csh` or `tcsh`, you must issue commands somewhat differently:

```
shell> setenv CC gcc
shell> ./configure
```

1.3 Overview of the MySQL Database Management System

1.3.1 What is MySQL?

MySQL, the most popular Open Source SQL database management system, is developed, distributed, and supported by Oracle Corporation.

The MySQL Web site (http://www.mysql.com/) provides the latest information about MySQL software.

- **MySQL is a database management system.**

  A database is a structured collection of data. It may be anything from a simple shopping list to a picture gallery or the vast amounts of information in a corporate network. To add, access, and process data stored in a computer database, you need a database management system such as MySQL Server. Since computers are very good at handling large amounts of data, database management systems play a central role in computing, as standalone utilities, or as parts of other applications.

- **MySQL databases are relational.**

  A relational database stores data in separate tables rather than putting all the data in one big storeroom. The database structures are organized into physical files optimized for speed. The logical model, with objects such as databases, tables, views, rows, and columns, offers a flexible

programming environment. You set up rules governing the relationships between different data fields, such as one-to-one, one-to-many, unique, required or optional, and “pointers” between different tables. The database enforces these rules, so that with a well-designed database, your application never sees inconsistent, duplicate, orphan, out-of-date, or missing data.

The SQL part of “MySQL” stands for “Structured Query Language”. SQL is the most common standardized language used to access databases. Depending on your programming environment, you might enter SQL directly (for example, to generate reports), embed SQL statements into code written in another language, or use a language-specific API that hides the SQL syntax.

SQL is defined by the ANSI/ISO SQL Standard. The SQL standard has been evolving since 1986 and several versions exist. In this manual, “SQL-92” refers to the standard released in 1992, “SQL:1999” refers to the standard released in 1999, and “SQL:2003” refers to the current version of the standard. We use the phrase “the SQL standard” to mean the current version of the SQL Standard at any time.

- **MySQL software is Open Source.**

  Open Source means that it is possible for anyone to use and modify the software. Anybody can download the MySQL software from the Internet and use it without paying anything. If you wish, you may study the source code and change it to suit your needs. The MySQL software uses the GPL (GNU General Public License), http://www.fsf.org/licenses/, to define what you may and may not do with the software in different situations. If you feel uncomfortable with the GPL or need to embed MySQL code into a commercial application, you can buy a commercially licensed version from us. See the MySQL Licensing Overview for more information (http://www.mysql.com/company/legal/licensing/).

- **The MySQL Database Server is very fast, reliable, scalable, and easy to use.**

  If that is what you are looking for, you should give it a try. MySQL Server can run comfortably on a desktop or laptop, alongside your other applications, web servers, and so on, requiring little or no attention. If you dedicate an entire machine to MySQL, you can adjust the settings to take advantage of all the memory, CPU power, and I/O capacity available. MySQL can also scale up to clusters of machines, networked together.

  MySQL Server was originally developed to handle large databases much faster than existing solutions and has been successfully used in highly demanding production environments for several years. Although under constant development, MySQL Server today offers a rich and useful set of functions. Its connectivity, speed, and security make MySQL Server highly suited for accessing databases on the Internet.

- **MySQL Server works in client/server or embedded systems.**

  The MySQL Database Software is a client/server system that consists of a multi-threaded SQL server that supports different back ends, several different client programs and libraries, administrative tools, and a wide range of application programming interfaces (APIs).

  We also provide MySQL Server as an embedded multi-threaded library that you can link into your application to get a smaller, faster, easier-to-manage standalone product.

- **A large amount of contributed MySQL software is available.**

  MySQL Server has a practical set of features developed in close cooperation with our users. It is very likely that your favorite application or language supports the MySQL Database Server.

The official way to pronounce “MySQL” is “My Ess Que Ell” (not “my sequel”), but we do not mind if you pronounce it as “my sequel” or in some other localized way.

1.3.2 The Main Features of MySQL

This section describes some of the important characteristics of the MySQL Database Software. In most respects, the roadmap applies to all versions of MySQL. For information about features as they are introduced into MySQL on a series-specific basis, see the “In a Nutshell” section of the appropriate Manual:

- MySQL 8.0: What Is New in MySQL 8.0
- MySQL 5.7: What Is New in MySQL 5.7
- MySQL 5.6: What Is New in MySQL 5.6
- MySQL 5.5: Section 1.4, “What Is New in MySQL 5.5”

Internals and Portability

- Written in C and C++.
- Tested with a broad range of different compilers.
- Works on many different platforms. See http://www.mysql.com/support/supportedplatforms/database.html.
- For portability, uses `CMake` in MySQL 5.5 and up. Previous series use GNU Automake, Autoconf, and Libtool.
- Tested with Purify (a commercial memory leakage detector) as well as with Valgrind, a GPL tool (http://developer.kde.org/~sewardj/).
- Uses multi-layered server design with independent modules.
- Designed to be fully multi-threaded using kernel threads, to easily use multiple CPUs if they are available.
- Provides transactional and nontransactional storage engines.
- Uses very fast B-tree disk tables (`MyISAM`) with index compression.
- Designed to make it relatively easy to add other storage engines. This is useful if you want to provide an SQL interface for an in-house database.
- Uses a very fast thread-based memory allocation system.
- Executes very fast joins using an optimized nested-loop join.
- Implements in-memory hash tables, which are used as temporary tables.
- Implements SQL functions using a highly optimized class library that should be as fast as possible. Usually there is no memory allocation at all after query initialization.
- Provides the server as a separate program for use in a client/server networked environment, and as a library that can be embedded (linked) into standalone applications. Such applications can be used in isolation or in environments where no network is available.

Data Types

- Many data types: signed/unsigned integers 1, 2, 3, 4, and 8 bytes long, `FLOAT`, `DOUBLE`, `CHAR`, `VARCHAR`, `BINARY`, `VARBINARY`, `TEXT`, `BLOB`, `DATE`, `TIME`, `DATETIME`, `TIMESTAMP`, `YEAR`, `SET`, `ENUM`, and OpenGIS spatial types. See Chapter 11, *Data Types*.
- Fixed-length and variable-length string types.

Statements and Functions

- Full operator and function support in the `SELECT` list and `WHERE` clause of queries. For example:

```
mysql> SELECT CONCAT(first_name, ' ', last_name)
    -> FROM citizen
    -> WHERE income/dependents > 10000 AND age > 30;
```

- Full support for SQL `GROUP BY` and `ORDER BY` clauses. Support for group functions (`COUNT()`, `AVG()`, `STD()`, `SUM()`, `MAX()`, `MIN()`, and `GROUP_CONCAT()`).
- Support for `LEFT OUTER JOIN` and `RIGHT OUTER JOIN` with both standard SQL and ODBC syntax.
- Support for aliases on tables and columns as required by standard SQL.
- Support for `DELETE`, `INSERT`, `REPLACE`, and `UPDATE` to return the number of rows that were changed (affected), or to return the number of rows matched instead by setting a flag when connecting to the server.
- Support for MySQL-specific `SHOW` statements that retrieve information about databases, storage engines, tables, and indexes. Support for the `INFORMATION_SCHEMA` database, implemented according to standard SQL.
- An `EXPLAIN` statement to show how the optimizer resolves a query.
- Independence of function names from table or column names. For example, `ABS` is a valid column name. The only restriction is that for a function call, no spaces are permitted between the function name and the "`(`" that follows it. See Section 9.3, "Keywords and Reserved Words".
- You can refer to tables from different databases in the same statement.

Security

- A privilege and password system that is very flexible and secure, and that enables host-based verification.
- Password security by encryption of all password traffic when you connect to a server.

Scalability and Limits

- Support for large databases. We use MySQL Server with databases that contain 50 million records. We also know of users who use MySQL Server with 200,000 tables and about 5,000,000,000 rows.
- Support for up to 64 indexes per table. Each index may consist of 1 to 16 columns or parts of columns. The maximum index width for `InnoDB` tables is either 767 bytes or 3072 bytes. See Section 14.11.1.7, "Limits on InnoDB Tables". The maximum index width for `MyISAM` tables is 1000 bytes. See Section 15.3, "The MyISAM Storage Engine". An index may use a prefix of a column for `CHAR`, `VARCHAR`, `BLOB`, or `TEXT` column types.

Connectivity

- Clients can connect to MySQL Server using several protocols:
  - Clients can connect using TCP/IP sockets on any platform.
  - On Windows systems, clients can connect using named pipes if the server is started with the `--enable-named-pipe` option. Windows servers also support shared-memory connections if started with the `--shared-memory` option. Clients can connect through shared memory by using the `--protocol=memory` option.
  - On Unix systems, clients can connect using Unix domain socket files.
- MySQL client programs can be written in many languages. A client library written in C is available for clients written in C or C++, or for any language that provides C bindings.

- APIs for C, C++, Eiffel, Java, Perl, PHP, Python, Ruby, and Tcl are available, enabling MySQL clients to be written in many languages. See Chapter 23, *Connectors and APIs*.
- The Connector/ODBC (MyODBC) interface provides MySQL support for client programs that use ODBC (Open Database Connectivity) connections. For example, you can use MS Access to connect to your MySQL server. Clients can be run on Windows or Unix. Connector/ODBC source is available. All ODBC 2.5 functions are supported, as are many others. See MySQL Connector/ODBC Developer Guide.
- The Connector/J interface provides MySQL support for Java client programs that use JDBC connections. Clients can be run on Windows or Unix. Connector/J source is available. See MySQL Connector/J 5.1 Developer Guide.
- MySQL Connector/Net enables developers to easily create .NET applications that require secure, high-performance data connectivity with MySQL. It implements the required ADO.NET interfaces and integrates into ADO.NET aware tools. Developers can build applications using their choice of .NET languages. MySQL Connector/Net is a fully managed ADO.NET driver written in 100% pure C#. See MySQL Connector/Net Developer Guide.

Localization

- The server can provide error messages to clients in many languages. See Section 10.2, “Setting the Error Message Language”.
- Full support for several different character sets, including `latin1` (cp1252), `german`, `big5`, `ujis`, several Unicode character sets, and more. For example, the Scandinavian characters “å”, “ä” and “ö” are permitted in table and column names.
- All data is saved in the chosen character set.
- Sorting and comparisons are done according to the default character set and collation. is possible to change this when the MySQL server is started (see Section 10.1.3.2, “Server Character Set and Collation”). To see an example of very advanced sorting, look at the Czech sorting code. MySQL Server supports many different character sets that can be specified at compile time and runtime.
- The server time zone can be changed dynamically, and individual clients can specify their own time zone. See Section 10.6, “MySQL Server Time Zone Support”.

Clients and Tools

- MySQL includes several client and utility programs. These include both command-line programs such as `mysqldump` and `mysqladmin`, and graphical programs such as MySQL Workbench.
- MySQL Server has built-in support for SQL statements to check, optimize, and repair tables. These statements are available from the command line through the `mysqlcheck` client. MySQL also includes `myisamchk`, a very fast command-line utility for performing these operations on `MyISAM` tables. See Chapter 4, *MySQL Programs*.
- MySQL programs can be invoked with the `--help` or `-?` option to obtain online assistance.

1.3.3 History of MySQL

We started out with the intention of using the `mSQL` database system to connect to our tables using our own fast low-level (ISAM) routines. However, after some testing, we came to the conclusion that `mSQL` was not fast enough or flexible enough for our needs. This resulted in a new SQL interface to our database but with almost the same API interface as `mSQL`. This API was designed to enable third-party code that was written for use with `mSQL` to be ported easily for use with MySQL.

MySQL is named after co-founder Monty Widenius's daughter, My.

The name of the MySQL Dolphin (our logo) is “Sakila,” which was chosen from a huge list of names suggested by users in our “Name the Dolphin” contest. The winning name was submitted by Ambrose

Twebaze, an Open Source software developer from Swaziland, Africa. According to Ambrose, the feminine name Sakila has its roots in SiSwati, the local language of Swaziland. Sakila is also the name of a town in Arusha, Tanzania, near Ambrose's country of origin, Uganda.

1.4 What Is New in MySQL 5.5

This section summarizes what has been added to, deprecated in, and removed from MySQL 5.5.

- Features Added in MySQL 5.5
- Features Deprecated in MySQL 5.5
- Features Removed in MySQL 5.5

Features Added in MySQL 5.5

The following features have been added to MySQL 5.5:

- **MySQL Enterprise Thread Pool.** The default thread-handling model in MySQL Server executes statements using one thread per client connection. As more clients connect to the server and execute statements, overall performance degrades. As of MySQL 5.5.16, MySQL Enterprise Edition distributions include a thread pool plugin that provides an alternative thread-handling model designed to reduce overhead and improve performance. The plugin implements a thread pool that increases server performance by efficiently managing statement execution threads for large numbers of client connections. For more information, see Section 5.5.3, “MySQL Enterprise Thread Pool”.

- **MySQL Enterprise Audit.** MySQL Enterprise Edition now includes MySQL Enterprise Audit, implemented using a server plugin named `audit_log`. MySQL Enterprise Audit uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines. When installed, the audit plugin enables MySQL Server to produce a log file containing an audit record of server activity. The log contents include when clients connect and disconnect, and what actions they perform while connected, such as which databases and tables they access. For more information, see Section 6.5.2, “MySQL Enterprise Audit”.

- **Pluggable authentication.** MySQL authentication supports two new capabilities, pluggable authentication and proxy users. With pluggable authentication, the server can use plugins to authenticate incoming client connections, and clients can load an authentication plugin that interacts properly with the corresponding server plugin. This capability enables clients to connect to the MySQL server with credentials that are appropriate for authentication methods other than the built-in MySQL authentication based on native MySQL passwords stored in the `mysql.user` table. For example, plugins can be created to use external authentication methods such as LDAP, Kerberos, PAM, or Windows login IDs. Proxy user capability enables a client who connects and authenticates as one user to be treated, for purposes of access control while connected, as having the privileges of a different user. In effect, one user impersonates another. Proxy capability depends on pluggable authentication because it is based on having an authentication plugin return to the server the user name that the connecting user impersonates. See Section 6.3.6, “Pluggable Authentication”, and Section 6.3.7, “Proxy Users”.

  As of MySQL 5.5.16, MySQL Enterprise Edition includes two plugins that enable MySQL Server to use external authentication methods to authenticate MySQL users:

  - PAM (Pluggable Authentication Modules) enables a system to access various kinds of authentication methods through a standard interface. A PAM authentication plugin enables MySQL Server to use PAM to authenticate MySQL users.

  - Distributions of MySQL for Windows include an authentication plugin that enables MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to

Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password.

These authentication plugins enable MySQL Server to accept connections from users defined outside the MySQL grant tables. They also support the MySQL proxy-user capability. Each plugin can return to MySQL a user name different from the login user, which means that the plugin can return the MySQL user that defines the privileges the externally authenticated user should have.

For more information, see Section 6.5.1.4, “PAM Pluggable Authentication”, and Section 6.5.1.5, “Windows Pluggable Authentication”.

- **Multi-core scalability.** Scalability on multi-core CPUs is improved. The trend in hardware development now is toward more cores rather than continued increases in CPU clock speeds, which renders “wait until CPUs get faster” a nonviable means of improving database performance. Instead, it is necessary to make better use of multiple cores to maximally exploit the processing cycles they make available. MySQL 5.5 takes advantage of features of SMP systems and tries to eliminate bottlenecks in MySQL architecture that hinder full use of multiple cores. The focus has been on `InnoDB`, especially locking and memory management. See Scalability Improvements.

- **Default storage engine.** The default storage engine for new tables is `InnoDB` rather than `MyISAM`. See Section 14.1, “Introduction to InnoDB”.

- **InnoDB I/O subsystem.** `InnoDB` I/O subsystem changes enable more effective use of available I/O capacity. See InnoDB I/O Subsystem Changes.

- **InnoDB storage engine.** MySQL 5.5 includes several `InnoDB` storage engine enhancements:

  - Indexes can be added or dropped without copying the table. See Section 14.16, “InnoDB Fast Index Creation”.

  - Tables can be compressed to significantly reduce storage requirements and I/O. See Section 14.12, “InnoDB Table Compression”.

  - `BLOB`, `TEXT`, and `VARCHAR` columns can be stored fully off page. See Section 14.14, “InnoDB Row Storage and Row Formats”.

  - File format management enhancements protect upward and downward compatibility. See Section 14.13, “InnoDB File-Format Management”.

  - `INFORMATION_SCHEMA` tables provide information about `InnoDB` compression and locking. See Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”.

  - `InnoDB` performance and scalability enhancements:

    - The `InnoDB` mutex and read/write lock implementation was improved. Use of Pthreads mutexes was replaced with calls to GCC - atomic builtins.

    - The memory allocator used by `InnoDB` is configurable. See Section 14.9.3, “Configuring the Memory Allocator for InnoDB”.

    - The extent to which `InnoDB` performs change buffering is configurable. See Section 14.9.4, “Configuring InnoDB Change Buffering”.

    - The adaptive hash index (AHI) feature makes `InnoDB` perform more like an in-memory database on systems with appropriate combinations of workload and ample memory for the buffer pool, without sacrificing transactional features or reliability. See Section 14.7.3, “Adaptive Hash Index”.

    - Different techniques can be used to limit the number of concurrently executing operating system threads to minimize context switching. See Section 14.9.5, “Configuring Thread Concurrency for InnoDB”.

- How InnoDB performs buffer pool read-ahead is configurable. See Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”.
- The number of background threads that service read and write I/O operations on data pages is configurable. See Section 14.9.6, “Configuring the Number of Background InnoDB I/O Threads”.
- Asynchronous I/O is supported on Linux systems. See innodb_use_native_aio.
- The overall I/O capacity available to InnoDB is configurable. See Section 14.9.8, “Configuring the InnoDB Master Thread I/O Rate”.
- How InnoDB performs buffer pool flushing is configurable. Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing”.
- The maximum delay between checking the availability of a mutex or rw-lock is configurable. See Section 14.9.9, “Configuring Spin Lock Polling”.
- InnoDB can be configured to minimize the amount of data brought into the buffer pool and never accessed again. See Section 14.9.2.3, “Making the Buffer Pool Scan Resistant”.
- Crash recovery performance was improved. See Section 8.5.8, “Optimizing InnoDB Configuration Variables”.
- Certain internal InnoDB operations can be profiled using the Performance Schema feature. See Section 14.19, “InnoDB Integration with MySQL Performance Schema”.
- The buffer pool can be divided into separate instances to reduce contention between threads that read and write to cached pages. See Section 14.9.2.2, “Configuring Multiple Buffer Pool Instances”.
- The limit on concurrent data modifying transactions was increased. See Section 14.7.8, “Undo Logs”.
- InnoDB can be configured to have purge operations performed by a separate thread, rather than by the master thread. See Section 14.9.10, “Configuring InnoDB Purge Scheduling”.

- InnoDB flexibility, ease of use, and reliability enhancements:
  - The innodb_file_per_table, innodb_stats_on_metadata, innodb_lock_wait_timeout, and innodb_adaptive_hash_index options can be set at runtime using a SET statement.
  - Operating system disk space can be reclaimed when truncating an InnoDB table. See Section 14.15.5, “Reclaiming Disk Space with TRUNCATE TABLE”.
  - InnoDB can be run in strict mode. See the innodb_strict_mode parameter documentation.
  - InnoDB provides greater control over the quality of optimizer statistics estimates. See Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”.
  - SHOW ENGINE INNODB MUTEX output is more compact. See Section 13.7.5.16, “SHOW ENGINE Syntax”.
  - SHOW ENGINE INNODB STATUS output displays counter information for the Innodb_buffer_pool_read_ahead and Innodb_buffer_pool_read_ahead_evicted global status variables, which you can use to fine-tune the innodb_random_read_ahead setting and evaluate the effectiveness of the read-ahead algorithm.

- **Diagnostic improvements.** There is better access to execution and performance information. Diagnostic improvements include Performance Schema (a feature for monitoring MySQL Server

execution at a low level), DTrace probes, expanded `SHOW ENGINE INNODB STATUS` output, Debug Sync, and a new status variable. See Diagnostic and Monitoring Capabilities.

- **Solaris.** Several modifications improve operation of MySQL Server on Solaris. See Enhanced Solaris Support.

- **MySQL NDB Cluster.** MySQL NDB Cluster is released as a separate product, with version 7.2 of the `NDB` storage engine being based on MySQL 5.5. Clustering support is not available in mainline MySQL Server 5.5 releases. For more information about MySQL NDB Cluster 7.2, see Chapter 18, *MySQL NDB Cluster 7.2*.

  NDB Cluster releases are identified by a 3-part NDB version number. NDB Cluster 7.5, now available as a General Availability (GA) release beginning with version 7.5.4, incorporates version 7.5 of the `NDB` storage engine. Previous GA releases still available for production, NDB Cluster 7.3 and NDB Cluster 7.4, incorporate `NDB` versions 7.3 and 7.4, respectively. For information about NDB Cluster 7.5, see MySQL NDB Cluster 7.5 and NDB Cluster 7.6. For more information about NDB Cluster 7.4 and NDB Cluster 7.3, see MySQL NDB Cluster 7.3 and NDB Cluster 7.4.

- **Semisynchronous replication.** A commit performed on the master side blocks before returning to the session that performed the transaction until at least one slave acknowledges that it has received and logged the events for the transaction. Semisynchronous replication is implemented through an optional plugin component. See Section 17.3.8, “Semisynchronous Replication”

- **Unicode.** Support for supplementary Unicode characters; that is, characters outside the Basic Multilingual Plane (BMP). These new Unicode character sets include supplementary characters: `utf16`, `utf32`, and `utf8mb4`. See Section 10.1.9, “Unicode Support”.

- **Partitioning.** Enhancements to table partitioning:

  - Two new types of user-defined partitioning are supported: `RANGE COLUMNS` partitioning is an extension to `RANGE` partitioning; `LIST COLUMNS` partitioning is an extension to `LIST` partitioning. Each of these extensions provides two enhancements to MySQL partitioning capabilities:

    - It is possible to define partitioning ranges or lists based on `DATE`, `DATETIME`, or string values (such as `CHAR` or `VARCHAR`).

      You can also define ranges or lists based on multiple column values when partitioning tables by `RANGE COLUMNS` or `LIST COLUMNS`, respectively. Such a range or list may refer to up to 16 columns.

    - For tables defined using these partitioning types, partition pruning can now optimize queries with `WHERE` conditions that use multiple comparisons between (different) column values and constants, such as `a = 10 AND b > 5` or `a < "2005-11-25" AND b = 10 AND c = 50`.

    See Section 19.2.1, “RANGE Partitioning”, and Section 19.2.2, “LIST Partitioning”.

  - It is now possible to delete all rows from one or more partitions of a partitioned table using the `ALTER TABLE ... TRUNCATE PARTITION` statement. Executing the statement deletes rows without affecting the structure of the table. The partitions named in the `TRUNCATE PARTITION` clause do not have to be contiguous.

  - Key caches are now supported for indexes on partitioned `MyISAM` tables, using the `CACHE INDEX` and `LOAD INDEX INTO CACHE` statements. In addition, a key cache can be defined for and loaded with indexes from an entire partitioned table, or for one or more partitions. In the latter case, the partitions are not required to be contiguous.

  - The new `TO_SECONDS()` function converts a date or datetime expression to a number of seconds since the year 0. This is a general-purpose function, but is useful for partitioning. You may use it in partitioning expressions, and partition pruning is supported for tables defined using such expressions.

- **SIGNAL and RESIGNAL.** Support for the SQL standard `SIGNAL` and `RESIGNAL` statements. See Section 13.6.7, “Condition Handling”.
- **Metadata locking.** The server now prevents DDL statements from compromising transaction serializibility by using a new class of locks called metadata locks. See Section 8.11.4, “Metadata Locking”.
- **IPv6 support.** MySQL Server can accept TCP/IP connections from clients connecting over IPv6. See Section 5.1.9, “IPv6 Support”.
- **XML.** Enhancements to XML functionality, including a new `LOAD XML INFILE` statement. See Section 13.2.7, “LOAD XML Syntax”.
- **Build configuration.** MySQL releases are now built using `CMake` rather than the GNU autotools. Accordingly, the instructions for installing MySQL from source have been updated to discuss how to build MySQL using `CMake`. See Section 2.9, “Installing MySQL from Source”.

  The build process is now similar enough on all platforms, including Windows, that there are no longer sections dedicated to notes for specific platforms.

Features Deprecated in MySQL 5.5

The following features are deprecated in MySQL 5.5 and may be or will be removed in a future series. Where alternatives are shown, applications should be updated to use them.

- Relying on implicit `GROUP BY` sorting in MySQL 5.5 is deprecated. To achieve a specific sort order of grouped results, it is preferable to use an explicit `ORDER BY` clause. `GROUP BY` sorting is a MySQL extension that may change in a future release; for example, to make it possible for the optimizer to order groupings in whatever manner it deems most efficient and to avoid the sorting overhead.
- The `YEAR(2)` data type. `YEAR(2)` columns in existing tables are treated as before, but `YEAR(2)` in new or altered tables are converted to `YEAR(4)`. For more information, see Section 11.3.4, “YEAR(2) Limitations and Migrating to YEAR(4)”.

  The `SHOW AUTHORS` and `SHOW CONTRIBUTORS` statements.
- The `--ignore-builtin-innodb` server option and `ignore_builtin_innodb` system variable. They do nothing and have no effect.
- The `--language` server option. Use the `lc_messages_dir` and `lc_messages` sytem variables instead.
- The `ALWAYS` value for the `--base64-output` option for `mysqlbinlog`.
- The `--config-file` option for `mysqld_multi`. Use `--defaults-extra-file` instead.
- Use of unambigious option prefixes. If an unambiguous prefix is given, a warning occurs to provide feedback. Option prefixes are no longer supported in MySQL 5.7; only full options are accepted.
- The `engine_condition_pushdown` system variable. Use the `engine_condition_pushdown` flag of the `optimizer_switch` variable instead.
- The `timed_mutexes` system variable. It does nothing and has no effect.
- The `storage_engine` system variable. Use `default_storage_engine` instead.
- Use of the data directory as the location for `my.cnf`.

Features Removed in MySQL 5.5

The following constructs are obsolete and have been removed in MySQL 5.5. Where alternatives are shown, applications should be updated to use them.

- The `language` system variable (use `lc_messages_dir` and `lc_messages`).
- The `log_bin_trust_routine_creators` system variable (use `log_bin_trust_function_creators`).
- The `myisam_max_extra_sort_file_size` system variable.
- The `record_buffer` system variable (use `read_buffer_size`).
- The `sql_log_update` system variable.
- The `Innodb_buffer_pool_read_ahead_rnd` and `Innodb_buffer_pool_read_ahead_seq` status variables (use `Innodb_buffer_pool_read_ahead` and `Innodb_buffer_pool_read_ahead_evicted`).
- The `table_lock_wait_timeout` system variable.
- The `table_type` system variable (use `default_storage_engine`).
- The `FRAC_SECOND` modifier for the `TIMESTAMPADD()` function (use `MICROSECOND`).
- The `TYPE` table option to specify the storage engine for `CREATE TABLE` or `ALTER TABLE` (use `ENGINE`).
- The `SHOW TABLE TYPES` SQL statement (use `SHOW ENGINES`).
- The `SHOW INNODB STATUS` and `SHOW MUTEX STATUS` SQL statements (use `SHOW ENGINE INNODB STATUS` and `SHOW ENGINE INNODB MUTEX`).
- The `SHOW PLUGIN` SQL statement (use `SHOW PLUGINS`).
- The `LOAD TABLE ... FROM MASTER` and `LOAD DATA FROM MASTER` SQL statements (use `mysqldump` or `mysqlhotcopy` to dump tables and `mysql` to reload dump files).
- The `BACKUP TABLE` and `RESTORE TABLE` SQL statements (use `mysqldump` or `mysqlhotcopy` to dump tables and `mysql` to reload dump files).
- `TIMESTAMP(N)` data type: The ability to specify a display width of *`N`* (use without *`N`*).
- The `--default-character-set` and `--default-collation` server options (use `--character-set-server` and `--collation-server`).
- The `--default-table-type` server option (use `--default-storage-engine`).
- The `--delay-key-write-for-all-tables` server option (use `--delay-key-write=ALL`).
- The `--enable-locking` and `--skip-locking` server options (use `--external-locking` and `--skip-external-locking`).
- The `--log-bin-trust-routine-creators` server option (use `--log-bin-trust-function-creators`).
- The `--log-long-format` server option.
- The `--log-update` server option.
- The `--master-`*`xxx`* server options to set replication parameters (use the `CHANGE MASTER TO` statement instead): `--master-host`, `--master-user`, `--master-password`, `--master-port`, `--master-connect-retry`, `--master-ssl`, `--master-ssl-ca`, `--master-ssl-capath`, `--master-ssl-cert`, `--master-ssl-cipher`, `--master-ssl-key`.
- The `--safe-show-database` server option.
- The `--skip-symlink` and `--use-symbolic-links` server options (use `--skip-symbolic-links` and `--symbolic-links`).

- The `--sql-bin-update-same` server option.
- The `--warnings` server option (use `--log-warnings`).
- The `--no-named-commands` option for `mysql` (use `--skip-named-commands`).
- The `--no-pager` option for `mysql` (use `--skip-pager`).
- The `--no-tee` option for `mysql` (use `--skip-tee`).
- The `--position` option for `mysqlbinlog` (use `--start-position`).
- The `--all` option for `mysqldump` (use `--create-options`).
- The `--first-slave` option for `mysqldump` (use `--lock-all-tables`).
- The `--config-file` option for `mysqld_multi` (use `--defaults-extra-file`).
- The `--set-variable=`*`var_name=value`* and `-O` *`var_name=value`* general-purpose options for setting program variables (use `--`*`var_name=value`*).
- The `--with-pstack` option for `configure` and the `--enable-pstack` option for `mysqld`.

Scalability Improvements

MySQL 5.5 modifications improve performance on SMP systems to increase scalability on multi-core systems. The changes affect `InnoDB` locking and memory management.

MySQL 5.5 incorporates changes in `InnoDB` that improve the performance of RW-locks by using atomic CPU instructions (on platforms where they are available), rather than less scalable mutexes. It is also possible for `InnoDB` memory allocation to be disabled and replaced by the normal `malloc` library, or by a different library that implements `malloc` such as `tcmalloc` on Linux or `mtalloc` on Solaris.

The reimplementation of RW-locks requires atomic instructions. A status variable, `Innodb_have_atomic_builtins`, shows whether the server was built with atomic instructions.

InnoDB I/O Subsystem Changes

MySQL 5.5 changes to the `InnoDB` I/O subsystem enable more effective use of available I/O capacity. The changes also provide more control over configuration of the I/O subsystem.

Background I/O Threads

`InnoDB` uses background threads to perform I/O for several kinds of activities, two of which are prefetching disk blocks and flushing dirty pages. Previously, `InnoDB` used only one thread each to perform these activities, but that can underutilize server capacity. MySQL 5.5 enables use of multiple background read and write threads, making it possible to read and write pages faster.

The patch makes the number of background I/O threads configurable using system variables: `innodb_read_io_threads` controls the number of threads to use for read prefetch requests. `innodb_write_io_threads` controls the number of threads to use for writing dirty pages from the buffer cache to disk. The default for both variables is 4.

The ability to increase the number of I/O threads can benefit systems that use multiple disks for `InnoDB`. However, the type of I/O being done should be considered. On systems that use buffered writes rather than direct writes, increasing the write thread count higher than 1 might yield little benefit because writes will be quick already.

Adjustable I/O Rate

Previously, the number of input/output operations per second (IOPS) that `InnoDB` will perform was a compile-time parameter. The rate was chosen to prevent background I/O from exhausting server capacity and the compiled-in value of 100 reflected an assumption that the server can perform 100

IOPS. However, many modern systems can exceed this, so the value is low and unnecessarily restricts I/O utilization.

MySQL 5.5 exposes this I/O rate parameter as a system variable, `innodb_io_capacity`. This variable can be set at server startup, which enables higher values to be selected for systems capable of higher I/O rates. Having a higher I/O rate can help the server handle a higher rate of row changes because it may be able to increase dirty-page flushing, deleted-row removal, and application of changes in the change buffer. The default value of `innodb_io_capacity` is 200. In general, you can increase the value as a function of the number of drives used for `InnoDB` I/O.

The ability to raise the I/O limit should be especially beneficial on platforms that support many IOPS. For example, systems that use multiple disks or solid-state disks for `InnoDB` are likely to benefit from the ability to control this parameter.

Diagnostic and Monitoring Capabilities

MySQL 5.5 provides improved access to execution and performance information. Diagnostic improvements include Performance Schema, Dtrace probes, expanded `SHOW ENGINE INNODB STATUS` output, Debug Sync, and a new status variable.

Performance Schema

Performance Schema is a feature for monitoring MySQL Server execution at a low level. See Chapter 22, *MySQL Performance Schema*.

DTrace Support

The DTrace probes work on Solaris, OS X, and FreeBSD. For information on using DTrace in MySQL, see Section 5.7, “Tracing mysqld Using DTrace”.

Enhanced `SHOW ENGINE INNODB STATUS` Output

The output from `SHOW ENGINE INNODB STATUS` includes more information due to changes made for `InnoDB Plugin`. A description of revisions to statement output follows.

A new `BACKGROUND THREAD` section has `srv_master_thread` lines that show work done by the main background thread.

```
----------
BACKGROUND THREAD
----------
srv_master_thread loops: 53 1_second, 44 sleeps, 5 10_second, 7 background,
  7 flush
srv_master_thread log flush and writes: 48
```

The `SEMAPHORES` section includes a line to show the number of spinlock rounds per OS wait for a mutex.

```
----------
SEMAPHORES
----------
...
Spin rounds per wait: 0.00 mutex, 20.00 RW-shared, 0.00 RW-excl
```

Debug Sync

The Debug Sync facility provides synchronization points for debugging, see MySQL Internals: Test Synchronization.

New Status Variable

The `Innodb_have_atomic_builtins` status variable provides information about availability of atomic instructions; see Scalability Improvements.

Enhanced Solaris Support

MySQL 5.5 incorporates several modifications for improved operation of MySQL Server on Solaris:

- DTrace support for execution monitoring. See Diagnostic and Monitoring Capabilities.
- Atomic instructions, which are needed for the improvements to RW-locking described in Scalability Improvements. Atomic instructions now are supported for Sun Studio on SPARC and x86 platforms. This extends their previous availability (supported for `gcc` 4.1 and up on all platforms).
- The SMP improvements described in Scalability Improvements, were originally intended for x86 platforms. In MySQL 5.5, these also work on SPARC platforms. Also, Solaris optimizations have been implemented.
- Large page support is enhanced for recent SPARC platforms. Standard use of large pages in MySQL attempts to use the largest size supported, up to 4MB. Under Solaris, a “super large pages” feature enables uses of pages up to 256MB. This feature can be enabled or disabled by using the `--super-large-pages` or `--skip-super-large-pages` option.
- Inline handling for `InnoDB` and processor instruction prefetching support, previously not enabled for builds created using Sun Studio, now are supported for that build environment.

1.5 MySQL Information Sources

This section lists sources of additional information that you may find helpful, such as MySQL web sites, mailing lists, user forums, and Internet Relay Chat.

1.5.1 MySQL Web Sites

The primary web site for MySQL documentation is http://dev.mysql.com/doc/. Online and downloadable documentation formats are available for the MySQL Reference Manual, MySQL Connectors, and more.

The MySQL developers provide information about new and upcoming features as the MySQL Server Blog.

1.5.2 MySQL Mailing Lists

This section introduces the MySQL mailing lists and provides guidelines as to how the lists should be used. When you subscribe to a mailing list, you receive all postings to the list as email messages. You can also send your own questions and answers to the list.

To subscribe to or unsubscribe from any of the mailing lists described in this section, visit http://lists.mysql.com/. For most of them, you can select the regular version of the list where you get individual messages, or a digest version where you get one large message per day.

Please *do not* send messages about subscribing or unsubscribing to any of the mailing lists, because such messages are distributed automatically to thousands of other users.

Your local site may have many subscribers to a MySQL mailing list. If so, the site may have a local mailing list, so that messages sent from `lists.mysql.com` to your site are propagated to the local list. In such cases, please contact your system administrator to be added to or dropped from the local MySQL list.

To have traffic for a mailing list go to a separate mailbox in your mail program, set up a filter based on the message headers. You can use either the `List-ID:` or `Delivered-To:` headers to identify list messages.

The MySQL mailing lists are as follows:

- `announce`

The list for announcements of new versions of MySQL and related programs. This is a low-volume list to which all MySQL users should subscribe.

- `mysql`

  The main list for general MySQL discussion. Please note that some topics are better discussed on the more-specialized lists. If you post to the wrong list, you may not get an answer.

- `bugs`

  The list for people who want to stay informed about issues reported since the last release of MySQL or who want to be actively involved in the process of bug hunting and fixing. See Section 1.6, “How to Report Bugs or Problems”.

- `internals`

  The list for people who work on the MySQL code. This is also the forum for discussions on MySQL development and for posting patches.

- `mysqldoc`

  The list for people who work on the MySQL documentation.

- `benchmarks`

  The list for anyone interested in performance issues. Discussions concentrate on database performance (not limited to MySQL), but also include broader categories such as performance of the kernel, file system, disk system, and so on.

- `packagers`

  The list for discussions on packaging and distributing MySQL. This is the forum used by distribution maintainers to exchange ideas on packaging MySQL and on ensuring that MySQL looks and feels as similar as possible on all supported platforms and operating systems.

- `java`

  The list for discussions about the MySQL server and Java. It is mostly used to discuss JDBC drivers such as MySQL Connector/J.

- `win32`

  The list for all topics concerning the MySQL software on Microsoft operating systems, such as Windows 9x, Me, NT, 2000, XP, and 2003.

- `myodbc`

  The list for all topics concerning connecting to the MySQL server with ODBC.

- `gui-tools`

  The list for all topics concerning MySQL graphical user interface tools such as MySQL Workbench.

- `cluster`

  The list for discussion of MySQL Cluster.

- `dotnet`

  The list for discussion of the MySQL server and the .NET platform. It is mostly related to MySQL Connector/Net.

- `plusplus`

The list for all topics concerning programming with the C++ API for MySQL.

- `perl`

  The list for all topics concerning Perl support for MySQL with `DBD::mysql`.

If you're unable to get an answer to your questions from a MySQL mailing list or forum, one option is to purchase support from Oracle. This puts you in direct contact with MySQL developers.

The following MySQL mailing lists are in languages other than English. These lists are not operated by Oracle.

- `<mysql-france-subscribe@yahoogroups.com>`

  A French mailing list.

- `<list@tinc.net>`

  A Korean mailing list. To subscribe, email `subscribe mysql your@email.address` to this list.

- `<mysql-de-request@lists.4t2.com>`

  A German mailing list. To subscribe, email `subscribe mysql-de your@email.address` to this list. You can find information about this mailing list at http://www.4t2.com/mysql/.

- `<mysql-br-request@listas.linkway.com.br>`

  A Portuguese mailing list. To subscribe, email `subscribe mysql-br your@email.address` to this list.

- `<mysql-alta@elistas.net>`

  A Spanish mailing list. To subscribe, email `subscribe mysql your@email.address` to this list.

1.5.2.1 Guidelines for Using the Mailing Lists

Please do not post mail messages from your browser with HTML mode turned on. Many users do not read mail with a browser.

When you answer a question sent to a mailing list, if you consider your answer to have broad interest, you may want to post it to the list instead of replying directly to the individual who asked. Try to make your answer general enough that people other than the original poster may benefit from it. When you post to the list, please make sure that your answer is not a duplication of a previous answer.

Try to summarize the essential part of the question in your reply. Do not feel obliged to quote the entire original message.

When answers are sent to you individually and not to the mailing list, it is considered good etiquette to summarize the answers and send the summary to the mailing list so that others may have the benefit of responses you received that helped you solve your problem.

1.5.3 MySQL Community Support at the MySQL Forums

The forums at http://forums.mysql.com are an important community resource. Many forums are available, grouped into these general categories:

- Migration
- MySQL Usage
- MySQL Connectors
- Programming Languages

- Tools
- 3rd-Party Applications
- Storage Engines
- MySQL Technology
- SQL Standards
- Business

1.5.4 MySQL Community Support on Internet Relay Chat (IRC)

In addition to the various MySQL mailing lists and forums, you can find experienced community people on Internet Relay Chat (IRC). These are the best networks/channels currently known to us:

freenode (see http://www.freenode.net/ for servers)

- `#mysql` is primarily for MySQL questions, but other database and general SQL questions are welcome. Questions about PHP, Perl, or C in combination with MySQL are also common.
- `#workbench` is primarily for MySQL Workbench related questions and thoughts, and it is also a good place to meet the MySQL Workbench developers.

If you are looking for IRC client software to connect to an IRC network, take a look at `xChat` (http://www.xchat.org/). X-Chat (GPL licensed) is available for Unix as well as for Windows platforms (a free Windows build of X-Chat is available at http://www.silverex.org/download/).

1.5.5 MySQL Enterprise

Oracle offers technical support in the form of MySQL Enterprise. For organizations that rely on the MySQL DBMS for business-critical production applications, MySQL Enterprise is a commercial subscription offering which includes:

- MySQL Enterprise Server
- MySQL Enterprise Monitor
- Monthly Rapid Updates and Quarterly Service Packs
- MySQL Knowledge Base
- 24x7 Technical and Consultative Support

MySQL Enterprise is available in multiple tiers, giving you the flexibility to choose the level of service that best matches your needs. For more information, see MySQL Enterprise.

1.6 How to Report Bugs or Problems

Before posting a bug report about a problem, please try to verify that it is a bug and that it has not been reported already:

- Start by searching the MySQL online manual at http://dev.mysql.com/doc/. We try to keep the manual up to date by updating it frequently with solutions to newly found problems. In addition, the release notes accompanying the manual can be particularly useful since it is quite possible that a newer version contains a solution to your problem. The release notes are available at the location just given for the manual.
- If you get a parse error for an SQL statement, please check your syntax closely. If you cannot find something wrong with it, it is extremely likely that your current version of MySQL Server doesn't support the syntax you are using. If you are using the current version and the manual doesn't cover the syntax that you are using, MySQL Server doesn't support your statement.

If the manual covers the syntax you are using, but you have an older version of MySQL Server, you should check the MySQL change history to see when the syntax was implemented. In this case, you have the option of upgrading to a newer version of MySQL Server.

- For solutions to some common problems, see Section B.5, “Problems and Common Errors”.
- Search the bugs database at http://bugs.mysql.com/ to see whether the bug has been reported and fixed.
- Search the MySQL mailing list archives at http://lists.mysql.com/. See Section 1.5.2, “MySQL Mailing Lists”.
- You can also use http://www.mysql.com/search/ to search all the Web pages (including the manual) that are located at the MySQL Web site.

If you cannot find an answer in the manual, the bugs database, or the mailing list archives, check with your local MySQL expert. If you still cannot find an answer to your question, please use the following guidelines for reporting the bug.

The normal way to report bugs is to visit http://bugs.mysql.com/, which is the address for our bugs database. This database is public and can be browsed and searched by anyone. If you log in to the system, you can enter new reports.

Bugs posted in the bugs database at http://bugs.mysql.com/ that are corrected for a given release are noted in the release notes.

If you find a sensitive security bug in MySQL Server, please let us know immediately by sending an email message to `<secalert_us@oracle.com>`. Exception: Support customers should report all problems, including security bugs, to Oracle Support at http://support.oracle.com/.

To discuss problems with other users, you can use one of the MySQL mailing lists. Section 1.5.2, “MySQL Mailing Lists”.

Writing a good bug report takes patience, but doing it right the first time saves time both for us and for yourself. A good bug report, containing a full test case for the bug, makes it very likely that we will fix the bug in the next release. This section helps you write your report correctly so that you do not waste your time doing things that may not help us much or at all. Please read this section carefully and make sure that all the information described here is included in your report.

Preferably, you should test the problem using the latest production or development version of MySQL Server before posting. Anyone should be able to repeat the bug by just using `mysql test < script_file` on your test case or by running the shell or Perl script that you include in the bug report. Any bug that we are able to repeat has a high chance of being fixed in the next MySQL release.

It is most helpful when a good description of the problem is included in the bug report. That is, give a good example of everything you did that led to the problem and describe, in exact detail, the problem itself. The best reports are those that include a full example showing how to reproduce the bug or problem. See Section 24.5, “Debugging and Porting MySQL”.

Remember that it is possible for us to respond to a report containing too much information, but not to one containing too little. People often omit facts because they think they know the cause of a problem and assume that some details do not matter. A good principle to follow is that if you are in doubt about stating something, state it. It is faster and less troublesome to write a couple more lines in your report than to wait longer for the answer if we must ask you to provide information that was missing from the initial report.

The most common errors made in bug reports are (a) not including the version number of the MySQL distribution that you use, and (b) not fully describing the platform on which the MySQL server is installed (including the platform type and version number). These are highly relevant pieces of information, and in 99 cases out of 100, the bug report is useless without them. Very often we get questions like, “Why doesn't this work for me?” Then we find that the feature requested wasn't

implemented in that MySQL version, or that a bug described in a report has been fixed in newer MySQL versions. Errors often are platform-dependent. In such cases, it is next to impossible for us to fix anything without knowing the operating system and the version number of the platform.

If you compiled MySQL from source, remember also to provide information about your compiler if it is related to the problem. Often people find bugs in compilers and think the problem is MySQL-related. Most compilers are under development all the time and become better version by version. To determine whether your problem depends on your compiler, we need to know what compiler you used. Note that every compiling problem should be regarded as a bug and reported accordingly.

If a program produces an error message, it is very important to include the message in your report. If we try to search for something from the archives, it is better that the error message reported exactly matches the one that the program produces. (Even the lettercase should be observed.) It is best to copy and paste the entire error message into your report. You should never try to reproduce the message from memory.

If you have a problem with Connector/ODBC (MyODBC), please try to generate a trace file and send it with your report. See How to Report Connector/ODBC Problems or Bugs.

If your report includes long query output lines from test cases that you run with the `mysql` command-line tool, you can make the output more readable by using the `--vertical` option or the `\G` statement terminator. The `EXPLAIN SELECT` example later in this section demonstrates the use of `\G`.

Please include the following information in your report:

- The version number of the MySQL distribution you are using (for example, MySQL 5.7.10). You can find out which version you are running by executing `mysqladmin version`. The `mysqladmin` program can be found in the `bin` directory under your MySQL installation directory.
- The manufacturer and model of the machine on which you experience the problem.
- The operating system name and version. If you work with Windows, you can usually get the name and version number by double-clicking your My Computer icon and pulling down the “Help/About Windows” menu. For most Unix-like operating systems, you can get this information by executing the command `uname -a`.
- Sometimes the amount of memory (real and virtual) is relevant. If in doubt, include these values.
- The contents of the `docs/INFO_BIN` file from your MySQL installation. This file contains information about how MySQL was configured and compiled.
- If you are using a source distribution of the MySQL software, include the name and version number of the compiler that you used. If you have a binary distribution, include the distribution name.
- If the problem occurs during compilation, include the exact error messages and also a few lines of context around the offending code in the file where the error occurs.
- If `mysqld` died, you should also report the statement that crashed `mysqld`. You can usually get this information by running `mysqld` with query logging enabled, and then looking in the log after `mysqld` crashes. See Section 24.5, “Debugging and Porting MySQL”.
- If a database table is related to the problem, include the output from the `SHOW CREATE TABLE` *`db_name.tbl_name`* statement in the bug report. This is a very easy way to get the definition of any table in a database. The information helps us create a situation matching the one that you have experienced.
- The SQL mode in effect when the problem occurred can be significant, so please report the value of the `sql_mode` system variable. For stored procedure, stored function, and trigger objects, the relevant `sql_mode` value is the one in effect when the object was created. For a stored procedure or function, the `SHOW CREATE PROCEDURE` or `SHOW CREATE FUNCTION` statement shows the relevant SQL mode, or you can query `INFORMATION_SCHEMA` for the information:

```
SELECT ROUTINE_SCHEMA, ROUTINE_NAME, SQL_MODE
FROM INFORMATION_SCHEMA.ROUTINES;
```

For triggers, you can use this statement:

```
SELECT EVENT_OBJECT_SCHEMA, EVENT_OBJECT_TABLE, TRIGGER_NAME, SQL_MODE
FROM INFORMATION_SCHEMA.TRIGGERS;
```

- For performance-related bugs or problems with `SELECT` statements, you should always include the output of `EXPLAIN SELECT ...`, and at least the number of rows that the `SELECT` statement produces. You should also include the output from `SHOW CREATE TABLE tbl_name` for each table that is involved. The more information you provide about your situation, the more likely it is that someone can help you.

  The following is an example of a very good bug report. The statements are run using the `mysql` command-line tool. Note the use of the `\G` statement terminator for statements that would otherwise provide very long output lines that are difficult to read.

  ```
  mysql> SHOW VARIABLES;
  mysql> SHOW COLUMNS FROM ...\G
         <output from SHOW COLUMNS>
  mysql> EXPLAIN SELECT ...\G
         <output from EXPLAIN>
  mysql> FLUSH STATUS;
  mysql> SELECT ...;
         <A short version of the output from SELECT,
         including the time taken to run the query>
  mysql> SHOW STATUS;
         <output from SHOW STATUS>
  ```

- If a bug or problem occurs while running `mysqld`, try to provide an input script that reproduces the anomaly. This script should include any necessary source files. The more closely the script can reproduce your situation, the better. If you can make a reproducible test case, you should upload it to be attached to the bug report.

  If you cannot provide a script, you should at least include the output from `mysqladmin variables extended-status processlist` in your report to provide some information on how your system is performing.

- If you cannot produce a test case with only a few rows, or if the test table is too big to be included in the bug report (more than 10 rows), you should dump your tables using `mysqldump` and create a `README` file that describes your problem. Create a compressed archive of your files using `tar` and `gzip` or `zip`. After you initiate a bug report for our bugs database at http://bugs.mysql.com/, click the Files tab in the bug report for instructions on uploading the archive to the bugs database.

- If you believe that the MySQL server produces a strange result from a statement, include not only the result, but also your opinion of what the result should be, and an explanation describing the basis for your opinion.

- When you provide an example of the problem, it is better to use the table names, variable names, and so forth that exist in your actual situation than to come up with new names. The problem could be related to the name of a table or variable. These cases are rare, perhaps, but it is better to be safe than sorry. After all, it should be easier for you to provide an example that uses your actual situation, and it is by all means better for us. If you have data that you do not want to be visible to others in the bug report, you can upload it using the Files tab as previously described. If the information is really top secret and you do not want to show it even to us, go ahead and provide an example using other names, but please regard this as the last choice.

- Include all the options given to the relevant programs, if possible. For example, indicate the options that you use when you start the `mysqld` server, as well as the options that you use to run any MySQL client programs. The options to programs such as `mysqld` and `mysql`, and to the `configure` script, are often key to resolving problems and are very relevant. It is never a bad idea

to include them. If your problem involves a program written in a language such as Perl or PHP, please include the language processor's version number, as well as the version for any modules that the program uses. For example, if you have a Perl script that uses the `DBI` and `DBD::mysql` modules, include the version numbers for Perl, `DBI`, and `DBD::mysql`.

- If your question is related to the privilege system, please include the output of `mysqladmin reload`, and all the error messages you get when trying to connect. When you test your privileges, you should execute `mysqladmin reload version` and try to connect with the program that gives you trouble.
- If you have a patch for a bug, do include it. But do not assume that the patch is all we need, or that we can use it, if you do not provide some necessary information such as test cases showing the bug that your patch fixes. We might find problems with your patch or we might not understand it at all. If so, we cannot use it.

  If we cannot verify the exact purpose of the patch, we will not use it. Test cases help us here. Show that the patch handles all the situations that may occur. If we find a borderline case (even a rare one) where the patch will not work, it may be useless.
- Guesses about what the bug is, why it occurs, or what it depends on are usually wrong. Even the MySQL team cannot guess such things without first using a debugger to determine the real cause of a bug.
- Indicate in your bug report that you have checked the reference manual and mail archive so that others know you have tried to solve the problem yourself.
- If your data appears corrupt or you get errors when you access a particular table, first check your tables with `CHECK TABLE`. If that statement reports any errors:
  - The `InnoDB` crash recovery mechanism handles cleanup when the server is restarted after being killed, so in typical operation there is no need to “repair” tables. If you encounter an error with `InnoDB` tables, restart the server and see whether the problem persists, or whether the error affected only cached data in memory. If data is corrupted on disk, consider restarting with the `innodb_force_recovery` option enabled so that you can dump the affected tables.
  - For non-transactional tables, try to repair them with `REPAIR TABLE` or with `myisamchk`. See Chapter 5, *MySQL Server Administration*.

  If you are running Windows, please verify the value of `lower_case_table_names` using the `SHOW VARIABLES LIKE 'lower_case_table_names'` statement. This variable affects how the server handles lettercase of database and table names. Its effect for a given value should be as described in Section 9.2.2, “Identifier Case Sensitivity”.
- If you often get corrupted tables, you should try to find out when and why this happens. In this case, the error log in the MySQL data directory may contain some information about what happened. (This is the file with the `.err` suffix in the name.) See Section 5.4.2, “The Error Log”. Please include any relevant information from this file in your bug report. Normally `mysqld` should *never* crash a table if nothing killed it in the middle of an update. If you can find the cause of `mysqld` dying, it is much easier for us to provide you with a fix for the problem. See Section B.5.1, “How to Determine What Is Causing a Problem”.
- If possible, download and install the most recent version of MySQL Server and check whether it solves your problem. All versions of the MySQL software are thoroughly tested and should work without problems. We believe in making everything as backward-compatible as possible, and you should be able to switch MySQL versions without difficulty. See Section 2.1.1, “Which MySQL Version and Distribution to Install”.

1.7 MySQL Standards Compliance

This section describes how MySQL relates to the ANSI/ISO SQL standards. MySQL Server has many extensions to the SQL standard, and here you can find out what they are and how to use them. You

can also find information about functionality missing from MySQL Server, and how to work around some of the differences.

The SQL standard has been evolving since 1986 and several versions exist. In this manual, “SQL-92” refers to the standard released in 1992, “SQL:1999” refers to the standard released in 1999, “SQL:2003” refers to the standard released in 2003, and “SQL:2008” refers to the most recent version of the standard, released in 2008. We use the phrase “the SQL standard” or “standard SQL” to mean the current version of the SQL Standard at any time.

One of our main goals with the product is to continue to work toward compliance with the SQL standard, but without sacrificing speed or reliability. We are not afraid to add extensions to SQL or support for non-SQL features if this greatly increases the usability of MySQL Server for a large segment of our user base. The `HANDLER` interface is an example of this strategy. See Section 13.2.4, “HANDLER Syntax”.

We continue to support transactional and nontransactional databases to satisfy both mission-critical 24/7 usage and heavy Web or logging usage.

MySQL Server was originally designed to work with medium-sized databases (10-100 million rows, or about 100MB per table) on small computer systems. Today MySQL Server handles terabyte-sized databases, but the code can also be compiled in a reduced version suitable for hand-held and embedded devices. The compact design of the MySQL server makes development in both directions possible without any conflicts in the source tree.

We are not targeting real-time support, although MySQL replication capabilities offer significant functionality.

MySQL supports ODBC levels 0 to 3.51.

MySQL supports high-availability database clustering using the `NDBCLUSTER` storage engine. See Chapter 18, *MySQL NDB Cluster 7.2*.

We are implementing XML functionality beginning in MySQL 5.1, which supports most of the W3C XPath standard. See Section 12.11, “XML Functions”.

Selecting SQL Modes

The MySQL server can operate in different SQL modes, and can apply these modes differently for different clients, depending on the value of the `sql_mode` system variable. DBAs can set the global SQL mode to match site server operating requirements, and each application can set its session SQL mode to its own requirements.

Modes affect the SQL syntax MySQL supports and the data validation checks it performs. This makes it easier to use MySQL in different environments and to use MySQL together with other database servers.

For more information on setting the SQL mode, see Section 5.1.8, “Server SQL Modes”.

Running MySQL in ANSI Mode

To run MySQL Server in ANSI mode, start `mysqld` with the `--ansi` option. Running the server in ANSI mode is the same as starting it with the following options:

```
--transaction-isolation=SERIALIZABLE --sql-mode=ANSI
```

To achieve the same effect at runtime, execute these two statements:

```
SET GLOBAL TRANSACTION ISOLATION LEVEL SERIALIZABLE;
SET GLOBAL sql_mode = 'ANSI';
```

You can see that setting the `sql_mode` system variable to `'ANSI'` enables all SQL mode options that are relevant for ANSI mode as follows:

```
mysql> SET GLOBAL sql_mode='ANSI';
mysql> SELECT @@global.sql_mode;
        -> 'REAL_AS_FLOAT,PIPES_AS_CONCAT,ANSI_QUOTES,IGNORE_SPACE,ANSI'
```

Running the server in ANSI mode with `--ansi` is not quite the same as setting the SQL mode to `'ANSI'` because the `--ansi` option also sets the transaction isolation level.

See Section 5.1.4, “Server Command Options”.

1.7.1 MySQL Extensions to Standard SQL

MySQL Server supports some extensions that you probably will not find in other SQL DBMSs. Be warned that if you use them, your code will not be portable to other SQL servers. In some cases, you can write code that includes MySQL extensions, but is still portable, by using comments of the following form:

```
/*! MySQL-specific code */
```

In this case, MySQL Server parses and executes the code within the comment as it would any other SQL statement, but other SQL servers will ignore the extensions. For example, MySQL Server recognizes the `STRAIGHT_JOIN` keyword in the following statement, but other servers will not:

```
SELECT /*! STRAIGHT_JOIN */ col1 FROM table1,table2 WHERE ...
```

If you add a version number after the `!` character, the syntax within the comment is executed only if the MySQL version is greater than or equal to the specified version number. The `KEY_BLOCK_SIZE` clause in the following comment is executed only by servers from MySQL 5.1.10 or higher:

```
CREATE TABLE t1(a INT, KEY (a)) /*!50110 KEY_BLOCK_SIZE=1024 */;
```

The following descriptions list MySQL extensions, organized by category.

- Organization of data on disk

  MySQL Server maps each database to a directory under the MySQL data directory, and maps tables within a database to file names in the database directory. This has a few implications:

  - Database and table names are case sensitive in MySQL Server on operating systems that have case-sensitive file names (such as most Unix systems). See Section 9.2.2, “Identifier Case Sensitivity”.
  - You can use standard system commands to back up, rename, move, delete, and copy tables that are managed by the `MyISAM` storage engine. For example, it is possible to rename a `MyISAM` table by renaming the `.MYD`, `.MYI`, and `.frm` files to which the table corresponds. (Nevertheless, it is preferable to use `RENAME TABLE` or `ALTER TABLE ... RENAME` and let the server rename the files.)

- General language syntax

  - By default, strings can be enclosed by `"` as well as `'`. If the `ANSI_QUOTES` SQL mode is enabled, strings can be enclosed only by `'` and the server interprets strings enclosed by `"` as identifiers.
  - `\` is the escape character in strings.
  - In SQL statements, you can access tables from different databases with the *`db_name.tbl_name`* syntax. Some SQL servers provide the same functionality but call this `User space`. MySQL Server doesn't support tablespaces such as used in statements like this: `CREATE TABLE ralph.my_table ... IN my_tablespace`.

- SQL statement syntax

- The `ANALYZE TABLE`, `CHECK TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` statements.
- The `CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE` statements. See Section 13.1.10, “CREATE DATABASE Syntax”, Section 13.1.21, “DROP DATABASE Syntax”, and Section 13.1.1, “ALTER DATABASE Syntax”.
- The `DO` statement.
- `EXPLAIN SELECT` to obtain a description of how tables are processed by the query optimizer.
- The `FLUSH` and `RESET` statements.
- The `SET` statement. See Section 13.7.4.1, “SET Syntax for Variable Assignment”.
- The `SHOW` statement. See Section 13.7.5, “SHOW Syntax”. The information produced by many of the MySQL-specific `SHOW` statements can be obtained in more standard fashion by using `SELECT` to query `INFORMATION_SCHEMA`. See Chapter 21, *INFORMATION_SCHEMA Tables*.
- Use of `LOAD DATA INFILE`. In many cases, this syntax is compatible with Oracle's `LOAD DATA INFILE`. See Section 13.2.6, “LOAD DATA INFILE Syntax”.
- Use of `RENAME TABLE`. See Section 13.1.32, “RENAME TABLE Syntax”.
- Use of `REPLACE` instead of `DELETE` plus `INSERT`. See Section 13.2.8, “REPLACE Syntax”.
- Use of `CHANGE col_name`, `DROP col_name`, or `DROP INDEX`, `IGNORE` or `RENAME` in `ALTER TABLE` statements. Use of multiple `ADD`, `ALTER`, `DROP`, or `CHANGE` clauses in an `ALTER TABLE` statement. See Section 13.1.7, “ALTER TABLE Syntax”.
- Use of index names, indexes on a prefix of a column, and use of `INDEX` or `KEY` in `CREATE TABLE` statements. See Section 13.1.17, “CREATE TABLE Syntax”.
- Use of `TEMPORARY` or `IF NOT EXISTS` with `CREATE TABLE`.
- Use of `IF EXISTS` with `DROP TABLE` and `DROP DATABASE`.
- The capability of dropping multiple tables with a single `DROP TABLE` statement.
- The `ORDER BY` and `LIMIT` clauses of the `UPDATE` and `DELETE` statements.
- `INSERT INTO tbl_name SET col_name = ...` syntax.
- The `DELAYED` clause of the `INSERT` and `REPLACE` statements.
- The `LOW_PRIORITY` clause of the `INSERT`, `REPLACE`, `DELETE`, and `UPDATE` statements.
- Use of `INTO OUTFILE` or `INTO DUMPFILE` in `SELECT` statements. See Section 13.2.9, “SELECT Syntax”.
- Options such as `STRAIGHT_JOIN` or `SQL_SMALL_RESULT` in `SELECT` statements.
- You don't need to name all selected columns in the `GROUP BY` clause. This gives better performance for some very specific, but quite normal queries. See Section 12.16, “Aggregate (GROUP BY) Functions”.
- You can specify `ASC` and `DESC` with `GROUP BY`, not just with `ORDER BY`.
- The ability to set variables in a statement with the `:=` assignment operator. See Section 9.4, “User-Defined Variables”.

- Data types

  - The `MEDIUMINT`, `SET`, and `ENUM` data types, and the various `BLOB` and `TEXT` data types.
  - The `AUTO_INCREMENT`, `BINARY`, `NULL`, `UNSIGNED`, and `ZEROFILL` data type attributes.
- Functions and operators
  - To make it easier for users who migrate from other SQL environments, MySQL Server supports aliases for many functions. For example, all string functions support both standard SQL syntax and ODBC syntax.
  - MySQL Server understands the `||` and `&&` operators to mean logical OR and AND, as in the C programming language. In MySQL Server, `||` and `OR` are synonyms, as are `&&` and `AND`. Because of this nice syntax, MySQL Server doesn't support the standard SQL `||` operator for string concatenation; use `CONCAT()` instead. Because `CONCAT()` takes any number of arguments, it is easy to convert use of the `||` operator to MySQL Server.
  - Use of `COUNT(DISTINCT value_list)` where *`value_list`* has more than one element.
  - String comparisons are case insensitive by default, with sort ordering determined by the collation of the current character set, which is `latin1` (cp1252 West European) by default. To perform case-sensitive comparisons instead, you should declare your columns with the `BINARY` attribute or use the `BINARY` cast, which causes comparisons to be done using the underlying character code values rather than a lexical ordering.
  - The `%` operator is a synonym for `MOD()`. That is, *`N % M`* is equivalent to `MOD(N,M)`. `%` is supported for C programmers and for compatibility with PostgreSQL.
  - The `=`, `<>`, `<=`, `<`, `>=`, `>`, `<<`, `>>`, `<=>`, `AND`, `OR`, or `LIKE` operators may be used in expressions in the output column list (to the left of the `FROM`) in `SELECT` statements. For example:

    ```
    mysql> SELECT col1=1 AND col2=2 FROM my_table;
    ```

  - The `LAST_INSERT_ID()` function returns the most recent `AUTO_INCREMENT` value. See Section 12.14, “Information Functions”.
  - `LIKE` is permitted on numeric values.
  - The `REGEXP` and `NOT REGEXP` extended regular expression operators.
  - `CONCAT()` or `CHAR()` with one argument or more than two arguments. (In MySQL Server, these functions can take a variable number of arguments.)
  - The `BIT_COUNT()`, `CASE`, `ELT()`, `FROM_DAYS()`, `FORMAT()`, `IF()`, `PASSWORD()`, `ENCRYPT()`, `MD5()`, `ENCODE()`, `DECODE()`, `PERIOD_ADD()`, `PERIOD_DIFF()`, `TO_DAYS()`, and `WEEKDAY()` functions.
  - Use of `TRIM()` to trim substrings. Standard SQL supports removal of single characters only.
  - The `GROUP BY` functions `STD()`, `BIT_OR()`, `BIT_AND()`, `BIT_XOR()`, and `GROUP_CONCAT()`. See Section 12.16, “Aggregate (GROUP BY) Functions”.

1.7.2 MySQL Differences from Standard SQL

We try to make MySQL Server follow the ANSI SQL standard and the ODBC SQL standard, but MySQL Server performs operations differently in some cases:

- There are several differences between the MySQL and standard SQL privilege systems. For example, in MySQL, privileges for a table are not automatically revoked when you delete a table. You must explicitly issue a `REVOKE` statement to revoke privileges for a table. For more information, see Section 13.7.1.5, “REVOKE Syntax”.

- The `CAST()` function does not support cast to `REAL` or `BIGINT`. See Section 12.10, “Cast Functions and Operators”.

1.7.2.1 SELECT INTO TABLE Differences

MySQL Server doesn't support the `SELECT ... INTO TABLE` Sybase SQL extension. Instead, MySQL Server supports the `INSERT INTO ... SELECT` standard SQL syntax, which is basically the same thing. See Section 13.2.5.1, “INSERT ... SELECT Syntax”. For example:

```
INSERT INTO tbl_temp2 (fld_id)
    SELECT tbl_temp1.fld_order_id
    FROM tbl_temp1 WHERE tbl_temp1.fld_order_id > 100;
```

Alternatively, you can use `SELECT ... INTO OUTFILE` or `CREATE TABLE ... SELECT`.

You can use `SELECT ... INTO` with user-defined variables. The same syntax can also be used inside stored routines using cursors and local variables. See Section 13.2.9.1, “SELECT ... INTO Syntax”.

1.7.2.2 UPDATE Differences

If you access a column from the table to be updated in an expression, `UPDATE` uses the current value of the column. The second assignment in the following statement sets `col2` to the current (updated) `col1` value, not the original `col1` value. The result is that `col1` and `col2` have the same value. This behavior differs from standard SQL.

```
UPDATE t1 SET col1 = col1 + 1, col2 = col1;
```

1.7.2.3 Foreign Key Differences

The MySQL implementation of foreign keys differs from the SQL standard in the following key respects:

- If there are several rows in the parent table that have the same referenced key value, `InnoDB` acts in foreign key checks as if the other parent rows with the same key value do not exist. For example, if you have defined a `RESTRICT` type constraint, and there is a child row with several parent rows, `InnoDB` does not permit the deletion of any of those parent rows.

  `InnoDB` performs cascading operations through a depth-first algorithm, based on records in the indexes corresponding to the foreign key constraints.

- A `FOREIGN KEY` constraint that references a non-`UNIQUE` key is not standard SQL but rather an `InnoDB` extension.

- If `ON UPDATE CASCADE` or `ON UPDATE SET NULL` recurses to update the *same table* it has previously updated during the same cascade, it acts like `RESTRICT`. This means that you cannot use self-referential `ON UPDATE CASCADE` or `ON UPDATE SET NULL` operations. This is to prevent infinite loops resulting from cascaded updates. A self-referential `ON DELETE SET NULL`, on the other hand, is possible, as is a self-referential `ON DELETE CASCADE`. Cascading operations may not be nested more than 15 levels deep.

- In an SQL statement that inserts, deletes, or updates many rows, foreign key constraints (like unique constraints) are checked row-by-row. When performing foreign key checks, `InnoDB` sets shared row-level locks on child or parent records that it must examine. MySQL checks foreign key constraints immediately; the check is not deferred to transaction commit. According to the SQL standard, the default behavior should be deferred checking. That is, constraints are only checked after the *entire SQL statement* has been processed. This means that it is not possible to delete a row that refers to itself using a foreign key.

For information about how the `InnoDB` storage engine handles foreign keys, see Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”.

1.7.2.4 '--' as the Start of a Comment

Standard SQL uses the C syntax `/* this is a comment */` for comments, and MySQL Server supports this syntax as well. MySQL also support extensions to this syntax that enable MySQL-specific SQL to be embedded in the comment, as described in Section 9.6, “Comment Syntax”.

Standard SQL uses “`--`” as a start-comment sequence. MySQL Server uses `#` as the start comment character. MySQL Server also supports a variant of the `--` comment style. That is, the `--` start-comment sequence must be followed by a space (or by a control character such as a newline). The space is required to prevent problems with automatically generated SQL queries that use constructs such as the following, where we automatically insert the value of the payment for `payment`:

```
UPDATE account SET credit=credit-payment
```

Consider about what happens if `payment` has a negative value such as `-1`:

```
UPDATE account SET credit=credit--1
```

`credit--1` is a valid expression in SQL, but `--` is interpreted as the start of a comment, part of the expression is discarded. The result is a statement that has a completely different meaning than intended:

```
UPDATE account SET credit=credit
```

The statement produces no change in value at all. This illustrates that permitting comments to start with `--` can have serious consequences.

Using our implementation requires a space following the `--` for it to be recognized as a start-comment sequence in MySQL Server. Therefore, `credit--1` is safe to use.

Another safe feature is that the `mysql` command-line client ignores lines that start with `--`.

1.7.3 How MySQL Deals with Constraints

MySQL enables you to work both with transactional tables that permit rollback and with nontransactional tables that do not. Because of this, constraint handling is a bit different in MySQL than in other DBMSs. We must handle the case when you have inserted or updated a lot of rows in a nontransactional table for which changes cannot be rolled back when an error occurs.

The basic philosophy is that MySQL Server tries to produce an error for anything that it can detect while parsing a statement to be executed, and tries to recover from any errors that occur while executing the statement. We do this in most cases, but not yet for all.

The options MySQL has when an error occurs are to stop the statement in the middle or to recover as well as possible from the problem and continue. By default, the server follows the latter course. This means, for example, that the server may coerce invalid values to the closest valid values.

Several SQL mode options are available to provide greater control over handling of bad data values and whether to continue statement execution or abort when errors occur. Using these options, you can configure MySQL Server to act in a more traditional fashion that is like other DBMSs that reject improper input. The SQL mode can be set globally at server startup to affect all clients. Individual clients can set the SQL mode at runtime, which enables each client to select the behavior most appropriate for its requirements. See Section 5.1.8, “Server SQL Modes”.

The following sections describe how MySQL Server handles different types of constraints.

1.7.3.1 PRIMARY KEY and UNIQUE Index Constraints

Normally, errors occur for data-change statements (such as `INSERT` or `UPDATE`) that would violate primary-key, unique-key, or foreign-key constraints. If you are using a transactional storage engine such as `InnoDB`, MySQL automatically rolls back the statement. If you are using a nontransactional storage engine, MySQL stops processing the statement at the row for which the error occurred and leaves any remaining rows unprocessed.

MySQL supports an `IGNORE` keyword for `INSERT`, `UPDATE`, and so forth. If you use it, MySQL ignores primary-key or unique-key violations and continues processing with the next row. See the section for the statement that you are using (Section 13.2.5, “INSERT Syntax”, Section 13.2.11, “UPDATE Syntax”, and so forth).

You can get information about the number of rows actually inserted or updated with the `mysql_info()` C API function. You can also use the `SHOW WARNINGS` statement. See Section 23.8.7.35, “mysql_info()”, and Section 13.7.5.41, “SHOW WARNINGS Syntax”.

Only `InnoDB` tables support foreign keys. See Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”.

1.7.3.2 FOREIGN KEY Constraints

Foreign keys let you cross-reference related data across tables, and foreign key constraints help keep this spread-out data consistent.

MySQL supports `ON UPDATE` and `ON DELETE` foreign key references in `CREATE TABLE` and `ALTER TABLE` statements. The available referential actions are `RESTRICT` (the default), `CASCADE`, `SET NULL`, and `NO ACTION`.

`SET DEFAULT` is also supported by the MySQL Server but is currently rejected as invalid by `InnoDB`. Since MySQL does not support deferred constraint checking, `NO ACTION` is treated as `RESTRICT`. For the exact syntax supported by MySQL for foreign keys, see Section 13.1.17.6, “Using FOREIGN KEY Constraints”.

`MATCH FULL`, `MATCH PARTIAL`, and `MATCH SIMPLE` are allowed, but their use should be avoided, as they cause the MySQL Server to ignore any `ON DELETE` or `ON UPDATE` clause used in the same statement. `MATCH` options do not have any other effect in MySQL, which in effect enforces `MATCH SIMPLE` semantics full-time.

MySQL requires that foreign key columns be indexed; if you create a table with a foreign key constraint but no index on a given column, an index is created.

You can obtain information about foreign keys from the `INFORMATION_SCHEMA.KEY_COLUMN_USAGE` table. An example of a query against this table is shown here:

```
mysql> SELECT TABLE_SCHEMA, TABLE_NAME, COLUMN_NAME, CONSTRAINT_NAME
     > FROM INFORMATION_SCHEMA.KEY_COLUMN_USAGE
     > WHERE REFERENCED_TABLE_SCHEMA IS NOT NULL;
+--------------+---------------+-------------+-----------------+
| TABLE_SCHEMA | TABLE_NAME    | COLUMN_NAME | CONSTRAINT_NAME |
+--------------+---------------+-------------+-----------------+
| fk1          | myuser        | myuser_id   | f               |
| fk1          | product_order | customer_id | f2              |
| fk1          | product_order | product_id  | f1              |
+--------------+---------------+-------------+-----------------+
3 rows in set (0.01 sec)
```

Only `InnoDB` tables support foreign keys. See Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”, for information specific to foreign key support in `InnoDB`.

1.7.3.3 Constraints on Invalid Data

By default, MySQL is forgiving of invalid or improper data values and coerces them to valid values for data entry. However, you can enable strict SQL mode to select more traditional treatment of bad values such that the server rejects them and aborts the statement in which they occur. See Section 5.1.8, “Server SQL Modes”.

This section describes the default (forgiving) behavior of MySQL, as well as the strict SQL mode and how it differs.

If you are not using strict mode, then whenever you insert an “incorrect” value into a column, such as a `NULL` into a `NOT NULL` column or a too-large numeric value into a numeric column, MySQL sets the column to the “best possible value” instead of producing an error: The following rules describe in more detail how this works:

- If you try to store an out of range value into a numeric column, MySQL Server instead stores zero, the smallest possible value, or the largest possible value, whichever is closest to the invalid value.
- For strings, MySQL stores either the empty string or as much of the string as can be stored in the column.
- If you try to store a string that does not start with a number into a numeric column, MySQL Server stores 0.
- Invalid values for `ENUM` and `SET` columns are handled as described in Section 1.7.3.4, “ENUM and SET Constraints”.
- MySQL permits you to store certain incorrect date values into `DATE` and `DATETIME` columns (such as `'2000-02-31'` or `'2000-02-00'`). In this case, when an application has not enabled strict SQL mode, it up to the application to validate the dates before storing them. If MySQL can store a date value and retrieve exactly the same value, MySQL stores it as given. If the date is totally wrong (outside the server's ability to store it), the special “zero” date value `'0000-00-00'` is stored in the column instead.
- If you try to store `NULL` into a column that doesn't take `NULL` values, an error occurs for single-row `INSERT` statements. For multiple-row `INSERT` statements or for `INSERT INTO ... SELECT` statements, MySQL Server stores the implicit default value for the column data type. In general, this is `0` for numeric types, the empty string (`''`) for string types, and the “zero” value for date and time types. Implicit default values are discussed in Section 11.6, “Data Type Default Values”.
- If an `INSERT` statement specifies no value for a column, MySQL inserts its default value if the column definition includes an explicit `DEFAULT` clause. If the definition has no such `DEFAULT` clause, MySQL inserts the implicit default value for the column data type.

The reason for using the preceding rules in nonstrict mode is that we can't check these conditions until the statement has begun executing. We can't just roll back if we encounter a problem after updating a few rows, because the storage engine may not support rollback. The option of terminating the statement is not that good; in this case, the update would be “half done,” which is probably the worst possible scenario. In this case, it is better to “do the best you can” and then continue as if nothing happened.

You can select stricter treatment of input values by using the `STRICT_TRANS_TABLES` or `STRICT_ALL_TABLES` SQL modes:

```
SET sql_mode = 'STRICT_TRANS_TABLES';
SET sql_mode = 'STRICT_ALL_TABLES';
```

`STRICT_TRANS_TABLES` enables strict mode for transactional storage engines, and also to some extent for nontransactional engines. It works like this:

- For transactional storage engines, bad data values occurring anywhere in a statement cause the statement to abort and roll back.

- For nontransactional storage engines, a statement aborts if the error occurs in the first row to be inserted or updated. (When the error occurs in the first row, the statement can be aborted to leave the table unchanged, just as for a transactional table.) Errors in rows after the first do not abort the statement, because the table has already been changed by the first row. Instead, bad data values are adjusted and result in warnings rather than errors. In other words, with `STRICT_TRANS_TABLES`, a wrong value causes MySQL to roll back all updates done so far, if that can be done without changing the table. But once the table has been changed, further errors result in adjustments and warnings.

For even stricter checking, enable `STRICT_ALL_TABLES`. This is the same as `STRICT_TRANS_TABLES` except that for nontransactional storage engines, errors abort the statement even for bad data in rows following the first row. This means that if an error occurs partway through a multiple-row insert or update for a nontransactional table, a partial update results. Earlier rows are inserted or updated, but those from the point of the error on are not. To avoid this for nontransactional tables, either use single-row statements or else use `STRICT_TRANS_TABLES` if conversion warnings rather than errors are acceptable. To avoid problems in the first place, do not use MySQL to check column content. It is safest (and often faster) to let the application ensure that it passes only valid values to the database.

With either of the strict mode options, you can cause errors to be treated as warnings by using `INSERT IGNORE` or `UPDATE IGNORE` rather than `INSERT` or `UPDATE` without `IGNORE`.

1.7.3.4 ENUM and SET Constraints

`ENUM` and `SET` columns provide an efficient way to define columns that can contain only a given set of values. See Section 11.4.4, “The ENUM Type”, and Section 11.4.5, “The SET Type”.

With strict mode enabled (see Section 5.1.8, “Server SQL Modes”), the definition of a `ENUM` or `SET` column acts as a constraint on values entered into the column. An error occurs for values that do not satisfy these conditions:

- An `ENUM` value must be one of those listed in the column definition, or the internal numeric equivalent thereof. The value cannot be the error value (that is, 0 or the empty string). For a column defined as `ENUM('a','b','c')`, values such as `''`, `'d'`, or `'ax'` are invalid and are rejected.
- A `SET` value must be the empty string or a value consisting only of the values listed in the column definition separated by commas. For a column defined as `SET('a','b','c')`, values such as `'d'` or `'a,b,c,d'` are invalid and are rejected.

Errors for invalid values can be suppressed in strict mode if you use `INSERT IGNORE` or `UPDATE IGNORE`. In this case, a warning is generated rather than an error. For `ENUM`, the value is inserted as the error member (`0`). For `SET`, the value is inserted as given except that any invalid substrings are deleted. For example, `'a,x,b,y'` results in a value of `'a,b'`.

1.8 Credits

The following sections list developers, contributors, and supporters that have helped to make MySQL what it is today.

1.8.1 Contributors to MySQL

Although Oracle Corporation and/or its affiliates own all copyrights in the `MySQL server` and the `MySQL manual`, we wish to recognize those who have made contributions of one kind or another to the `MySQL distribution`. Contributors are listed here, in somewhat random order:

- Gianmassimo Vigazzola `<qwerg@mbox.vol.it>` or `<qwerg@tin.it>`

  The initial port to Win32/NT.

- Per Eric Olsson

For constructive criticism and real testing of the dynamic record format.

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  Win32 port with Borland compiler. `mysqlshutdown.exe` and `mysqlwatch.exe`.

- David J. Hughes

  For the effort to make a shareware SQL database. At TcX, the predecessor of MySQL AB, we started with `mSQL`, but found that it couldn't satisfy our purposes so instead we wrote an SQL interface to our application builder Unireg. `mysqladmin` and `mysql` client are programs that were largely influenced by their `mSQL` counterparts. We have put a lot of effort into making the MySQL syntax a superset of `mSQL`. Many of the API's ideas are borrowed from `mSQL` to make it easy to port free `mSQL` programs to the MySQL API. The MySQL software doesn't contain any code from `mSQL`. Two files in the distribution (`client/insert_test.c` and `client/select_test.c`) are based on the corresponding (noncopyrighted) files in the `mSQL` distribution, but are modified as examples showing the changes necessary to convert code from `mSQL` to MySQL Server. (`mSQL` is copyrighted David J. Hughes.)

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  Czech sorting order.

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  FROM_UNIXTIME() time formatting, ENCRYPT() functions, and bison advisor. Active mailing list member.

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  Irix setup.

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  `DBD::mysql` questions.

- Boyd Lynn Gerber <gerberb@zenez.com>

  SCO-related questions.

- Richard Mehalick <RM186061@shellus.com>

  `xmysql`-related questions and basic installation questions.

- Zeev Suraski <bourbon@netvision.net.il>

  Apache module configuration questions (log & auth), PHP-related questions, SQL syntax-related questions and other general questions.

- Francesc Guasch <frankie@citel.upc.es>

  General questions.

- Jonathan J Smith <jsmith@wtp.net>

  Questions pertaining to OS-specifics with Linux, SQL syntax, and other things that might need some work.

- David Sklar <sklar@student.net>

  Using MySQL from PHP and Perl.

- Alistair MacDonald <A.MacDonald@uel.ac.uk>

  Is flexible and can handle Linux and perhaps HP-UX.

- John Lyon <jlyon@imag.net>

  Questions about installing MySQL on Linux systems, using either `.rpm` files or compiling from source.

- Lorvid Ltd. <lorvid@WOLFENET.com>

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DBD, Linux, some SQL syntax questions.

1.8.2 Documenters and translators

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  Ongoing help with making this manual correct and understandable. That includes rewriting Monty's and David's attempts at English into English as other people know it.

- Kim Aldale

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  For the first MySQL manual. And a lot of spelling/language fixes for the FAQ (that turned into the MySQL manual a long time ago).

- Yan Cailin

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  French error messages.

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German error messages.

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1.8.3 Packages that support MySQL

The following is a list of creators/maintainers of some of the most important API/packages/applications that a lot of people use with MySQL.

We cannot list every possible package here because the list would then be way to hard to maintain. For other packages, please refer to the software portal at http://solutions.mysql.com/software/.

- Tim Bunce, Alligator Descartes

  For the `DBD` (Perl) interface.

- Andreas Koenig <a.koenig@mind.de>

  For the Perl interface for MySQL Server.

- Jochen Wiedmann <wiedmann@neckar-alb.de>

  For maintaining the Perl `DBD::mysql` module.

- Eugene Chan <eugene@acenet.com.sg>

  For porting PHP for MySQL Server.

- Georg Richter

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- Giovanni Maruzzelli <maruzz@matrice.it>

  For porting iODBC (Unix ODBC).

- Xavier Leroy <Xavier.Leroy@inria.fr>

  The author of LinuxThreads (used by the MySQL Server on Linux).

1.8.4 Tools that were used to create MySQL

The following is a list of some of the tools we have used to create MySQL. We use this to express our thanks to those that has created them as without these we could not have made MySQL what it is today.

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  From whom we got an excellent compiler (`gcc`), an excellent debugger (`gdb` and the `libc` library (from which we have borrowed `strto.c` to get some code working in Linux).

- Free Software Foundation & The XEmacs development team

  For a really great editor/environment.

- Julian Seward

  Author of `valgrind`, an excellent memory checker tool that has helped us find a lot of otherwise hard to find bugs in MySQL.

- Dorothea Lütkehaus and Andreas Zeller

  For `DDD` (The Data Display Debugger) which is an excellent graphical front end to `gdb`).

1.8.5 Supporters of MySQL

Although Oracle Corporation and/or its affiliates own all copyrights in the `MySQL server` and the `MySQL manual`, we wish to recognize the following companies, which helped us finance the development of the `MySQL server`, such as by paying us for developing a new feature or giving us hardware for development of the `MySQL server`.

- VA Linux / Andover.net

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- NuSphere

  Editing of the MySQL manual.

- Stork Design studio

  The MySQL Web site in use between 1998-2000.

- Intel

  Contributed to development on Windows and Linux platforms.

- Compaq

  Contributed to Development on Linux/Alpha.

- SWSoft

  Development on the embedded `mysqld` version.

- FutureQuest

  The `--skip-show-database` option.

Chapter 2 Installing and Upgrading MySQL

Table of Contents

2.1 General Installation Guidance 43
2.1.1 Which MySQL Version and Distribution to Install 43
2.1.2 How to Get MySQL 45
2.1.3 Verifying Package Integrity Using MD5 Checksums or GnuPG 45
2.1.4 Installation Layouts 59
2.1.5 Compiler-Specific Build Characteristics 59
2.2 Installing MySQL on Unix/Linux Using Generic Binaries 59
2.3 Installing MySQL on Microsoft Windows 62
2.3.1 MySQL Installation Layout on Microsoft Windows 65
2.3.2 Choosing an Installation Package 65
2.3.3 MySQL Installer for Windows 66
2.3.4 MySQL Notifier 84
2.3.5 Installing MySQL on Microsoft Windows Using an MSI Package 95
2.3.6 MySQL Server Instance Configuration Wizard 101
2.3.7 Installing MySQL on Microsoft Windows Using a `noinstall` ZIP Archive 115
2.3.8 Troubleshooting a Microsoft Windows MySQL Server Installation 123
2.3.9 Windows Postinstallation Procedures 124
2.3.10 Upgrading MySQL on Windows 126
2.4 Installing MySQL on OS X 128
2.4.1 General Notes on Installing MySQL on OS X 128
2.4.2 Installing MySQL on OS X Using Native Packages 129
2.4.3 Installing a MySQL Launch Daemon 133
2.4.4 Installing and Using the MySQL Preference Pane 136
2.5 Installing MySQL on Linux 140
2.5.1 Installing MySQL on Linux Using RPM Packages 141
2.5.2 Installing MySQL on Linux Using Debian Packages 146
2.5.3 Deploying MySQL on Linux with Docker 146
2.5.4 Installing MySQL on Linux Using Native Package Managers 153
2.6 Installing MySQL Using Unbreakable Linux Network (ULN) 156
2.7 Installing MySQL on Solaris 157
2.7.1 Installing MySQL on Solaris Using a Solaris PKG 158
2.8 Installing MySQL on FreeBSD 159
2.9 Installing MySQL from Source 159
2.9.1 MySQL Layout for Source Installation 161
2.9.2 Installing MySQL Using a Standard Source Distribution 161
2.9.3 Installing MySQL Using a Development Source Tree 166
2.9.4 MySQL Source-Configuration Options 167
2.9.5 Dealing with Problems Compiling MySQL 179
2.9.6 MySQL Configuration and Third-Party Tools 181
2.10 Postinstallation Setup and Testing 181
2.10.1 Initializing the Data Directory 182
2.10.2 Starting the Server 185
2.10.3 Testing the Server 188
2.10.4 Securing the Initial MySQL Accounts 190
2.10.5 Starting and Stopping MySQL Automatically 194
2.11 Upgrading or Downgrading MySQL 195
2.11.1 Upgrading MySQL 195
2.11.2 Downgrading MySQL 205
2.11.3 Rebuilding or Repairing Tables or Indexes 210
2.11.4 Copying MySQL Databases to Another Machine 211
2.12 Perl Installation Notes 212
2.12.1 Installing Perl on Unix 212

2.12.2 Installing ActiveState Perl on Windows 213
2.12.3 Problems Using the Perl DBI/DBD Interface 214

This chapter describes how to obtain and install MySQL. A summary of the procedure follows and later sections provide the details. If you plan to upgrade an existing version of MySQL to a newer version rather than install MySQL for the first time, see Section 2.11.1, “Upgrading MySQL”, for information about upgrade procedures and about issues that you should consider before upgrading.

If you are interested in migrating to MySQL from another database system, see Section A.8, “MySQL 5.5 FAQ: Migration”, which contains answers to some common questions concerning migration issues.

If you are migrating from MySQL Enterprise Edition to MySQL Community Server, see Section 2.11.2.2, “Downgrading from MySQL Enterprise Edition to MySQL Community Server”.

Installation of MySQL generally follows the steps outlined here:

1. **Determine whether MySQL runs and is supported on your platform.**

   Please note that not all platforms are equally suitable for running MySQL, and that not all platforms on which MySQL is known to run are officially supported by Oracle Corporation. For information about those platforms that are officially supported, see http://www.mysql.com/support/supportedplatforms/database.html on the MySQL Web site.

2. **Choose which distribution to install.**

   Several versions of MySQL are available, and most are available in several distribution formats. You can choose from pre-packaged distributions containing binary (precompiled) programs or source code. When in doubt, use a binary distribution. Oracle also provides access to the MySQL source code for those who want to see recent developments and test new code. To determine which version and type of distribution you should use, see Section 2.1.1, “Which MySQL Version and Distribution to Install”.

3. **Download the distribution that you want to install.**

   For instructions, see Section 2.1.2, “How to Get MySQL”. To verify the integrity of the distribution, use the instructions in Section 2.1.3, “Verifying Package Integrity Using MD5 Checksums or GnuPG”.

4. **Install the distribution.**

   To install MySQL from a binary distribution, use the instructions in Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

   To install MySQL from a source distribution or from the current development source tree, use the instructions in Section 2.9, “Installing MySQL from Source”.

5. **Perform any necessary postinstallation setup.**

   After installing MySQL, see Section 2.10, “Postinstallation Setup and Testing” for information about making sure the MySQL server is working properly. Also refer to the information provided in Section 2.10.4, “Securing the Initial MySQL Accounts”. This section describes how to secure the initial MySQL user accounts, *which have no passwords* until you assign passwords. The section applies whether you install MySQL using a binary or source distribution.

6. If you want to run the MySQL benchmark scripts, Perl support for MySQL must be available. See Section 2.12, “Perl Installation Notes”.

Instructions for installing MySQL on different platforms and environments is available on a platform by platform basis:

- **Unix, Linux, FreeBSD**

For instructions on installing MySQL on most Linux and Unix platforms using a generic binary (for example, a `.tar.gz` package), see Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

For information on building MySQL entirely from the source code distributions or the source code repositories, see Section 2.9, “Installing MySQL from Source”

For specific platform help on installation, configuration, and building from source see the corresponding platform section:

- Linux, including notes on distribution specific methods, see Section 2.5, “Installing MySQL on Linux”.
- Solaris, including PKG and IPS formats, see Section 2.7, “Installing MySQL on Solaris”.
- IBM AIX, see Section 2.7, “Installing MySQL on Solaris”.
- FreeBSD, see Section 2.8, “Installing MySQL on FreeBSD”.

- **Microsoft Windows**

  For instructions on installing MySQL on Microsoft Windows, using either the MySQL Installer standalone MSI, or Zipped binary, see Section 2.3, “Installing MySQL on Microsoft Windows”.

  For information about managing MySQL instances, see Section 2.3.4, “MySQL Notifier”.

  For details and instructions on building MySQL from source code using Microsoft Visual Studio, see Section 2.9, “Installing MySQL from Source”.

- **OS X**

  For installation on OS X, including using both the binary package and native PKG formats, see Section 2.4, “Installing MySQL on OS X”.

  For information on making use of an OS X Launch Daemon to automatically start and stop MySQL, see Section 2.4.3, “Installing a MySQL Launch Daemon”.

  For information on the MySQL Preference Pane, see Section 2.4.4, “Installing and Using the MySQL Preference Pane”.

2.1 General Installation Guidance

The immediately following sections contain the information necessary to choose, download, and verify your distribution. The instructions in later sections of the chapter describe how to install the distribution that you choose. For binary distributions, see the instructions at Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries” or the corresponding section for your platform if available. To build MySQL from source, use the instructions in Section 2.9, “Installing MySQL from Source”.

2.1.1 Which MySQL Version and Distribution to Install

MySQL is available on a number of operating systems and platforms. For information about those platforms that are officially supported, see http://www.mysql.com/support/supportedplatforms/database.html on the MySQL Web site.

When preparing to install MySQL, decide which version and distribution format (binary or source) to use.

First, decide whether to install a development release or a General Availability (GA) release. Development releases have the newest features, but are not recommended for production use. GA

releases, also called production or stable releases, are meant for production use. We recommend using the most recent GA release.

The naming scheme in MySQL 5.5 uses release names that consist of three numbers and an optional suffix; for example, **mysql-5.5.1-m2**. The numbers within the release name are interpreted as follows:

- The first number (**5**) is the major version number.
- The second number (**5**) is the minor version number. Taken together, the major and minor numbers constitute the release series number. The series number describes the stable feature set.
- The third number (**1**) is the version number within the release series. This is incremented for each new bugfix release. In most cases, the most recent version within a series is the best choice.

Release names can also include a suffix to indicate the stability level of the release. Releases within a series progress through a set of suffixes to indicate how the stability level improves. The possible suffixes are:

- **m*N*** (for example, **m1**, **m2**, **m3**, ...) indicates a milestone number. MySQL development uses a milestone model, in which each milestone introduces a small subset of thoroughly tested features. Following the releases for one milestone, development proceeds with another small number of releases that focuses on the next set of features. From one milestone to the next, feature interfaces may change or features may even be removed, based on feedback provided by community members who try these earily releases. Features within milestone releases may be considered to be of pre-production quality.
- **rc** indicates a Release Candidate (RC). Release candidates are believed to be stable, having passed all of MySQL's internal testing. New features may still be introduced in RC releases, but the focus shifts to fixing bugs to stabilize features introduced earlier within the series.
- Absence of a suffix indicates a General Availability (GA) or Production release. GA releases are stable, having successfully passed through the earlier release stages, and are believed to be reliable, free of serious bugs, and suitable for use in production systems.

Development within a series begins with milestone releases, followed by RC releases, and finally reaches GA status releases.

After choosing which MySQL version to install, decide which distribution format to install for your operating system. For most use cases, a binary distribution is the right choice. Binary distributions are available in native format for many platforms, such as RPM packages for Linux or DMG packages for OS X. Distributions are also available in more generic formats such as Zip archives or compressed `tar` files. On Windows, you can use the MySQL Installer to install a binary distribution.

Under some circumstances, it may be preferable to install MySQL from a source distribution:

- You want to install MySQL at some explicit location. The standard binary distributions are ready to run at any installation location, but you might require even more flexibility to place MySQL components where you want.
- You want to configure `mysqld` with features that might not be included in the standard binary distributions. Here is a list of the most common extra options used to ensure feature availability:
  - `-DWITH_LIBWRAP=1` for TCP wrappers support.
  - `-DWITH_ZLIB={system|bundled}` for features that depend on compression
  - `-DWITH_DEBUG=1` for debugging support

  For additional information, see Section 2.9.4, “MySQL Source-Configuration Options”.
- You want to configure `mysqld` without some features that are included in the standard binary distributions. For example, distributions normally are compiled with support for all character sets. If

you want a smaller MySQL server, you can recompile it with support for only the character sets you need.

- You want to read or modify the C and C++ code that makes up MySQL. For this purpose, obtain a source distribution.
- Source distributions contain more tests and examples than binary distributions.

2.1.2 How to Get MySQL

Check our downloads page at http://dev.mysql.com/downloads/ for information about the current version of MySQL and for downloading instructions. For a complete up-to-date list of MySQL download mirror sites, see http://dev.mysql.com/downloads/mirrors.html. You can also find information there about becoming a MySQL mirror site and how to report a bad or out-of-date mirror.

To obtain the latest development source, see Section 2.9.3, “Installing MySQL Using a Development Source Tree”.

2.1.3 Verifying Package Integrity Using MD5 Checksums or GnuPG

After downloading the MySQL package that suits your needs and before attempting to install it, make sure that it is intact and has not been tampered with. There are three means of integrity checking:

- MD5 checksums
- Cryptographic signatures using `GnuPG`, the GNU Privacy Guard
- For RPM packages, the built-in RPM integrity verification mechanism

The following sections describe how to use these methods.

If you notice that the MD5 checksum or GPG signatures do not match, first try to download the respective package one more time, perhaps from another mirror site.

2.1.3.1 Verifying the MD5 Checksum

After you have downloaded a MySQL package, you should make sure that its MD5 checksum matches the one provided on the MySQL download pages. Each package has an individual checksum that you can verify against the package that you downloaded. The correct MD5 checksum is listed on the downloads page for each MySQL product, and you will compare it against the MD5 checksum of the file (product) that you download.

Each operating system and setup offers its own version of tools for checking the MD5 checksum. Typically the command is named `md5sum`, or it may be named `md5`, and some operating systems do not ship it at all. On Linux, it is part of the **GNU Text Utilities** package, which is available for a wide range of platforms. You can also download the source code from http://www.gnu.org/software/textutils/. If you have OpenSSL installed, you can use the command `openssl md5 package_name` instead. A Windows implementation of the `md5` command line utility is available from http://www.fourmilab.ch/md5/. `winMd5Sum` is a graphical MD5 checking tool that can be obtained from http://www.nullriver.com/index/products/winmd5sum. Our Microsoft Windows examples will assume the name `md5.exe`.

Linux and Microsoft Windows examples:

```
shell> md5sum mysql-standard-5.5.60-linux-i686.tar.gz
aaab65abbec64d5e907dcd41b8699945  mysql-standard-5.5.60-linux-i686.tar.gz
```

```
shell> md5.exe mysql-installer-community-5.5.60.msi
aaab65abbec64d5e907dcd41b8699945  mysql-installer-community-5.5.60.msi
```

You should verify that the resulting checksum (the string of hexadecimal digits) matches the one displayed on the download page immediately below the respective package.

Note

Make sure to verify the checksum of the *archive file* (for example, the `.zip`, `.tar.gz`, or `.msi` file) and not of the files that are contained inside of the archive. In other words, verify the file before extracting its contents.

2.1.3.2 Signature Checking Using GnuPG

Another method of verifying the integrity and authenticity of a package is to use cryptographic signatures. This is more reliable than using MD5 checksums, but requires more work.

We sign MySQL downloadable packages with GnuPG (GNU Privacy Guard). GnuPG is an Open Source alternative to the well-known Pretty Good Privacy (PGP) by Phil Zimmermann. Most Linux distributions ship with GnuPG installed by default. Otherwise, see http://www.gnupg.org/ for more information about GnuPG and how to obtain and install it.

To verify the signature for a specific package, you first need to obtain a copy of our public GPG build key, which you can download from http://pgp.mit.edu/. The key that you want to obtain is named `mysql-build@oss.oracle.com`. Alternatively, you can copy and paste the key directly from the following text:

```
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: GnuPG v1.4.5 (GNU/Linux)

mQGiBD4+owwRBAC14GIfUfCyEDSIePvEW3SAFUdJBtoQHH/nJKZyQT7h9bPlUWC3
RODjQReyCITRrdwyrKUGku2FmeVGwn2u2WmDMNABLnpprWPkBdCk96+OmSLN9brZ
fw2vOUgCmYv2hW0hyDHuvYlQA/BThQoADgj8AW6/0Lo7V1W9/8VuHP0gQwCgvzV3
BqOxRznNCRCRxAuAuVztHRcEAJooQK1+iSiunZMYD1WufeXfshc57S/+yeJkegNW
hxwR9pRWVArNYJdDRT+rf2RUe3vpquKNQU/hnEIUHJRQqYHo8gTxvxXNQc7fJYLV
K2HtkrPbP72vwsEKMYhhr0eKCbtLGfls9krjJ6sBgACyP/Vb7hiPwxh6rDZ7ITnE
kYpXBACmWpP8NJTkamEnPCia2ZoOHODANwpUkP43I7jsDmgtobZX9qnrAXw+uNDI
QJEXM6FSbi0LLtZciNlYsafwAPEOMDKpMqAK6IyisNtPvaLd8lH0bPAnWqcyefep
rv0sxxqUEMcM3o7wwgfN83POkDasDbs3pjwPhxvhz6//62zQJ7Q2TXlTUUwgUmVs
ZWFzZSBFbmdpbmVlcmluZyA8bXlzcWwtYnVpbGRAb3NzLm9yYWNsZS5jb20+iGwE
ExECACwCGyMCHgECF4ACGQEGCwkIBwMCBhUKCQgCAwUWAgMBAAUCWKcFIAUJHirJ
FAAKCRCMcY07UHLh9VcFAJ46pUyVd8BZ2r5CppMC1tmyQ3ceRgCfVPwuVsiS0VER
5WUqtAQDt+DoetCIaQQTEQIAKQIbIwYLCQgHAwIEFQIIAwQWAgMBAh4BAheAAhkB
BQJTAdRmBQkaZsvLAAoJEIxxjTtQcuH1X4MAoKNLWAbCBUj96637kv6Xa/fJuX5m
AJwPtmgDfjUe2iuhXdTrFEPT19SB6ohmBBMRAgAmAhsjBgsJCAcDAgQVAggDBBYC
AwECHgECF4AFAk53PioFCRP7AhUACgkQjHGNO1By4fUmzACeJdfqgc9gWTUhgmcM
AOmG4RjwuxcAoKfM+U8yMOGELi+TRif7MtKEms6piGkEExECACkCGyMGCwkIBwMC
BBUCCAMEFgIDAQIeAQIXgAIZAQUCUZSROgUJFTchqgAKCRCMcY07UHLh9YtAAJ9X
rA/ymlmozPZn+A9ls8/uwMcTsQCfaQMNq1dNkhH2kyByc3Rx9/W2xfqJARwEEAEC
AAYFAlAS6+UACgkQ8aIC+GoXHivrWwf/dtLk/x+NC2VMDlg+vOeM0qgG1IlhXZfi
NsEisvvGaz4m8fSFRGe+1bvvfDoKRhxiGXU48RusjixzvBb6KTMuY6JpOVfz9Dj3
H9spYriHa+i6rYySXZIpOhfLiMnTy7NH2OvYCyNzSS/ciIUACIfH/2NH8zNT5CNF
1uPNRs7HsHzzz7pOlTjtTWiF4cq/Ij6Z6CNrmdj+SiMvjYN9u6sdEKGtoNtpycgD
5HGKR+I7Nd/7v56yhaUe4FpuvsNXig86K9tI6MUFS8CUyy7Hj3kVBZOUWVBM053k
nGdALSygQr50DA3jMGKVl4ZnHje2RVWRmFTr5YWoRTMxUSQPMLpBNIkBHAQQAQIA
BgUCU1B+vQAKCRAohbcD0zcc8dWwCACWXXWDXIcAWRUw+j3ph8dr9u3SItljn3wB
c7clpclKWPuLvTz7lGgzlVB0s8hH4xgkSA+zLzl6u56mpUzskFl7f1I3Ac9GGpM4
0M5vmmR9hwlD1HdZtGfbD+wkjlqgitNLoRcGdRf/+U7x09GhSS7Bf339sunIX6sM
gXSC4L32D3zDjF5icGdb0kj+3lCrRmp853dGyA3ff9yUiBkxcKNawpi7Vz3D2ddU
pOF3BP+8NKPg4P2+srKgkFbd4HidcISQCt3rY4vaTkEkLKg0nNA6U4r0YgOa7wIT
SsxFlntMMzaRg53QtK0+YkH0KuZR3GY8B7pi+tlgycyVR7mIFo7riQEcBBABCAAG
BQJWgVd0AAoJEEZu4b/gk4UKk9MH/Rnt7EccPjSJC5CrB2AU5LY2Dsr+PePI2ubP
WsEdG82qSjjGpbhIH8LSg/PzQoGHiFWMmmZWJktRT+dcgLbs3b2VwCNAwCE8jOHd
UkQhEowgomdNvHiBHKHjP4/lF68KOPiO/2mxYYkmpM7BWf3kB57DJ5CTi3/JLoN7
zF40qIs/p09ePvnwStpglbbtUn7XPO+1/Ee8VHzimABom52PkQIuxNiVUzLVn3bS
Wqrd5ecuqLk6yzjPXd2XhDHWC9Twpl68GePru6EzQtusi0m6S/sHgEXqh/IxrFZV
JlljF75JvosZq5zeulr0i6kOij+Y1p6MFffihITZ1gTmk+CLvK2JASIEEAECAAwF
Ak53QS4FAwASdQAACgkQlxC4m8pXrXwJ8Qf/be/UO9mqfoc2sMyhwMpN4/fdBWwf
LkA12FXQDOQMvwH9HsmEjnfUgYKXschZRi+DuHXe1P7l8G2aQLubhBsQf9ejKvRF
TzuWMQkdIq+6Koulxv6ofkCcv3d1xtO2W7nb5yxcpVBPrRfGFGebJvZa58DymCNg
yGtAU6AOz4veavNmI2+GIDQsY66+tYDvZ+CxwzdYu+HDV9HmrJfc6deM0mnBn7SR
jqzxJPgoTQhihTav6q/R5/2p5NvQ/H84OgS6GjosfGc2duUDzCP/kheMRKfzuyKC
OHQPtJuIj8++gfpHtEU7IDUX1So3c9n0PdpeBvclsDbpRnCNxQWU4mBot4kBIgQQ
AQIADAUCToi2GQUDABJ1AAAKCRCXELibyletfLZAB/9oRqx+NC98UQD/wlxCRytz
```

```
vi/MuPnbgQUPLHEap10tvEi33S/H/xDR/tcGofY4cjAvo5skZXXeWq93Av7PACUb
zkg0X0eSr2oL6wy66xfov72AwSuX+iUK68qtKaLqRLitM02y8aNRV/ggKvt7UMvG
mOvs5yLaYlobyvGaFC2ClfkNOt2MlVnQZCmnYBCwOktPGkExiu2yZMifcYGxQcpH
KVFG59KeF2cM2d4xYM8HJqkSGGW306LFVSyeRwG+wbttgLpD5bM/T2b3fF/J35ra
CSMLZearRTq8aygPl+XM7MM2eR946aw6jmOsgNBErbvvIdQj6LudAZj+8imcXV2K
iQEiBBABAgAMBQJOmdnRBQMAEnUAAAoJEJcQuJvKV618AvIIAIEF1ZJ+Ry7WOdKF
5oeQ/ynaYUigzN92fW/9zB8yuQlngkFJGidYMbci1tR1siziIVJFusR3ZonqAPGK
/SUta9Y6KWLhmc7c5UnEHklq/NfdMZ2WVSIykXlctqw0sbb+z1ecEd4G8u9j5ill
MO1B36rQayYAPoeXLX8dY4VyFLVGaQ00rWQBYFZrpw16ATWbWGJP332NSfCk4zZq
6kXEW07q0st3YBgAAGdNQyEeZCa4d4pBRSX6189Kjg6GDnIcaiOF6HO6PLr9fRlL
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tkGTuLmlCGwIV6lviDZD3RJf5375VFnaHv7eXfwQxCwE+BxG3CURrjfxjaxMTmMP
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s7D1F1hlgFQuNIkBIgQQAQIADAUCTrzZHAUDABJ1AAAKCRCXELibyletfMUpB/4s
07dREULIBnA1D6qr3fHsQJNZqbAuyDlvgGGLWzoyEDs+1JMFFlaa+EeLIo1386GU
2DammDC23p3IB79uQhJeD2Z1TcVg4cA64SfF/CHca5coeRSrdAiudzU/cgLGtXIP
/OaFamXgdMxAhloLFbSHPCZkyb00phVa8+xeIVDrK1HByZsNIXy/SSK8U26S2PVZ
2o14fWvKbJ1Aga8N6DuWY/D8P2mi3RAbiuZgfzkmKL5idH/wSKfnFKdTgJzssdCc
1jZEGVk5rFYcWOrJARHeP/tsnb/UxKBEsNtO7e3N2e/rLVnEykVIO066hz7xZK/V
NBSpx3k3qj4XPK41IHy2iQEiBBABAgAMBQJOzqO8BQMAEnUAAAoJEJcQuJvKV618
2twH/0IzjXLxN45nvIfEjC75a+i9ZSLlqR8lsHL4GpEScFKI0a0lT4IVAIY2RKG+
MAs2eHm0UfKuwGs5jluRZ9RqKrc61sY0XQV9/7znY9Db16ghX04JjknOKs/fPi87
rvKkB/QxJWS8qbb/erRmW+cPNjbRxTFPS5JIwFWHA16ieFEpvdAgKV6nfvJVTq1r
jPDcnIA9CJN2SmUFx9Qx3SRc6ITbam1hjFnY6sCh6AUhxLI2f1mq1xH9PqEy42Um
68prRqTyJ7Iox1g/UDDkeeUcAg7T1viTz7uXpS3Wrq4zzo4yOpaJfLDR3pI5g2Zk
SNGTMo6aySE4OABt8i1Pc1Pm6AmJASIEEAECAAwFAk7yPFYFAwASdQAACgkQlxC4
m8pXrXzXiAf9FrXe0lgcPM+tYOWMLhv5gXJi2VUBaLxpyRXm/kJcmxInKq1GCd3y
D4/FLHNu3ZcCz/uklPAbZXWI0O6ewq0LWsRtklmJjWiedH+hGyaTv95VklojRIBd
8nBaJ6M98rljMBHTFwWvjQFVf4FLRJQZqHlvjcCkq2Dd9BWJpGXvr/gpKkmMJYNK
/ftfZRcChb35NI19WRpOhj9u808OPcqKVvZBcPwFGV5cEBzmAC94J7JcD8+S8Ik8
iUJMQGGL3QcmZOBozovh86hj7KTSEBHlLXl832z89H1hLeuLbnXoGLv3zeUFSxkv
1h35LhZLqIMDQRXLuUzxGHMBpLhPyGWRJ4kBIgQQAQIADAUCTwQJFwUDABJ1AAAK
CRCXELibyletfABvB/9Cy69cjOqLGywITs3Cpg//40jmdhSAVxilJivP6J5bubFH
DJlVTx541Dv5h4hTG2BQuueQ4q1VCpSGW+rHcdhPyvmZGRz1rxdQQGh1Dv0Bod2c
3PJVSYPSrRSwCZJkJHOtVRBdjK4mkZb5aFTza+Tor9kxzj4FcXVd4KAS+hHQHYHc
Ar8tt2eOLzqdEFTULeGiSoNn+PVzvzdfhndphK+8F2jfQ2UKuc01O7k0Yn9xZVx0
OG6fE1gStzLv7C5amWLRd8+xh+MN0G8MgNglpBoExsEMMlPBYSUHa6lxpdMNMuib
rIyVncE9X8QOhImt8K0sNn/EdbuldJNGYbDLt7O4iQEiBBABAgAMBQJPFdTcBQMA
EnUAAAoJEJcQuJvKV6184owH+wZ/uLpezXnSxigeH1sig72QEXMrNd5DVHCJdig3
bo+K5YmmN710/m5z+63XKUEWpd6/knajObgckThzWftNeK1SSFQGPmoYZP9EZnSU
7L+/dSUpExbj842G5LYagrCyMGtlxRywWEmbi72TKS/JOK0jLiOdvVy+PHrZSu0D
TVQ7cJh1BmPsbz7zzxjmcI5l+7B7K7RHZHq45nDLoIabwDacj7BXvBK0Ajqz4QyJ
GQUjXC7q+88I+ptPvOXlE5nI/NbiCJOMI6d/bWN1KwYrC80fZuFaznfQFcPyUaDw
yRaun+K3kEji2wXecq+yMmLUEp01TKsUeOL50HD6hHH07W+JASIEEAECAAwFAk85
bQsFAwASdQAACgkQlxC4m8pXrXwKPQgAlkbUsTr7nkq+haOk0jKpaHWEbRMEGMrB
I3F7E+RDO6V/8y4Jtn04EYDc8GgZMBah+mOgeINq3y8jRMYV5jVtZXv2MWYFUcjM
kVBKeqhi/pGEjmUdmdt3DlPv3Z+fMTMRmAocI981iY/go8PVPg/+nrR6cFK2xxnO
R8TacikJBFeSfkkORg1tDzjjYv1B5ZIEkpplepl5ahJBBq7cpYhTdY6Yk0Sz0J8w
EdffLSaNxrRuWLrRhWzZU7p9bFzfb/7OHc21dJnB7wKv5VvtgE+jiQw9tOKaf5hc
SgRYuF6heu+B25gc5Uu88lo409mZ7oxQ6hDCn7JHvzh0rhmSN+Kid4kBIgQQAQIA
DAUCT0qQrQUDABJ1AAAKCRCXELibyletfC9UB/4o2ggJYM0CLxEpP0GU8UKOh3+/
zm1DN7Qe4kY2iCtF1plKHQaTgt5FlgRCFaiXcVv7WzGz/FnmxonR1leLl+kfRlwy
PPnoI/AWPCy/NO4Cl5KnjsSmsdDUpObwZ4KYsdilZR7ViJu2swdAIgnXBUwrlRJR
7CK4TAKrTeonRgVSrVx8Vt//8/cYj73CLq8oY/KK0iHiQrSwo44uyhdiFIAssjyX
n6/2E+w0zgvPexNSNNROHQ8pjbq+NTY6GwKIGsaej3UTRwQ7psvKXz8y7xdzmOAr
/khGvxB5gjkx02pimjeia8v66aH6rbnojJMAovNUS4EHdHnulv4rovC8Kf9iiQEi
BBABAgAMBQJPVdsaBQMAEnUAAAoJEJcQuJvKV618vVEIALFXPBzcAO1SnQarBLzy
YMVZZumPvSXKnUHAO+6kjApXPJ+qFRdUaSNshZxVKY9Zryblu4ol/fLUTt0CliSD
IxD6L4GXEm4VYYCl4lPO3bVsJnGITLFwQGHM27EmjVoTiD8Ch7kPq2EXr3dMRgzj
pdz+6aHGSUfOdLTPXufDvW83bEWGaRVuTJKw+wIrcuRqQ+ucWJgJGwcE4zeHjZad
Jx1XUm1X+BbI73uiQussyjhhQVVNU7QEdrjyuscaZ/H38wjUwNbylxDPB4I8quC1
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```

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```

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=HfUN
-----END PGP PUBLIC KEY BLOCK-----
```

To import the build key into your personal public GPG keyring, use `gpg --import`. For example, if you have saved the key in a file named `mysql_pubkey.asc`, the import command looks like this:

```
shell> gpg --import mysql_pubkey.asc
gpg: key 5072E1F5: public key "MySQL Release Engineering
<mysql-build@oss.oracle.com>" imported
gpg: Total number processed: 1
gpg:               imported: 1
gpg: no ultimately trusted keys found
```

You can also download the key from the public keyserver using the public key id, `5072E1F5`:

```
shell> gpg --recv-keys 5072E1F5
gpg: requesting key 5072E1F5 from hkp server keys.gnupg.net
gpg: key 5072E1F5: "MySQL Release Engineering <mysql-build@oss.oracle.com>"
1 new user ID
gpg: key 5072E1F5: "MySQL Release Engineering <mysql-build@oss.oracle.com>"
53 new signatures
gpg: no ultimately trusted keys found
gpg: Total number processed: 1
gpg:           new user IDs: 1
gpg:         new signatures: 53
```

If you want to import the key into your RPM configuration to validate RPM install packages, you should be able to import the key directly:

```
shell> rpm --import mysql_pubkey.asc
```

If you experience problems or require RPM specific information, see Section 2.1.3.4, “Signature Checking Using RPM”.

After you have downloaded and imported the public build key, download your desired MySQL package and the corresponding signature, which also is available from the download page. The signature file has the same name as the distribution file with an `.asc` extension, as shown by the examples in the following table.

Table 2.1 MySQL Package and Signature Files for Source files

File Type	File Name
Distribution file	`mysql-standard-5.5.60-linux-i686.tar.gz`

File Type	File Name
Signature file	mysql-standard-5.5.60-linux-i686.tar.gz.asc

Make sure that both files are stored in the same directory and then run the following command to verify the signature for the distribution file:

```
shell> gpg --verify package_name.asc
```

If the downloaded package is valid, you will see a "Good signature" similar to:

```
shell> gpg --verify mysql-standard-5.5.60-linux-i686.tar.gz.asc
gpg: Signature made Tue 01 Feb 2011 02:38:30 AM CST using DSA key ID 5072E1F5
gpg: Good signature from "MySQL Release Engineering <mysql-build@oss.oracle.com>"
```

The `Good signature` message indicates that the file signature is valid, when compared to the signature listed on our site. But you might also see warnings, like so:

```
shell> gpg --verify mysql-standard-5.5.60-linux-i686.tar.gz.asc
gpg: Signature made Wed 23 Jan 2013 02:25:45 AM PST using DSA key ID 5072E1F5
gpg: checking the trustdb
gpg: no ultimately trusted keys found
gpg: Good signature from "MySQL Release Engineering <mysql-build@oss.oracle.com>"
gpg: WARNING: This key is not certified with a trusted signature!
gpg:          There is no indication that the signature belongs to the owner.
Primary key fingerprint: A4A9 4068 76FC BD3C 4567  70C8 8C71 8D3B 5072 E1F5
```

That is normal, as they depend on your setup and configuration. Here are explanations for these warnings:

- *gpg: no ultimately trusted keys found*: This means that the specific key is not "ultimately trusted" by you or your web of trust, which is okay for the purposes of verifying file signatures.
- *WARNING: This key is not certified with a trusted signature! There is no indication that the signature belongs to the owner.*: This refers to your level of trust in your belief that you possess our real public key. This is a personal decision. Ideally, a MySQL developer would hand you the key in person, but more commonly, you downloaded it. Was the download tampered with? Probably not, but this decision is up to you. Setting up a web of trust is one method for trusting them.

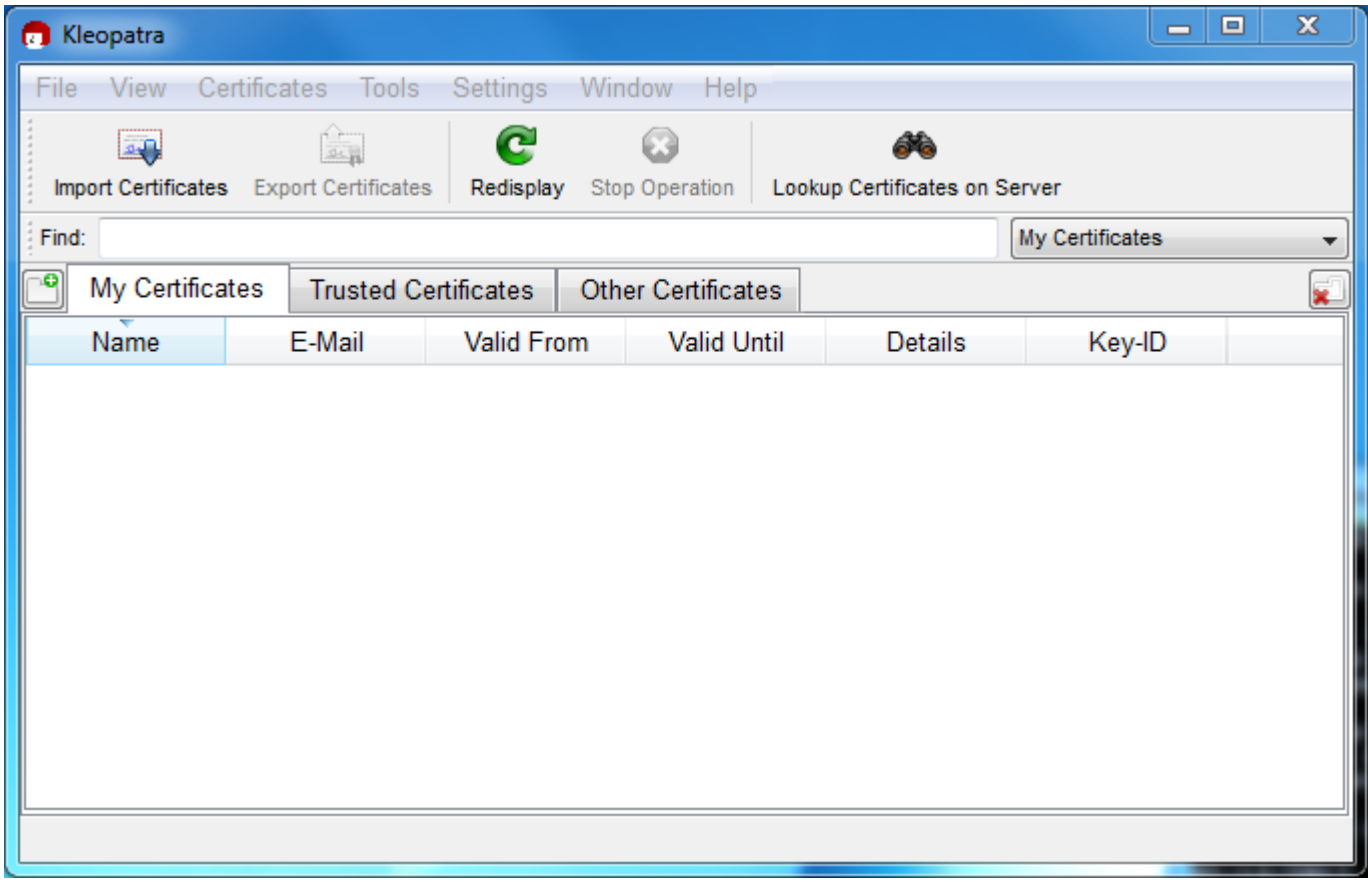
See the GPG documentation for more information on how to work with public keys.

2.1.3.3 Signature Checking Using Gpg4win for Windows

The Section 2.1.3.2, “Signature Checking Using GnuPG” section describes how to verify MySQL downloads using GPG. That guide also applies to Microsoft Windows, but another option is to use a GUI tool like Gpg4win. You may use a different tool but our examples are based on Gpg4win, and utilize its bundled `Kleopatra` GUI.

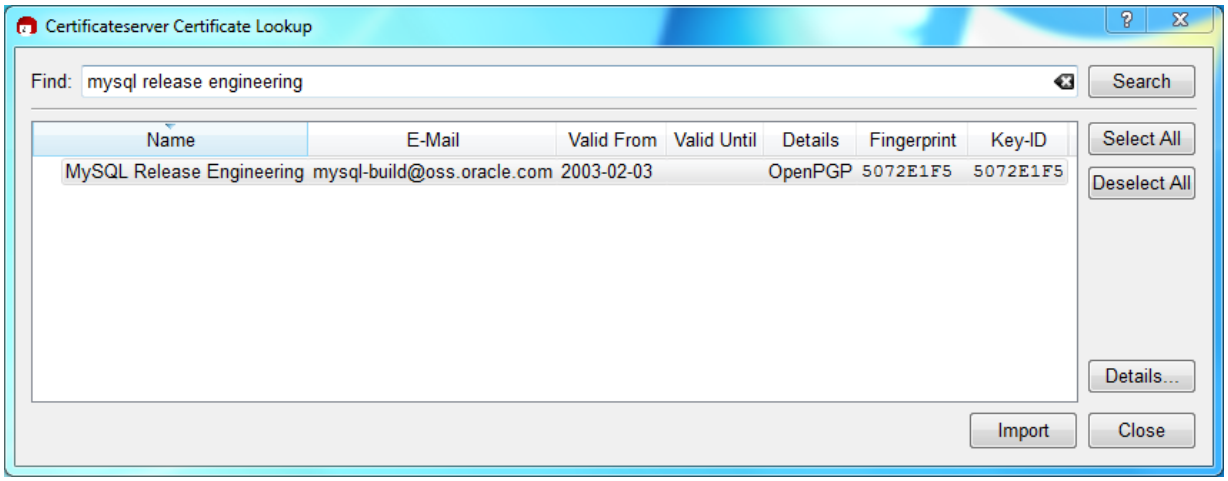
Download and install Gpg4win, and then load Kleopatra. The dialog should look similar to:

Figure 2.1 Initial screen after loading Kleopatra



Next, add the MySQL Release Engineering certificate. Do this by clicking **File**, **Lookup Certificates on Server**. Type "Mysql Release Engineering" into the search box and press **Search**.

Figure 2.2 Finding the MySQL Release Engineering certificate

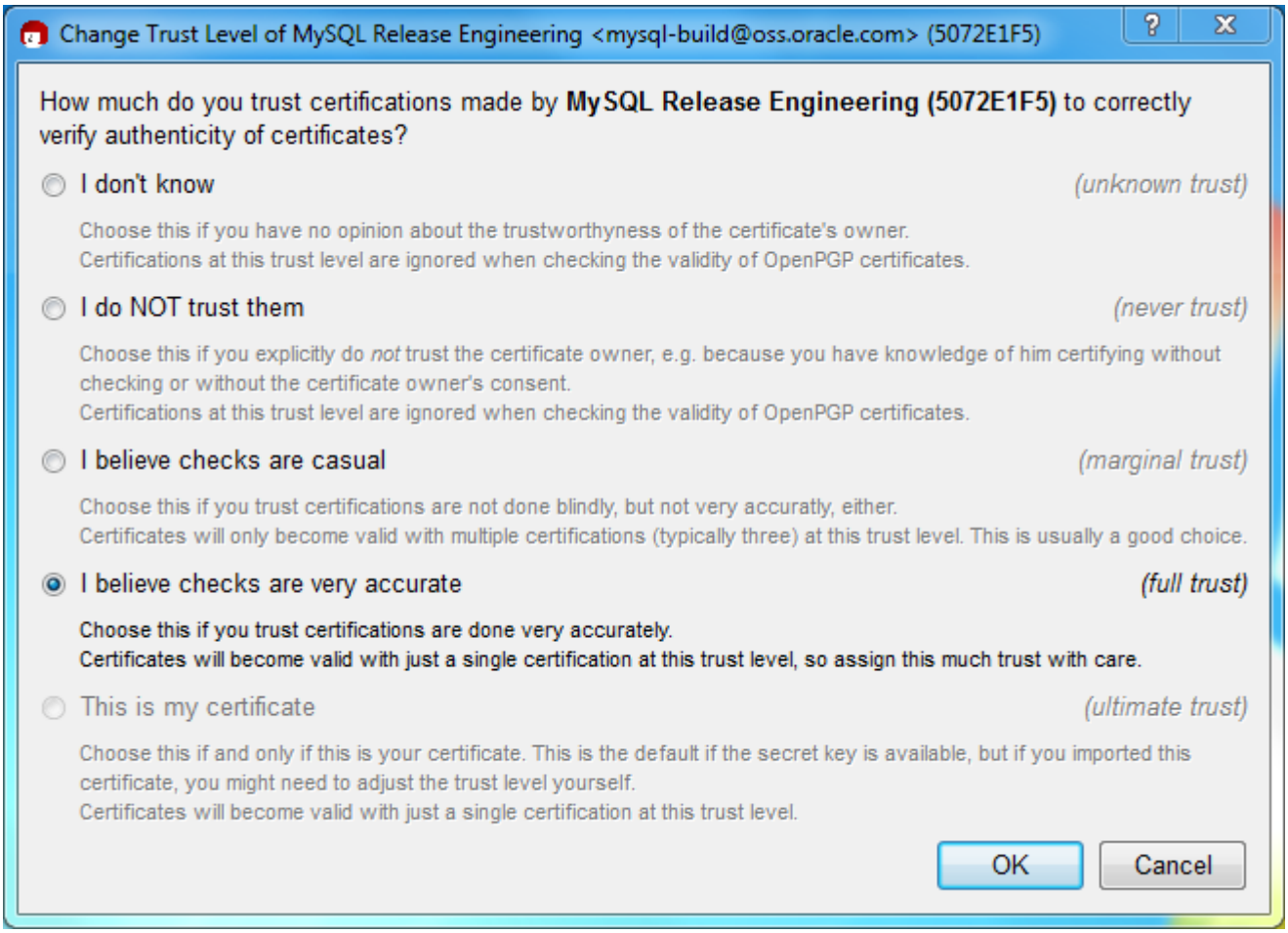


Select the "MySQL Release Engineering" certificate. The Fingerprint and Key-ID must be "5072E1F5", or choose **Details...** to confirm the certificate is valid. Now, import it by clicking **Import**. An import dialog will be displayed, choose **Okay**, and this certificate will now be listed under the **Imported Certificates** tab.

Next, configure the trust level for our certificate. Select our certificate, then from the main menu select **Certificates**, **Change Owner Trust...**. We suggest choosing **I believe checks are very accurate** for

our certificate, as otherwise you might not be able to verify our signature. Select **I believe checks are very accurate** and then press **OK**.

Figure 2.3 Changing the Trust level



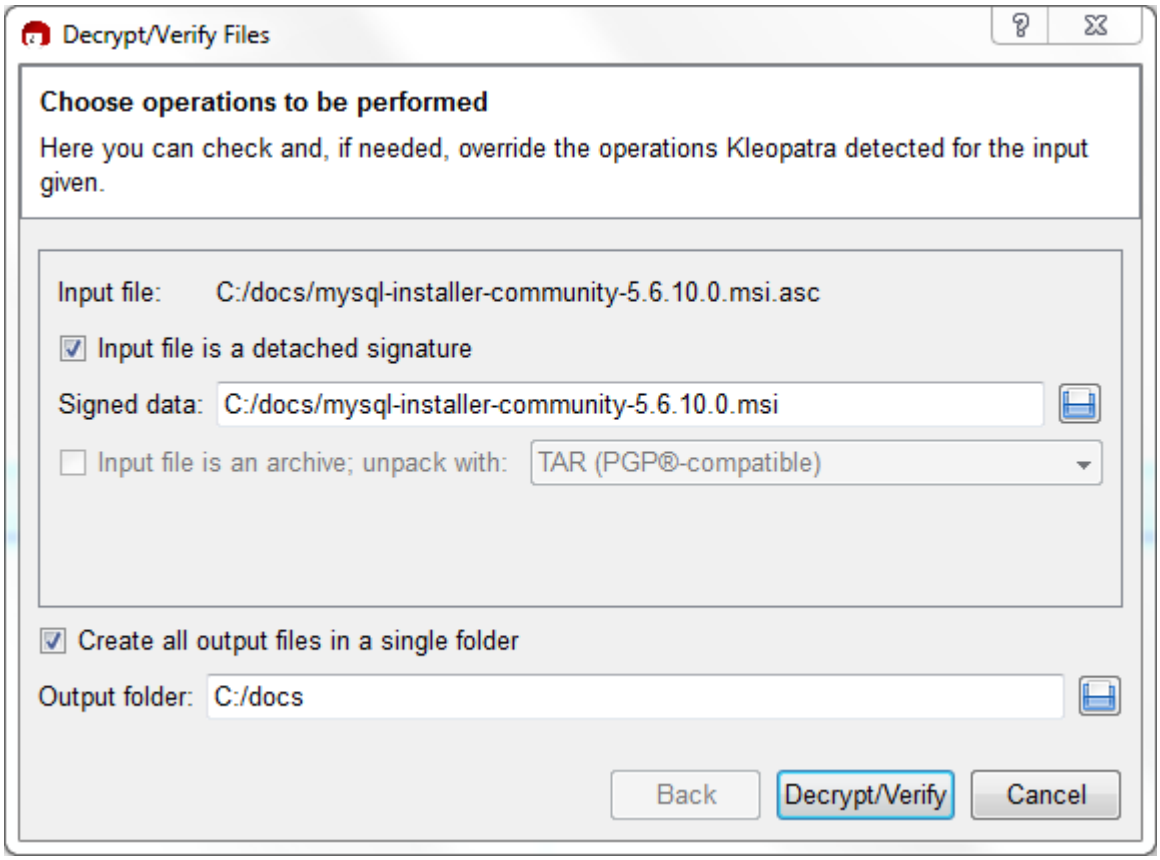
Next, verify the downloaded MySQL package file. This requires files for both the packaged file, and the signature. The signature file must have the same name as the packaged file but with an appended `.asc` extension, as shown by the example in the following table. The signature is linked to on the downloads page for each MySQL product. You must create the `.asc` file with this signature.

Table 2.2 MySQL Package and Signature Files for MySQL Installer for Microsoft Windows

File Type	File Name
Distribution file	`mysql-installer-community-5.5.60.msi`
Signature file	`mysql-installer-community-5.5.60.msi.asc`

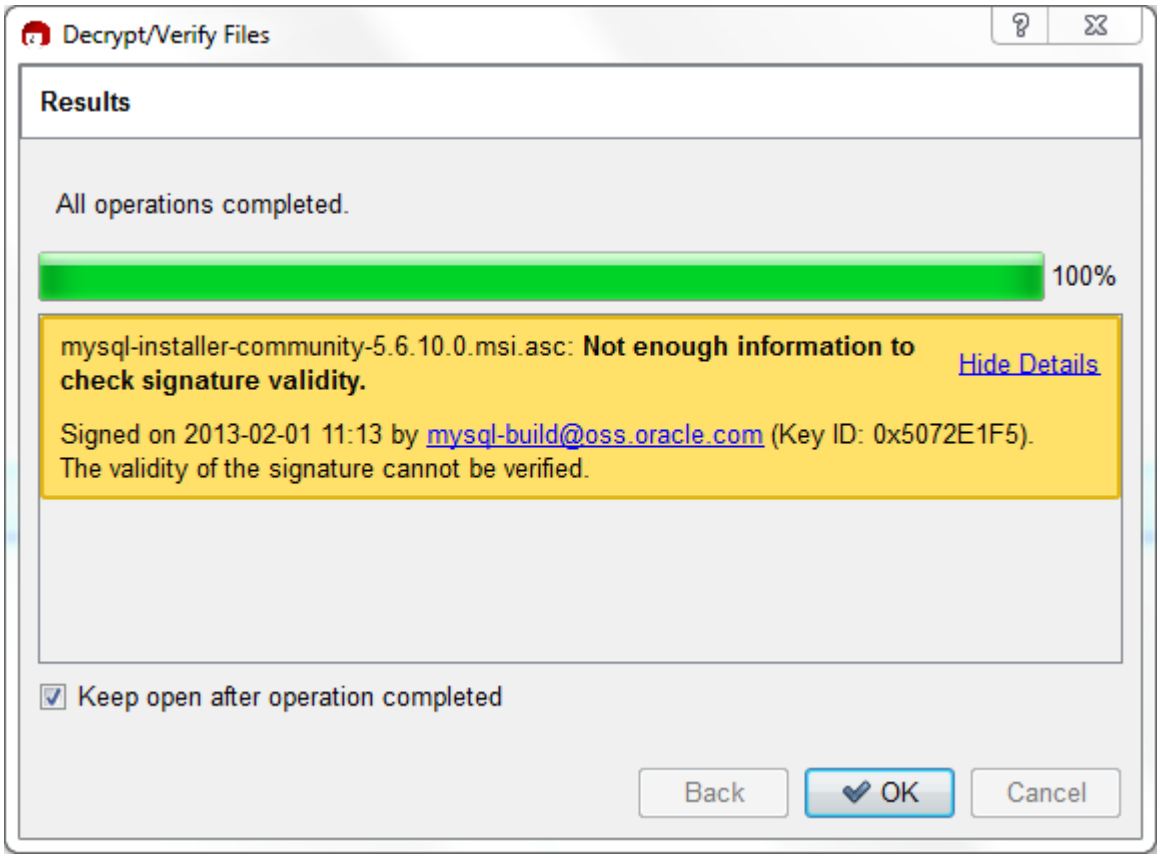
Make sure that both files are stored in the same directory and then run the following command to verify the signature for the distribution file. Either drag and drop the signature (`.asc`) file into Kleopatra, or load the dialog from **File**, **Decrypt/Verify Files...**, and then choose either the `.msi` or `.asc` file.

Figure 2.4 The Decrypt/Verify Files dialog



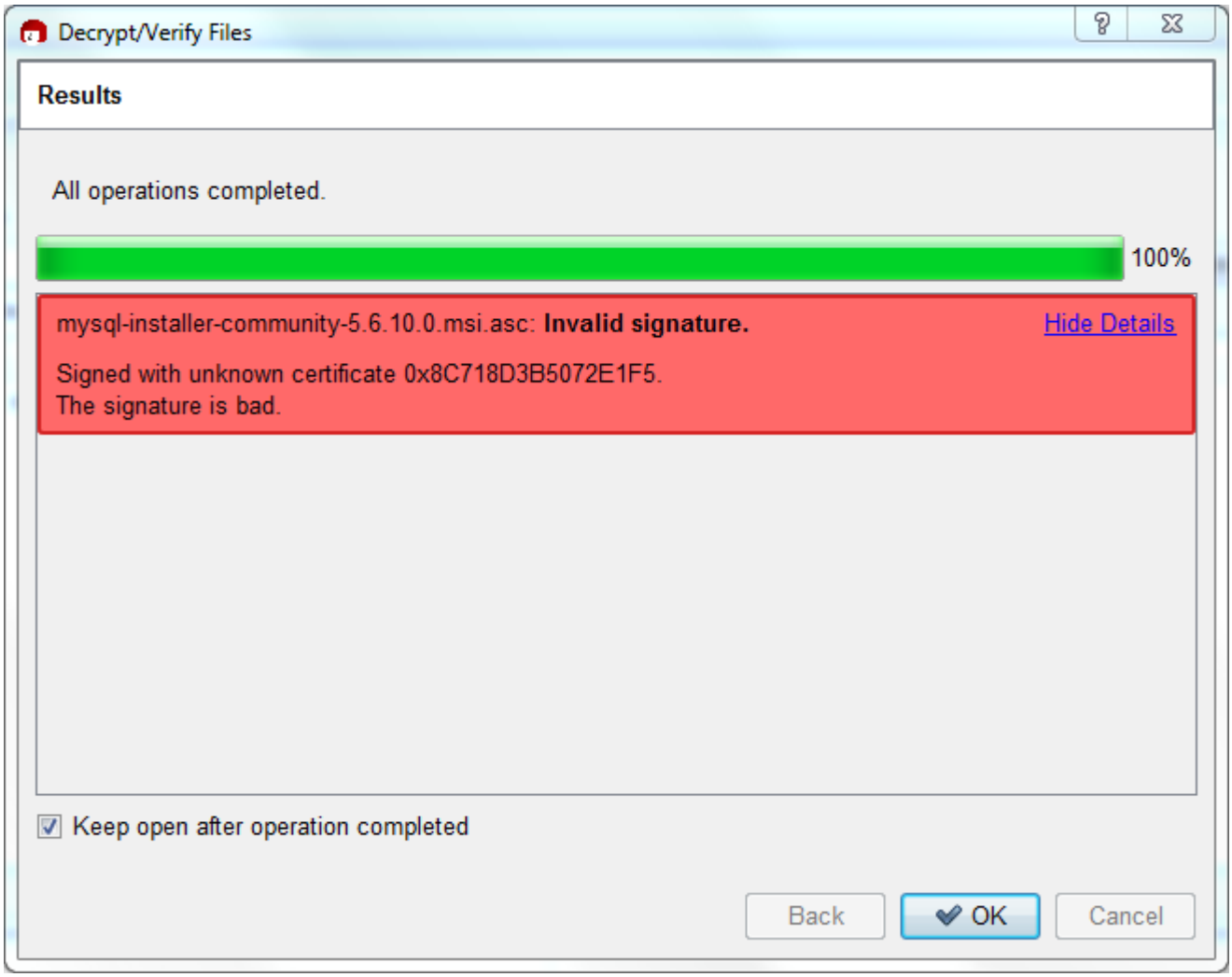
Click **Decrypt/Verify** to check the file. The two most common results will look like the following, and although the yellow warning looks problematic, the following means that the file check passed with success. You may now run this installer.

Figure 2.5 The Decrypt/Verify Results: Good



Seeing a red "The signature is bad" error means the file is invalid. Do not execute the MSI file if you see this error.

Figure 2.6 The Decrypt/Verify Results: Bad



The Section 2.1.3.2, “Signature Checking Using GnuPG” section explains why you probably don't see a green `Good signature` result.

2.1.3.4 Signature Checking Using RPM

For RPM packages, there is no separate signature. RPM packages have a built-in GPG signature and MD5 checksum. You can verify a package by running the following command:

```
shell> rpm --checksig package_name.rpm
```

Example:

```
shell> rpm --checksig MySQL-server-5.5.60-0.glibc23.i386.rpm
MySQL-server-5.5.60-0.glibc23.i386.rpm: md5 gpg OK
```

Note

If you are using RPM 4.1 and it complains about `(GPG) NOT OK (MISSING KEYS: GPG#5072e1f5)`, even though you have imported the MySQL public build key into your own GPG keyring, you need to import the key into the RPM keyring first. RPM 4.1 no longer uses your personal GPG keyring (or GPG itself). Rather, RPM maintains a separate keyring because it is a system-wide application and a user's GPG public keyring is a user-specific file. To import the

MySQL public key into the RPM keyring, first obtain the key, then use `rpm --import` to import the key. For example:

```
shell> gpg --export -a 5072e1f5 > 5072e1f5.asc
shell> rpm --import 5072e1f5.asc
```

Alternatively, `rpm` also supports loading the key directly from a URL, and you can use this manual page:

```
shell> rpm --import http://dev.mysql.com/doc/refman/5.5/en/checking-gpg-signature.html
```

If you need to obtain the MySQL public key, see Section 2.1.3.2, “Signature Checking Using GnuPG”.

2.1.4 Installation Layouts

The installation layout differs for different installation types (for example, native packages, binary tarballs, and source tarballs), which can lead to confusion when managing different systems or using different installation sources. The individual layouts are given in the corresponding installation type or platform chapter, as described following. Note that the layout of installations from vendors other than Oracle may differ from these layouts.

- Section 2.3.1, “MySQL Installation Layout on Microsoft Windows”
- Section 2.9.1, “MySQL Layout for Source Installation”
- Table 2.3, “MySQL Installation Layout for Generic Unix/Linux Binary Package”
- Table 2.10, “MySQL Installation Layout for Linux RPM Packages”
- Table 2.9, “MySQL Installation Layout on OS X”

2.1.5 Compiler-Specific Build Characteristics

In some cases, the compiler used to build MySQL affects the features available for use. The notes in this section apply for binary distributions provided by Oracle Corporation or that you compile yourself from source.

`icc` (Intel C++ Compiler) Builds

A server built with `icc` has these characteristics:

- SSL support is not included.

2.2 Installing MySQL on Unix/Linux Using Generic Binaries

Oracle provides a set of binary distributions of MySQL. These include generic binary distributions in the form of compressed `tar` files (files with a `.tar.gz` extension) for a number of platforms, and binaries in platform-specific package formats for selected platforms.

This section covers the installation of MySQL from a compressed `tar` file binary distribution. For other platform-specific package formats, see the other platform-specific sections. For example, for Windows distributions, see Section 2.3, “Installing MySQL on Microsoft Windows”.

To obtain MySQL, see Section 2.1.2, “How to Get MySQL”.

MySQL compressed `tar` file binary distributions have names of the form `mysql-`*`VERSION`*`-`*`OS`*`.tar.gz`, where *`VERSION`* is a number (for example, `5.5.60`), and *`OS`* indicates the type of operating system for which the distribution is intended (for example, `pc-linux-i686` or `winx64`).

Warning

If you have previously installed MySQL using your operating system native package management system, such as `yum` or `apt-get`, you may experience problems installing using a native binary. Make sure your previous MySQL installation has been removed entirely (using your package management system), and that any additional files, such as old versions of your data files, have also been removed. You should also check for configuration files such as `/etc/my.cnf` or the `/etc/mysql` directory and delete them.

Warning

MySQL has a dependency on the `libaio` library. Data directory initialization and subsequent server startup steps will fail if this library is not installed locally. If necessary, install it using the appropriate package manager. For example, on Yum-based systems:

```
shell> yum search libaio  # search for info
shell> yum install libaio # install library
```

Or, on APT-based systems:

```
shell> apt-cache search libaio # search for info
shell> apt-get install libaio1 # install library
```

If you run into problems and need to file a bug report, please use the instructions in Section 1.6, “How to Report Bugs or Problems”.

On Unix, to install a compressed `tar` file binary distribution, unpack it at the installation location you choose (typically `/usr/local/mysql`). This creates the directories shown in the following table.

Table 2.3 MySQL Installation Layout for Generic Unix/Linux Binary Package

Directory	Contents of Directory
`bin`, `scripts`	`mysqld` server, client and utility programs
`data`	Log files, databases
`docs`	MySQL manual in Info format
`man`	Unix manual pages
`include`	Include (header) files
`lib`	Libraries
`share`	Miscellaneous support files, including error messages, sample configuration files, SQL for database installation
`sql-bench`	Benchmarks

Debug versions of the `mysqld` binary are available as `mysqld-debug`. To compile your own debug version of MySQL from a source distribution, use the appropriate configuration options to enable debugging support. See Section 2.9, “Installing MySQL from Source”.

To install and use a MySQL binary distribution, the command sequence looks like this:

```
shell> groupadd mysql
shell> useradd -r -g mysql -s /bin/false mysql
shell> cd /usr/local
shell> tar zxvf /path/to/mysql-VERSION-OS.tar.gz
shell> ln -s full-path-to-mysql-VERSION-OS mysql
```

```
shell> cd mysql
shell> chown -R mysql .
shell> chgrp -R mysql .
shell> scripts/mysql_install_db --user=mysql
shell> chown -R root .
shell> chown -R mysql data
# Next command is optional
shell> cp support-files/my-medium.cnf /etc/my.cnf
shell> bin/mysqld_safe --user=mysql &
# Next command is optional
shell> cp support-files/mysql.server /etc/init.d/mysql.server
```

Note

This procedure assumes that you have `root` (administrator) access to your system. Alternatively, you can prefix each command using the `sudo` (Linux) or `pfexec` (Solaris) command.

Note

The procedure does not assign passwords to MySQL accounts. To do so, use the instructions in Section 2.10.4, “Securing the Initial MySQL Accounts”.

A more detailed version of the preceding description for installing a binary distribution follows.

Create a mysql User and Group

If your system does not already have a user and group to use for running `mysqld`, you may need to create one. The following commands add the `mysql` group and the `mysql` user. You might want to call the user and group something else instead of `mysql`. If so, substitute the appropriate name in the following instructions. The syntax for `useradd` and `groupadd` may differ slightly on different versions of Unix, or they may have different names such as `adduser` and `addgroup`.

```
shell> groupadd mysql
shell> useradd -r -g mysql -s /bin/false mysql
```

Note

Because the user is required only for ownership purposes, not login purposes, the `useradd` command uses the `-r` and `-s /bin/false` options to create a user that does not have login permissions to your server host. Omit these options if your `useradd` does not support them.

Obtain and Unpack the Distribution

Pick the directory under which you want to unpack the distribution and change location into it. The example here unpacks the distribution under `/usr/local`. The instructions, therefore, assume that you have permission to create files and directories in `/usr/local`. If that directory is protected, you must perform the installation as `root`.

```
shell> cd /usr/local
```

Obtain a distribution file using the instructions in Section 2.1.2, “How to Get MySQL”. For a given release, binary distributions for all platforms are built from the same MySQL source distribution.

Unpack the distribution, which creates the installation directory. Then create a symbolic link to that directory. `tar` can uncompress and unpack the distribution if it has `z` option support:

```
shell> tar zxvf /path/to/mysql-VERSION-OS.tar.gz
```

```
shell> ln -s full-path-to-mysql-VERSION-OS mysql
```

The `tar` command creates a directory named `mysql-VERSION-OS`. The `ln` command makes a symbolic link to that directory. This enables you to refer more easily to the installation directory as `/usr/local/mysql`.

To install MySQL from a compressed `tar` file binary distribution, your system must have GNU `gunzip` to uncompress the distribution and a reasonable `tar` to unpack it. If your `tar` program supports the `z` option, it can both uncompress and unpack the file.

GNU `tar` is known to work. The standard `tar` provided with some operating systems is not able to unpack the long file names in the MySQL distribution. You should download and install GNU `tar`, or if available, use a preinstalled version of GNU tar. Usually this is available as `gnutar`, `gtar`, or as `tar` within a GNU or Free Software directory, such as `/usr/sfw/bin` or `/usr/local/bin`. GNU `tar` is available from http://www.gnu.org/software/tar/.

If your `tar` does not have `z` option support, use `gunzip` to unpack the distribution and `tar` to unpack it. Replace the preceding `tar` command with the following alternative command to uncompress and extract the distribution:

```
shell> gunzip < /path/to/mysql-VERSION-OS.tar.gz | tar xvf -
```

Perform Postinstallation Setup

The remainder of the installation process involves setting distribution ownership and access permissions, initializing the data directory, starting the MySQL server, and setting up the configuration file. For instructions, see Section 2.10, “Postinstallation Setup and Testing”.

2.3 Installing MySQL on Microsoft Windows

Important

MySQL Community 5.5 Server requires the Microsoft Visual C++ 2008 Redistributable Package to run on Windows platforms. Users should make sure the package has been installed on the system before installing the server. The package is available at the Microsoft Download Center.

MySQL is available for Microsoft Windows, for both 32-bit and 64-bit versions. For supported Windows platform information, see http://www.mysql.com/support/supportedplatforms/database.html.

There are different methods to install MySQL on Microsoft Windows.

MySQL Installer Method

The simplest and recommended method is to download MySQL Installer (for Windows) and let it install and configure all of the MySQL products on your system. Here is how:

1. Download MySQL Installer from http://dev.mysql.com/downloads/installer/ and execute it.

Note

Unlike the standard MySQL Installer, the smaller "web-community" version does not bundle any MySQL applications but it will download the MySQL products you choose to install.

2. Choose the appropriate **Setup Type** for your system. Typically you will choose **Developer Default** to install MySQL server and other MySQL tools related to MySQL development, helpful tools like MySQL Workbench. Or, choose the **Custom** setup type to manually select your desired MySQL products.

Note

Multiple versions of MySQL server can exist on a single system. You can choose one or multiple versions.

3. Complete the installation process by following the instructions. This will install several MySQL products and start the MySQL server.

MySQL is now installed. If you configured MySQL as a service, then Windows will automatically start MySQL server every time you restart your system.

Note

You probably also installed other helpful MySQL products like MySQL Workbench and MySQL Notifier on your system. Consider loading Chapter 26, *MySQL Workbench* to check your new MySQL server connection, and Section 2.3.4, “MySQL Notifier” to view the connection's status. By default, these two programs automatically start after installing MySQL.

This process also installs the MySQL Installer application on your system, and later you can use MySQL Installer to upgrade or reconfigure your MySQL products.

Additional Installation Information

It is possible to run MySQL as a standard application or as a Windows service. By using a service, you can monitor and control the operation of the server through the standard Windows service management tools. For more information, see Section 2.3.7.7, “Starting MySQL as a Windows Service”.

Generally, you should install MySQL on Windows using an account that has administrator rights. Otherwise, you may encounter problems with certain operations such as editing the `PATH` environment variable or accessing the `Service Control Manager`. When installed, MySQL does not need to be executed using a user with Administrator privileges.

For a list of limitations on the use of MySQL on the Windows platform, see Section C.10.6, “Windows Platform Limitations”.

In addition to the MySQL Server package, you may need or want additional components to use MySQL with your application or development environment. These include, but are not limited to:

- To connect to the MySQL server using ODBC, you must have a Connector/ODBC driver. For more information, including installation and configuration instructions, see MySQL Connector/ODBC Developer Guide.

  Note

  MySQL Installer will install and configure Connector/ODBC for you.

- To use MySQL server with .NET applications, you must have the Connector/Net driver. For more information, including installation and configuration instructions, see MySQL Connector/Net Developer Guide.

  Note

  MySQL Installer will install and configure MySQL Connector/Net for you.

MySQL distributions for Windows can be downloaded from http://dev.mysql.com/downloads/. See Section 2.1.2, “How to Get MySQL”.

MySQL for Windows is available in several distribution formats, detailed here. Generally speaking, you should use MySQL Installer. It contains more features and MySQL products than the older MSI, is simpler to use than the compressed file, and you need no additional tools to get MySQL up and running. MySQL Installer automatically installs MySQL Server and additional MySQL products, creates an options file, starts the server, and enables you to create default user accounts. For more information on choosing a package, see Section 2.3.2, “Choosing an Installation Package”.

- Binary installer distributions. There are two different installable distributions that come packaged as a Microsoft Windows Installer (MSI) package that you can install manually or automatically on your systems. The preferred MySQL Installer package includes MySQL Server and additional MySQL products including MySQL Workbench, MySQL Notifier, and MySQL for Excel. MySQL Installer can also be used to upgrade these product in the future. The older MSI package contains all the files you need to install and configure MySQL server, but no additional components.

  For instructions on installing MySQL using MySQL Installer, see Section 2.3.3, “MySQL Installer for Windows”.

- The standard binary distribution (packaged as a compressed file) contains all of the necessary files that you unpack into your chosen location. This package contains all of the files in the full Windows MSI Installer package, but does not include an installation program.

  For instructions on installing MySQL using the compressed file, see Section 2.3.7, “Installing MySQL on Microsoft Windows Using a `noinstall` ZIP Archive”.

- The source distribution format contains all the code and support files for building the executables using the Visual Studio compiler system.

  For instructions on building MySQL from source on Windows, see Section 2.9, “Installing MySQL from Source”.

MySQL on Windows considerations:

- **Large Table Support**

  If you need tables with a size larger than 4GB, install MySQL on an NTFS or newer file system. Do not forget to use `MAX_ROWS` and `AVG_ROW_LENGTH` when you create tables. See Section 13.1.17, “CREATE TABLE Syntax”.

- **MySQL and Virus Checking Software**

  Virus-scanning software such as Norton/Symantec Anti-Virus on directories containing MySQL data and temporary tables can cause issues, both in terms of the performance of MySQL and the virus-scanning software misidentifying the contents of the files as containing spam. This is due to the fingerprinting mechanism used by the virus-scanning software, and the way in which MySQL rapidly updates different files, which may be identified as a potential security risk.

  After installing MySQL Server, it is recommended that you disable virus scanning on the main directory (`datadir`) used to store your MySQL table data. There is usually a system built into the virus-scanning software to enable specific directories to be ignored.

  In addition, by default, MySQL creates temporary files in the standard Windows temporary directory. To prevent the temporary files also being scanned, configure a separate temporary directory for MySQL temporary files and add this directory to the virus scanning exclusion list. To do this, add a configuration option for the `tmpdir` parameter to your `my.ini` configuration file. For more information, see Section 2.3.7.2, “Creating an Option File”.

- **Running MySQL on a 4K Sector Hard Drive**

  Running the MySQL server on a 4K sector hard drive on Windows is not supported with `innodb_flush_method=async_unbuffered`, which is the default setting. The workaround is to use `innodb_flush_method=normal`.

2.3.1 MySQL Installation Layout on Microsoft Windows

For MySQL 5.5 on Windows, the default installation directory is `C:\Program Files\MySQL\MySQL Server 5.5`. Some Windows users prefer to install in `C:\mysql`, the directory that formerly was used as the default. However, the layout of the subdirectories remains the same.

All of the files are located within this parent directory, using the structure shown in the following table.

Table 2.4 Default MySQL Installation Layout for Microsoft Windows

Directory	Contents of Directory	Notes
`bin`, `scripts`	`mysqld` server, client and utility programs	
`%ALLUSERSPROFILE%\MySQL\MySQL Server 5.5\`	Log files, databases (Windows XP, Windows Server 2003)	The Windows system variable `%ALLUSERSPROFILE%` defaults to `C:\Documents and Settings\All Users\Application Data`
`%PROGRAMDATA%\MySQL\MySQL Server 5.5\`	Log files, databases (Vista, Windows 7, Windows Server 2008, and newer)	The Windows system variable `%PROGRAMDATA%` defaults to `C:\ProgramData`
`examples`	Example programs and scripts	
`include`	Include (header) files	
`lib`	Libraries	
`share`	Miscellaneous support files, including error messages, character set files, sample configuration files, SQL for database installation	

If you install MySQL using a Windows MSI package, this package creates and sets up the data directory that the installed server will use, but as of MySQL 5.5.5, it also creates a pristine “template” data directory named `data` under the installation directory. This directory can be useful when the machine will be used to run multiple instances of MySQL: After an installation has been performed using an MSI package, the template data directory can be copied to set up additional MySQL instances. See Section 5.6, “Running Multiple MySQL Instances on One Machine”.

2.3.2 Choosing an Installation Package

For MySQL 5.5, there are multiple installation package formats to choose from when installing MySQL on Windows.

Note

MySQL Installer and the "Complete Package" methods for installing MySQL are similar, but different. The MySQL Installer is the newer and more advanced option, and it includes all functionality found within the "Complete Package."

Note

Program Database (PDB) files (with file name extension `pdb`) provide information for debugging your MySQL installation in the event of a problem. These files are included in ZIP Archive distributions (but not MSI distributions) of MySQL.

- **MySQL Installer**: This package has a file name similar to `mysql-installer-community-5.5.60.0.msi` or `mysql-installer-commercial-5.5.60.0.msi`, and utilizes MSIs to automatically install MySQL server and other products. It will download and apply updates to itself, and for each of the installed products. It also configures the installed MySQL server.

  MySQL Installer can install and manage (add, modify, upgrade, and remove) many other MySQL products, including:

  - Applications – MySQL Workbench, MySQL for Visual Studio, MySQL Notifier, MySQL for Excel, MySQL Utilities
  - Connectors – MySQL Connector/C, MySQL Connector/C++, MySQL Connector/Net, Connector/ODBC, MySQL Connector/Python, MySQL Connector/J
  - Documentation – MySQL Manual (PDF format), samples and examples

  MySQL Installer will run on all Windows platforms that are supported by MySQL (see http://www.mysql.com/support/supportedplatforms/database.html).

  Note

  Because MySQL Installer is not a native component of Microsoft Windows and depends on .NET, it will not work on minimal installation options like the "Server Core" version of Windows Server 2008.

  For instructions on installing MySQL using MySQL Installer, see Section 2.3.3, “MySQL Installer for Windows”.

- **The Complete Package (MSI Installer)**: This package has a file name similar to `mysql-5.5.60-win32.msi` or `mysql-5.5.60-winx64.msi`, and contains all files needed for a complete Windows installation, including the Configuration Wizard. This package includes optional components such as the embedded server and benchmark suite.

- **The `noinstall` ZIP Archive**: This package has a file name similar to `mysql-5.5.60-win32.zip` or `mysql-5.5.60-winx64.zip`, and contains all the files found in the Complete install package, with the exception of the GUI. It also contains PDB files. This package does not include an automated installer, and must be manually installed and configured.

MySQL Installer is recommended for most users.

Your choice of install package affects the installation process you must follow. If you choose to use MySQL Installer, see Section 2.3.3, “MySQL Installer for Windows”. If you choose to install a standard MSI package, see Section 2.3.5, “Installing MySQL on Microsoft Windows Using an MSI Package”. If you choose to install a `noinstall` ZIP archive, see Section 2.3.7, “Installing MySQL on Microsoft Windows Using a `noinstall` ZIP Archive”.

2.3.3 MySQL Installer for Windows

MySQL Installer is a standalone application designed to ease the complexity of installing and managing MySQL products that run on Microsoft Windows. It supports the following MySQL products:

- MySQL Servers

  MySQL Installer can install and manage multiple, separate MySQL server instances on the same host at the same time. For example, MySQL Installer can install, configure, and upgrade a separate instance of MySQL 5.6, MySQL 5.7, and MySQL 8.0 on the same host. MySQL Installer does not permit server upgrades between major and minor version numbers, but does permit upgrades within a release series (such as 5.7.18 to 5.7.19).

  A host *cannot* have both community and commercial editions of MySQL server installed.

- MySQL Applications

  MySQL Workbench, MySQL Shell, MySQL Router, MySQL for Visual Studio, MySQL for Excel, MySQL Notifier, and MySQL Utilities.

- MySQL Connectors

  MySQL Connector/Net, MySQL Connector/Python, MySQL Connector/Node.js MySQL Connector/ODBC, MySQL Connector/J, MySQL Connector/C, and MySQL Connector/C++.

- Documentation and Samples

  MySQL Reference Manuals (by version) in PDF format and MySQL database samples (by version).

MySQL Installer Community Edition

Download this edition from http://dev.mysql.com/downloads/installer/ to install the community version of all MySQL products for Windows. Select one of the following MySQL Installer package options:

- *Web:* Contains MySQL Installer and configuration files only. The web package downloads only the MySQL products you select to install, but it requires an internet connection for each download. The size of this file is approximately 2 MB; the name of the file has the form `mysql-installer-community-web-VERSION.N.msi` where `VERSION` is the MySQL server version number such as 5.7 and `N` is the package number, which begins at 0.

- *Full:* Bundles all of the MySQL products for Windows (including the MySQL server). The file size is over 300 MB, and its name has the form `mysql-installer-community-VERSION.N.msi` where `VERSION` is the MySQL Server version number such as 5.7 and `N` is the package number, which begins at 0.

MySQL Installer Commercial Edition

Download this edition from https://edelivery.oracle.com/ to install the commercial edition of all MySQL products for Windows. The Commercial Edition includes all of the products in the Community Edition and also includes the following products:

- Workbench SE/EE
- MySQL Enterprise Backup
- MySQL Enterprise Firewall

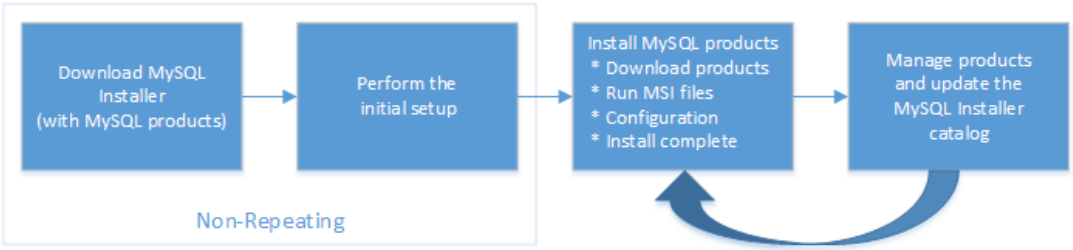
This edition integrates with your My Oracle Support (MOS) account. For knowledge-base content and patches, see My Oracle Support.

2.3.3.1 MySQL Installer Initial Setup

- MySQL Installer Licensing and Support Authentication
- Choosing a Setup Type
- Path Conflicts
- Check Requirements
- MySQL Installer Configuration Files

When you download MySQL Installer for the first time, a setup wizard guides you through the initial installation of MySQL products. As the following figure shows, the initial setup is a one-time activity in the overall process. MySQL Installer detects existing MySQL products installed on the host during its initial setup and adds them to the list of products to be managed.

Figure 2.7 MySQL Installer Process Overview



MySQL Installer extracts configuration files (described later) to the hard drive of the host during the initial setup. Although MySQL Installer is a 32-bit application, it can install both 32-bit and 64-bit binaries.

The initial setup adds a link to the Start menu under the **MySQL** group. Click **Start**, **All Programs**, **MySQL**, **MySQL Installer** to open MySQL Installer.

MySQL Installer Licensing and Support Authentication

MySQL Installer requires you to accept the license agreement before it will install new MySQL packages. After you accept the terms of the agreement, you can add, update, reconfigure, and remove all of the products and features provided by the MySQL Installer edition you downloaded.

For the commercial edition, entering your My Oracle Support (MOS) credentials is optional when installing bundled MySQL products, but your credentials are required when choosing unbundled MySQL products that MySQL Installer must download. An unbundled product is any MSI file that you download using MySQL Installer after the initial setup. Your credentials must match the user name and password that you have registered with Oracle for access to the support site.

Choosing a Setup Type

During the initial setup, you are prompted to select the MySQL products to be installed on the host. One alternative is to use a predetermined setup type that matches your setup requirements. Choosing one of the following setup types determines the initial installation only and does not limit your ability to install or update MySQL products for Windows later:

- **Developer Default**: Install the following products that compliment application development with MySQL:
  - MySQL Server (Installs the version that you selected when you downloaded MySQL Installer.)
  - MySQL Shell
  - MySQL Router
  - MySQL Workbench
  - MySQL for Visual Studio
  - MySQL for Excel
  - MySQL Notifier
  - MySQL Connectors (.NET / Python / ODBC / Java / C / C++)
  - MySQL Utilities
  - MySQL Documentation
  - MySQL Samples and Examples

- **Server only**: Only install the MySQL server. This setup type installs the general availability (GA) or development release server that you selected when you downloaded MySQL Installer. It uses the default installation and data paths.
- **Client only**: Only install the most recent MySQL applications and MySQL connectors. This setup type is similar to the `Developer Default` type, except that it does not include MySQL server or the client programs typically bundled with the server, such as `mysql` or `mysqladmin`.
- **Full**: Install all available MySQL products.
- **Custom** The custom setup type enables you to filter and select individual MySQL products from the MySQL Installer catalog.

  Use the `Custom` setup type to install:

  - A product or product version that is not available from the usual download locations. The catalog contains all product releases, including the other releases between pre-release (or development) and GA.
  - An instance of MySQL server using an alternative installation path, data path, or both. For instructions on how to adjust the paths, see Setting Alternative Server Paths with MySQL Installer.
  - Two or more MySQL server versions on the same host at the same time (for example, 5.6, 5.7, and 8.0).
  - A specific combination of products and features not offered as a predetermine setup type. For example, you can install a single product, such as MySQL Workbench, instead of installing all client applications for Windows.

Path Conflicts

When the default installation or data folder (required by MySQL server) for a product to be installed already exists on the host, the wizard displays the **Path Conflict** step to identify each conflict and enable you to take action to avoid having files in the existing folder overwritten by the new installation. You see this step in the initial setup only when MySQL Installer detects a conflict.

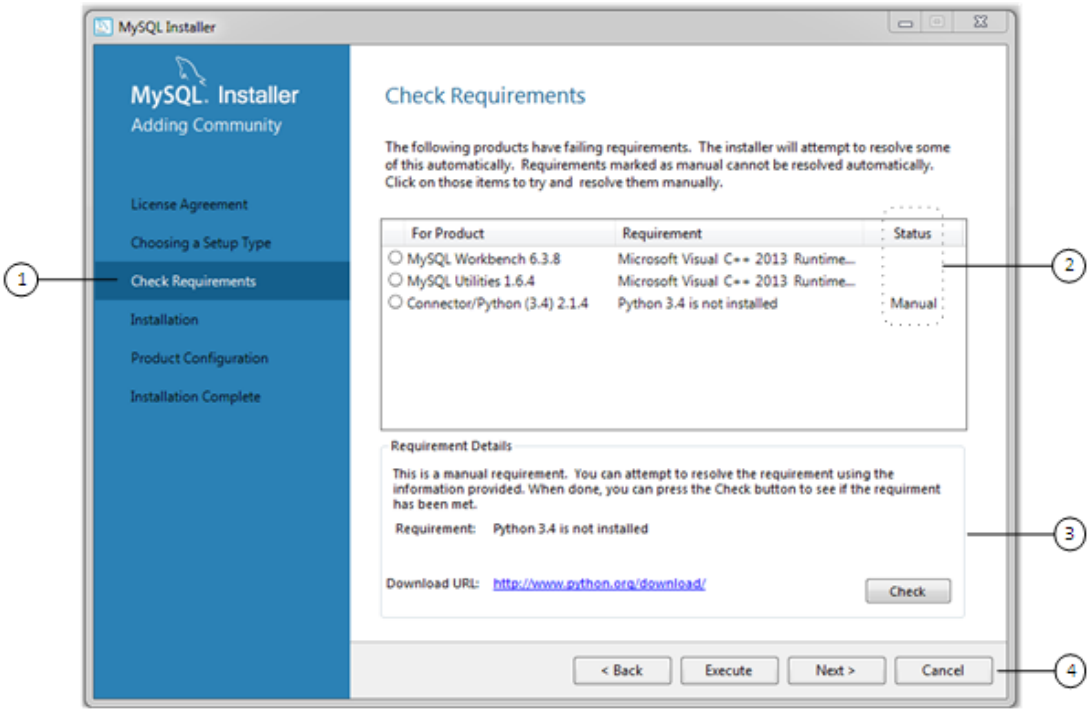
To resolve the path conflict, do one of the following:

- Select a product from the list to display the conflict options. A warning symbol indicates which path is in conflict. Use the browse button to choose a new path and then click **Next**.
- Click **Back** to choose a different setup type or product version, if applicable. The `Custom` setup type enables you to select individual product versions.
- Click **Next** to ignore the conflict and overwrite files in the existing folder.
- Delete the existing product. Click **Cancel** to stop the initial setup and close MySQL Installer. Open MySQL Installer again from the Start menu and delete the installed product from the host using the Delete operation from the dashboard.

Check Requirements

MySQL Installer uses entries in the `package-rules.xml` file to determine whether the prerequisite software for each product is installed on the host. When the requirements check fails, MySQL Installer displays the **Check Requirements** step to help you update the host. The following figure identifies and describes the key areas of this step.

Figure 2.8 Check Requirements



Description of Check Requirements Elements

1. Shows the current step in the initial setup. Steps in this list may change slightly depending on the products already installed on the host, the availability of prerequisite software, and the products to be installed on the host.

2. Lists all pending installation requirements by product and indicates the status as follows:

   - A blank space in the **Status** column means that MySQL Installer can attempt to download and install the required software for you.

   - The word *Manual* in the **Status** column means that you must satisfy the requirement manually. Select each product in the list to see its requirement details.

3. Describes the requirement in detail to assist you with each manual resolution. When possible, a download URL is provided. After you download and install the required software, click **Check** to verify that the requirement has been met.

4. Provides the following set operations to proceed:

   - **Back** – Return to the previous step. This action enables you to select a different the setup type.

   - **Execute** – Have MySQL Installer attempt to download and install the required software for all items without a manual status. Manual requirements are resolved by you and verified with the **Check** button.

   - **Next** – Do not execute the request to apply the requirements automatically and proceed to the installation without including the products that fail the check requirements step.

   - **Cancel** – Stop the installation of MySQL products. Because MySQL Installer is already installed, the initial setup begins again when you open MySQL Installer from the Start menu and click **Add** from the dashboard. For a description of the available management operations, see Product Catalog.

MySQL Installer Configuration Files

All MySQL Installer files are located within the `C:\Program Files (x86)` and `C:\ProgramData` folders. The following table describes the files and folders that define MySQL Installer as a standalone application.

Note

Installed MySQL products are neither altered nor removed when you update or uninstall MySQL Installer.

Table 2.5 MySQL Installer Configuration Files

File or Folder	Description	Folder Hierarchy
`MySQL Installer for Windows`	This folder contains all of the files needed to run MySQL Installer and MySQLInstallerConsole.exe, a command-line program with similar functionality.	`C:\Program Files (x86)`
`Templates`	The `Templates` folder has one file for each version of MySQL server. Template files contain keys and formulas to calculate some values dynamically.	`C:\ProgramData\MySQL \MySQL Installer for Windows\Manifest`
`package-rules.xml`	This file contains the prerequisites for every product to be installed.	`C:\ProgramData\MySQL \MySQL Installer for Windows\Manifest`
`produts.xml`	The `products` file (or product catalog) contains a list of all products available for download.	`C:\ProgramData\MySQL \MySQL Installer for Windows\Manifest`
`Product Cache`	The `Product Cache` folder contains all standalone MSI files bundled with the full package or downloaded afterward.	`C:\ProgramData\MySQL \MySQL Installer for Windows`

2.3.3.2 Installation Workflow with MySQL Installer

MySQL Installer provides a wizard-like tool to install and configure new MySQL products for Windows. Unlike the initial setup, which runs only once, MySQL Installer invokes the wizard each time you download or install a new product. For first-time installations, the steps of the initial setup proceed directly into the steps of the installation.

Note

Full permissions are granted to the user executing MySQL Installer to all generated files, such as `my.ini`. This does not apply to files and directories for specific products, such as the MySQL server data directory in `%ProgramData%` that is owned by `SYSTEM`.

Products installed and configured on a host follow a general pattern that might require your input during the various steps. MySQL Installer loads all selected products together using the following workflow:

- Product download. If you installed the full (not web) MySQL Installer package, all MSI files were loaded to the `Product Cache` folder during the initial setup and are not downloaded again. Otherwise, the status of each product changes from `Downloading` to `Downloaded`.
- Product installation. The status of each product in the list changes from `Ready to Install` to `Installing` to `Complete`. During the process, click **Show Details** to view the installation actions.

If you cancel the installation at this point, the products are installed, but the server (if installed) is not yet configured. To restart the server configuration, open MySQL Installer from the Start menu and click the **Reconfigure** link next to the appropriate server in the dashboard.

- Product configuration. This step applies to MySQL server and samples in most cases. The status for each item in the list should indicate, `Ready to Configure`. Click **Next** to begin the step-by-step configuration of all items in the list.

  The configuration options presented during this step depend on which version of the database you selected to install. After the installation completes, you can reconfigure MySQL server from the MySQL Installer dashboard.

- Installation compete. This step finalizes the installation and enables you to start some applications when the installation finishes.

InnoDB Cluster Sandbox Test Setup

You have two options to implement a high-availability solution when you install MySQL Server 5.7.17 or higher using MySQL Installer:

- Standalone MySQL Server / Classic MySQL Replication (default)

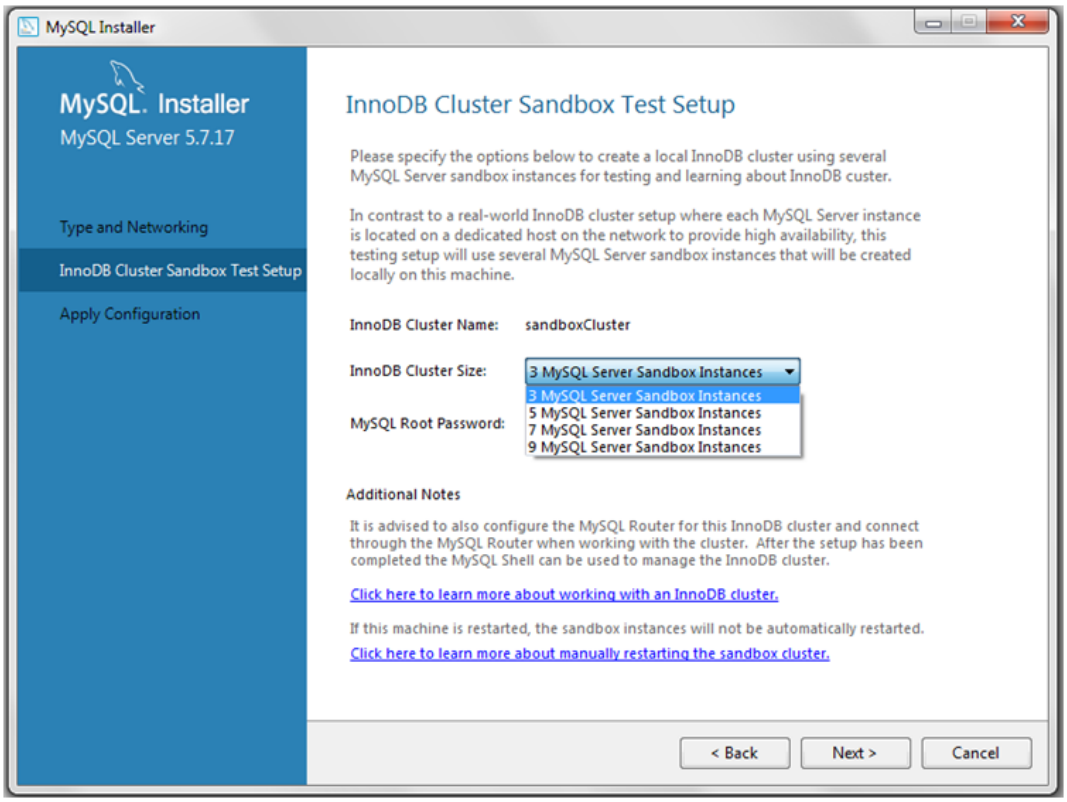
  Select this option to begin the initial configuration of a standalone MySQL server. You can configure multiple servers with classic MySQL Replication manually or use MySQL Shell 1.0.9 or higher to configure a production InnoDB cluster.

  For a description of the server configuration options that apply to a standalone MySQL server on Windows, see Server Configuration with MySQL Installer.

- InnoDB Cluster Sandbox Test Setup (for testing only)

  Select this option to create and configure InnoDB cluster sandbox instances locally for testing. You can configure an InnoDB cluster sandbox to have three, five, seven, or nine MySQL server instances. Use the **Reconfigure** quick action in the MySQL Installer toolbar to adjust the number of instances in the InnoDB cluster after the configuration has finished.

Figure 2.9 InnoDB Cluster Sandbox Test Setup



The InnoDB cluster sandbox, named `sandboxCluster` by default, is available on selected ports. After the configuration executes, click the **Summary** tab to view the specific ports that apply to your cluster.

You can use MySQL Installer to install MySQL Shell 1.0.9, if it is not installed. MySQL Shell enables you to manage the sandbox instances. To connect with the MySQL Shell on port 3310, execute the following command:

```
shell> mysqlsh root@localhost:3310
```

MySQL Installer also provides a wizard for configuring MySQL Router to connect to the test InnoDB cluster that was created in this step. For configuration details, see MySQL Router Configuration. To learn more about MySQL Router operations, see Routing for MySQL InnoDB cluster.

Server Configuration with MySQL Installer

MySQL Installer handles the initial configuration of the MySQL server. For example:

- It creates the configuration file (`my.ini`) that is used to configure the MySQL server. The values written to this file are influenced by choices you make during the installation process. Some definitions are host dependent. For example, query_cache is enabled if the host has fewer than three cores.

  Note

  Query cache was deprecated in MySQL 5.7 and removed in MySQL 8.0 (and later).

- By default, a Windows service for the MySQL server is added.
- Provides default installation and data paths for MySQL server. For instructions on how to change the default paths, see Setting Alternative Server Paths with MySQL Installer.

- It can optionally create MySQL server user accounts with configurable permissions based on general roles, such as DB Administrator, DB Designer, and Backup Admin. It optionally creates a Windows user named `MysqlSys` with limited privileges, which would then run the MySQL Server.

  User accounts may also be added and configured in MySQL Workbench.

- Checking **Show Advanced Options** allows additional **Logging Options** to be set. This includes defining custom file paths for the error log, general log, slow query log (including the configuration of seconds it requires to execute a query), and the binary log.

During the configuration process, click **Next** to proceed to the next step or **Back** to return to the previous step. Click **Execute** at the final step to apply the server configuration.

The sections that follow describe the server configuration options that apply to MySQL server on Windows. The server version you installed will determine which steps and options you can configure.

- Type and Networking
- Accounts and Roles
- Windows Service
- Plugins and Extensions
- Advanced Options
- Apply Server Configuration

Type and Networking

- Server Configuration Type

  Choose the MySQL server configuration type that describes your setup. This setting defines the amount of system resources (memory) that will be assigned to your MySQL server instance.

  - **Development**: A machine that will host many other applications, and typically this is your personal workstation. This option configures MySQL to use the least amount of memory.
  - **Server**: Several other applications will be running on this machine, such as a web server. This option configures MySQL to use a medium amount of memory.
  - **Dedicated**: A machine that is dedicated to running the MySQL server. Because no other major applications will run on this server, such as a web server, this option configures MySQL to use the majority of available memory.

- Connectivity

  Connectivity options control how the connection to MySQL is made. Options include:

  - **TCP/IP**: You may enable TCP/IP Networking here as otherwise only local host connections are allowed. Also define the **Port Number** and whether to open the firewall port for network access. If the port number is in use already, you will see the information icon ( ) next to the default value and **Next** is disabled until you provide a new port number.
  - **Named Pipe**: Enable and define the pipe name, similar to using the `--enable-named-pipe` option.
  - **Shared Memory**: Enable and then define the memory name, similar to using the `--shared-memory` option.

- Advanced Configuration

Check **Show Advanced Options** to set additional logging options in a later step. This includes defining custom file paths for the error log, general log, slow query log (including the configuration of seconds it requires to execute a query), and the binary log.

- MySQL Enterprise Firewall (Commercial Edition only)

  The **Enable Enterprise Firewall** check box is selected by default. For post-installation instructions, see MySQL Enterprise Firewall.

Accounts and Roles

- Root Account Password

  Assigning a root password is required and you will be asked for it when performing other MySQL Installer operations. Password strength is evaluated when you repeat the password in the box provided. For descriptive information regarding password requirements or status, move your mouse pointer over the information icon ( ) when it appears.

- MySQL User Accounts

  Optionally, you can create additional MySQL user accounts with predefined user roles. Each predefined role, such as DB Admin, are configured with their own set of privileges. For example, the DB Admin role has more privileges than the DB Designer role. Click the **Role** drop-down list for a description of each role.

Note

If the MySQL server is installed, then you must also enter the current root password.

Windows Service

On the Windows platform, MySQL server can run as a named service managed by the operating system and be configured to start up automatically when Windows starts. Alternatively, you can configure MySQL server to run as an executable program that requires manual configuration.

- **Configure MySQL server as a Windows service** (Selected by default.)

  When the default configuration option is selected, you can also select the following:

  - **Start the MySQL Server at System Startup**

    When selected (default), the service startup type is set to Automatic; otherwise, the startup type is set to Manual.

  - **Run Windows Service as**

    When **Standard System Account** is selected (default), the service logs on as Network Service.

    The **Custom User** option must have privileges to log on to Microsoft Windows as a service. The **Next** button will be disabled until this user is configured with the required privileges.

    A custom user is configured in Windows by searching for "local security policy" in the Start menu. In the Local Security Policy window, select **Local Policies**, **User Rights Assignment**, and then **Log On As A Service** to open the property dialog. Click **Add User or Group** to add the custom user and then click **OK** in each dialog to save the changes.

- Deselect the Windows Service option

Plugins and Extensions

The **Plugins and Extensions** step is visible during a new installation of MySQL server version 5.7.12 (or higher) only. If you are upgrading from a previous MySQL version, then you need to open MySQL Installer again and select the **Reconfigure** MySQL server option.

- **Enable X Protocol / MySQL as a Document Store** (Selected by default.)

  When the X Protocol option is selected, MySQL Installer loads and starts the X Plugin. Without the X Plugin running, X Protocol clients cannot connect to the server.

  - **Port Number:** *33060*

    Requires an unused port. The default port number is 33060.

  - **Open Firewall port for network access**

    Open by default when the X Protocol is selected.

  For more information about using MySQL as a document store and the X Plugin, see Key Concepts and X Plugin.

Advanced Options

This step is available if the **Show Advanced Configuration** check box was selected during the **Type and Networking** step. To enable this step now, click **Back** to return to the **Type and Networking** step and select the check box.

Advanced configuration options are related to the following MySQL log files:

- Error log
- General log
- Slow query log
- Bin log

Apply Server Configuration

All configuration settings are applied to the MySQL server when you click **Execute**. Use the **Configuration Steps** tab to follow the progress of each action; the icon for each toggles from white to green on success. Otherwise, the process stops and displays an error message if an individual action times out. Click the **Log** tab to view the log.

When the installation is done and you click **Finish**, MySQL Installer and the installed MySQL products are added to the Microsoft Windows Start menu under the `MySQL` group. Opening MySQL Installer loads the dashboard where installed MySQL products are listed and other MySQL Installer operations are available.

Setting Alternative Server Paths with MySQL Installer

You can change the default installation path, the data path, or both when you install MySQL server. After you have installed the server, the paths cannot be altered without removing and reinstalling the server instance.

To change paths for MySQL server

1. Identify the MySQL server to change and display the **Advanced Options** link.

   a. Navigate to the **Select Products and Features** step by doing one of the following:

      i. If this is an initial setup, select the `Custom` setup type and click **Next**.

ii. If MySQL Installer is installed already, launch it from the Start menu and then click **Add** from the dashboard.

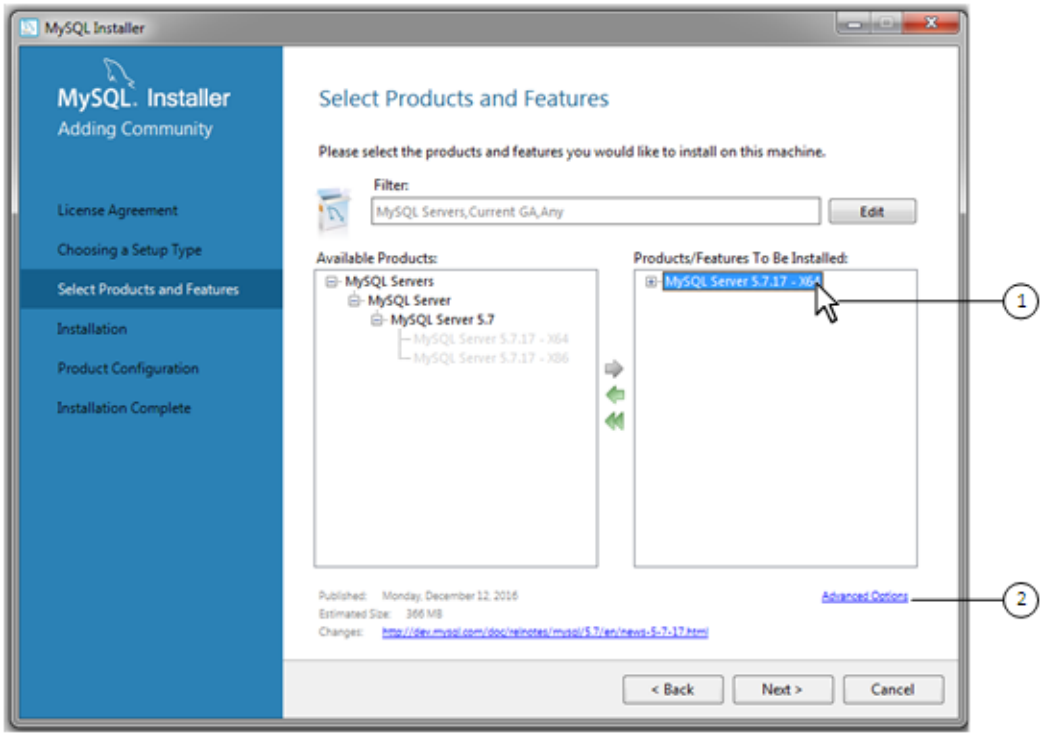
b. Click **Edit** to filter the list of products, locate the server instance to be installed in the **Available Products** list.

c. With the server instance selected, use the arrow to move the selected server to the **Products/Features To Be Installed** list.

d. Click the server to select it. When you select the server, the **Advanced Options** link appears. For details, see the figure that follows.

2. Click **Advanced Options** to open a dialog window with the path-setting options. After setting the path, click **Next** to continue with the configuration steps.

Figure 2.10 Change MySQL Server Path



MySQL Applications, Connectors, and Documentation

MySQL Installer provides you with a suite of tools for developing and managing business-critical applications on Windows. The suite consist of applications, connectors, documentation, and samples.

During the initial setup, choose any predetermined setup type, except `Server only`, to install the latest GA version of the tools. Use the `Custom` setup type to install an individual tool or specific version. If MySQL Installer is installed on the host already, use the **Add** operation to select and install tools from the MySQL Installer dashboard.

MySQL Router Configuration

MySQL Installer provides a configuration wizard that can bootstrap an installed instance of MySQL Router 2.1.3 or later to route traffic between MySQL applications and an InnoDB cluster. When configured, MySQL Router runs as a local Windows service. For detailed information about using MySQL Router with an InnoDB cluster, see Routing for MySQL InnoDB cluster.

To configure MySQL Router, do the following:

1. Set up InnoDB cluster. For instructions on how to configure an InnoDB cluster sandbox on the local host using MySQL Installer, see InnoDB Cluster Sandbox Test Setup. InnoDB cluster requires MySQL Server 5.7.17 or higher.

   For general InnoDB cluster information, see InnoDB Cluster.

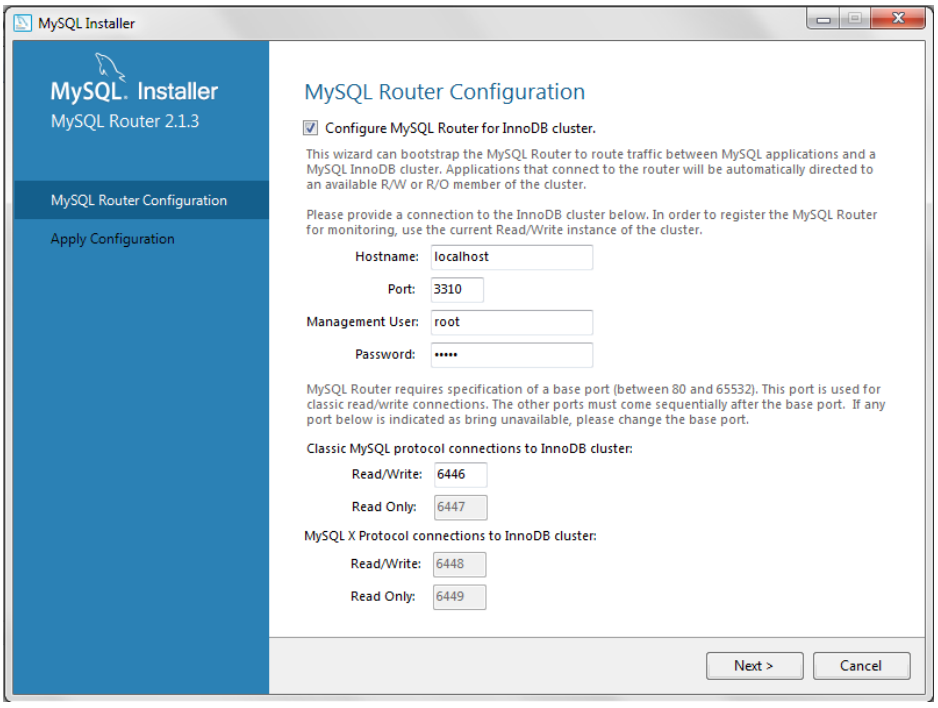
2. Using MySQL Installer, download and install the MySQL Router application. After the installation finishes, the configuration wizard prompts you for information. Select the **Configure MySQL Router for InnoDB cluster** check box to begin the configuration and provide the following configuration values:

   - **Hostname:** localhost by default.
   - **Port:** The port number of the primary server in the InnoDB cluster. The default is 3310.
   - **Management User:** An administrative user with root-level privileges.
   - **Password:** The password for the management user.
   - **Classic MySQL protocol connections to InnoDB cluster**

     Read/Write: Set the first base port number to one that is unused (between 80 and 65532) and the wizard will select the remaining ports for you.

     The figure that follows shows an example of the MySQL Router configuration screen.

   Figure 2.11 MySQL Router Configuration

3. Click **Next** and then **Execute** to apply the configuration. Click **Finish** to close MySQL Installer or return to the MySQL Installer dashboard.

2.3.3.3 MySQL Installer Product Catalog and Dashboard

- Product Catalog
- MySQL Installer Dashboard
- Locating Products to Install

This section describes the MySQL Installer product catalog and the dashboard.

Product Catalog

The product catalog stores the complete list of released MySQL products for Microsoft Windows that are available to download from MySQL Downloads. By default, and when an Internet connection is present, MySQL Installer updates the catalog daily. You can also update the catalog manually from the dashboard (described later).

An up-to-date catalog performs the following actions:

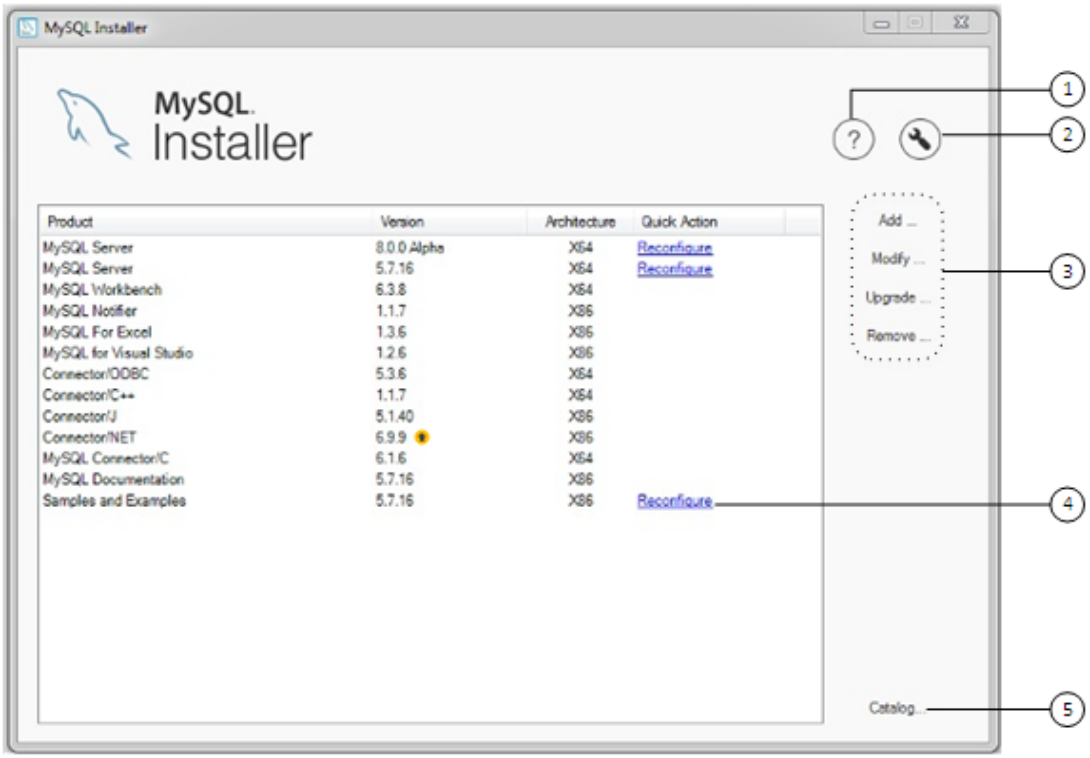
- Populates the **Available Products** pane of the Select Products and Features step. This step appears when you select:
  - The `Custom` setup type during the initial setup.
  - The **Add** operation from the dashboard.
- Identifies when product updates are available for the installed products listed in the dashboard.

The catalog includes all development releases (Pre-Release), general releases (Current GA), and minor releases (Other Releases). Products in the catalog will vary somewhat, depending on the MySQL Installer edition that you download.

MySQL Installer Dashboard

The MySQL Installer dashboard is the default screen that you see when you start MySQL Installer after the initial setup finishes. If you closed MySQL Installer before the setup was finished, MySQL Installer resumes the initial setup before it displays the dashboard.

Figure 2.12 MySQL Installer Dashboard Elements



Description of MySQL Installer Dashboard Elements

1. The About MySQL button (?) shows the current version of MySQL Installer and general information about MySQL. The version number is located above the **Back** button.

Always include this version number when reporting a problem with MySQL Installer.

2. The MySQL Installer Options button ( ) enables you to schedule daily automatic catalog updates. By default, catalog updates are scheduled at the hour when MySQL Installer was first installed. When new products or product versions are available, MySQL Installer adds them to the catalog and then displays an arrow icon ( ) next to the version number of installed products listed in the dashboard.

   Use this option to enable or disable automatic catalog updates and to reset the time of day when the MySQL Installer updates the catalog automatically. For specific settings, see the task named `ManifestUpdate` in the Windows Task Scheduler.

3. MySQL Installer dashboard operations provide a variety of actions that apply to installed products or products listed in the catalog. To initiate the following operations, first click the operation link and then select the product or products to manage:

   - **Add**: This operation opens the Select Products and Features screen. From there, you can filter the product in the product catalog, select one or more products to download (as needed), and begin the installation. For hints about using the filter, see Locating Products to Install.
   - **Modify**: Use this operation to add or remove the features associated with installed products. Features that you can modify vary in complexity by product. When the **Program Shortcut** check box is selected, the product appears in the Start menu under the `MySQL` group.
   - **Upgrade**: This operation loads the Select Products to Upgrade screen and populates it with all the upgrade candidates. An installed product can have more than one upgrade version and requires a current product catalog.

     Note

     MySQL Installer does not permit server upgrades between major and minor version numbers, but does permit upgrades within a release series, such as an upgrade from MySQL 5.7.18 to MySQL 5.7.19.

     To choose a new product version:

     a. Confirm that the check box next to product name in the **Upgradeable Products** pane has a check mark. Deselect the products that you do not intend to upgrade at this time.

     b. Click a product in the list to highlight it. This action populates the **Upgradeable Versions** pane with the details of each available version for the selected product: version number, published date, and a `Changes` link to open the release notes for that version.

     MySQL Installer upgrades all of the selected products in one action. Click **Show Details** to view the actions performed by MySQL Installer.

   - **Remove** This operation opens the Remove Products screen and populates it with the MySQL products installed on the host. Select the MySQL products you want to remove (uninstall) and then click **Execute** to begin the removal process.

     To select products to remove, do one of the following:

     - Select the check box for one or more products.
     - Select the **Product** check box to select all products.

4. The **Reconfigure** link in the Quick Action column next to each installed server loads the current configuration values for the server and then cycles through all configuration steps enabling you to change the options and values. On completion, MySQL Installer stops the server, applies the

configuration changes, and restarts the server for you. For a description of each configuration option, see Server Configuration with MySQL Installer.

Installed `Samples and Examples` associated with a specific MySQL server version can be also be reconfigured to apply feature-configuration changes, if any. You must provide credentials with root privileges to reconfigure these items.

5. The **Catalog** link enables you to download the latest catalog of MySQL products manually and then to integrate those product changes with MySQL Installer. The catalog-download action does not perform an upgrade of the products already installed on the host. Instead, it returns to the dashboard and displays an arrow icon in the Version column for each installed product that has a newer version. Use the **Upgrade** operation to install the newer product version.

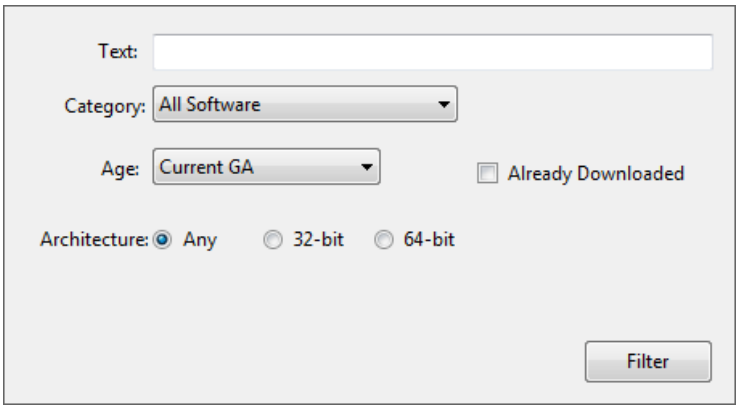
   You can also use the **Catalog** link to display the current change history of each product without downloading the new catalog. Select the **Do not update at this time** check box to view the change history only.

Locating Products to Install

MySQL products in the catalog are listed by category: MySQL Servers, Applications, MySQL Connectors, and Documentation. Only the latest GA versions appear in the **Available Products** pane by default. If you are looking for a pre-GA or older version of a product, it may not be visible in the default list.

To change the default product list, click **Add** on the dashboard to open the Select Products and Features screen, and then click **Edit**. Modify the product values and then click **Filter**.

Figure 2.13 Filter Available Products



Reset one or more of the following values to filter the list of available products:

- Text: Filter by text.
- Category: All Software (default), MySQL Servers, Applications, MySQL Connectors, or Documentation (for samples and documentation).
- Age: Pre-Release, Current GA (default), or Other Releases.
- Already Downloaded (the check box is deselected by default).
- Architecture: Any (default), 32-bit, or 64-bit.

2.3.3.4 MySQLInstallerConsole Reference

`MySQLInstallerConsole.exe` provides command-line functionality that is similar to MySQL Installer. It is installed when MySQL Installer is initially executed and then available within the `MySQL Installer` directory. Typically, that is in `C:\Program Files (x86)\MySQL\MySQL Installer \`, and the console must be executed with administrative privileges.

To use, invoke the command prompt with administrative privileges by choosing **Start**, **Accessories**, then right-click on **Command Prompt** and choose `Run as administrator`. And from the command line, optionally change the directory to where `MySQLInstallerConsole.exe` is located:

```
C:\> cd Program Files (x86)\MySQL\MySQL Installer for Windows
C:\Program Files (x86)\MySQL\MySQL Installer for Windows> MySQLInstallerConsole.exe help
=================== Start Initialization ===================
MySQL Installer is running in Community mode

Attempting to update manifest.
Initializing product requirements
Loading product catalog
Checking for product catalog snippets
Checking for product packages in the bundle
Categorizing product catalog
Finding all installed packages.
Your product catalog was last updated at 11/1/2016 4:10:38 PM
=================== End Initialization ===================

The following commands are available:

Configure - Configures one or more of your installed programs.
Help      - Provides list of available commands.
Install   - Install and configure one or more available MySQL programs.
List      - Provides an interactive way to list all products available.
Modify    - Modifies the features of installed products.
Remove    - Removes one or more products from your system.
Status    - Shows the status of all installed products.
Update    - Update the current product catalog.
Upgrade   - Upgrades one or more of your installed programs.
```

`MySQLInstallerConsole.exe` supports the following options, which are specified on the command line:

Note

Configuration block values that contain a colon (":") must be wrapped in double quotes. For example, installdir="C:\MySQL\MySQL Server 8.0".

- `configure` *`[product1]:[setting]=[value]; [product2]:[setting]=[value]; [...]`*

  Configure one or more MySQL products on your system. Multiple setting=value pairs can be configured for each product.

  Switches include:

  - `-showsettings` : Displays the available options for the selected product, by passing in the product name after `-showsettings`.
  - `-silent` : Disable confirmation prompts.

  ```
  C:\> MySQLInstallerConsole configure -showsettings server
  C:\> MySQLInstallerConsole configure server:port=3307
  ```

- `help` *`[command]`*

  Displays a help message with usage examples, and then exits. Pass in an additional command to receive help specific to that command.

  ```
  C:\> MySQLInstallerConsole help
  C:\> MySQLInstallerConsole help install
  ```

- `install` *`[product]:[features]:[config block]:[config block]:[config block]; [...]`*

Install one or more MySQL products on your system.

Switches and syntax options include:

- `-type=[SetupType]` : Installs a predefined set of software. The "SetupType" can be one of the following:

  Note

  Non-custom setup types can only be chosen if no other MySQL products are installed.

  - **Developer**: Installs a complete development environment.
  - **Server**: Installs a single MySQL server
  - **Client**: Installs client programs and libraries
  - **Full**: Installs everything
  - **Custom**: Installs user selected products. This is the default option.
- `-showsettings` : Displays the available options for the selected product, by passing in the product name after `-showsettings`.
- `-silent` : Disable confirmation prompts.
- `[config block]`: One or more configuration blocks can be specified. Each configuration block is a semicolon separated list of key value pairs. A block can include either a "config" or "user" type key, where "config" is the default type if one is not defined.

  Configuration block values that contain a colon (":") must be wrapped in double quotes. For example, `installdir="C:\MySQL\MySQL Server 8.0"`.

  Only one "config" type block can be defined per product. A "user" block should be defined for each user that should be created during the product's installation.

  Note

  Adding users is not supported when a product is being reconfigured.
- `[feature]`: The feature block is a semicolon separated list of features, or '*' to select all features.

```
C:\> MySQLInstallerConsole install server;5.6.25:*:port=3307;serverid=2:type=user;username=foo;passwo
C:\> MySQLInstallerConsole install server;5.6.25;x64 -silent
```

An example that passes in additional configuration blocks, broken up by `^` to fit this screen:

```
C:\> MySQLInstallerConsole install server;5.6.25;x64:*:type=config;openfirewall=true; ^
         generallog=true;binlog=true;serverid=3306;enable_tcpip=true;port=3306;rootpasswd=pass; ^
         installdir="C:\MySQL\MySQL Server 5.6":type=user;datadir="C:\MySQL\data";username=foo;passw
```

- `list`

Lists an interactive console where all of the available MySQL products can be searched. Execute `MySQLInstallerConsole list` to launch the console, and enter in a substring to search.

```
C:\> MySQLInstallerConsole list
```

- `modify [product1:-removelist|+addlist] [product2:-removelist|+addlist] [...]`

  Modifies or displays features of a previously installed MySQL product.

  - `-silent` : Disable confirmation prompts.

```
C:\> MySQLInstallerConsole modify server
C:\> MySQLInstallerConsole modify server:+documentation
C:\> MySQLInstallerConsole modify server:-debug
```

- `remove [product1] [product2] [...]`

  Removes one ore more products from your system.

  - `*` : Pass in `*` to remove all of the MySQL products.
  - `-continue` : Continue the operation even if an error occurs.
  - `-silent` : Disable confirmation prompts.

```
C:\> MySQLInstallerConsole remove *
C:\> MySQLInstallerConsole remove server
```

- `status`

  Provides a quick overview of the MySQL products that are installed on the system. Information includes product name and version, architecture, date installed, and install location.

```
C:\> MySQLInstallerConsole status
```

- `update`

  Downloads the latest MySQL product catalog to your system. On success, the download catalog will be applied the next time either MySQLInstaller or MySQLInstallerConsole is executed.

```
C:\> MySQLInstallerConsole update
```

Note

The **Automatic Catalog Update** GUI option executes this command from the Windows Task Scheduler.

- `upgrade [product1:version] [product2:version] [...]`

  Upgrades one or more products on your system. Syntax options include:

  - `*` : Pass in `*` to upgrade all products to the latest version, or pass in specific products.
  - `!` : Pass in `!` as a version number to upgrade the MySQL product to its latest version.
  - `-silent` : Disable confirmation prompts.

```
C:\> MySQLInstallerConsole upgrade *
C:\> MySQLInstallerConsole upgrade workbench:6.3.5
C:\> MySQLInstallerConsole upgrade workbench:!
C:\> MySQLInstallerConsole upgrade workbench:6.3.5 excel:1.3.2
```

2.3.4 MySQL Notifier

MySQL Notifier is a tool that enables you to monitor and adjust the status of your local and remote MySQL server instances through an indicator that resides in the system tray. MySQL Notifier also gives quick access to MySQL Workbench through its context menu.

The MySQL Notifier is installed by MySQL Installer, and (by default) will start-up when Microsoft Windows is started.

To install, download and execute the MySQL Installer, be sure the MySQL Notifier product is selected, then proceed with the installation. See the MySQL Installer manual for additional details.

For notes detailing the changes in each release of MySQL Notifier, see the MySQL Notifier Release Notes.

Visit the MySQL Notifier forum for additional MySQL Notifier help and support.

Features include:

- Start, Stop, and Restart instances of the MySQL Server.
- Automatically detects (and adds) new MySQL Server services. These are listed under **Manage Monitored Items**, and may also be configured.
- The Tray icon changes, depending on the status. It's green if all monitored MySQL Server instances are running, or red if at least one service is stopped. The **Update MySQL Notifier tray icon based on service status** option, which dictates this behavior, is enabled by default for each service.
- Links to other applications like MySQL Workbench, MySQL Installer, and the MySQL Utilities. For example, choosing **Manage Instance** will load the MySQL Workbench Server Administration window for that particular instance.
- If MySQL Workbench is also installed, then the **Manage Instance** and **SQL Editor** options are available for local (but not remote) MySQL instances.
- Monitors both local and remote MySQL instances.

2.3.4.1 MySQL Notifier Usage

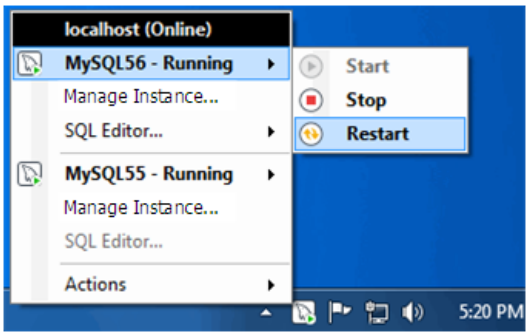
MySQL Notifier resides in the system tray and provides visual status information for your MySQL server instances. A green icon is displayed at the top left corner of the tray icon if the current MySQL server is running, or a red icon if the service is stopped.

MySQL Notifier automatically adds discovered MySQL services on the local machine, and each service is saved and configurable. By default, the **Automatically add new services whose name contains** option is enabled and set to `mysql`. Related **Notifications Options** include being notified when new services are either discovered or experience status changes, and are also enabled by default. And uninstalling a service will also remove the service from MySQL Notifier.

Clicking the system tray icon will reveal several options, as the follow figures show:

The Service Instance menu is the main MySQL Notifier window, and enables you to Stop, Start, and Restart the MySQL server.

Figure 2.14 MySQL Notifier Service Instance menu

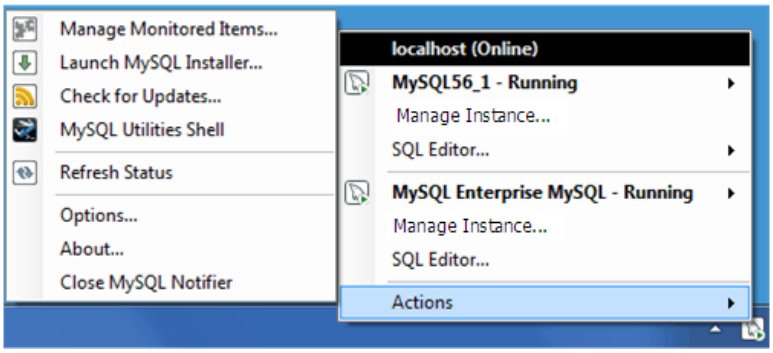


The **Actions** menu includes several links to external applications (if they are installed), and a **Refresh Status** option to manually refresh the status of all monitored services (in both local and remote computers) and MySQL instances.

Note

The main menu will not show the **Actions** menu when there are no services being monitored by MySQL Notifier.

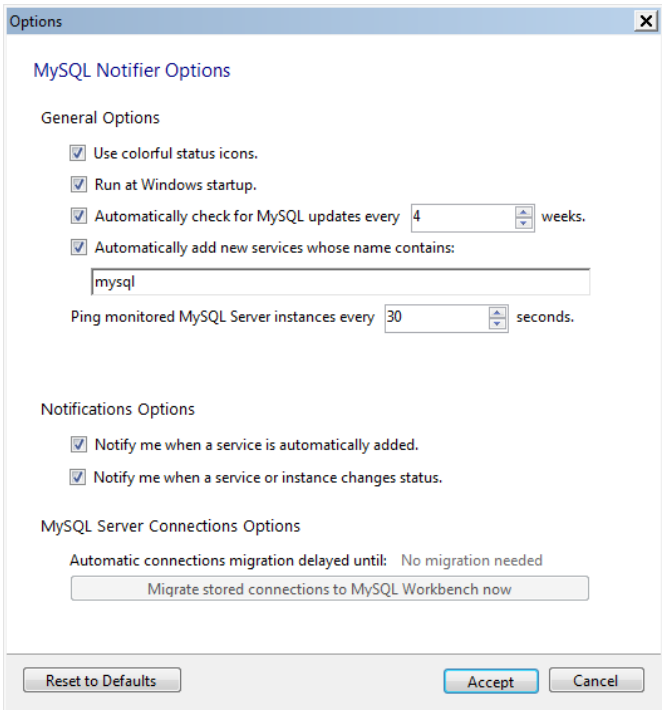
Figure 2.15 MySQL Notifier Actions menu



The **Actions**, **Options** menu configures MySQL Notifier and includes options to:

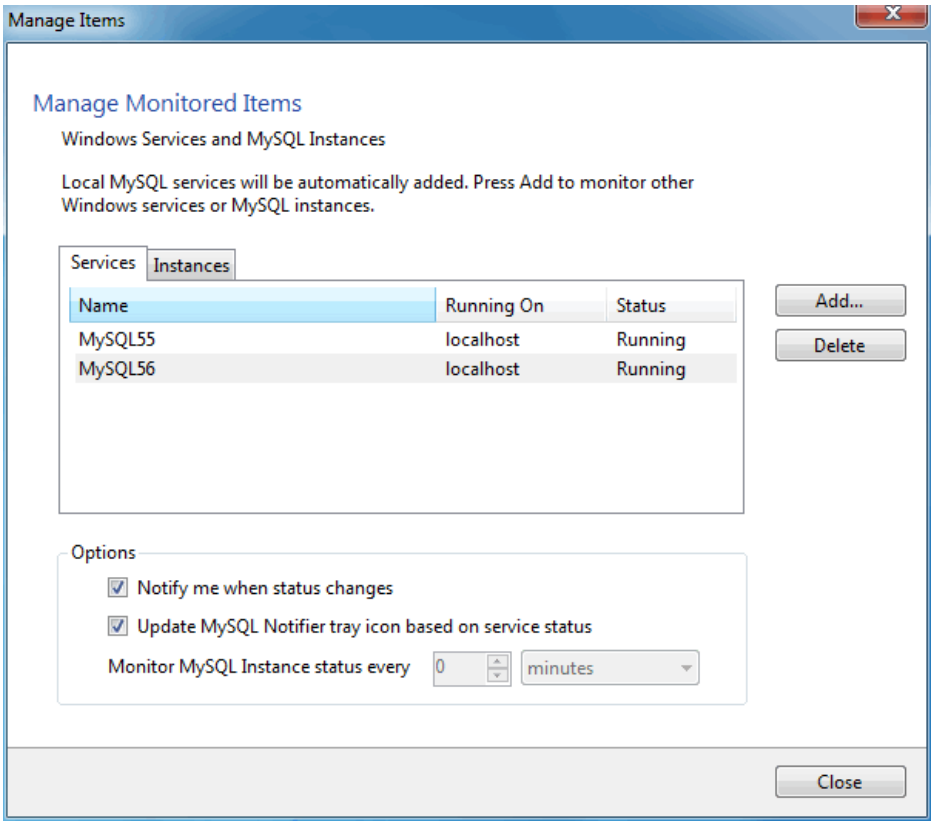
- **Use colorful status icons**: Enables a colorful style of icons for the tray of MySQL Notifier.
- **Run at Windows Startup**: Allows the application to be loaded when Microsoft Windows starts.
- **Automatically Check For Updates Every** # **Weeks**: Checks for a new version of MySQL Notifier, and runs this check every # weeks.
- **Automatically add new services whose name contains:** The text used to filter services and add them automatically to the monitored list of the local computer running MySQL Notifier, and on remote computers already monitoring Windows services.
- **Ping monitored MySQL Server instances every** # **seconds**: The interval (in seconds) to ping monitored MySQL Server instances for status changes. Longer intervals might be necessary if the list of monitored remote instances is large.
- **Notify me when a service is automatically added**: Will display a balloon notification from the taskbar when a newly discovered service is added to the monitored services list.
- **Notify me when a service changes status**: Will display a balloon notification from the taskbar when a monitored service changes its status.
- **Automatic connections migration delayed until:** When there are connections to migrate, postpone the migration by one hour, one day, one week, one month, or indefinitely.

Figure 2.16 MySQL Notifier Options menu



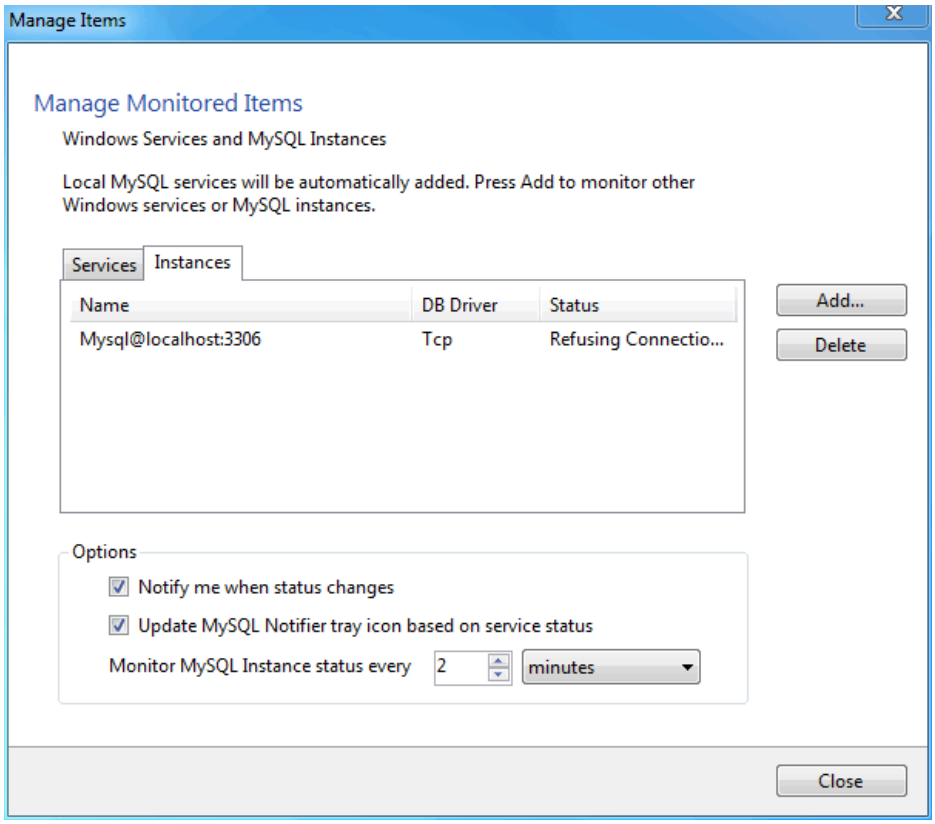
The **Actions**, **Manage Monitored Items** menu enables you to configure the monitored services and MySQL instances. First, with the **Services** tab open:

Figure 2.17 MySQL Notifier Manage Services menu



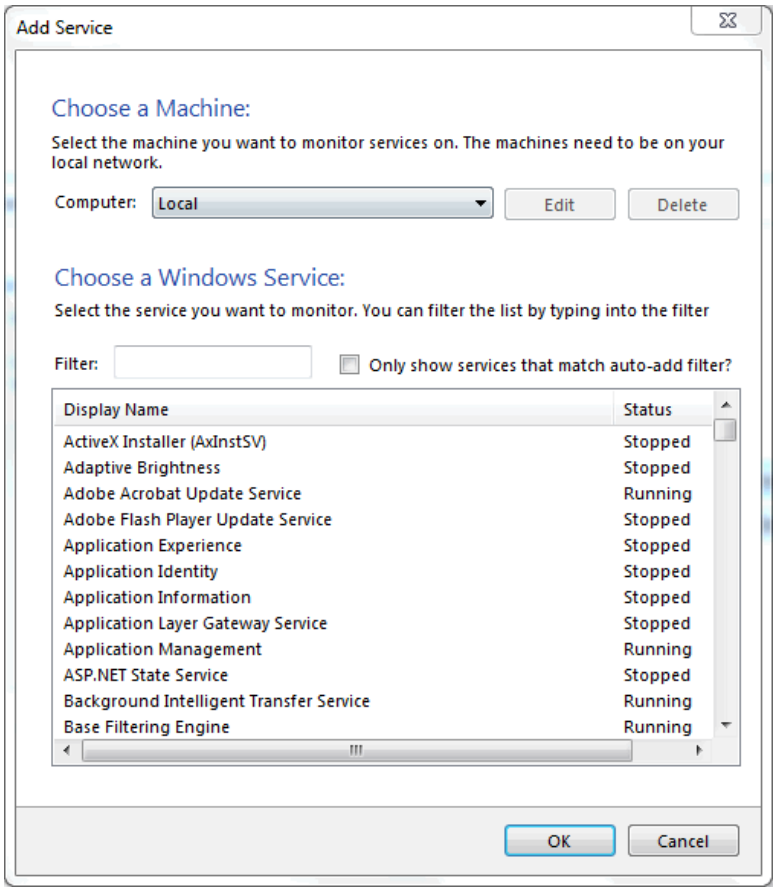
The **Instances** tab is similar:

Figure 2.18 MySQL Notifier Manage Instances menu



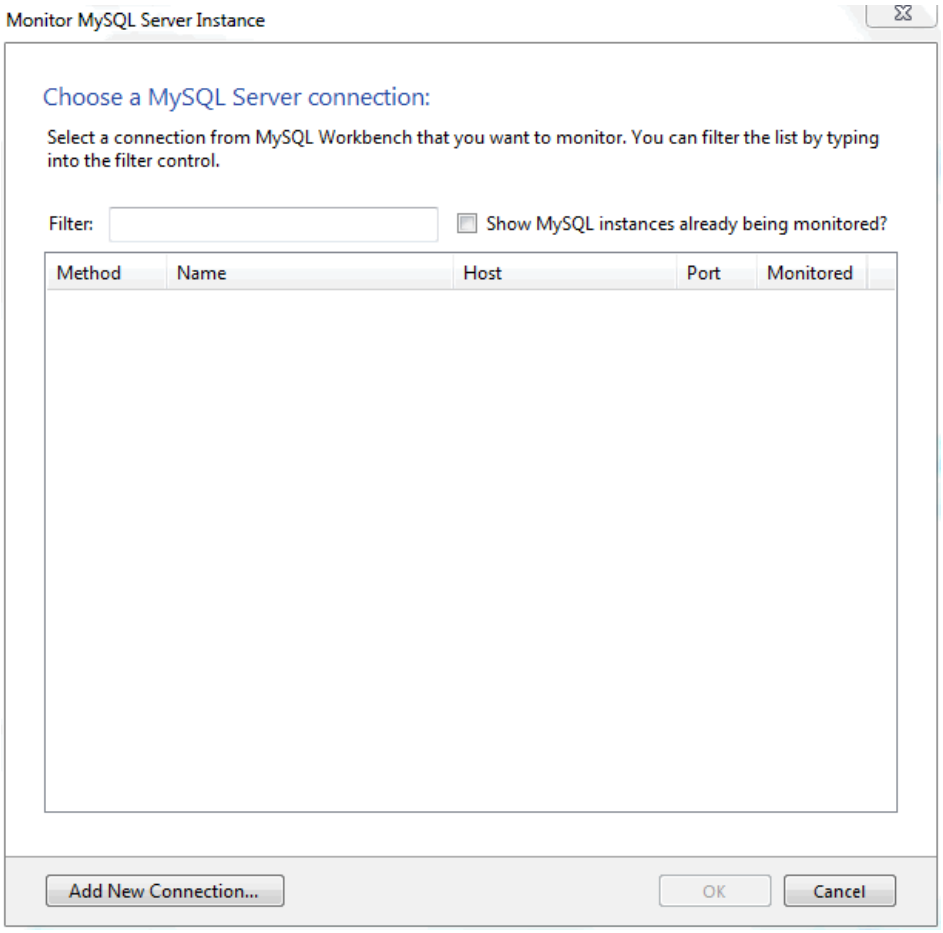
Adding a service or instance (after clicking **Add** in the **Manage Monitored Items** window) enables you to select a running Microsoft Windows service or instance connection, and configure MySQL Notifier to monitor it. Add a new service or instance by clicking service name from the list, then **OK** to accept. Multiple services and instances may be selected.

Figure 2.19 MySQL Notifier Adding new services



Add instances:

Figure 2.20 MySQL Notifier Adding new instances



Troubleshooting

For issues that are not documented here, visit the MySQL Notifier Support Forum for MySQL Notifier help and support.

- *Problem*: attempting to start/stop/restart a MySQL service might generate an error similar to "The Service **MySQL*VERSION*** failed the most recent status change request with the message "The service **mysql*VERSION*** was not found in the Windows Services".

  Explanation: this is a case-sensitivity issue, in that the service name is **MySQL*VERSION*** compared to having **mysql*VERSION*** in the configuration file.

  Solution: either update your MySQL Notifier configuration file with the correct information, or stop MySQL Notifier and delete this configuration file. The MySQL Notifier configuration file is located at `%APPDATA%\Oracle\MySQL Notifier\settings.config` where `%APPDATA%` is a variable and depends on your system. A typical location is "C:\Users*YourUsername*\AppData\Running\Oracle\MySQL Notifier\settings.config" where *YourUsername* is your system's user name. In this file, and within the ServerList section, change the ServerName values from lowercase to the actual service names. For example, change **mysql*VERSION*** to **MySQL*VERSION***, save, and then restart MySQL Notifier. Alternatively, stop MySQL Notifier, delete this file, then restart MySQL Notifier.

- *Problem*: when connecting to a remote computer for the purpose of monitoring a remote Windows service, the **Add Service** dialog does not always show all the services shown in the Windows Services console.

  Explanation: this behavior is governed by the operating system and the outcome is expected when working with nondomain user accounts. For a complete description of the behavior, see the User Account Control and WMI article from Microsoft.

Solution: when the remote computer is in a compatible domain, it is recommended that domain user accounts are used to connect through WMI to a remote computer. For detailed setup instructions using WMI, see Section 2.3.4.2, “Setting Up Remote Monitoring in MySQL Notifier”.

Alternatively, when domain user accounts are not available, Microsoft provides a less secure workaround that should only be implemented with caution. For more information, see the Description of User Account Control and remote restrictions in Windows Vista KB article from Microsoft.

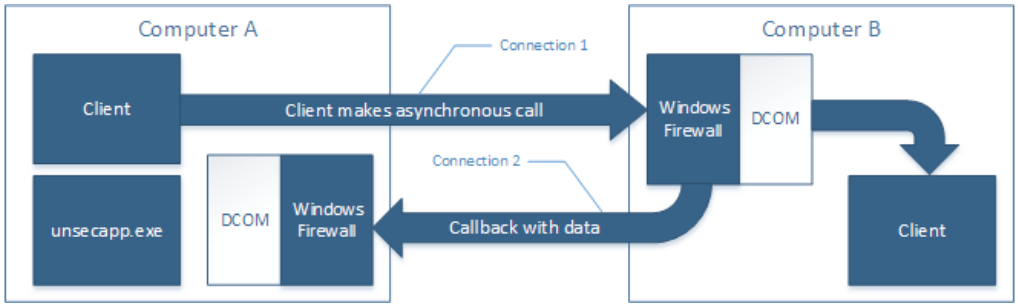
2.3.4.2 Setting Up Remote Monitoring in MySQL Notifier

MySQL Notifier uses Windows Management Instrumentation (WMI) to manage and monitor services on remote computers. This section explains how it works and how to set up your system to monitor remote MySQL instances.

In order to configure WMI, it is important to understand that the underlying Distributed Component Object Model (DCOM) architecture is doing the WMI work. Specifically, MySQL Notifier is using asynchronous notification queries on remote Microsoft Windows hosts as .NET events. These events send an asynchronous callback to the computer running MySQL Notifier so it knows when a service status has changed on the remote computer. Asynchronous notifications offer the best performance compared to semisynchronous notifications or synchronous notifications that use timers.

Asynchronous notification requires the remote computer to send a callback to the client computer (thus opening a reverse connection), so the Windows Firewall and DCOM settings must be properly configured for the communication to function properly.

Figure 2.21 MySQL Notifier Distributed Component Object Model (DCOM)



Most of the common errors thrown by asynchronous WMI notifications are related to Windows Firewall blocking the communication, or to DCOM / WMI settings not being set up properly. For a list of common errors with solutions, see Common Errors.

The following steps are required to make WMI function. These steps are divided between two machines. A single host computer that runs MySQL Notifier (Computer A), and multiple remote machines that are being monitored (Computer B).

Computer running MySQL Notifier (Computer A)

1. Enable remote administration by either editing the **Group Policy Editor**, or using `NETSH`:

   Using the **Group Policy Editor**:

   a. Click **Start**, click **Run**, type `GPEDIT.MSC`, and then click **OK**.

   b. Under the **Local Computer Policy** heading, expand **Computer Configuration**.

   c. Expand **Administrative Templates**, then **Network**, **Network Connections**, and then **Windows Firewall**.

   d. If the computer is in the domain, then double-click **Domain Profile**; otherwise, double-click **Standard Profile**.

e. Double-click **Windows Firewall: Allow inbound remote administration exception** to open a configuration window.

f. Check the **Enabled** option button and then click **OK**.

Using the `NETSH` command:

Note

The "netsh firewall" command is deprecated as of Microsoft Server 2008 and Vista, and replaced with "netsh advfirewall firewall".

a. Open a command prompt window with Administrative rights (you can right-click the Command Prompt icon and select **Run as Administrator**).

b. Execute the following command:

```
NETSH advfirewall firewall set service RemoteAdmin enable
```

2. Open the DCOM port TCP 135:

a. Open a command prompt window with Administrative rights (you can right-click the Command Prompt icon and select **Run as Administrator**).

b. Execute the following command:

```
NETSH advfirewall firewall add rule name=DCOM_TCP135 protocol=TCP localport=135 dir=in action=allow
```

3. Add the client application that contains the sink for the callback (`MySqlNotifier.exe`) to the Windows Firewall Exceptions List (use either the Windows Firewall configuration or `NETSH`):

Using the Windows Firewall configuration:

a. In the Control Panel, double-click **Windows Firewall**.

b. In the Windows Firewall window's left panel, click **Allow a program or feature through Windows Firewall**.

c. In the Allowed Programs window, click **Change Settings** and do one of the following:

- If `MySqlNotifier.exe` is in the Allowed programs and features list, make sure it is checked for the type of networks the computer connects to (Private, Public or both).
- If `MySqlNotifier.exe` is not in the list, click **Allow another program...**.

  i. In the **Add a Program** window, select the `MySqlNotifier.exe` if it exists in the Programs list, otherwise click Browse... and go to the directory where `MySqlNotifier.exe` was installed to select it, then click **Add**.

  ii. Make sure `MySqlNotifier.exe` is checked for the type of networks the computer connects to (Private, Public or both).

Using the `NETSH` command:

a. Open a command prompt window with Administrative rights (you can right-click the Command Prompt icon and click **Run as Administrator**).

b. Execute the following command, where you change "*`[YOUR_INSTALL_DIRECTORY]`*":

```
NETSH advfirewall firewall add rule name=MySqlNotifier program=[YOUR_INSTALL_DIRECTORY]\MySqlNot
```

4. If Computer B is either a member of `WORKGROUP` or is in a different domain that is untrusted by Computer A, then the callback connection (Connection 2) is created as an Anonymous connection. To grant Anonymous connections DCOM Remote Access permissions:

   a. Click **Start**, click **Run**, type `DCOMCNFG`, and then click **OK**.

   b. In the Component Services dialog box, expand Component Services, expand Computers, and then right-click **My Computer** and click **Properties**.

   c. In the My Computer Properties dialog box, click the **COM Security** tab.

   d. Under Access Permissions, click **Edit Limits**.

   e. In the Access Permission dialog box, select **ANONYMOUS LOGON name** in the Group or user names box. In the Allow column under Permissions for User, select **Remote Access**, and then click **OK**.

Monitored Remote Computer (Computer B)

If the user account that is logged on to the computer running the MySQL Notifier (Computer A) is a local administrator on the remote computer (Computer B), such that the same account is an administrator on Computer B, you can skip to the "Allow for remote administration" step.

Setting DCOM security to allow a non-administrator user to access a computer remotely:

1. Grant "DCOM remote launch" and activation permissions for a user or group:

   a. Click **Start**, click **Run**, type `DCOMCNFG`, and then click **OK**.

   b. In the Component Services dialog box, expand Component Services, expand Computers, and then right-click **My Computer** and click **Properties**.

   c. In the My Computer Properties dialog box, click the **COM Security** tab.

   d. Under Launch and Activation Permission, click **Edit Limits**.

   e. In the **Launch and Activation Permission** dialog box, follow these steps if your name or your group does not appear in the Groups or user names list:

      i. In the **Launch and Activation Permission** dialog box, click **Add**.

      ii. In the Select Users or Groups dialog box, add your name and the group in the **Enter the object names to select** box, and then click **OK**.

   f. In the **Launch and Activation Permission** dialog box, select your user and group in the Group or user names box. In the Allow column under Permissions for User, select **Remote Launch**, select **Remote Activation**, and then click **OK**.

   Grant DCOM remote access permissions:

   a. Click **Start**, click **Run**, type `DCOMCNFG`, and then click **OK**.

   b. In the Component Services dialog box, expand Component Services, expand Computers, and then right-click **My Computer** and click **Properties**.

   c. In the My Computer Properties dialog box, click the **COM Security** tab.

   d. Under Access Permissions, click **Edit Limits**.

e. In the Access Permission dialog box, select **ANONYMOUS LOGON name** in the Group or user names box. In the Allow column under Permissions for User, select **Remote Access**, and then click **OK**.

2. Allowing non-administrator users access to a specific WMI namespace:

   a. In the Control Panel, double-click **Administrative Tools**.

   b. In the Administrative Tools window, double-click **Computer Management**.

   c. In the Computer Management window, expand the **Services and Applications** tree.

   d. Right-click the WMI Control icon and select **Properties**.

   e. In the WMI Control Properties window, click the **Security** tab.

   f. In the Security tab, select the namespace and click **Security**. Root/CIMV2 is a commonly used namespace.

   g. Locate the appropriate account and check **Remote Enable** in the Permissions list.

3. Allow for remote administration by either editing the **Group Policy Editor** or using `NETSH`:

   Using the **Group Policy Editor**:

   a. Click **Start**, click **Run**, type `GPEDIT.MSC`, and then click **OK**.

   b. Under the Local Computer Policy heading, double-click **Computer Configuration**.

   c. Double-click **Administrative Templates**, then **Network**, **Network Connections**, and then **Windows Firewall**.

   d. If the computer is in the domain, then double-click **Domain Profile**; otherwise, double-click **Standard Profile**.

   e. Click **Windows Firewall: Allow inbound remote administration exception**.

   f. On the Action menu either select **Edit**, or double-click the selection from the previous step.

   g. Check the **Enabled** radio button, and then click **OK**.

   Using the `NETSH` command:

   a. Open a command prompt window with Administrative rights (you can right-click the Command Prompt icon and click Run as Administrator).

   b. Execute the following command:

   ```
   NETSH advfirewall firewall set service RemoteAdmin enable
   ```

4. Confirm that the user account you are logging in with uses the `Name` value and not the `Full Name` value:

   a. In the **Control Panel**, double-click **Administrative Tools**.

   b. In the **Administrative Tools** window, double-click **Computer Management**.

   c. In the **Computer Management** window, expand the **System Tools** then **Local Users and Groups**.

d. Click the **Users** node, and on the right side panel locate your user and make sure it uses the **Name** value to connect, and not the **Full Name** value.

Common Errors

- `0x80070005`
  - DCOM Security was not configured properly (see Computer B, the `Setting DCOM security...` step).
  - The remote computer (Computer B) is a member of WORKGROUP or is in a domain that is untrusted by the client computer (Computer A) (see Computer A, the `Grant Anonymous connections DCOM Remote Access permissions` step).
- `0x8007000E`
  - The remote computer (Computer B) is a member of WORKGROUP or is in a domain that is untrusted by the client computer (Computer A) (see Computer A, the `Grant Anonymous connections DCOM Remote Access permissions` step).
- `0x80041003`
  - Access to the remote WMI namespace was not configured properly (see Computer B, the `Allowing non-administrator users access to a specific WMI namespace` step).
- `0x800706BA`
  - The DCOM port is not open on the client computers (Computer A) firewall. See the `Open the DCOM port TCP 135` step for Computer A.
  - The remote computer (Computer B) is inaccessible because its network location is set to Public. Make sure you can access it through the Windows Explorer.

2.3.5 Installing MySQL on Microsoft Windows Using an MSI Package

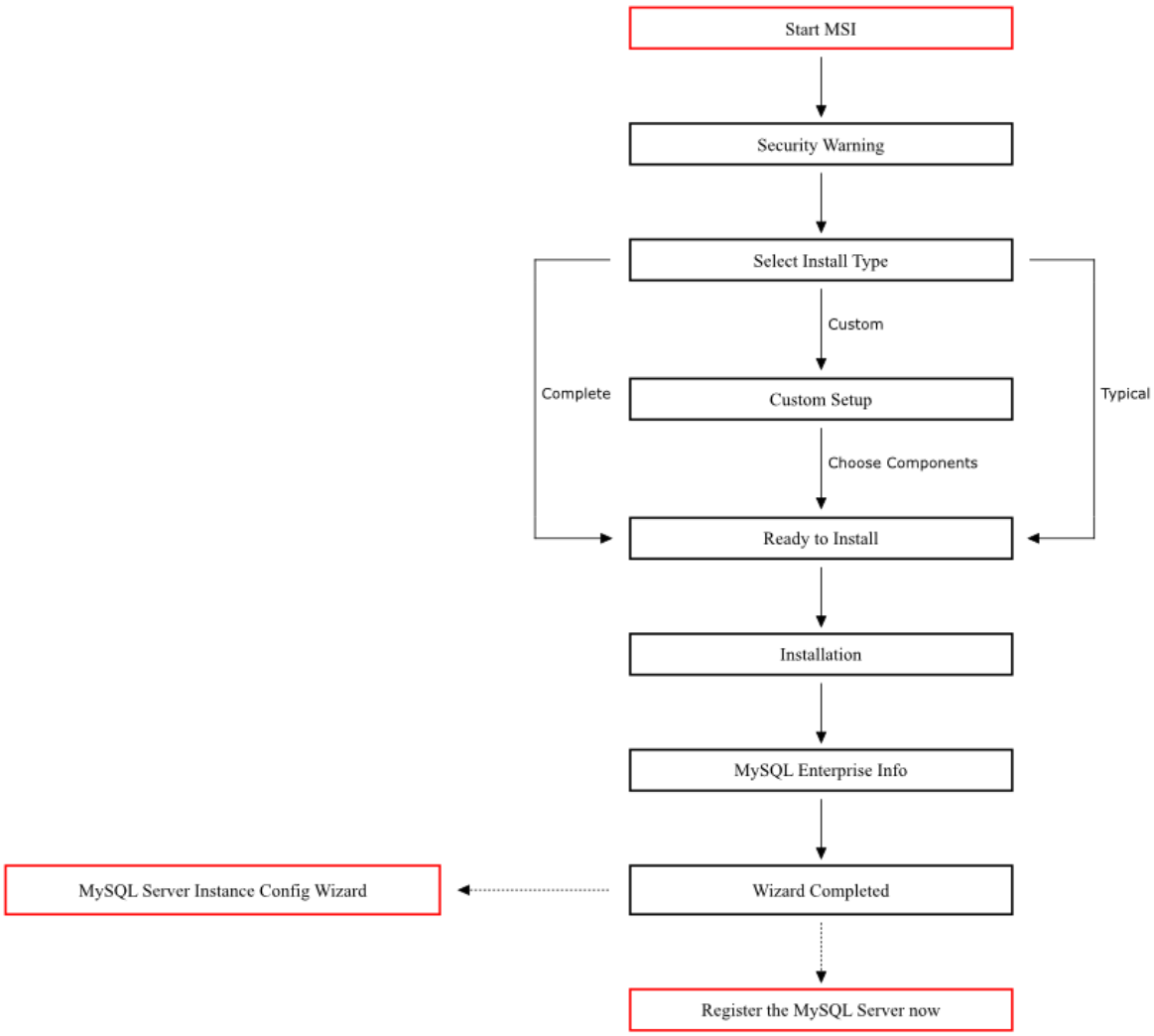
The MSI package is designed to install and configure MySQL in such a way that you can immediately get started using MySQL.

The MySQL Installation Wizard and MySQL Configuration Wizard are available in the Complete install package, which is recommended for most standard MySQL installations. Exceptions include users who need to install multiple instances of MySQL on a single server host and advanced users who want complete control of server configuration.

- For information on installing using the GUI MSI installer process, see Section 2.3.5.1, “Using the MySQL Installation Wizard”.
- For information on installing using the command line using the MSI package, see Section 2.3.5.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”.
- If you have previously installed MySQL using the MSI package and want to remove MySQL, see Section 2.3.5.3, “Removing MySQL When Installed from the MSI Package”.

The workflow sequence for using the installer is shown in the figure below:

Figure 2.22 Installation Workflow for Windows Using MSI Installer



Note

Microsoft Windows XP and later include a firewall which specifically blocks ports. If you plan on using MySQL through a network port then you should open and create an exception for this port before performing the installation. To check and if necessary add an exception to the firewall settings:

1. First ensure that you are logged in as an Administrator or a user with Administrator privileges.
2. Go to the **Control Panel**, and double click the **Windows Firewall** icon.
3. Choose the **Allow a program through Windows Firewall** option and click the **Add port** button.
4. Enter `MySQL` into the **Name** text box and `3306` (or the port of your choice) into the **Port number** text box.
5. Also ensure that the **TCP** protocol radio button is selected.
6. If you wish, you can also limit access to the MySQL server by choosing the **Change scope** button.

7. Confirm your choices by clicking the **OK** button.

Additionally, when running the MySQL Installation Wizard on Windows Vista or newer, ensure that you are logged in as a user with administrative rights.

Note

When using Windows Vista or newer, you may want to disable User Account Control (UAC) before performing the installation. If you do not do so, then MySQL may be identified as a security risk, which will mean that you need to enable MySQL. You can disable the security checking by following these instructions:

1. Open **Control Panel**.
2. Under the **User Accounts and Family Safety**, select **Add or remove user accounts.**
3. Click the **Got to the main User Accounts page** link.
4. Click on **Turn User Account Control on or off**. You may be prompted to provide permission to change this setting. Click **Continue**.
5. Deselect or uncheck the check box next to **Use User Account Control (UAC) to help protect your computer**. Click **OK** to save the setting.

You will need to restart to complete the process. Click **Restart Now** to reboot the machine and apply the changes. You can then follow the instructions below for installing Windows.

2.3.5.1 Using the MySQL Installation Wizard

MySQL Installation Wizard is an installer for the MySQL server that uses the latest installer technologies for Microsoft Windows. The MySQL Installation Wizard, in combination with the MySQL Configuration Wizard, enables a user to install and configure a MySQL server that is ready for use immediately after installation.

The MySQL Installation Wizard is the standard installer for all MySQL server distributions, version 4.1.5 and higher. Users of previous versions of MySQL need to shut down and remove their existing MySQL installations manually before installing MySQL with the MySQL Installation Wizard. See Upgrading MySQL with the Installation Wizard, for more information on upgrading from a previous version.

Microsoft has included an improved version of their Microsoft Windows Installer (MSI) in the recent versions of Windows. MSI has become the de-facto standard for application installations on Windows 2000, Windows XP, and Windows Server 2003. The MySQL Installation Wizard makes use of this technology to provide a smoother and more flexible installation process.

The Microsoft Windows Installer Engine was updated with the release of Windows XP; those using a previous version of Windows can reference this Microsoft Knowledge Base article for information on upgrading to the latest version of the Windows Installer Engine.

In addition, Microsoft has introduced the WiX (Windows Installer XML) toolkit recently. This is the first highly acknowledged Open Source project from Microsoft. We have switched to WiX because it is an Open Source project and it enables us to handle the complete Windows installation process in a flexible manner using scripts.

Improving the MySQL Installation Wizard depends on the support and feedback of users like you. If you find that the MySQL Installation Wizard is lacking some feature important to you, or if you discover a bug, please report it in our bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”.

Downloading and Starting the MySQL Installation Wizard

The MySQL installation packages can be downloaded from http://dev.mysql.com/downloads/. If the package you download is contained within a ZIP archive, you need to extract the archive first.

Note

If you are installing on Windows Vista or newer, it is best to open a network port before beginning the installation. To do this, first ensure that you are logged in as an Administrator, go to the `Control Panel`, and double-click the `Windows Firewall` icon. Choose the `Allow a program through Windows Firewall` option and click the **Add port** button. Enter `MySQL` into the **Name** text box and `3306` (or the port of your choice) into the **Port number** text box. Also ensure that the **TCP** protocol radio button is selected. If you wish, you can also limit access to the MySQL server by choosing the **Change scope** button. Confirm your choices by clicking the **OK** button. If you do not open a port prior to installation, you cannot configure the MySQL server immediately after installation. Additionally, when running the MySQL Installation Wizard on Windows Vista or newer, ensure that you are logged in as a user with administrative rights.

The process for starting the wizard depends on the contents of the installation package you download. If there is a `setup.exe` file present, double-click it to start the installation process. If there is an `.msi` file present, double-click it to start the installation process.

Choosing an Install Type

There are three installation types available: **Typical**, **Complete**, and **Custom**.

The **Typical** installation type installs the MySQL server, the `mysql` command-line client, and the command-line utilities. The command-line clients and utilities include `mysqldump`, `myisamchk`, and several other tools to help you manage the MySQL server.

The **Complete** installation type installs all components included in the installation package. The full installation package includes components such as the embedded server library, the benchmark suite, support scripts, and documentation.

The **Custom** installation type gives you complete control over which packages you wish to install and the installation path that is used. See The Custom Install Dialog, for more information on performing a custom install.

If you choose the **Typical** or **Complete** installation types and click the **Next** button, you advance to the confirmation screen to verify your choices and begin the installation. If you choose the **Custom** installation type and click the **Next** button, you advance to the custom installation dialog, described in The Custom Install Dialog.

The Custom Install Dialog

If you wish to change the installation path or the specific components that are installed by the MySQL Installation Wizard, choose the **Custom** installation type.

A tree view on the left side of the custom install dialog lists all available components. Components that are not installed have a red **X** icon; components that are installed have a gray icon. To change whether a component is installed, click that component's icon and choose a new option from the drop-down list that appears.

You can change the default installation path by clicking the **Change...** button to the right of the displayed installation path.

After choosing your installation components and installation path, click the **Next** button to advance to the confirmation dialog.

The Confirmation Dialog

After you choose an installation type and optionally choose your installation components, you advance to the confirmation dialog. Your installation type and installation path are displayed for you to review.

To install MySQL if you are satisfied with your settings, click the **Install** button. To change your settings, click the **Back** button. To exit the MySQL Installation Wizard without installing MySQL, click the **Cancel** button.

The final screen of the installer provides a summary of the installation and gives you the option to launch the MySQL Configuration Wizard, which you can use to create a configuration file, install the MySQL service, and configure security settings.

Changes Made by MySQL Installation Wizard

When you click the **Install** button, the MySQL Installation Wizard begins the installation process and makes certain changes to your system which are described in the sections that follow.

Changes to the Registry

The MySQL Installation Wizard creates one Windows registry key in a typical install situation, located in `HKEY_LOCAL_MACHINE\SOFTWARE\MySQL AB`.

The MySQL Installation Wizard creates a key named after the release series of the server that is being installed, such as `MySQL Server 5.5`. It contains two string values, `Location` and `Version`. The `Location` string contains the path to the installation directory. In a default installation it contains `C:\Program Files\MySQL\MySQL Server 5.5\`. The `Version` string contains the release number. For example, for an installation of MySQL Server 5.5.60, the key contains a value of `5.5.60`.

These registry keys are used to help external tools identify the installed location of the MySQL server, preventing a complete scan of the hard-disk to determine the installation path of the MySQL server. The registry keys are not required to run the server, and if you install MySQL using the `noinstall` ZIP archive, the registry keys are not created.

Changes to the Start Menu

The MySQL Installation Wizard creates a new entry in the Windows **Start** menu under a common MySQL menu heading named after the release series of MySQL that you have installed. For example, if you install MySQL 5.5, the MySQL Installation Wizard creates a **MySQL Server 5.5** section in the **Start** menu.

The following entries are created within the new **Start** menu section:

- **MySQL Command-Line Client**: This is a shortcut to the `mysql` command-line client and is configured to connect as the `root` user. The shortcut prompts for a `root` user password when you connect.
- **MySQL Server Instance Config Wizard**: This is a shortcut to the MySQL Configuration Wizard. Use this shortcut to configure a newly installed server, or to reconfigure an existing server.
- **MySQL Documentation**: This is a link to the MySQL server documentation that is stored locally in the MySQL server installation directory.

Changes to the File System

The MySQL Installation Wizard by default installs the MySQL 5.5 server to `C:\Program Files\MySQL\MySQL Server 5.5`, where `Program Files` is the default location for applications in your system, and `5.5` is the release series of your MySQL server. This is the recommended location for the MySQL server, replacing the former default location `C:\mysql`.

By default, all MySQL applications are stored in a common directory at `C:\Program Files\MySQL`, where `Program Files` is the default location for applications in your Windows installation. A typical MySQL installation on a developer machine might look like this:

```
C:\Program Files\MySQL\MySQL Server 5.5
C:\Program Files\MySQL\MySQL Workbench 5.1 OSS
```

This approach makes it easier to manage and maintain all MySQL applications installed on a particular system.

The default location of the data directory is the `AppData` directory configured for the user that installed the MySQL application.

Upgrading MySQL with the Installation Wizard

The MySQL Installation Wizard can perform server upgrades automatically using the upgrade capabilities of MSI. That means you do not need to remove a previous installation manually before installing a new release. The installer automatically shuts down and removes the previous MySQL service before installing the new version.

Automatic upgrades are available only when upgrading between installations that have the same major and minor version numbers. For example, you can upgrade automatically from MySQL 5.5.5 to MySQL 5.5.6, but not from MySQL 5.1 to MySQL 5.5.

See Section 2.3.10, “Upgrading MySQL on Windows”.

2.3.5.2 Automating MySQL Installation on Microsoft Windows Using the MSI Package

The Microsoft Installer (MSI) supports a both a *quiet* and a *passive* mode that can be used to install MySQL automatically without requiring intervention. You can use this either in scripts to automatically install MySQL or through a terminal connection such as Telnet where you do not have access to the standard Windows user interface. The MSI packages can also be used in combination with Microsoft's Group Policy system (part of Windows Server 2003 and Windows Server 2008) to install MySQL across multiple machines.

To install MySQL from one of the MSI packages automatically from the command line (or within a script), you need to use the `msiexec.exe` tool. For example, to perform a quiet installation (which shows no dialog boxes or progress):

```
shell> msiexec /i mysql-5.5.60.msi /quiet
```

The `/i` indicates that you want to perform an installation. The `/quiet` option indicates that you want no interactive elements.

To provide a dialog box showing the progress during installation, and the dialog boxes providing information on the installation and registration of MySQL, use `/passive` mode instead of `/quiet`:

```
shell> msiexec /i mysql-5.5.60.msi /passive
```

Regardless of the mode of the installation, installing the package in this manner performs a 'Typical' installation, and installs the default components into the standard location.

You can also use this method to uninstall MySQL by using the `/uninstall` or `/x` options:

```
shell> msiexec /x mysql-5.5.60.msi /uninstall
```

To install MySQL and configure a MySQL instance from the command line, see Section 2.3.6.13, “MySQL Server Instance Config Wizard: Creating an Instance from the Command Line”.

For information on using MSI packages to install software automatically using Group Policy, see How to use Group Policy to remotely install software in Windows Server 2003.

2.3.5.3 Removing MySQL When Installed from the MSI Package

To uninstall MySQL when you installed it using the MSI package, you must use the **Add/Remove Programs** tool within **Control Panel**. To do this:

1. Right-click the **start** menu and choose **Control Panel**.
2. If the Control Panel is set to category mode (you will see **Pick a category** at the top of the **Control Panel** window), double-click **Add or Remove Programs**. If the Control is set to classic mode, double-click the **Add or Remove Programs** icon.
3. Find MySQL in the list of installed software. MySQL Server is installed against release series numbers (MySQL 5.1, MySQL 5.5, etc.). Select the version that you want to remove and click **Remove**.
4. You will be prompted to confirm the removal. Click **Yes** to remove MySQL.

When MySQL is removed using this method, only the installed components are removed. Any database information (including the tables and data), import or export files, log files, and binary logs produced during execution are kept in their configured location.

If you try to install MySQL again the information will be retained and you will be prompted to enter the password configured with the original installation.

If you want to delete MySQL completely:

- Delete the associated data directory. On Windows XP and Windows Server 2003, the default data directory is the configured AppData directory, which is `C:\Documents and Settings\All Users\Application Data\MySQL` by default.
- On Windows 7 and Windows Server 2008, the default data directory location is `C:\ProgramData\Mysql`.

Note

The `C:\ProgramData` directory is hidden by default. You must change your folder options to view the hidden file. Choose **Organize**, **Folder and search options**, **Show hidden folders**.

2.3.6 MySQL Server Instance Configuration Wizard

The MySQL Server Instance Configuration Wizard helps automate the process of configuring your server. It creates a custom MySQL configuration file (`my.ini` or `my.cnf`) by asking you a series of questions and then applying your responses to a template to generate the configuration file that is tuned to your installation.

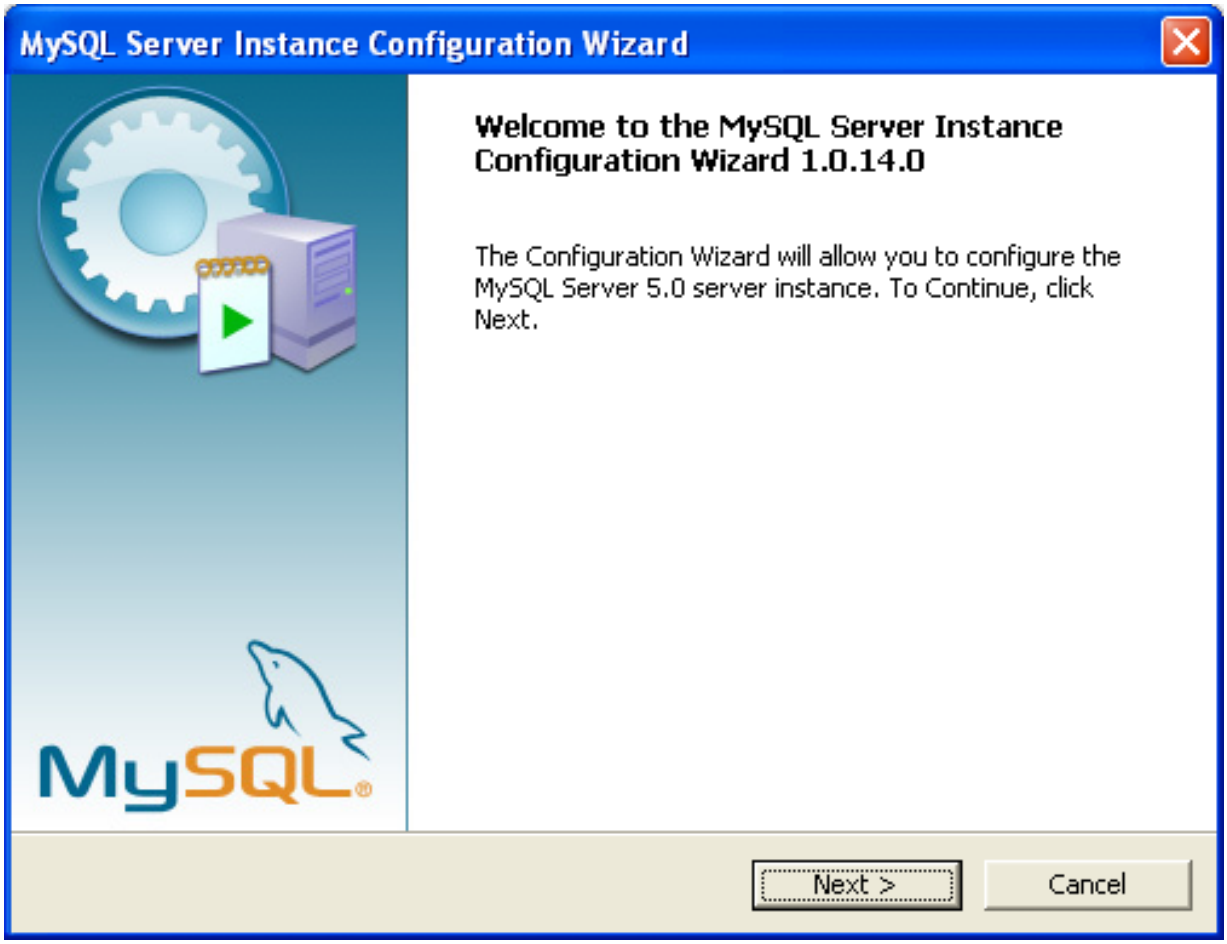
The MySQL Server Instance Configuration Wizard is included with the MySQL 5.5 server. The MySQL Server Instance Configuration Wizard is only available for Windows.

2.3.6.1 Starting the MySQL Server Instance Configuration Wizard

The MySQL Server Instance Configuration Wizard is normally started as part of the installation process. You should only need to run the MySQL Server Instance Configuration Wizard again when you need to change the configuration parameters of your server.

If you chose not to open a port prior to installing MySQL on Windows Vista or newer, you can choose to use the MySQL Server Configuration Wizard after installation. However, you must open a port in the Windows Firewall. To do this see the instructions given in Downloading and Starting the MySQL Installation Wizard. Rather than opening a port, you also have the option of adding MySQL as a program that bypasses the Windows Firewall. One or the other option is sufficient—you need not do

both. Additionally, when running the MySQL Server Configuration Wizard on Windows Vista or newer, ensure that you are logged in as a user with administrative rights.



You can launch the MySQL Configuration Wizard by clicking the **MySQL Server Instance Config Wizard** entry in the **MySQL** section of the Windows **Start** menu.

Alternatively, you can navigate to the `bin` directory of your MySQL installation and launch the `MySQLInstanceConfig.exe` file directly.

The MySQL Server Instance Configuration Wizard places the `my.ini` file in the installation directory for the MySQL server. This helps associate configuration files with particular server instances.

To ensure that the MySQL server knows where to look for the `my.ini` file, an argument similar to this is passed to the MySQL server as part of the service installation:

```
--defaults-file="C:\Program Files\MySQL\MySQL Server 5.5\my.ini"
```

Here, *`C:\Program Files\MySQL\MySQL Server 5.5`* is replaced with the installation path to the MySQL Server. The `--defaults-file` option instructs the MySQL server to read the specified file for configuration options when it starts.

Apart from making changes to the `my.ini` file by running the MySQL Server Instance Configuration Wizard again, you can modify it by opening it with a text editor and making any necessary changes. You can also modify the server configuration with the http://www.mysql.com/products/administrator/ utility. For more information about server configuration, see Section 5.1.4, “Server Command Options”.

MySQL clients and utilities such as the `mysql` and `mysqldump` command-line clients are not able to locate the `my.ini` file located in the server installation directory. To configure the client and utility applications, create a new `my.ini` file in the Windows installation directory (for example, `C:\WINDOWS`).

Under Windows Server 2003, Windows Server 2000, Windows XP, and Windows Vista, MySQL Server Instance Configuration Wizard will configure MySQL to work as a Windows service. To start and stop MySQL you use the `Services` application that is supplied as part of the Windows Administrator Tools.

2.3.6.2 Choosing a Maintenance Option

If the MySQL Server Instance Configuration Wizard detects an existing configuration file, you have the option of either reconfiguring your existing server, or removing the server instance by deleting the configuration file and stopping and removing the MySQL service.

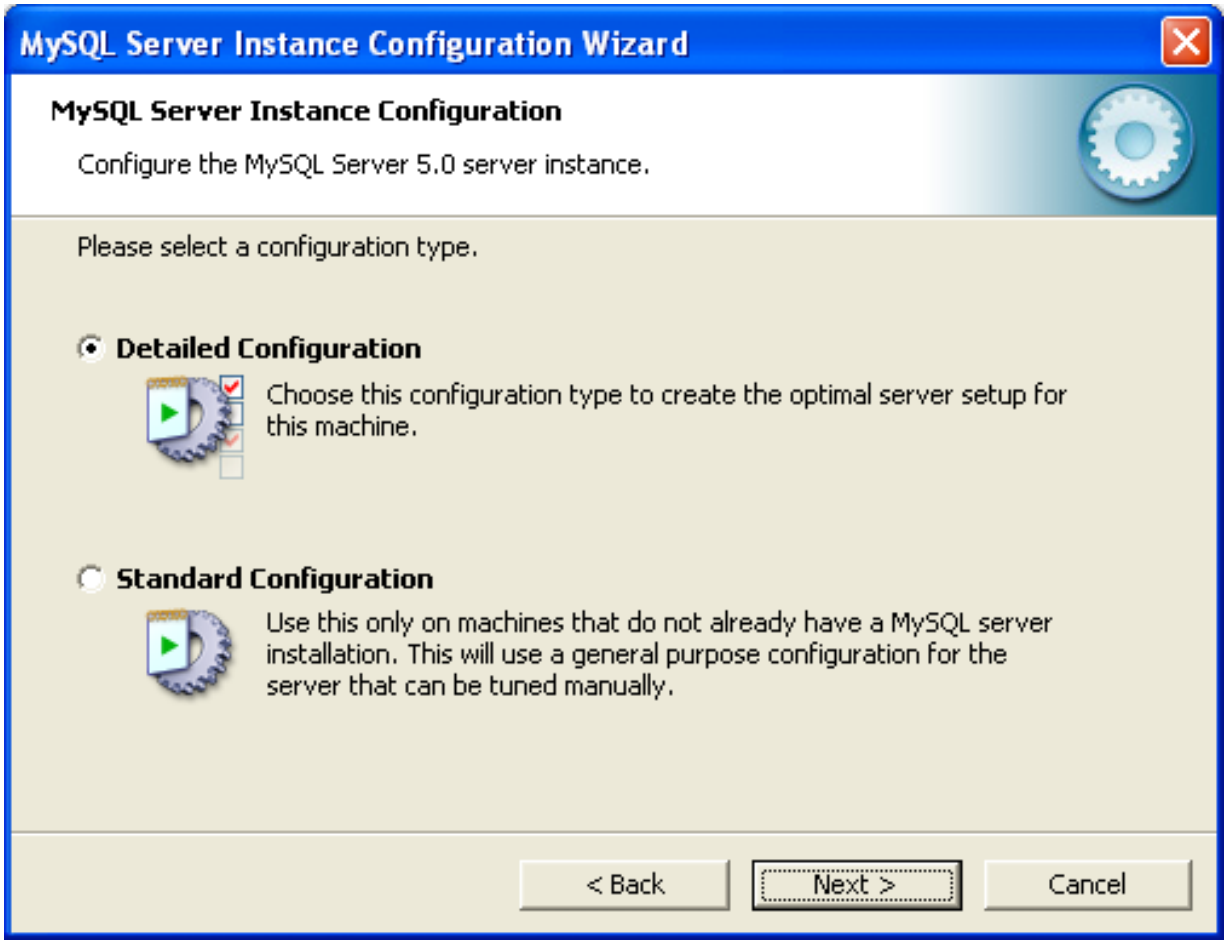
To reconfigure an existing server, choose the **Re-configure Instance** option and click the **Next** button. Any existing configuration file is not overwritten, but renamed (within the same directory) using a timestamp (Windows) or sequential number (Linux). To remove the existing server instance, choose the **Remove Instance** option and click the **Next** button.

If you choose the **Remove Instance** option, you advance to a confirmation window. Click the **Execute** button. The MySQL Server Configuration Wizard stops and removes the MySQL service, and then deletes the configuration file. The server installation and its `data` folder are not removed.

If you choose the **Re-configure Instance** option, you advance to the **Configuration Type** dialog where you can choose the type of installation that you wish to configure.

2.3.6.3 Choosing a Configuration Type

When you start the MySQL Server Instance Configuration Wizard for a new MySQL installation, or choose the **Re-configure Instance** option for an existing installation, you advance to the **Configuration Type** dialog.



There are two configuration types available: **Detailed Configuration** and **Standard Configuration**. The **Standard Configuration** option is intended for new users who want to get started with

MySQL quickly without having to make many decisions about server configuration. The **Detailed Configuration** option is intended for advanced users who want more fine-grained control over server configuration.

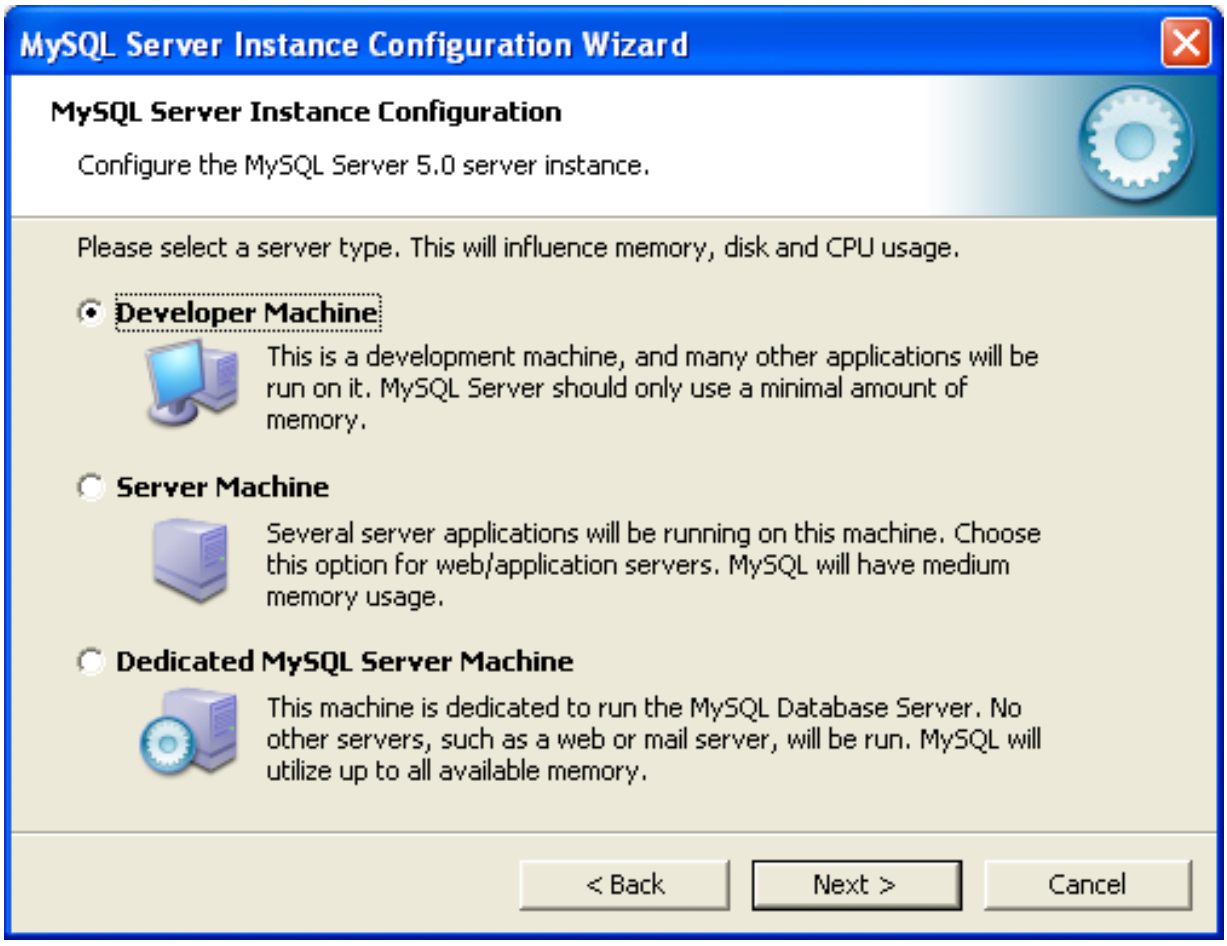
If you are new to MySQL and need a server configured as a single-user developer machine, the **Standard Configuration** should suit your needs. Choosing the **Standard Configuration** option causes the MySQL Configuration Wizard to set all configuration options automatically with the exception of **Service Options** and **Security Options**.

The **Standard Configuration** sets options that may be incompatible with systems where there are existing MySQL installations. If you have an existing MySQL installation on your system in addition to the installation you wish to configure, the **Detailed Configuration** option is recommended.

To complete the **Standard Configuration**, please refer to the sections on **Service Options** and **Security Options** in Section 2.3.6.10, “The Service Options Dialog”, and Section 2.3.6.11, “The Security Options Dialog”, respectively.

2.3.6.4 The Server Type Dialog

There are three different server types available to choose from. The server type that you choose affects the decisions that the MySQL Server Instance Configuration Wizard makes with regard to memory, disk, and processor usage.



- **Developer Machine**: Choose this option for a typical desktop workstation where MySQL is intended only for personal use. It is assumed that many other desktop applications are running. The MySQL server is configured to use minimal system resources.
- **Server Machine**: Choose this option for a server machine where the MySQL server is running alongside other server applications such as FTP, email, and Web servers. The MySQL server is configured to use a moderate portion of the system resources.

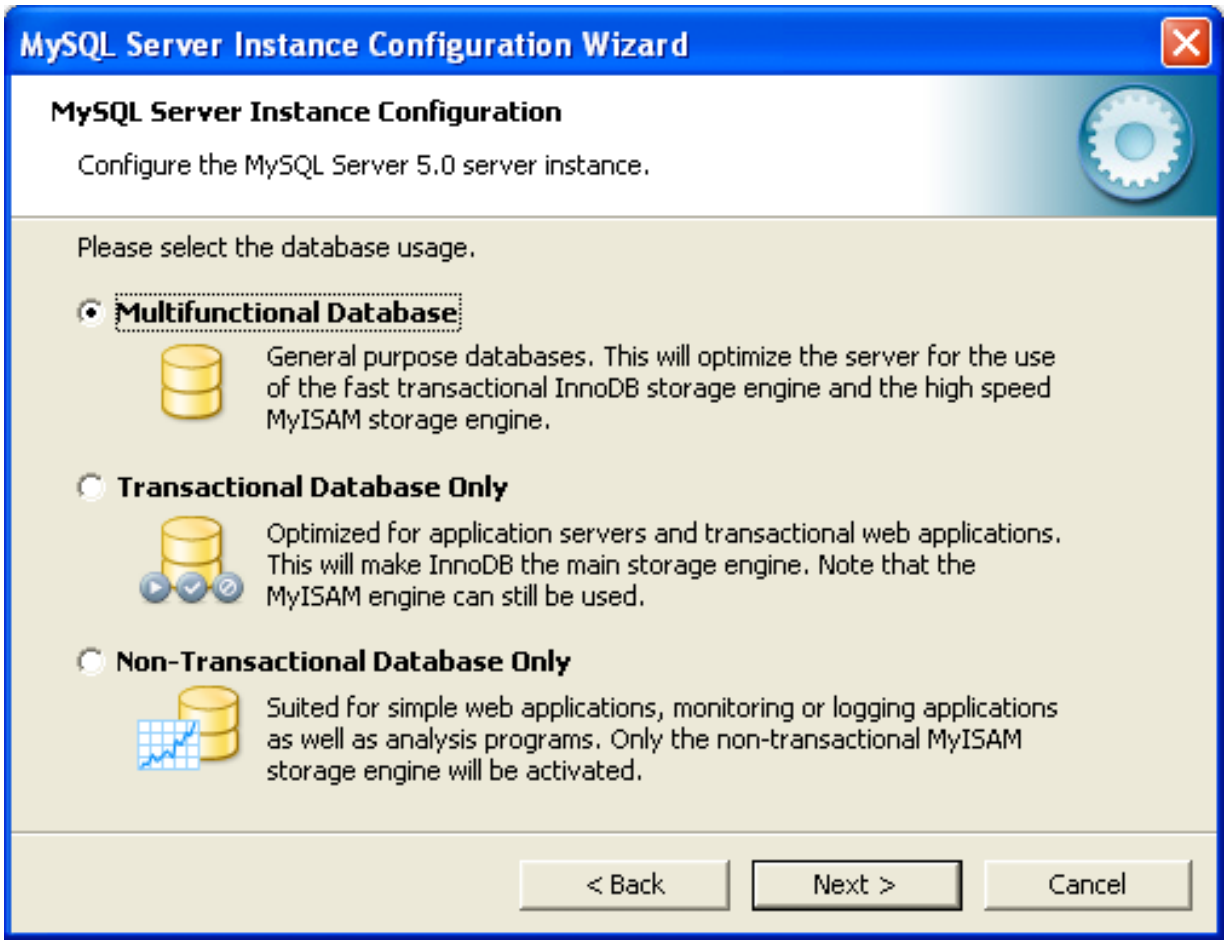
- **Dedicated MySQL Server Machine**: Choose this option for a server machine that is intended to run only the MySQL server. It is assumed that no other applications are running. The MySQL server is configured to use all available system resources.

Note

By selecting one of the preconfigured configurations, the values and settings of various options in your `my.cnf` or `my.ini` will be altered accordingly. The default values and options as described in the reference manual may therefore be different to the options and values that were created during the execution of the configuration wizard.

2.3.6.5 The Database Usage Dialog

The **Database Usage** dialog enables you to indicate the storage engines that you expect to use when creating MySQL tables. The option you choose determines whether the `InnoDB` storage engine is available and what percentage of the server resources are available to `InnoDB`.



- **Multifunctional Database**: This option enables both the `InnoDB` and `MyISAM` storage engines and divides resources evenly between the two. This option is recommended for users who use both storage engines on a regular basis.

- **Transactional Database Only**: This option enables both the `InnoDB` and `MyISAM` storage engines, but dedicates most server resources to the `InnoDB` storage engine. This option is recommended for users who use `InnoDB` almost exclusively and make only minimal use of `MyISAM`.

- **Non-Transactional Database Only**: This option disables the `InnoDB` storage engine completely and dedicates all server resources to the `MyISAM` storage engine. This option is recommended for users who do not use `InnoDB`.

The Configuration Wizard uses a template to generate the server configuration file. The **Database Usage** dialog sets one of the following option strings:

```
Multifunctional Database:        MIXED
Transactional Database Only:     INNODB
Non-Transactional Database Only: MYISAM
```

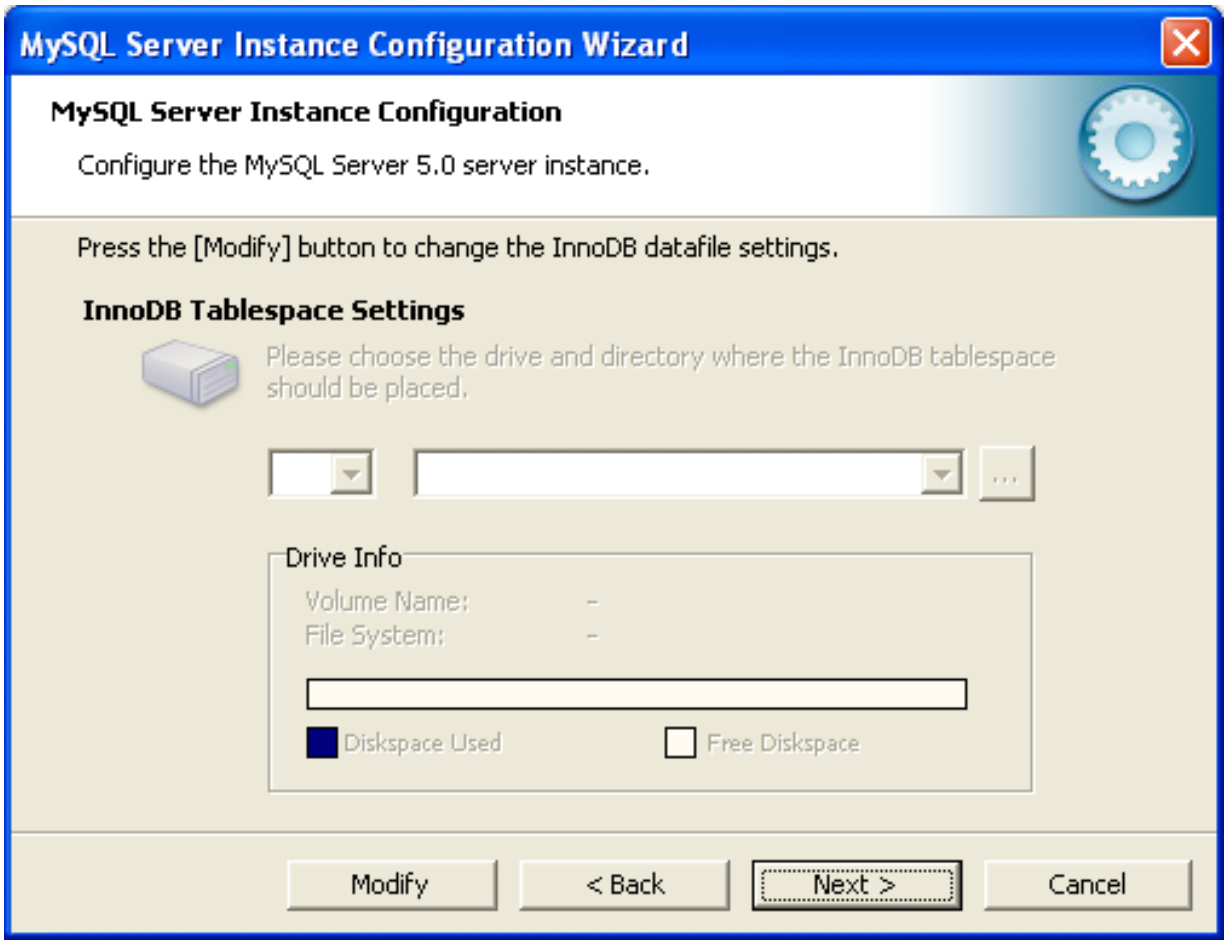
When these options are processed through the default template (my-template.ini) the result is:

```
Multifunctional Database:
default-storage-engine=InnoDB
_myisam_pct=50

Transactional Database Only:
default-storage-engine=InnoDB
_myisam_pct=5

Non-Transactional Database Only:
default-storage-engine=MyISAM
_myisam_pct=100
skip-innodb
```

The `_myisam_pct` value is used to calculate the percentage of resources dedicated to `MyISAM`. The remaining resources are allocated to `InnoDB`.

2.3.6.6 The InnoDB Tablespace Dialog

Some users may want to locate the `InnoDB` tablespace files in a different location than the MySQL server data directory. Placing the tablespace files in a separate location can be desirable if your system has a higher capacity or higher performance storage device available, such as a RAID storage system.

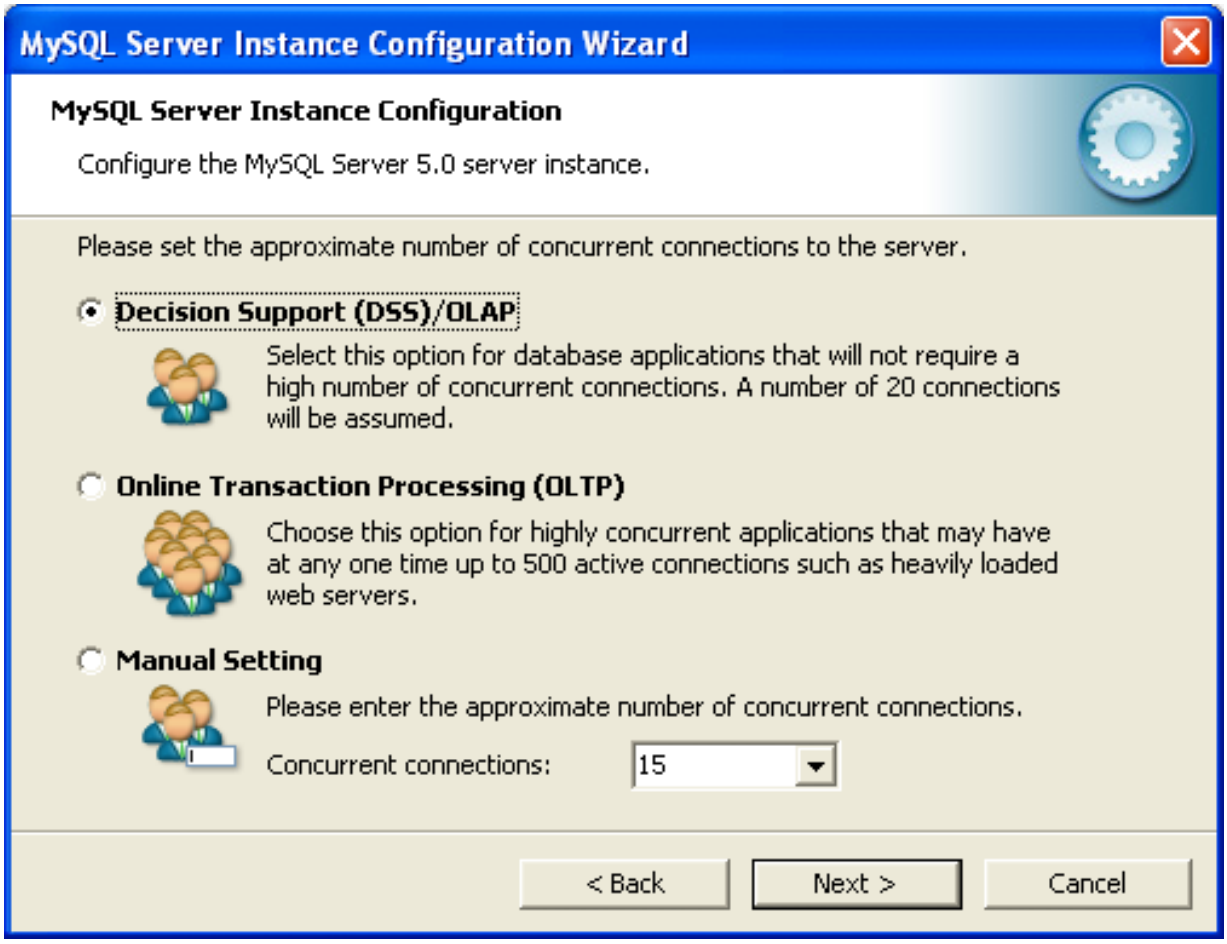


To change the default location for the `InnoDB` tablespace files, choose a new drive from the drop-down list of drive letters and choose a new path from the drop-down list of paths. To create a custom path, click the **...** button.

If you are modifying the configuration of an existing server, you must click the **Modify** button before you change the path. In this situation you must move the existing tablespace files to the new location manually before starting the server.

2.3.6.7 The Concurrent Connections Dialog

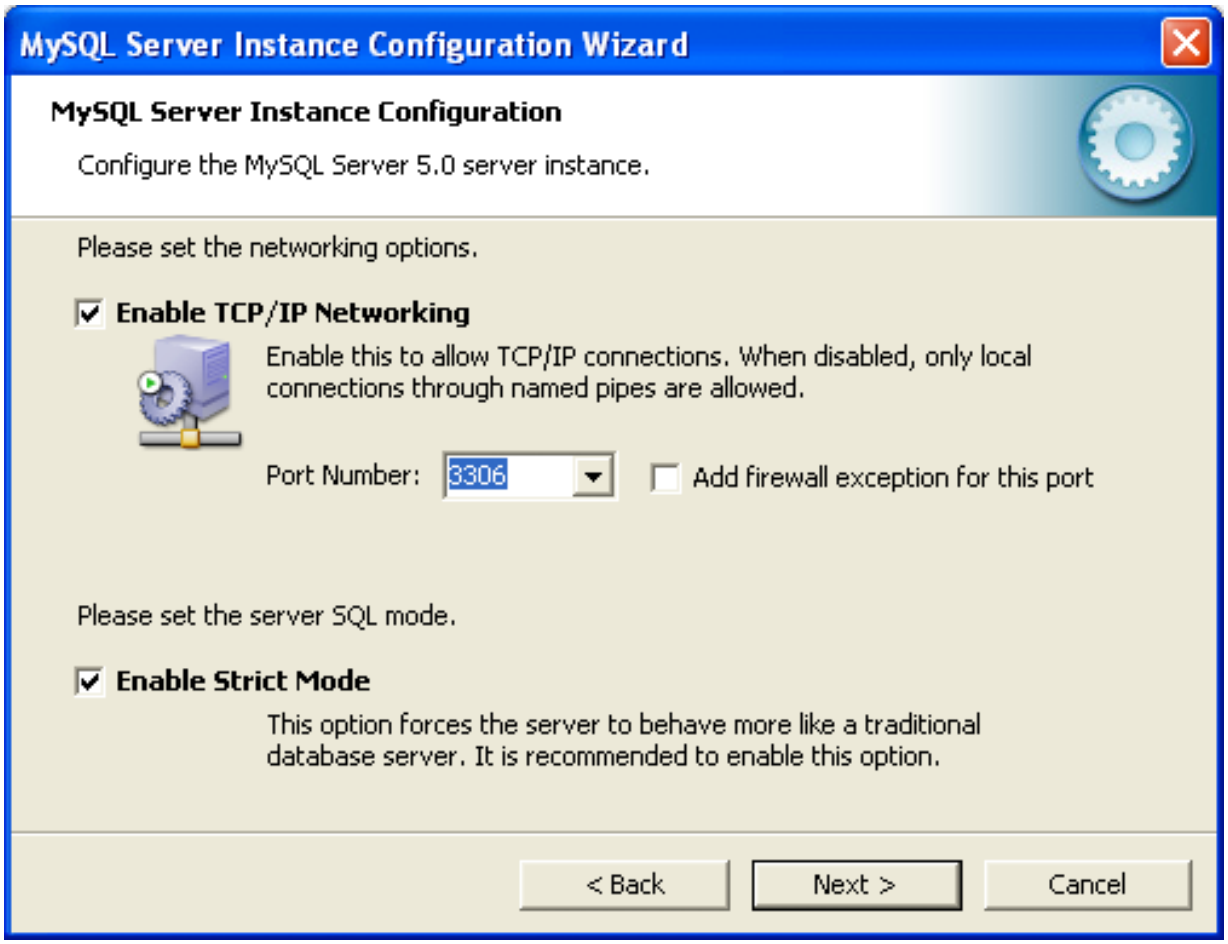
To prevent the server from running out of resources, it is important to limit the number of concurrent connections to the MySQL server that can be established. The **Concurrent Connections** dialog enables you to choose the expected usage of your server, and sets the limit for concurrent connections accordingly. It is also possible to set the concurrent connection limit manually.



- **Decision Support (DSS)/OLAP**: Choose this option if your server does not require a large number of concurrent connections. The maximum number of connections is set at 100, with an average of 20 concurrent connections assumed.
- **Online Transaction Processing (OLTP)**: Choose this option if your server requires a large number of concurrent connections. The maximum number of connections is set at 500.
- **Manual Setting**: Choose this option to set the maximum number of concurrent connections to the server manually. Choose the number of concurrent connections from the drop-down box provided, or enter the maximum number of connections into the drop-down box if the number you desire is not listed.

2.3.6.8 The Networking and Strict Mode Options Dialog

Use the **Networking Options** dialog to enable or disable TCP/IP networking and to configure the port number that is used to connect to the MySQL server.



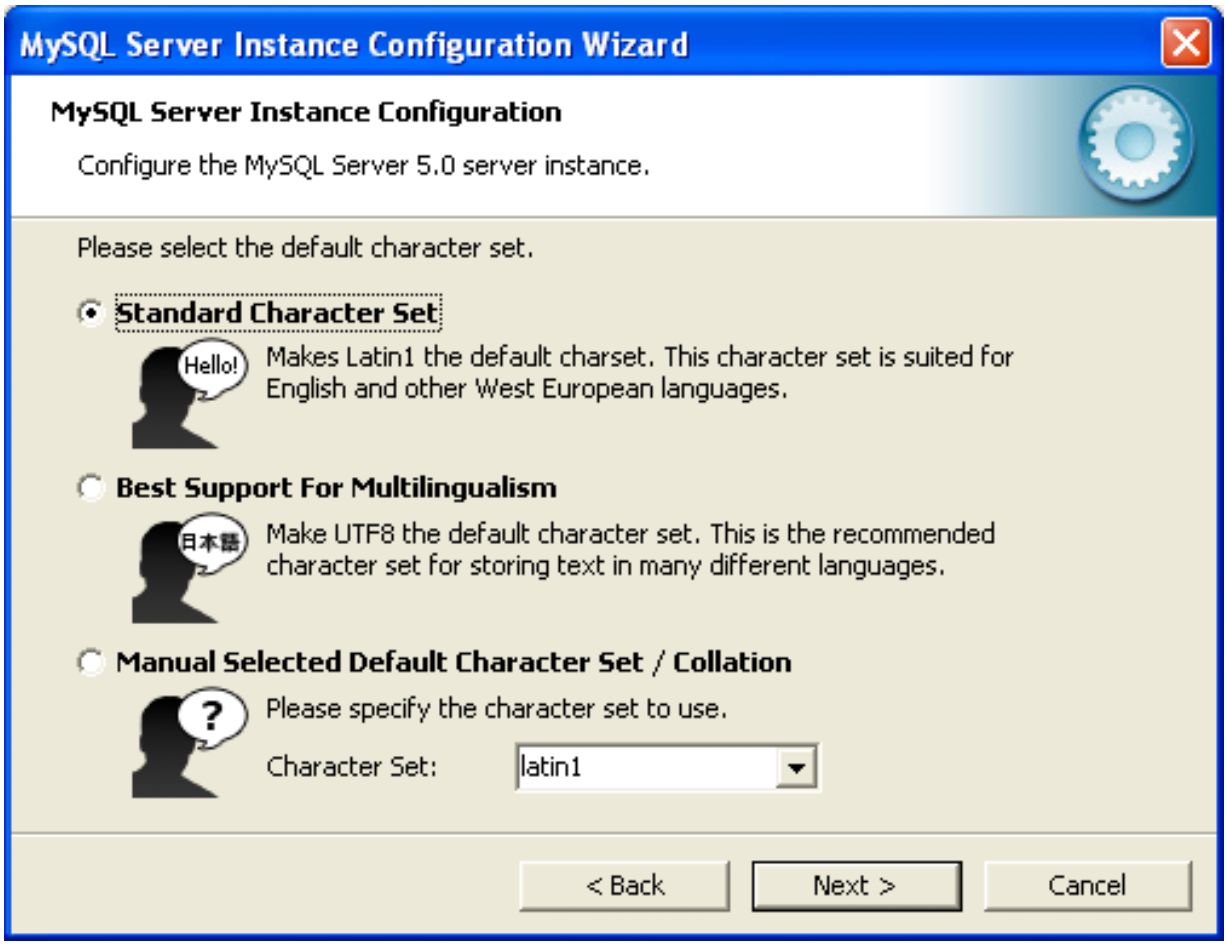
TCP/IP networking is enabled by default. To disable TCP/IP networking, uncheck the box next to the **Enable TCP/IP Networking** option.

Port 3306 is used by default. To change the port used to access MySQL, choose a new port number from the drop-down box or type a new port number directly into the drop-down box. If the port number you choose is in use, you are prompted to confirm your choice of port number.

Set the **Server SQL Mode** to either enable or disable strict mode. Enabling strict mode (default) makes MySQL behave more like other database management systems. *If you run applications that rely on MySQL's old "forgiving" behavior, make sure to either adapt those applications or to disable strict mode.* For more information about strict mode, see Section 5.1.8, "Server SQL Modes".

2.3.6.9 The Character Set Dialog

The MySQL server supports multiple character sets and it is possible to set a default server character set that is applied to all tables, columns, and databases unless overridden. Use the **Character Set** dialog to change the default character set of the MySQL server.



- **Standard Character Set**: Choose this option if you want to use `latin1` as the default server character set. `latin1` is used for English and many Western European languages.
- **Best Support For Multilingualism**: Choose this option if you want to use `utf8` as the default server character set. This is a Unicode character set that can store characters from many different languages.
- **Manual Selected Default Character Set / Collation**: Choose this option if you want to pick the server's default character set manually. Choose the desired character set from the provided drop-down list.

2.3.6.10 The Service Options Dialog

On Windows platforms, the MySQL server can be installed as a Windows service. When installed this way, the MySQL server can be started automatically during system startup, and even restarted automatically by Windows in the event of a service failure.

The MySQL Server Instance Configuration Wizard installs the MySQL server as a service by default, using the service name `MySQL`. If you do not wish to install the service, uncheck the box next to the **Install As Windows Service** option. You can change the service name by picking a new service name from the drop-down box provided or by entering a new service name into the drop-down box.

Note

Service names can include any legal character except forward (`/`) or backward (`\`) slashes, and must be less than 256 characters long.

Warning

If you are installing multiple versions of MySQL onto the same machine, you *must* choose a different service name for each version that you install. If you do not choose a different service for each installed version then the service manager information will be inconsistent and this will cause problems when you try to uninstall a previous version.

If you have already installed multiple versions using the same service name, you must manually edit the contents of the `HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services` parameters within the Windows registry to update the association of the service name with the correct server version.

Typically, when installing multiple versions you create a service name based on the version information. For example, you might install MySQL 5.x as `mysql5`, or specific versions such as MySQL 5.5.0 as `mysql50500`.

To install the MySQL server as a service but not have it started automatically at startup, uncheck the box next to the **Launch the MySQL Server Automatically** option.

2.3.6.11 The Security Options Dialog

The content of the security options portion of the MySQL Server Instance Configuration Wizard will depend on whether this is a new installation, or modifying an existing installation.

- **Setting the root password for a new installation**

  It is strongly recommended that you set a `root` password for your MySQL server, and the MySQL Server Instance Config Wizard requires by default that you do so. If you do not wish to set a `root` password, uncheck the box next to the **Modify Security Settings** option.

- To set the `root` password, enter the desired password into both the **New root password** and **Confirm** boxes.

  Setting the root password for an existing installation

  If you are modifying the configuration of an existing configuration, or you are installing an upgrade and the MySQL Server Instance Configuration Wizard has detected an existing MySQL system, then you must enter the existing password for `root` before changing the configuration information.

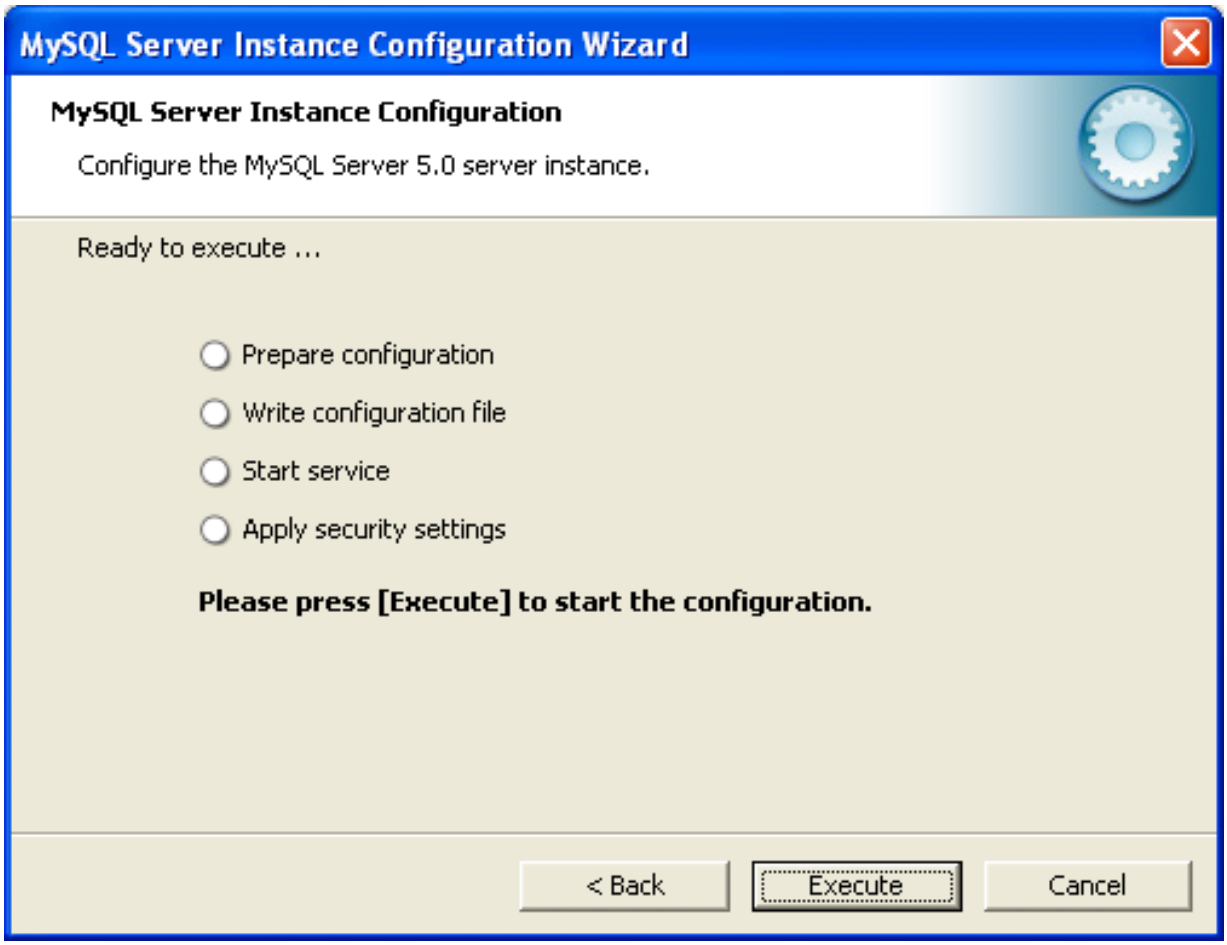
  If you want to change the current `root` password, enter the desired new password into both the **New root password** and **Confirm** boxes.

To permit `root` logins from across the network, check the box next to the **Enable root access from remote machines** option. This decreases the security of your `root` account.

To create an anonymous user account, check the box next to the **Create An Anonymous Account** option. Creating an anonymous account can decrease server security and cause login and permission difficulties. For this reason, it is not recommended.

2.3.6.12 The Confirmation Dialog

The final dialog in the MySQL Server Instance Configuration Wizard is the **Confirmation Dialog**. To start the configuration process, click the **Execute** button. To return to a previous dialog, click the **Back** button. To exit the MySQL Server Instance Configuration Wizard without configuring the server, click the **Cancel** button.



After you click the **Execute** button, the MySQL Server Instance Configuration Wizard performs a series of tasks and displays the progress onscreen as the tasks are performed.

The MySQL Server Instance Configuration Wizard first determines configuration file options based on your choices using a template prepared by MySQL developers and engineers. This template is named `my-template.ini` and is located in your server installation directory.

The MySQL Configuration Wizard then writes these options to the corresponding configuration file.

If you chose to create a service for the MySQL server, the MySQL Server Instance Configuration Wizard creates and starts the service. If you are reconfiguring an existing service, the MySQL Server Instance Configuration Wizard restarts the service to apply your configuration changes.

If you chose to set a `root` password, the MySQL Configuration Wizard connects to the server, sets your new `root` password, and applies any other security settings you may have selected.

After the MySQL Server Instance Configuration Wizard has completed its tasks, it displays a summary. Click the **Finish** button to exit the MySQL Server Configuration Wizard.

2.3.6.13 MySQL Server Instance Config Wizard: Creating an Instance from the Command Line

In addition to using the GUI interface to the MySQL Server Instance Config Wizard, you can also create instances automatically from the command line.

To use the MySQL Server Instance Config Wizard on the command line, you need to use the `MySQLInstanceConfig.exe` command that is installed with MySQL in the `bin` directory within the installation directory. `MySQLInstanceConfig.exe` takes a number of command-line arguments the set the properties that would normally be selected through the GUI interface, and then creates a new

configuration file (`my.ini`) by combining these selections with a template configuration file to produce the working configuration file.

The main command line options are provided in the table below. Some of the options are required, while some options are optional.

Table 2.6 MySQL Server Instance Config Wizard Command Line Options

Option	Description
Required Parameters	
`-nPRODUCTNAME`	The name of the instance when installed
`-pPATH`	Path of the base directory for installation. This is equivalent to the directory when using the `basedir` configuration parameter
`-vVERSION`	The version tag to use for this installation
Action to Perform	
`-i`	Install an instance
`-r`	Remove an instance
`-s`	Stop an existing instance
`-q`	Perform the operation quietly
`-lFILENAME`	Sae the installation progress in a logfile
Config File to Use	
`-tFILENAME`	Path to the template config file that will be used to generate the installed configuration file
`-cFILENAME`	Path to a config file to be generated

The `-t` and `-c` options work together to set the configuration parameters for a new instance. The `-t` option specifies the template configuration file to use as the basic configuration, which are then merged with the configuration parameters generated by the MySQL Server Instance Config Wizard into the configuration file specified by the `-c` option.

A sample template file, `my-template.ini` is provided in the toplevel MySQL installation directory. The file contains elements are replaced automatically by the MySQL Server Instance Config Wizard during configuration.

If you specify a configuration file that already exists, the existing configuration file will be saved in the file with the original, with the date and time added. For example, the `mysql.ini` will be copied to `mysql 2009-10-27 1646.ini.bak`.

The parameters that you can specify on the command line are listed in the table below.

Table 2.7 MySQL Server Instance Config Wizard Parameters

Parameter	Description
`ServiceName=$`	Specify the name of the service to be created
`AddBinToPath={yes | no}`	Specifies whether to add the binary directory of MySQL to the standard `PATH` environment variable
`ServerType={DEVELOPMENT | SERVER | DEDICATED}`	Specify the server type. For more information, see Section 2.3.6.4, “The Server Type Dialog”
`DatabaseType={MIXED | INNODB | MYISAM}`	Specify the default database type. For more information, see Section 2.3.6.5, “The Database Usage Dialog”
`ConnectionUsage={DSS | OLTP}`	Specify the type of connection support, this automates the setting for the number of concurrent connections (see the `ConnectionCount` parameter).

Parameter	Description
	For more information, see Section 2.3.6.7, “The Concurrent Connections Dialog”
`ConnectionCount=#`	Specify the number of concurrent connections to support. For more information, see Section 2.3.6.4, “The Server Type Dialog”
`SkipNetworking={yes | no}`	Specify whether network support should be supported. Specifying `yes` disables network access altogether
`Port=#`	Specify the network port number to use for network connections. For more information, see Section 2.3.6.8, “The Networking and Strict Mode Options Dialog”
`StrictMode={yes | no}`	Specify whether to use the `strict` SQL mode. For more information, see Section 2.3.6.8, “The Networking and Strict Mode Options Dialog”
`Charset=$`	Specify the default character set. For more information, see Section 2.3.6.9, “The Character Set Dialog”
`RootPassword=$`	Specify the root password
`RootCurrentPassword=$`	Specify the current root password then stopping or reconfiguring an existing service

Note

When specifying options on the command line, you can enclose the entire command-line option and the value you are specifying using double quotation marks. This enables you to use spaces in the options. For example, `"-cC:\mysql.ini"`.

The following command installs a MySQL Server 5.5 instance from the directory `C:\Program Files\MySQL\MySQL Server 5.5` using the service name `MySQL55` and setting the root password to 1234.

```
shell> MySQLInstanceConfig.exe -i -q "-lC:\mysql_install_log.txt" »
   "-nMySQL Server 5.5" "-pC:\Program Files\MySQL\MySQL Server 5.5" -v5.5.60 »
   "-tmy-template.ini" "-cC:\mytest.ini" ServerType=DEVELOPMENT DatabaseType=MIXED »
   ConnectionUsage=DSS Port=3311 ServiceName=MySQL55 RootPassword=1234
```

In the above example, a log file will be generated in `mysql_install_log.txt` containing the information about the instance creation process. The log file generated by the above example is shown below:

```
Welcome to the MySQL Server Instance Configuration Wizard 1.0.16.0
Date: 2009-10-27 17:07:21

Installing service ...

Product Name:         MySQL Server 5.5
Version:              5.5.60
Installation Path:    C:\Program Files\MySQL\MySQL Server 5.5\

Creating configuration file C:\mytest.ini using template my-template.ini.
Options:
DEVELOPMENT
MIXED
DSS
STRICTMODE

Variables:
port: 3311
default-character-set: latin1
basedir: "C:/Program Files/MySQL/MySQL Server 5.5/"
datadir: "C:/Program Files/MySQL/MySQL Server 5.5/Data/"
```

```
Creating Windows service entry.
Service name: "MySQL55"
Parameters:   "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --defaults-file="C:\mytest.ini" MySQ
Windows service MySQL55 installed.
```

When using the command line, the return values in the following table indicate an error performing the specified option.

Table 2.8 Return Value from MySQL Server Instance Config Wizard

Value	Description
2	Configuration template file cannot be found
3	The Windows service entry cannot be created
4	Could not connect to the Service Control Manager
5	The MySQL service cannot be started
6	The MySQL service cannot be stopped
7	The security settings cannot be applied
8	The configuration file cannot be written
9	The Windows service entry cannot be removed

You can perform an installation of MySQL automatically using the MSI package. For more information, see Section 2.3.5.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”.

2.3.7 Installing MySQL on Microsoft Windows Using a noinstall ZIP Archive

Users who are installing from the noinstall package can use the instructions in this section to manually install MySQL. The process for installing MySQL from a ZIP Archive package is as follows:

1. Extract the archive to the desired install directory
2. Create an option file
3. Choose a MySQL server type
4. Start the MySQL server
5. Secure the default user accounts

This process is described in the sections that follow.

2.3.7.1 Extracting the Install Archive

To install MySQL manually, do the following:

1. If you are upgrading from a previous version please refer to Section 2.3.10, “Upgrading MySQL on Windows”, before beginning the upgrade process.
2. Make sure that you are logged in as a user with administrator privileges.
3. Choose an installation location. Traditionally, the MySQL server is installed in C:\mysql. The MySQL Installation Wizard installs MySQL under C:\Program Files\MySQL. If you do not install MySQL at C:\mysql, you must specify the path to the install directory during startup or in an option file. See Section 2.3.7.2, “Creating an Option File”.

Note

The MySQL Installer installs MySQL under C:\Program Files\MySQL.

4. Extract the install archive to the chosen installation location using your preferred file-compression tool. Some tools may extract the archive to a folder within your chosen installation location. If this occurs, you can move the contents of the subfolder into the chosen installation location.

2.3.7.2 Creating an Option File

If you need to specify startup options when you run the server, you can indicate them on the command line or place them in an option file. For options that are used every time the server starts, you may find it most convenient to use an option file to specify your MySQL configuration. This is particularly true under the following circumstances:

- The installation or data directory locations are different from the default locations (`C:\Program Files\MySQL\MySQL Server 5.5` and `C:\Program Files\MySQL\MySQL Server 5.5\data`).
- You need to tune the server settings, such as memory, cache, or InnoDB configuration information.

When the MySQL server starts on Windows, it looks for option files in several locations, such as the Windows directory, `C:\`, and the MySQL installation directory (for the full list of locations, see Section 4.2.6, “Using Option Files”). The Windows directory typically is named something like `C:\WINDOWS`. You can determine its exact location from the value of the `WINDIR` environment variable using the following command:

```
C:\> echo %WINDIR%
```

MySQL looks for options in each location first in the `my.ini` file, and then in the `my.cnf` file. However, to avoid confusion, it is best if you use only one file. If your PC uses a boot loader where `C:` is not the boot drive, your only option is to use the `my.ini` file. Whichever option file you use, it must be a plain text file.

Note

When using the MySQL Installer to install MySQL Server, it will create the `my.ini` at the default location. And as of MySQL Server 5.5.27, the user running MySQL Installer is granted full permissions to this new `my.ini`.

In other words, be sure that the MySQL Server user has permission to read the `my.ini` file.

You can also make use of the example option files included with your MySQL distribution; see Section 5.1.2, “Server Configuration Defaults”.

An option file can be created and modified with any text editor, such as Notepad. For example, if MySQL is installed in `E:\mysql` and the data directory is in `E:\mydata\data`, you can create an option file containing a `[mysqld]` section to specify values for the `basedir` and `datadir` options:

```
[mysqld]
# set basedir to your installation path
basedir=E:/mysql
# set datadir to the location of your data directory
datadir=E:/mydata/data
```

Microsoft Windows path names are specified in option files using (forward) slashes rather than backslashes. If you do use backslashes, double them:

```
[mysqld]
# set basedir to your installation path
basedir=E:\\mysql
# set datadir to the location of your data directory
datadir=E:\\mydata\\data
```

The rules for use of backslash in option file values are given in Section 4.2.6, “Using Option Files”.

The data directory is located within the AppData directory for the user running MySQL.

If you would like to use a data directory in a different location, you should copy the entire contents of the data directory to the new location. For example, if you want to use E:\mydata as the data directory instead, you must do two things:

1. Move the entire data directory and all of its contents from the default location (for example C:\Program Files\MySQL\MySQL Server 5.5\data) to E:\mydata.
2. Use a --datadir option to specify the new data directory location each time you start the server.

2.3.7.3 Selecting a MySQL Server Type

The following table shows the available servers for Windows in MySQL 5.5.

Binary	Description
mysqld	Optimized binary with named-pipe support
mysqld-debug	Like mysqld, but compiled with full debugging and automatic memory allocation checking

All of the preceding binaries are optimized for modern Intel processors, but should work on any Intel i386-class or higher processor.

Each of the servers in a distribution support the same set of storage engines. The SHOW ENGINES statement displays which engines a given server supports.

All Windows MySQL 5.5 servers have support for symbolic linking of database directories.

MySQL supports TCP/IP on all Windows platforms. MySQL servers on Windows also support named pipes, if you start the server with the --enable-named-pipe option. It is necessary to use this option explicitly because some users have experienced problems with shutting down the MySQL server when named pipes were used. The default is to use TCP/IP regardless of platform because named pipes are slower than TCP/IP in many Windows configurations.

2.3.7.4 Starting the Server for the First Time

This section gives a general overview of starting the MySQL server. The following sections provide more specific information for starting the MySQL server from the command line or as a Windows service.

The information here applies primarily if you installed MySQL using the noinstall version, or if you wish to configure and test MySQL manually rather than with the GUI tools.

Note

MySQL server will automatically start after using MySQL Installer, and MySQL Notifier can be used to start/stop/restart at any time.

The examples in these sections assume that MySQL is installed under the default location of C:\Program Files\MySQL\MySQL Server 5.5. Adjust the path names shown in the examples if you have MySQL installed in a different location.

Clients have two options. They can use TCP/IP, or they can use a named pipe if the server supports named-pipe connections.

MySQL for Windows also supports shared-memory connections if the server is started with the --shared-memory option. Clients can connect through shared memory by using the --protocol=MEMORY option.

For information about which server binary to run, see Section 2.3.7.3, “Selecting a MySQL Server Type”.

Testing is best done from a command prompt in a console window (or “DOS window”). In this way you can have the server display status messages in the window where they are easy to see. If something is wrong with your configuration, these messages make it easier for you to identify and fix any problems.

To start the server, enter this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --console
```

For a server that includes InnoDB support, you should see the messages similar to those following as it starts (the path names and sizes may differ):

```
InnoDB: The first specified datafile c:\ibdata\ibdata1 did not exist:
InnoDB: a new database to be created!
InnoDB: Setting file c:\ibdata\ibdata1 size to 209715200
InnoDB: Database physically writes the file full: wait...
InnoDB: Log file c:\iblogs\ib_logfile0 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile0 size to 31457280
InnoDB: Log file c:\iblogs\ib_logfile1 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile1 size to 31457280
InnoDB: Log file c:\iblogs\ib_logfile2 did not exist: new to be created
InnoDB: Setting log file c:\iblogs\ib_logfile2 size to 31457280
InnoDB: Doublewrite buffer not found: creating new
InnoDB: Doublewrite buffer created
InnoDB: creating foreign key constraint system tables
InnoDB: foreign key constraint system tables created
011024 10:58:25  InnoDB: Started
```

When the server finishes its startup sequence, you should see something like this, which indicates that the server is ready to service client connections:

```
mysqld: ready for connections
Version: '5.5.60'  socket: ''  port: 3306
```

The server continues to write to the console any further diagnostic output it produces. You can open a new console window in which to run client programs.

If you omit the --console option, the server writes diagnostic output to the error log in the data directory (C:\Program Files\MySQL\MySQL Server 5.5\data by default). The error log is the file with the .err extension, and may be set using the --log-error option.

Note

The accounts that are listed in the MySQL grant tables initially have no passwords. After starting the server, you should set up passwords for them using the instructions in Section 2.10.4, “Securing the Initial MySQL Accounts”.

2.3.7.5 Starting MySQL from the Windows Command Line

The MySQL server can be started manually from the command line. This can be done on any version of Windows.

Note

MySQL Notifier can also be used to start/stop/restart the MySQL server.

To start the mysqld server from the command line, you should start a console window (or “DOS window”) and enter this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld"
```

The path to mysqld may vary depending on the install location of MySQL on your system.

You can stop the MySQL server by executing this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqladmin" -u root shutdown
```

Note

If the MySQL root user account has a password, you need to invoke mysqladmin with the -p option and supply the password when prompted.

This command invokes the MySQL administrative utility mysqladmin to connect to the server and tell it to shut down. The command connects as the MySQL root user, which is the default administrative account in the MySQL grant system.

Note

Users in the MySQL grant system are wholly independent from any login users under Microsoft Windows.

If mysqld doesn't start, check the error log to see whether the server wrote any messages there to indicate the cause of the problem. By default, the error log is located in the C:\Program Files\MySQL\MySQL Server 5.5\data directory. It is the file with a suffix of .err, or may be specified by passing in the --log-error option. Alternatively, you can try to start the server with the --console option; in this case, the server may display some useful information on the screen that will help solve the problem.

The last option is to start mysqld with the --standalone and --debug options. In this case, mysqld writes a log file C:\mysqld.trace that should contain the reason why mysqld doesn't start. See Section 24.5.3, “The DBUG Package”.

Use mysqld --verbose --help to display all the options that mysqld supports.

2.3.7.6 Customizing the PATH for MySQL Tools

To make it easier to invoke MySQL programs, you can add the path name of the MySQL bin directory to your Windows system PATH environment variable:

- On the Windows desktop, right-click the **My Computer** icon, and select **Properties**.
- Next select the **Advanced** tab from the **System Properties** menu that appears, and click the **Environment Variables** button.
- Under **System Variables**, select **Path**, and then click the **Edit** button. The **Edit System Variable** dialogue should appear.
- Place your cursor at the end of the text appearing in the space marked **Variable Value**. (Use the **End** key to ensure that your cursor is positioned at the very end of the text in this space.) Then enter the complete path name of your MySQL bin directory (for example, C:\Program Files\MySQL\MySQL Server 5.5\bin)

  Note

  There must be a semicolon separating this path from any values present in this field.

  Dismiss this dialogue, and each dialogue in turn, by clicking **OK** until all of the dialogues that were opened have been dismissed. You should now be able to invoke any MySQL executable program by typing its name at the DOS prompt from any directory on the system, without having to supply the path. This includes the servers, the mysql client, and all MySQL command-line utilities such as mysqladmin and mysqldump.

  You should not add the MySQL bin directory to your Windows PATH if you are running multiple MySQL servers on the same machine.

Warning

You must exercise great care when editing your system PATH by hand; accidental deletion or modification of any portion of the existing PATH value can leave you with a malfunctioning or even unusable system.

2.3.7.7 Starting MySQL as a Windows Service

On Windows, the recommended way to run MySQL is to install it as a Windows service, so that MySQL starts and stops automatically when Windows starts and stops. A MySQL server installed as a service can also be controlled from the command line using NET commands, or with the graphical Services utility. Generally, to install MySQL as a Windows service you should be logged in using an account that has administrator rights.

Note

MySQL Notifier can also be used to monitor the status of the MySQL service.

The Services utility (the Windows Service Control Manager) can be found in the Windows Control Panel (under **Administrative Tools** on Windows 2000, XP, Vista, and Server 2003). To avoid conflicts, it is advisable to close the Services utility while performing server installation or removal operations from the command line.

Installing the service

Before installing MySQL as a Windows service, you should first stop the current server if it is running by using the following command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqladmin"
        -u root shutdown
```

Note

If the MySQL root user account has a password, you need to invoke mysqladmin with the -p option and supply the password when prompted.

This command invokes the MySQL administrative utility mysqladmin to connect to the server and tell it to shut down. The command connects as the MySQL root user, which is the default administrative account in the MySQL grant system.

Note

Users in the MySQL grant system are wholly independent from any login users under Windows.

Install the server as a service using this command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --install
```

The service-installation command does not start the server. Instructions for that are given later in this section.

To make it easier to invoke MySQL programs, you can add the path name of the MySQL bin directory to your Windows system PATH environment variable:

- On the Windows desktop, right-click the **My Computer** icon, and select **Properties**.
- Next select the **Advanced** tab from the **System Properties** menu that appears, and click the **Environment Variables** button.
- Under **System Variables**, select **Path**, and then click the **Edit** button. The **Edit System Variable** dialogue should appear.

- Place your cursor at the end of the text appearing in the space marked **Variable Value**. (Use the **End** key to ensure that your cursor is positioned at the very end of the text in this space.) Then enter the complete path name of your MySQL bin directory (for example, C:\Program Files\MySQL\MySQL Server 5.5\bin), and there should be a semicolon separating this path from any values present in this field. Dismiss this dialogue, and each dialogue in turn, by clicking **OK** until all of the dialogues that were opened have been dismissed. You should now be able to invoke any MySQL executable program by typing its name at the DOS prompt from any directory on the system, without having to supply the path. This includes the servers, the mysql client, and all MySQL command-line utilities such as mysqladmin and mysqldump.

  You should not add the MySQL bin directory to your Windows PATH if you are running multiple MySQL servers on the same machine.

Warning

You must exercise great care when editing your system PATH by hand; accidental deletion or modification of any portion of the existing PATH value can leave you with a malfunctioning or even unusable system.

The following additional arguments can be used when installing the service:

- You can specify a service name immediately following the --install option. The default service name is MySQL.
- If a service name is given, it can be followed by a single option. By convention, this should be --defaults-file=*file_name* to specify the name of an option file from which the server should read options when it starts.

  The use of a single option other than --defaults-file is possible but discouraged. --defaults-file is more flexible because it enables you to specify multiple startup options for the server by placing them in the named option file.
- You can also specify a --local-service option following the service name. This causes the server to run using the LocalService Windows account that has limited system privileges. This account is available only for Windows XP or newer. If both --defaults-file and --local-service are given following the service name, they can be in any order.

For a MySQL server that is installed as a Windows service, the following rules determine the service name and option files that the server uses:

- If the service-installation command specifies no service name or the default service name (MySQL) following the --install option, the server uses the a service name of MySQL and reads options from the [mysqld] group in the standard option files.
- If the service-installation command specifies a service name other than MySQL following the --install option, the server uses that service name. It reads options from the [mysqld] group and the group that has the same name as the service in the standard option files. This enables you to use the [mysqld] group for options that should be used by all MySQL services, and an option group with the service name for use by the server installed with that service name.
- If the service-installation command specifies a --defaults-file option after the service name, the server reads options the same way as described in the previous item, except that it reads options only from the named file and ignores the standard option files.

As a more complex example, consider the following command:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld"
         --install MySQL --defaults-file=C:\my-opts.cnf
```

Here, the default service name (MySQL) is given after the --install option. If no --defaults-file option had been given, this command would have the effect of causing the server to read the

[mysqld] group from the standard option files. However, because the --defaults-file option is present, the server reads options from the [mysqld] option group, and only from the named file.

Note

On Windows, if the server is started with the --defaults-file and --install options, --install must be first. Otherwise, mysqld.exe will attempt to start the MySQL server.

You can also specify options as Start parameters in the Windows Services utility before you start the MySQL service.

Finally, before trying to start the MySQL service, make sure the user variables %TEMP% and %TMP% (and also %TMPDIR%, if it has ever been set) for the system user who is to run the service are pointing to a folder to which the user has write access. The default user for running the MySQL service is LocalSystem, and the default value for its %TEMP% and %TMP% is C:\Windows\Temp, a directory LocalSystem has write access to by default. However, if there are any changes to that default setup (for example, changes to the user who runs the service or to the mentioned user variables, or the --tmpdir option has been used to put the temporary directory somewhere else), the MySQL service might fail to run because write access to the temporary directory has not been granted to the proper user.

Starting the service

After a MySQL server instance has been installed as a service, Windows starts the service automatically whenever Windows starts. The service also can be started immediately from the Services utility, or by using a NET START MySQL command. The NET command is not case sensitive.

When run as a service, mysqld has no access to a console window, so no messages can be seen there. If mysqld does not start, check the error log to see whether the server wrote any messages there to indicate the cause of the problem. The error log is located in the MySQL data directory (for example, C:\Program Files\MySQL\MySQL Server 5.5\data). It is the file with a suffix of .err.

When a MySQL server has been installed as a service, and the service is running, Windows stops the service automatically when Windows shuts down. The server also can be stopped manually by using the Services utility, the NET STOP MySQL command, or the mysqladmin shutdown command.

You also have the choice of installing the server as a manual service if you do not wish for the service to be started automatically during the boot process. To do this, use the --install-manual option rather than the --install option:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --install-manual
```

Removing the service

To remove a server that is installed as a service, first stop it if it is running by executing NET STOP MySQL. Then use the --remove option to remove it:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --remove
```

If mysqld is not running as a service, you can start it from the command line. For instructions, see Section 2.3.7.5, “Starting MySQL from the Windows Command Line”.

If you encounter difficulties during installation, see Section 2.3.8, “Troubleshooting a Microsoft Windows MySQL Server Installation”.

For more information about stopping or removing a MySQL Windows service, see Section 5.6.2.2, “Starting Multiple MySQL Instances as Windows Services”.

2.3.7.8 Testing The MySQL Installation

You can test whether the MySQL server is working by executing any of the following commands:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqlshow"
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqlshow" -u root mysql
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqladmin" version status proc
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysql" test
```

If `mysqld` is slow to respond to TCP/IP connections from client programs, there is probably a problem with your DNS. In this case, start `mysqld` with the `--skip-name-resolve` option and use only `localhost` and IP addresses in the `Host` column of the MySQL grant tables. (Be sure that an account exists that specifies an IP address or you may not be able to connect.)

You can force a MySQL client to use a named-pipe connection rather than TCP/IP by specifying the `--pipe` or `--protocol=PIPE` option, or by specifying `.` (period) as the host name. Use the `--socket` option to specify the name of the pipe if you do not want to use the default pipe name.

If you have set a password for the `root` account, deleted the anonymous account, or created a new user account, then to connect to the MySQL server you must use the appropriate `-u` and `-p` options with the commands shown previously. See Section 4.2.2, “Connecting to the MySQL Server”.

For more information about `mysqlshow`, see Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”.

2.3.8 Troubleshooting a Microsoft Windows MySQL Server Installation

When installing and running MySQL for the first time, you may encounter certain errors that prevent the MySQL server from starting. This section helps you diagnose and correct some of these errors.

Your first resource when troubleshooting server issues is the error log. The MySQL server uses the error log to record information relevant to the error that prevents the server from starting. The error log is located in the data directory specified in your `my.ini` file. The default data directory location is `C:\Program Files\MySQL\MySQL Server 5.5\data`, or `C:\ProgramData\Mysql` on Windows 7 and Windows Server 2008. The `C:\ProgramData` directory is hidden by default. You need to change your folder options to see the directory and contents. For more information on the error log and understanding the content, see Section 5.4.2, “The Error Log”.

For information regarding possible errors, also consult the console messages displayed when the MySQL service is starting. Use the `NET START MySQL` command from the command line after installing `mysqld` as a service to see any error messages regarding the starting of the MySQL server as a service. See Section 2.3.7.7, “Starting MySQL as a Windows Service”.

The following examples show other common error messages you might encounter when installing MySQL and starting the server for the first time:

- If the MySQL server cannot find the `mysql` privileges database or other critical files, it displays these messages:

  ```
  System error 1067 has occurred.
  Fatal error: Can't open and lock privilege tables:
  Table 'mysql.user' doesn't exist
  ```

  These messages often occur when the MySQL base or data directories are installed in different locations than the default locations (`C:\Program Files\MySQL\MySQL Server 5.5` and `C:\Program Files\MySQL\MySQL Server 5.5\data`, respectively).

  This situation can occur when MySQL is upgraded and installed to a new location, but the configuration file is not updated to reflect the new location. In addition, old and new configuration files might conflict. Be sure to delete or rename any old configuration files when upgrading MySQL.

If you have installed MySQL to a directory other than `C:\Program Files\MySQL\MySQL Server 5.5`, ensure that the MySQL server is aware of this through the use of a configuration (`my.ini`) file. Put the `my.ini` file in your Windows directory, typically `C:\WINDOWS`. To determine its exact location from the value of the `WINDIR` environment variable, issue the following command from the command prompt:

```
C:\> echo %WINDIR%
```

You can create or modify an option file with any text editor, such as Notepad. For example, if MySQL is installed in `E:\mysql` and the data directory is `D:\MySQLdata`, you can create the option file and set up a `[mysqld]` section to specify values for the `basedir` and `datadir` options:

```
[mysqld]
# set basedir to your installation path
basedir=E:/mysql
# set datadir to the location of your data directory
datadir=D:/MySQLdata
```

Microsoft Windows path names are specified in option files using (forward) slashes rather than backslashes. If you do use backslashes, double them:

```
[mysqld]
# set basedir to your installation path
basedir=C:\\Program Files\\MySQL\\MySQL Server 5.5
# set datadir to the location of your data directory
datadir=D:\\MySQLdata
```

The rules for use of backslash in option file values are given in Section 4.2.6, “Using Option Files”.

If you change the `datadir` value in your MySQL configuration file, you must move the contents of the existing MySQL data directory before restarting the MySQL server.

See Section 2.3.7.2, “Creating an Option File”.

- If you reinstall or upgrade MySQL without first stopping and removing the existing MySQL service and install MySQL using the MySQL Installer, you might see this error:

```
Error: Cannot create Windows service for MySql. Error: 0
```

This occurs when the Configuration Wizard tries to install the service and finds an existing service with the same name.

One solution to this problem is to choose a service name other than `mysql` when using the configuration wizard. This enables the new service to be installed correctly, but leaves the outdated service in place. Although this is harmless, it is best to remove old services that are no longer in use.

To permanently remove the old `mysql` service, execute the following command as a user with administrative privileges, on the command line:

```
C:\> sc delete mysql
[SC] DeleteService SUCCESS
```

If the `sc` utility is not available for your version of Windows, download the `delsrv` utility from http://www.microsoft.com/windows2000/techinfo/reskit/tools/existing/delsrv-o.asp and use the `delsrv mysql` syntax.

2.3.9 Windows Postinstallation Procedures

GUI tools exist that perform most of the tasks described in this section, including:

- MySQL Installer: Used to install and upgrade MySQL products.
- MySQL Workbench: Manages the MySQL server and edits SQL statements.
- MySQL Notifier: Starts, stops, or restarts the MySQL server, and monitors its status.
- MySQL for Excel: Edits MySQL data with Microsoft Excel.

On Windows, you need not create the data directory and the grant tables. MySQL Windows distributions include the grant tables with a set of preinitialized accounts in the `mysql` database under the data directory.

Regarding passwords, if you installed MySQL using the MySQL Installer, you may have already assigned passwords to the accounts. (See Section 2.3.3, “MySQL Installer for Windows”.) Otherwise, use the password-assignment procedure given in Section 2.10.4, “Securing the Initial MySQL Accounts”.

Before assigning passwords, you might want to try running some client programs to make sure that you can connect to the server and that it is operating properly. Make sure that the server is running (see Section 2.3.7.4, “Starting the Server for the First Time”). You can also set up a MySQL service that runs automatically when Windows starts (see Section 2.3.7.7, “Starting MySQL as a Windows Service”).

These instructions assume that your current location is the MySQL installation directory and that it has a `bin` subdirectory containing the MySQL programs used here. If that is not true, adjust the command path names accordingly.

If you installed MySQL using MySQL Installer (see Section 2.3.3, “MySQL Installer for Windows”), the default installation directory is `C:\Program Files\MySQL\MySQL Server 5.5`:

```
C:\> cd "C:\Program Files\MySQL\MySQL Server 5.5"
```

A common installation location for installation from a ZIP archive is `C:\mysql`:

```
C:\> cd C:\mysql
```

Alternatively, add the `bin` directory to your `PATH` environment variable setting. That enables your command interpreter to find MySQL programs properly, so that you can run a program by typing only its name, not its path name. See Section 2.3.7.6, “Customizing the PATH for MySQL Tools”.

With the server running, issue the following commands to verify that you can retrieve information from the server. The output should be similar to that shown here.

Use `mysqlshow` to see what databases exist:

```
C:\> bin\mysqlshow
+--------------------+
|     Databases      |
+--------------------+
| information_schema |
| mysql              |
| performance_schema |
| test               |
+--------------------+
```

The list of installed databases may vary, but will always include the minimum of `mysql` and `information_schema`.

The preceding command (and commands for other MySQL programs such as `mysql`) may not work if the correct MySQL account does not exist. For example, the program may fail with an error, or you may not be able to view all databases. If you installed MySQL using MySQL Installer, the `root` user will have been created automatically with the password you supplied. In this case, you should use the

`-u root` and `-p` options. (You must use those options if you have already secured the initial MySQL accounts.) With `-p`, the client program prompts for the `root` password. For example:

```
C:\> bin\mysqlshow -u root -p
Enter password: (enter root password here)
+--------------------+
|     Databases      |
+--------------------+
| information_schema |
| mysql              |
| performance_schema |
| test               |
+--------------------+
```

If you specify a database name, `mysqlshow` displays a list of the tables within the database:

```
C:\> bin\mysqlshow mysql
Database: mysql
+---------------------------+
|          Tables           |
+---------------------------+
| columns_priv              |
| db                        |
| event                     |
| func                      |
| general_log               |
| help_category             |
| help_keyword              |
| help_relation             |
| help_topic                |
| host                      |
| ndb_binlog_index          |
| plugin                    |
| proc                      |
| procs_priv                |
| proxies_priv              |
| servers                   |
| slow_log                  |
| tables_priv               |
| time_zone                 |
| time_zone_leap_second     |
| time_zone_name            |
| time_zone_transition      |
| time_zone_transition_type |
| user                      |
+---------------------------+
```

Use the `mysql` program to select information from a table in the `mysql` database:

```
C:\> bin\mysql -e "SELECT User, Host, plugin FROM mysql.user" mysql
+------+-----------+-----------------------+
| User | Host      | plugin                |
+------+-----------+-----------------------+
| root | localhost | mysql_native_password |
+------+-----------+-----------------------+
```

For more information about `mysql` and `mysqlshow`, see Section 4.5.1, “`mysql` — The MySQL Command-Line Tool”, and Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”.

2.3.10 Upgrading MySQL on Windows

To upgrade MySQL on Windows, follow these steps:

1. Review Section 2.11.1, “Upgrading MySQL”, for additional information on upgrading MySQL that is not specific to Windows.

2. Always back up your current MySQL installation before performing an upgrade. See Section 7.2, “Database Backup Methods”.

3. Download the latest Windows distribution of MySQL from http://dev.mysql.com/downloads/.

4. Before upgrading MySQL, stop the server. If the server is installed as a service, stop the service with the following command from the command prompt:

```
C:\> NET STOP MySQL
```

   If you are not running the MySQL server as a service, use `mysqladmin` to stop it. For example, before upgrading from MySQL 5.1 to 5.5, use `mysqladmin` from MySQL 5.1 as follows:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.1\bin\mysqladmin" -u root shutdown
```

Note

If the MySQL `root` user account has a password, invoke `mysqladmin` with the `-p` option and enter the password when prompted.

5. Before upgrading to MySQL 5.5 from a version previous to 4.1.5, or from a version of MySQL installed from a ZIP archive to a version of MySQL installed with the MySQL Installation Wizard, you must first manually remove the previous installation and MySQL service (if the server is installed as a service).

   To remove the MySQL service, use the following command:

```
C:\> C:\mysql\bin\mysqld --remove
```

   If you do not remove the existing service, the MySQL Installation Wizard may fail to properly install the new MySQL service.

6. If you are using the MySQL Installer, start it as described in Section 2.3.3, “MySQL Installer for Windows”.

   If you are using the MySQL Installation Wizard, start the wizard as described in Section 2.3.5.1, “Using the MySQL Installation Wizard”.

7. If you are upgrading MySQL from a ZIP archive, extract the archive. You may either overwrite your existing MySQL installation (usually located at `C:\mysql`), or install it into a different directory, such as `C:\mysql5`. Overwriting the existing installation is recommended. However, for upgrades (as opposed to installing for the first time), you must remove the data directory from your existing MySQL installation to avoid replacing your current data files. To do so, follow these steps:

   a. Unzip the ZIP archive in some location other than your current MySQL installation

   b. Remove the data directory

   c. Rezip the ZIP archive

   d. Unzip the modified ZIP archive on top of your existing installation

   Alternatively:

   a. Unzip the ZIP archive in some location other than your current MySQL installation

   b. Remove the data directory

   c. Move the data directory from the current MySQL installation to the location of the just-removed data directory

d. Remove the current MySQL installation

e. Move the unzipped installation to the location of the just-removed installation

8. If you were running MySQL as a Windows service and you had to remove the service earlier in this procedure, reinstall the service. (See Section 2.3.7.7, “Starting MySQL as a Windows Service”.)

9. Restart the server. For example, use `NET START MySQL` if you run MySQL as a service, or invoke `mysqld` directly otherwise.

10. As Administrator, run `mysql_upgrade` to check your tables, attempt to repair them if necessary, and update your grant tables if they have changed so that you can take advantage of any new capabilities. See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

11. If you encounter errors, see Section 2.3.8, “Troubleshooting a Microsoft Windows MySQL Server Installation”.

2.4 Installing MySQL on OS X

For a list of OS X versions that the MySQL server supports, see http://www.mysql.com/support/supportedplatforms/database.html.

MySQL for OS X is available in a number of different forms:

- Native Package Installer, which uses the native OS X installer (DMG) to walk you through the installation of MySQL. For more information, see Section 2.4.2, “Installing MySQL on OS X Using Native Packages”. You can use the package installer with OS X. The user you use to perform the installation must have administrator privileges.

- Compressed TAR archive, which uses a file packaged using the Unix `tar` and `gzip` commands. To use this method, you will need to open a `Terminal` window. You do not need administrator privileges using this method, as you can install the MySQL server anywhere using this method. For more information on using this method, you can use the generic instructions for using a tarball, Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

  In addition to the core installation, the Package Installer also includes Section 2.4.3, “Installing a MySQL Launch Daemon” and Section 2.4.4, “Installing and Using the MySQL Preference Pane”, both of which simplify the management of your installation.

For additional information on using MySQL on OS X, see Section 2.4.1, “General Notes on Installing MySQL on OS X”.

2.4.1 General Notes on Installing MySQL on OS X

You should keep the following issues and notes in mind:

- As of MySQL server 5.5.45, the DMG bundles a launchd daemon instead of the deprecated startup item. Startup items do not function as of OS X 10.10 (Yosemite), so using launchd is preferred. The available MySQL preference pane under OS X **System Preferences** was also updated to use launchd.

- You may need (or want) to create a specific `mysql` user to own the MySQL directory and data. You can do this through the `Directory Utility`, and the `mysql` user should already exist. For use in single user mode, an entry for `_mysql` (note the underscore prefix) should already exist within the system `/etc/passwd` file.

- Because the MySQL package installer installs the MySQL contents into a version and platform specific directory, you can use this to upgrade and migrate your database between versions. You will need to either copy the `data` directory from the old version to the new version, or alternatively

specify an alternative `datadir` value to set location of the data directory. By default, the MySQL directories are installed under `/usr/local/`.

- You might want to add aliases to your shell's resource file to make it easier to access commonly used programs such as `mysql` and `mysqladmin` from the command line. The syntax for `bash` is:

```
alias mysql=/usr/local/mysql/bin/mysql
alias mysqladmin=/usr/local/mysql/bin/mysqladmin
```

For `tcsh`, use:

```
alias mysql /usr/local/mysql/bin/mysql
alias mysqladmin /usr/local/mysql/bin/mysqladmin
```

Even better, add `/usr/local/mysql/bin` to your `PATH` environment variable. You can do this by modifying the appropriate startup file for your shell. For more information, see Section 4.2.1, “Invoking MySQL Programs”.

- After you have copied over the MySQL database files from the previous installation and have successfully started the new server, you should consider removing the old installation files to save disk space. Additionally, you should also remove older versions of the Package Receipt directories located in `/Library/Receipts/mysql-VERSION.pkg`.
- Prior to OS X 10.7, MySQL server was bundled with OS X Server.

2.4.2 Installing MySQL on OS X Using Native Packages

The package is located inside a disk image (`.dmg`) file that you first need to mount by double-clicking its icon in the Finder. It should then mount the image and display its contents.

Note

Before proceeding with the installation, be sure to stop all running MySQL server instances by using either the MySQL Manager Application (on OS X Server), the preference pane, or `mysqladmin shutdown` on the command line.

When installing from the package version, you can also install the MySQL preference pane, which will enable you to control the startup and execution of your MySQL server from System Preferences. For more information, see Section 2.4.4, “Installing and Using the MySQL Preference Pane”.

When installing using the package installer, the files are installed into a directory within `/usr/local` matching the name of the installation version and platform. For example, the installer file `mysql-5.5.60-osx10.9-x86_64.dmg` installs MySQL into `/usr/local/mysql-5.5.60-osx10.9-x86_64/` . The following table shows the layout of the installation directory.

Table 2.9 MySQL Installation Layout on OS X

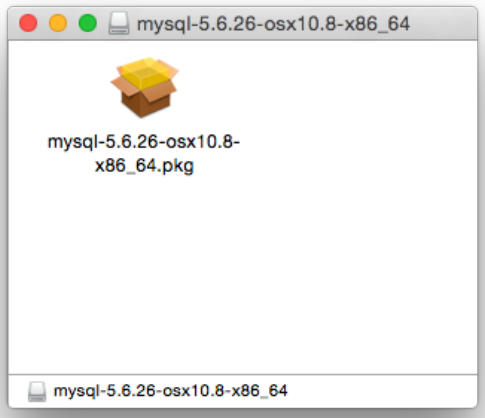
Directory	Contents of Directory
`bin`, `scripts`	`mysqld` server, client and utility programs
`data`	Log files, databases
`docs`	Helper documents, like the Release Notes and build information
`include`	Include (header) files
`lib`	Libraries
`man`	Unix manual pages

Directory	Contents of Directory
`mysql-test`	MySQL test suite
`share`	Miscellaneous support files, including error messages, sample configuration files, SQL for database installation
`sql-bench`	Benchmarks
`support-files`	Scripts and sample configuration files
`/tmp/mysql.sock`	Location of the MySQL Unix socket

During the package installer process, a symbolic link from `/usr/local/mysql` to the version/platform specific directory created during installation will be created automatically.

1. Download and open the MySQL package installer, which is provided on a disk image (`.dmg`) that includes the main MySQL installation package file. Double-click the disk image to open it.

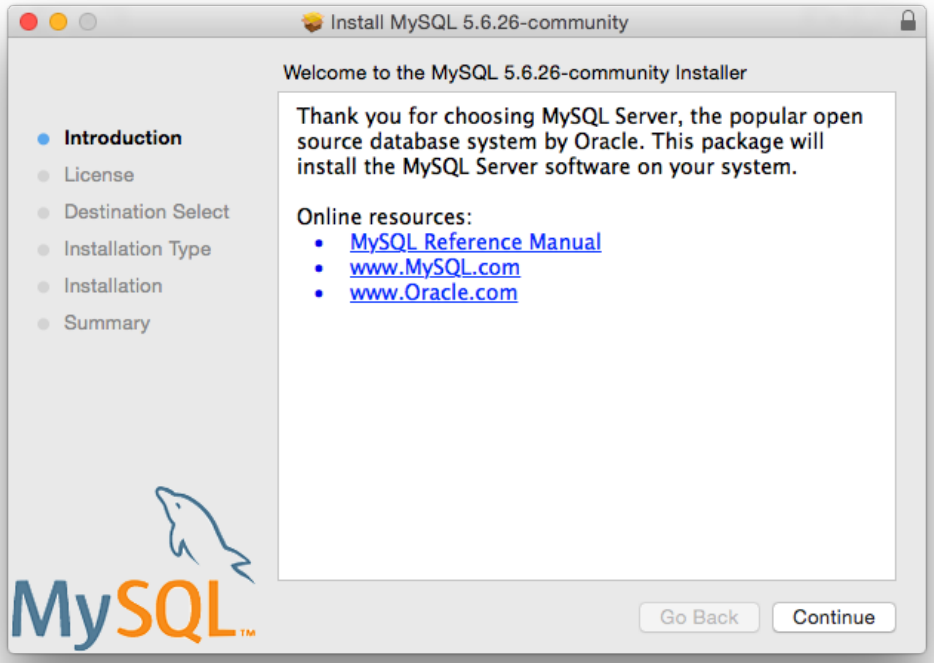
   Figure 2.23 MySQL Package Installer: DMG Contents

2. Double-click the MySQL installer package. It will be named according to the version of MySQL you have downloaded. For example, if you have downloaded MySQL server 5.5.60, double-click `mysql-5.5.60-osx-10.9-x86_64.pkg`.

3. You will be presented with the opening installer dialog. Click **Continue** to begin installation.

Figure 2.24 MySQL Package Installer: Introduction



4. If you have downloaded the community version of MySQL, you will be shown a copy of the relevant GNU General Public License. Click **Continue** and then **Agree** to continue.

5. From the **Installation Type** page you can either click **Install** to execute the installation wizard using all defaults, click **Customize** to alter which components to install (MySQL server, Preference Pane, Launchd Support -- all enabled by default).

Note

Although the **Change Install Location** option is visible, the installation location cannot be changed.

Figure 2.25 MySQL Package Installer: Installation Type

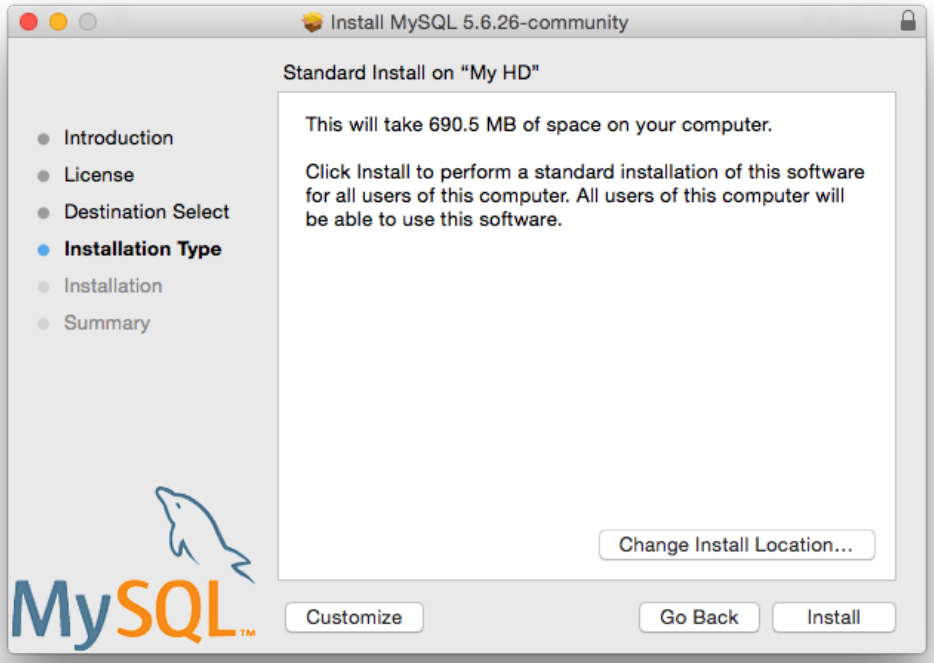
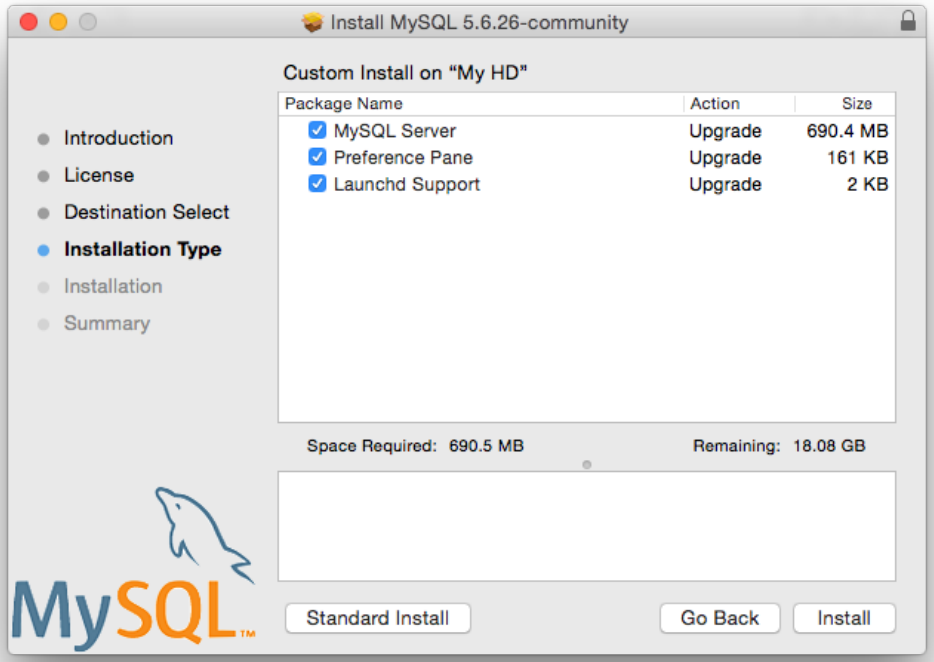


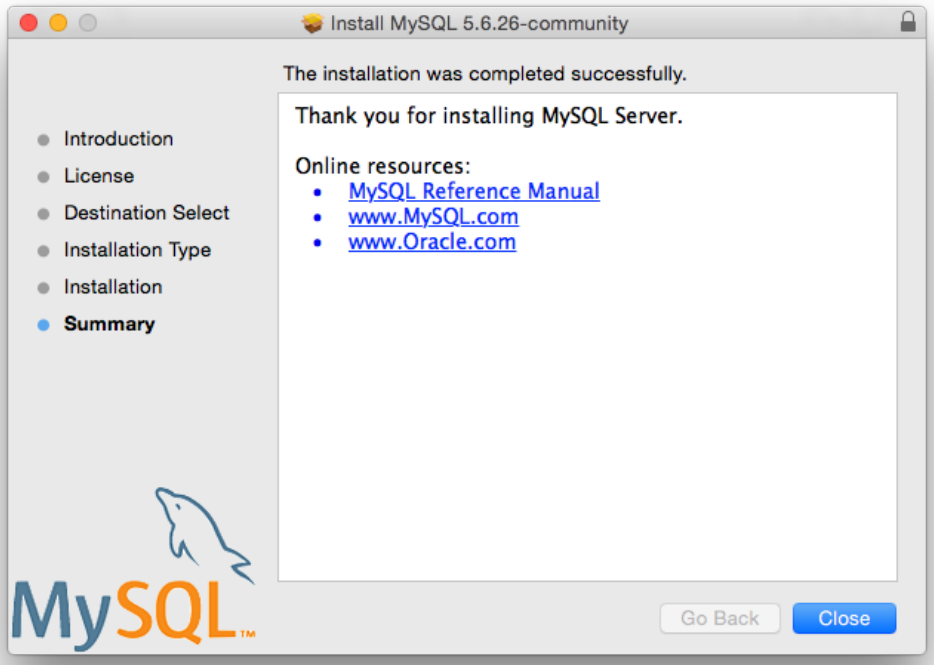
Figure 2.26 MySQL Package Installer: Customize



6. Click **Install** to begin the installation process.

7. Once the installation has been completed successfully, you will be shown an **Install Succeeded** message with a short summary. Now, **Close** the wizard and begin using the MySQL server.

Figure 2.27 MySQL Package Installer: Summary



MySQL server is now installed, but it is not loaded (started) by default. Use either launchctl from the command line, or start MySQL by clicking "Start" using the MySQL preference pane. For additional information, see Section 2.4.3, “Installing a MySQL Launch Daemon”, and Section 2.4.4, “Installing and Using the MySQL Preference Pane”.

2.4.3 Installing a MySQL Launch Daemon

OS X uses launch daemons to automatically start, stop, and manage processes and applications such as MySQL.

Note

Before MySQL 5.5.45, the OS X builds installed startup items instead of launchd daemons. However, startup items do not function as of OS X 10.10 (Yosemite). The OS X builds now install launchd daemons.

By default, the installation package (DMG) on OS X installs a launchd file named `/Library/LaunchDaemons/com.oracle.oss.mysql.mysqld.plist` that contains a plist definition similar to:

```
<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE plist PUBLIC "-//Apple Computer//DTD PLIST 1.0//EN"
  "http://www.apple.com/DTDs/PropertyList-1.0.dtd">
<plist version="1.0">
<dict>
    <key>Label</key>            <string>com.oracle.oss.mysql.mysqld</string>
    <key>ProcessType</key>      <string>Interactive</string>
```

```
    <key>Disabled</key>          <false/>
    <key>RunAtLoad</key>         <true/>
    <key>KeepAlive</key>         <true/>
    <key>SessionCreate</key>     <true/>
    <key>LaunchOnlyOnce</key>    <false/>
    <key>UserName</key>          <string>_mysql</string>
    <key>GroupName</key>         <string>_mysql</string>
    <key>ExitTimeOut</key>       <integer>600</integer>
    <key>Program</key>           <string>/usr/local/mysql/bin/mysqld</string>
    <key>ProgramArguments</key>
        <array>
            <string>/usr/local/mysql/bin/mysqld</string>
            <string>--user=_mysql</string>
            <string>--basedir=/usr/local/mysql</string>
            <string>--datadir=/usr/local/mysql/data</string>
            <string>--plugin-dir=/usr/local/mysql/lib/plugin</string>
            <string>--log-error=/usr/local/mysql/data/mysqld.local.err</string>
            <string>--pid-file=/usr/local/mysql/data/mysqld.local.pid</string>
            <string>--port=3306</string>
        </array>
    <key>WorkingDirectory</key>  <string>/usr/local/mysql</string>
</dict>
</plist>
```

Note

Some users report that adding a plist DOCTYPE declaration causes the launchd operation to fail, despite it passing the lint check. We suspect it's a copy-n-paste error. The md5 checksum of a file containing the above snippet is 60d7963a0bb2994b69b8b9c123db09df.

To enable the launchd service, you can either:

- Click **Start MySQL Server** from the MySQL preference pane.

Figure 2.28 MySQL Preference Pane: Location

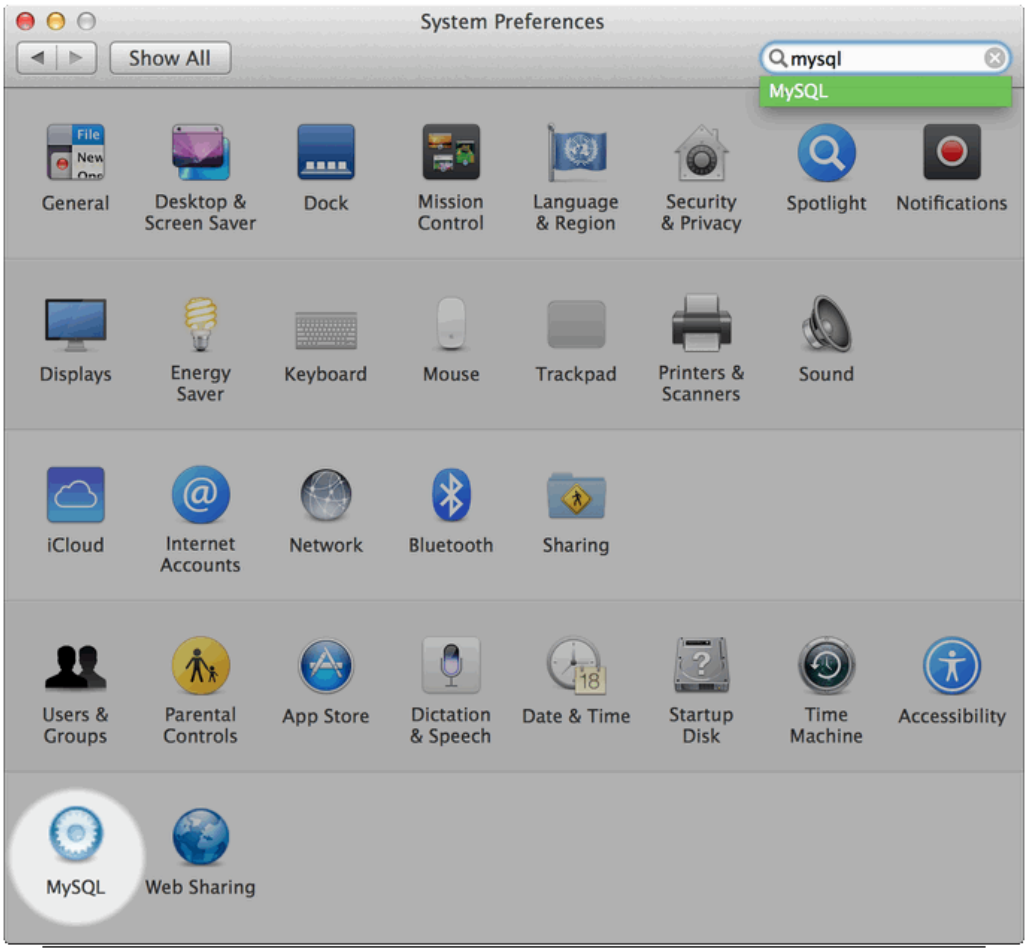


Figure 2.29 MySQL Preference Pane: Usage

- Or, manually load the launchd file.

```
shell> cd /Library/LaunchDaemons
shell> sudo launchctl load -F com.oracle.oss.mysql.mysqld.plist
```

Note

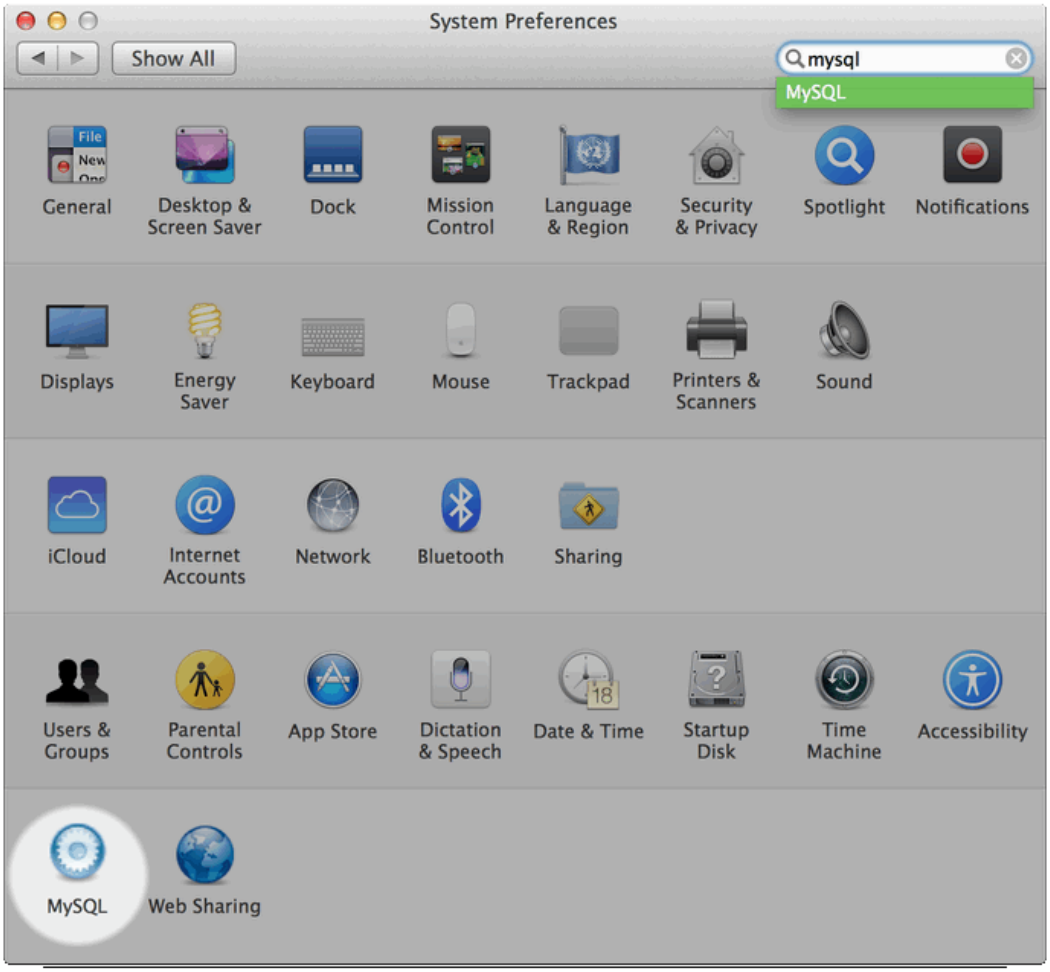
When upgrading MySQL server, the launchd installation process will remove the old startup items that were installed with MySQL server 5.5.44 and below.

2.4.4 Installing and Using the MySQL Preference Pane

The MySQL Installation Package includes a MySQL preference pane that enables you to start, stop, and control automated startup during boot of your MySQL installation.

This preference pane is installed by default, and is listed under your system's *System Preferences* window.

Figure 2.30 MySQL Preference Pane: Location



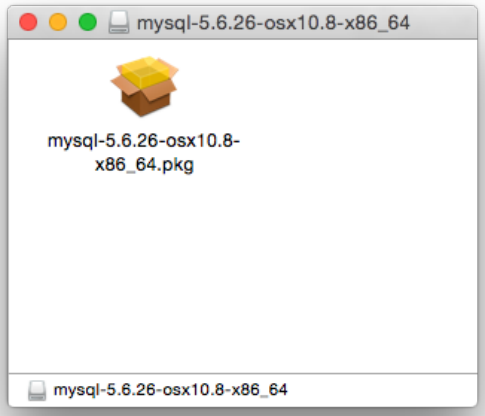
To install the MySQL Preference Pane:

1. Download and open the MySQL package installer, which is provided on a disk image (`.dmg`) that includes the main MySQL installation package.

Note

Before MySQL 5.5.45, OS X packages included the deprecated startup items instead of launchd daemons, and the preference pane managed that intstead of launchd.

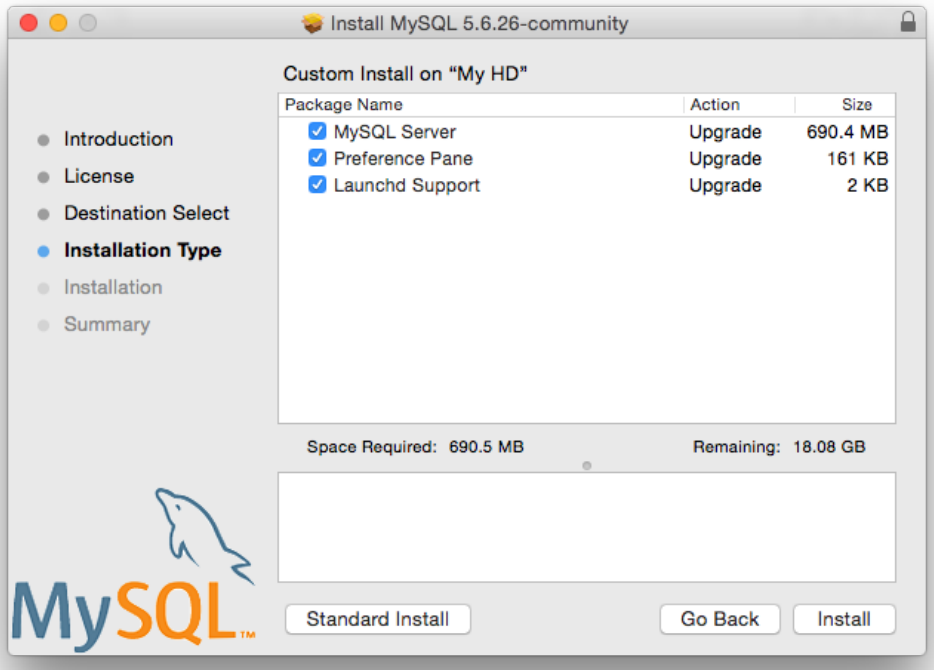
Figure 2.31 MySQL Package Installer: DMG Contents



2. Go through the process of installing the MySQL server, as described in the documentation at Section 2.4.2, “Installing MySQL on OS X Using Native Packages”.

3. Click **Customize** at the **Installation Type** step. The "Preference Pane" option is listed there and enabled by default.

Figure 2.32 MySQL Installer on OS X: Customize



4. Complete the MySQL server installation process.

Note

The MySQL preference pane only starts and stops MySQL installation installed from the MySQL package installation that have been installed in the default location.

Once the MySQL preference pane has been installed, you can control your MySQL server instance using the preference pane. To use the preference pane, open the **System Preferences...** from the Apple menu. Select the MySQL preference pane by clicking the MySQL logo within the **bottom** section of the preference panes list.

Figure 2.33 MySQL Preference Pane: Location

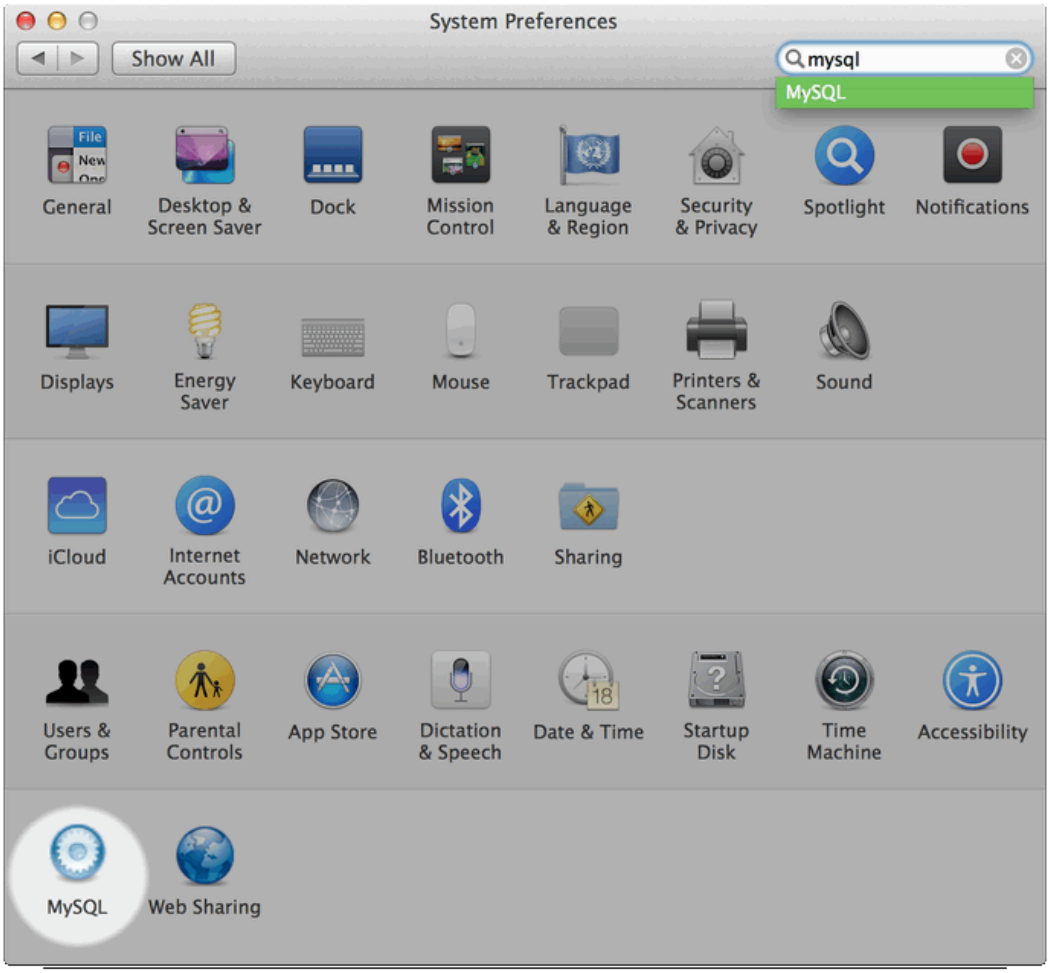
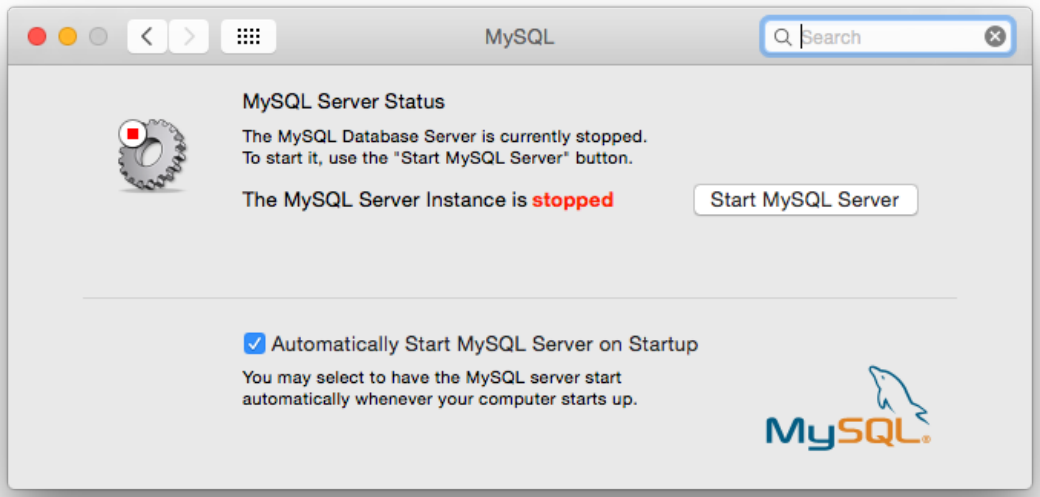


Figure 2.34 MySQL Preference Pane: Usage



The MySQL Preference Pane shows the current status of the MySQL server, showing **stopped** (in red) if the server is not running and **running** (in green) if the server has already been started. The preference pane also shows the current setting for whether the MySQL server has been set to start automatically.

- **To start the MySQL server using the preference pane:**

  Click **Start MySQL Server**. You may be prompted for the username and password of a user with administrator privileges to start the MySQL server.

- **To stop the MySQL server using the preference pane:**

  Click **Stop MySQL Server**. You may be prompted for the username and password of a user with administrator privileges to stop the MySQL server.

- **To automatically start the MySQL server when the system boots:**

  Check the check box next to **Automatically Start MySQL Server on Startup**.

- **To disable automatic MySQL server startup when the system boots:**

  Uncheck the check box next to **Automatically Start MySQL Server on Startup**.

You can close the `System Preferences...` window once you have completed your settings.

2.5 Installing MySQL on Linux

Linux supports a number of different solutions for installing MySQL. The recommended method is to use one of the distributions from Oracle. If you choose this method, there are several options available:

- Installing from a generic binary package in `.tar.gz` format. For details, see Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.
- Extracting and compiling MySQL from a source distribution. For details, see Section 2.9, “Installing MySQL from Source”.
- Installing using a precompiled RPM package. For details, see Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”.

- Installing using a precompiled Debian package. For details, see Section 2.5.2, “Installing MySQL on Linux Using Debian Packages”.
- Deploying MySQL Server with Docker. For details, see Section 2.5.3, “Deploying MySQL on Linux with Docker”
- Installing using Oracle's Unbreakable Linux Network (ULN). For details, see Section 2.6, “Installing MySQL Using Unbreakable Linux Network (ULN)”.

As an alternative, you can use the native package manager within your Linux distribution to automatically download and install MySQL for you. Native package installations can take care of the download and dependencies required to run MySQL, but the MySQL version will often be some versions behind the currently available release. You will also normally be unable to install development releases, as these are not usually made available in the native repository. For more information on using the native package installers, see Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”.

Note

For many Linux installations, you will want to set up MySQL to be started automatically when your machine starts. Many of the native package installations perform this operation for you, but for source, binary and RPM solutions you may need to set this up separately. The required script, `mysql.server`, can be found in the `support-files` directory under the MySQL installation directory or in a MySQL source tree. You can install it as `/etc/init.d/mysql` for automatic MySQL startup and shutdown. See Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”.

2.5.1 Installing MySQL on Linux Using RPM Packages

Note

To install or upgrade to MySQL 5.5.31, be sure to read the special instructions at the end of this section.

The recommended way to install MySQL on RPM-based Linux distributions is by using the RPM packages. The RPMs that we provide to the community should work on all versions of Linux that support RPM packages and use `glibc` 2.3. To obtain RPM packages, see Section 2.1.2, “How to Get MySQL”.

For non-RPM Linux distributions, you can install MySQL using a `.tar.gz` package. See Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

Installations created from our Linux RPM distributions result in files under the system directories shown in the following table.

Table 2.10 MySQL Installation Layout for Linux RPM Packages

Directory	Contents of Directory
`/usr/bin`	Client programs and scripts
`/usr/sbin`	The `mysqld` server
`/var/lib/mysql`	Log files, databases
`/var/lib/mysql-files`	Value of `secure_file_priv`
`/usr/share/info`	MySQL manual in Info format
`/usr/share/man`	Unix manual pages
`/usr/include/mysql`	Include (header) files
`/usr/lib/mysql`	Libraries

Directory	Contents of Directory
`/usr/share/mysql`	Miscellaneous support files, including error messages, character set files, sample configuration files, SQL for database installation
`/usr/share/sql-bench`	Benchmarks

Note

RPM distributions of MySQL are also provided by other vendors. Be aware that they may differ from those built by Oracle in features, capabilities, and conventions (including communication setup), and that the instructions in this manual do not necessarily apply to installing them. The vendor's instructions should be consulted instead. Because of these differences, RPM packages built by Oracle check whether such RPMs built by other vendors are installed. If so, the RPM does not install and produces a message explaining this.

Conflicts can arise when an RPM from another vendor is already installed, such as when a vendor's conventions about which files belong with the server and which belong with the client library differ from the breakdown used for Oracle packages. In such cases, attempts to install an Oracle RPM with `rpm -i` may result in messages that files in the RPM to be installed conflict with files from an installed package (denoted `mysql-libs` in the following paragraphs).

Each MySQL release provides a `MySQL-shared-compat` package that is meant to replace `mysql-libs` and provides a replacement-compatible client library for older MySQL series. `MySQL-shared-compat` is set up to make `mysql-libs` obsolete, but `rpm` explicitly refuses to replace obsoleted packages when invoked with `-i` (unlike `-U`), which is why installation with `rpm -i` produces a conflict.

`MySQL-shared-compat` can safely be installed alongside `mysql-libs` because libraries are installed to different locations. Therefore, it is possible to install `MySQL-shared-compat` first, then manually remove `mysql-libs` before continuing with the installation. After `mysql-libs` is removed, the dynamic linker stops looking for the client library in the location where `mysql-libs` puts it, and the library provided by the `MySQL-shared-compat` package takes over.

Another alternative is to install packages using `yum`. In a directory containing all RPM packages for a MySQL release, `yum install MySQL*rpm` installs them in the correct order and removes `mysql-libs` in one step without conflicts.

In most cases, you need install only the `MySQL-server` and `MySQL-client` packages to get a functional standard MySQL installation. The other packages are not required for a standard installation.

RPMs for NDB Cluster. Standard MySQL server RPMs built by MySQL do not provide support for the `NDBCLUSTER` storage engine.

Important

When upgrading an NDB Cluster RPM installation, you must upgrade *all* installed RPMs, including the `Server` and `Client` RPMs.

For more information about installing NDB Cluster from RPMs, see Section 18.2, “NDB Cluster Installation”.

For upgrades, if your installation was originally produced by installing multiple RPM packages, it is best to upgrade all the installed packages, not just some. For example, if you previously installed the server and client RPMs, do not upgrade just the server RPM.

If the data directory exists at RPM installation time, the installation process does not modify existing data. This has the effect, for example, that accounts in the grant tables are not initialized to the default set of accounts.

If you get a dependency failure when trying to install MySQL packages (for example, `error: removing these packages would break dependencies: libmysqlclient.so.10 is needed by ...`), you should also install the `MySQL-shared-compat` package, which includes the shared libraries for older releases for backward compatibility.

The following list shows the available RPM packages. The names shown here use a suffix of `.glibc23.i386.rpm`, but particular packages can have different suffixes, described later. If you plan to install multiple RPM packages, you may wish to download the RPM Bundle `tar` file instead, which contains multiple RPM packages so that you need not download them separately.

- `MySQL-server-`*`VERSION`*`.glibc23.i386.rpm`

  The MySQL server. You need this unless you only want to connect to a MySQL server running on another machine.

- `MySQL-client-`*`VERSION`*`.glibc23.i386.rpm`

  The standard MySQL client programs. You probably always want to install this package.

- `MySQL-devel-`*`VERSION`*`.glibc23.i386.rpm`

  The libraries and include files needed to compile other MySQL clients, such as the Perl MySQL module. Install this RPM if you intend to compile C API applications.

- `MySQL-shared-`*`VERSION`*`.glibc23.i386.rpm`

  The shared libraries (`libmysqlclient.so*`) that certain languages and applications need to dynamically load and use MySQL. It contains single-threaded and thread-safe libraries. Install this RPM if you intend to compile or run C API applications that depend on the shared client library. Prior to MySQL 5.5.6, if you install this package, do not install the `MySQL-shared-compat` package.

- `MySQL-shared-compat-`*`VERSION`*`.glibc23.i386.rpm`

  The shared libraries for older releases. It contains single-threaded and thread-safe libraries. Install this package if you have applications installed that are dynamically linked against older versions of MySQL but you want to upgrade to the current version without breaking the library dependencies. Before MySQL 5.5.6, `MySQL-shared-compat` also includes the libraries for the current release, so if you install it, you should not also install `MySQL-shared`. As of 5.5.6, `MySQL-shared-compat` does not include the current library version, so there is no conflict.

  As of MySQL 5.5.23, the `MySQL-shared-compat` RPM package enables users of Red Hat-provided `mysql-*-5.1` RPM packages to migrate to Oracle-provided `MySQL-*-5.5` packages. `MySQL-shared-compat` replaces the Red Hat `mysql-libs` package by replacing `libmysqlclient.so` files of the latter package, thus satisfying dependencies of other packages on `mysql-libs`. This change affects only users of Red Hat (or Red Hat-compatible) RPM packages. Nothing is different for users of Oracle RPM packages.

- `MySQL-embedded-`*`VERSION`*`.glibc23.i386.rpm`

  The embedded MySQL server library.

- `MySQL-test-`*`VERSION`*`.glibc23.i386.rpm`

  The MySQL test suite.

- `MySQL-`*`VERSION`*`.src.rpm`

The source code for all of the previous packages. It can also be used to rebuild the RPMs on other architectures (for example, SPARC).

In RPM package names, the suffix (following the *VERSION* value) has the following syntax:

```
.PLATFORM.CPU.rpm
```

The *PLATFORM* and *CPU* values indicate the type of system for which the package is built. *PLATFORM* indicates the platform and *CPU* indicates the processor type or family.

All packages are dynamically linked against `glibc` 2.3. The *PLATFORM* value indicates whether the package is platform independent or intended for a specific platform, as shown in the following table.

Table 2.11 MySQL Linux RPM Package Platforms

***PLATFORM* Value**	**Intended Use**
`glibc23`	Platform independent, should run on any Linux distribution that supports `glibc` 2.3
`rhel4`, `rhel5`	Red Hat Enterprise Linux 4 or 5
`el6`	Enterprise Linux 6
`sles10`, `sles11`	SuSE Linux Enterprise Server 10 or 11

In MySQL 5.5, only `glibc23` packages are available currently.

The *CPU* value indicates the processor type or family for which the package is built, as shown in the following table.

Table 2.12 MySQL Linux RPM Package CPU Identifiers

***CPU* Value**	**Intended Processor Type or Family**
`i386`, `i586`, `i686`	Pentium processor or better, 32 bit
`x86_64`	64-bit x86 processor
`ia64`	Itanium (IA-64) processor

To see all files in an RPM package (for example, a `MySQL-server` RPM), run a command like this (modify the platform and CPU identifiers appropriately for your system):

```
shell> rpm -qpl MySQL-server-VERSION.glibc23.i386.rpm
```

To perform a standard minimal installation, install the server and client RPMs:

```
shell> rpm -i MySQL-server-VERSION.glibc23.i386.rpm
shell> rpm -i MySQL-client-VERSION.glibc23.i386.rpm
```

To install only the client programs, install just the client RPM:

```
shell> rpm -i MySQL-client-VERSION.glibc23.i386.rpm
```

RPM provides a feature to verify the integrity and authenticity of packages before installing them. To learn more about this feature, see Section 2.1.3, “Verifying Package Integrity Using MD5 Checksums or GnuPG”.

The server RPM places data under the `/var/lib/mysql` directory. The RPM also creates a login account for a user named `mysql` (if one does not exist) to use for running the MySQL server, and creates the appropriate entries in `/etc/init.d/` to start the server automatically at boot time. (This means that if you have performed a previous installation and have made changes to its startup script, you may want to make a copy of the script so that you can reinstall it after you install a newer RPM.)

See Section 2.10.5, “Starting and Stopping MySQL Automatically”, for more information on how MySQL can be started automatically at system startup.

In MySQL 5.5.5 and later, during a new installation using RPM packages, the server boot scripts are installed, but the MySQL server is not started at the end of the installation, since the status of the server during an unattended installation is not known.

In MySQL 5.5.5 and later, during an upgrade installation using RPM packages, if the MySQL server is running when the upgrade occurs, the MySQL server is stopped, the upgrade occurs, and the MySQL server is restarted. If the MySQL server is not already running when the RPM upgrade occurs, the MySQL server is not started at the end of the installation.

If something goes wrong, you can find more information in the binary installation section. See Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

Note

The accounts created in the MySQL grant tables for an RPM installation initially have no passwords. After starting the server, you should assign passwords to them using the instructions in Section 2.10, “Postinstallation Setup and Testing”.

An RPM installation creates a user named `mysql` and a group named `mysql` on the system using the `useradd`, `groupadd`, and `usermod` commands. Those commands require appropriate administrative privileges, which is required for locally managed users and groups (as listed in the `/etc/passwd` and `/etc/group` files) by the RPM installation process being run by `root`.

If you log in as the `mysql` user, you may find that MySQL displays “Invalid (old?) table or database name” errors that mention `.mysqlgui`, `lost+found`, `.mysqlgui`, `.bash_history`, `.fonts.cache-1`, `.lesshst`, `.mysql_history`, `.profile`, `.viminfo`, and similar files created by MySQL or operating system utilities. You can safely ignore these error messages or remove the files or directories that cause them if you do not need them.

For nonlocal user management (LDAP, NIS, and so forth), the administrative tools may require additional authentication (such as a password), and will fail if the installing user does not provide this authentication. Even if they fail, the RPM installation will not abort but succeed, and this is intentional. If they failed, some of the intended transfer of ownership may be missing, and it is recommended that the system administrator then manually ensures some appropriate user and group exists and manually transfers ownership following the actions in the RPM spec file.

In MySQL 5.5.31, the RPM spec file has been updated, which has the following consequences:

- For a non-upgrade installation (no existing MySQL version installed), it possible to install MySQL using `yum`.
- For upgrades, it is necessary to clean up any earlier MySQL installations. In effect, the update is performed by removing the old installations and installing the new one.

Additional details follow.

For a non-upgrade installation of MySQL 5.5.31, it is possible to install using `yum`:

```
shell> yum install MySQL-server-NEWVERSION.glibc23.i386.rpm
```

For upgrades to MySQL 5.5.31, the upgrade is performed by removing the old installation and installing the new one. To do this, use the following procedure:

1. Remove the existing 5.5.*X* installation. *`OLDVERSION`* is the version to remove.

   ```
   shell> rpm -e MySQL-server-OLDVERSION.glibc23.i386.rpm
   ```

   Repeat this step for all installed MySQL RPMs.

2. Install the new version. *NEWVERSION* is the version to install.

```
shell> rpm -ivh MySQL-server-NEWVERSION.glibc23.i386.rpm
```

Alternatively, the removal and installation can be done using `yum`:

```
shell> yum remove MySQL-server-OLDVERSION.glibc23.i386.rpm
shell> yum install MySQL-server-NEWVERSION.glibc23.i386.rpm
```

For some Linux distributions, it might be necessary to increase the limit on number of file descriptors available to `mysqld`. See Section B.5.2.18, “File Not Found and Similar Errors”

2.5.2 Installing MySQL on Linux Using Debian Packages

Oracle provides Debian packages for installation on Debian or Debian-like Linux systems. To obtain a package, see Section 2.1.2, “How to Get MySQL”.

Note

Debian distributions of MySQL are also provided by other vendors. Be aware that they may differ from those built by us in features, capabilities, and conventions (including communication setup), and that the instructions in this manual do not necessarily apply to installing them. The vendor's instructions should be consulted instead.

Debian package files have names in `mysql-`*MVER*`-`*DVER*`-`*CPU*`.deb` format. *MVER* is the MySQL version and *DVER* is the Debian version. The *CPU* value indicates the processor type or family for which the package is built, as shown in the following table.

Table 2.13 MySQL Installation Packages for Linux CPU Identifiers

CPU Value	Intended Processor Type or Family
`i686`	Pentium processor or better, 32 bit
`x86_64`	64-bit x86 processor

After downloading a Debian package, use the following command to install it;

```
shell> dpkg -i mysql-MVER-DVER-CPU.deb
```

The Debian package installs files in the `/opt/mysql/server-5.5` directory.

You may also need to install the `libaio` library if it is not already present on your system:

```
shell> sudo apt-get install libaio1
```

2.5.3 Deploying MySQL on Linux with Docker

The Docker deployment framework supports easy installation and configuration of MySQL Server. This section explains how to use a MySQL Server Docker image.

You need to have Docker installed on your system before you can use a MySQL Server Docker image. See Install Docker for instructions.

Important

You need to either run `docker` commands with `sudo`, or create a `docker` usergroup, and then add to it any users who want to run `docker` commands. See details here. Because Docker containers are always run with root

privileges, you should understand the Docker daemon attack surface and properly mitigate the related risks.

The instructions for using the MySQL Docker container are divided into two sections.

2.5.3.1 Basic Steps for MySQL Server Deployment with Docker

- Downloading a MySQL Server Docker Image
- Starting a MySQL Server Instance
- Connecting to MySQL Server from within the Container
- Container Shell Access
- Stopping and Deleting a MySQL Container
- More Topics on Deploying MySQL Server with Docker

Downloading a MySQL Server Docker Image

Downloading the server image in a separate step is not strictly necessary; however, performing this step before you create your Docker container ensures your local image is up to date. To download the MySQL Community Server image, run this command:

```
docker pull mysql/mysql-server:tag
```

The *tag* is the label for the image version you want to pull (for example, `5.5`, `5.6`, `5.7`, `8.0`, or `latest`). If **`:tag`** is omitted, the `latest` label is used, and the image for the latest GA version of MySQL Community Server is downloaded. Refer to the list of tags for available versions on the mysql/mysql-server page in the Docker Hub.

You can list downloaded Docker images with this command:

```
shell> docker images
REPOSITORY           TAG                 IMAGE ID            CREATED             SIZE
mysql/mysql-server   latest              3157d7f55f8d        4 weeks ago         241MB
```

Starting a MySQL Server Instance

Start a new Docker container for the MySQL Server with this command:

```
docker run --name=mysql1 -d mysql/mysql-server:tag
```

The `--name` option, for supplying a custom name for your server container (`mysql1` in the example), is optional; if no container name is supplied, a random one is generated. If the Docker image of the specified name and tag has not been downloaded by an earlier `docker pull` or `docker run` command, the image is now downloaded. After download completes, initialization for the container begins, and the container appears in the list of running containers when you run the `docker ps` command; for example:

```
shell> docker ps
CONTAINER ID   IMAGE                COMMAND                  CREATED             STATUS
a24888f0d6f4   mysql/mysql-server   "/entrypoint.sh my..."   14 seconds ago      Up 13 seconds (health:
```

The container initialization might take some time. When the server is ready for use, the `STATUS` of the container in the output of the `docker ps` command changes from `(health: starting)` to `(healthy)`.

The `-d` option used in the `docker run` command above makes the container run in the background. Use this command to monitor the output from the container:

```
docker logs mysql1
```

Once initialization is finished, the command's output is going to contain the random password generated for the root user; check the password with, for example, this command:

```
shell> docker logs mysql1 2>&1 | grep GENERATED
GENERATED ROOT PASSWORD: Axegh3kAJyDLaRuBemecis&EShOs
```

Connecting to MySQL Server from within the Container

Once the server is ready, you can run the `mysql` client within the MySQL Server container you just started, and connect it to the MySQL Server. Use the `docker exec -it` command to start a `mysql` client inside the Docker container you have started, like the following:

```
docker exec -it mysql1 mysql -uroot -p
```

When asked, enter the generated root password (see the last step in Starting a MySQL Server Instance above on how to find the password). After you have connected a `mysql` client to the server, you should reset the server root password by issuing this statement:

```
mysql> ALTER USER 'root'@'localhost' IDENTIFIED BY 'newpassword';
```

Substitute *`newpassword`* with the password of your choice. Once the password is reset, the server is ready for use.

Container Shell Access

To have shell access to your MySQL Server container, use the `docker exec -it` command to start a bash shell inside the container:

```
shell> docker exec -it mysql1 bash
bash-4.2#
```

You can then run Linux commands inside the container. For example, to view contents in the server's data directory inside the container, use this command:

```
bash-4.2# ls /var/lib/mysql
auto.cnf    ca.pem      client-key.pem  ib_logfile0  ibdata1  mysql       mysql.sock.lock    private_key.pe
ca-key.pem  client-cert.pem  ib_buffer_pool  ib_logfile1  ibtmp1   mysql.sock  performance_schema  public_k
```

Stopping and Deleting a MySQL Container

To stop the MySQL Server container we have created, use this command:

```
docker stop mysql1
```

`docker stop` sends a SIGTERM signal to the `mysqld` process, so that the server is shut down gracefully.

Also notice that when the main process of a container (`mysqld` in the case of a MySQL Server container) is stopped, the Docker container stops automatically.

To start the MySQL Server container again:

```
docker start mysql1
```

To stop and start again the MySQL Server container with a single command:

```
docker restart mysql1
```

To delete the MySQL container, stop it first, and then use the `docker rm` command:

```
docker stop mysql1
```

```
docker rm mysql1
```

If you want the Docker volume for the server's data directory to be deleted at the same time, add the `-v` option to the `docker rm` command.

More Topics on Deploying MySQL Server with Docker

For more topics on deploying MySQL Server with Docker like server configuration, persisting data and configuration, server error log, and container environment variables, see Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”.

2.5.3.2 More Topics on Deploying MySQL Server with Docker

- The Optimized MySQL Installation for Docker
- Configuring the MySQL Server
- Persisting Data and Configuration Changes
- Running Additional Initialization Scripts
- Connect to MySQL from an Application in Another Docker Container
- Server Error Log
- Docker Environment Variables

The Optimized MySQL Installation for Docker

Docker images for MySQL are optimized for code size, which means they only include crucial components that are expected to be relevant for the majority of users who run MySQL instances in Docker containers. A MySQL Docker installation is different from a common, non-Docker installation in the following aspects:

- Included binaries are limited to:
  - /usr/bin/my_print_defaults
  - /usr/bin/mysql
  - /usr/bin/mysql_config
  - /usr/bin/mysql_install_db
  - /usr/bin/mysql_tzinfo_to_sql
  - /usr/bin/mysql_upgrade
  - /usr/bin/mysqladmin
  - /usr/bin/mysqlcheck
  - /usr/bin/mysqldump
  - /usr/sbin/mysqld
- All binaries are stripped; they contain no debug information.

Configuring the MySQL Server

When you start the MySQL Docker container, you can pass configuration options to the server through the `docker run` command; for example, for the MySQL Server:

```
docker run --name mysql1 -d mysql/mysql-server --character-set-server=utf8mb4 --collation-server=utf8mb
```

The command starts your MySQL Server with `utf8mb4` as the default character set and `utf8mb4_col` as the default collation for your databases.

Another way to configure the MySQL Server is to prepare a configuration file and mount it at the location of the server configuration file inside the container. See Persisting Data and Configuration Changes for details.

Persisting Data and Configuration Changes

Docker containers are in principle ephemeral, and any data or configuration are expected to be lost if the container is deleted or corrupted (see discussions here). Docker volumes, however, provides a mechanism to persist data created inside a Docker container. At its initialization, the MySQL Server container creates a Docker volume for the server data directory. The JSON output for running the `docker inspect` command on the container has a `Mount` key, whose value provides information on the data directory volume:

```
shell> docker inspect mysql1
...
 "Mounts": [
            {
                "Type": "volume",
                "Name": "4f2d463cfc4bdd4baebcb098c97d7da3337195ed2c6572bc0b89f7e845d27652",
                "Source": "/var/lib/docker/volumes/4f2d463cfc4bdd4baebcb098c97d7da3337195ed2c6572bc0b89f7e8
                "Destination": "/var/lib/mysql",
                "Driver": "local",
                "Mode": "",
                "RW": true,
                "Propagation": ""
            }
        ],
...
```

The output shows that the source folder `/var/lib/docker/volumes/4f2d463cfc4bdd4baebcb098c97d7da3337195ed2c6572bc0b89f7e845d27652/_data`, in which data is persisted on the host, has been mounted at `/var/lib/mysql`, the server data directory inside the container.

Another way to preserve data is to bind-mount a host directory using the `--mount` option when creating the container. The same technique can be used to persist the configuration of the server. The following command creates a MySQL Server container and bind-mounts both the data directory and the server configuration file:

```
docker run --name=mysql1 \
--mount type=bind,src=/path-on-host-machine/my.cnf,dst=/etc/my.cnf \
--mount type=bind,src=/path-on-host-machine/datadir,dst=/var/lib/mysql \
-d mysql/mysql-server:tag
```

The command mounts *`path-on-host-machine/my.cnf`* at `/etc/my.cnf` (the server configuration file inside the container), and *`path-on-host-machine/datadir`* at `/var/lib/mysql` (the data directory inside the container). The following conditions must be met for the bind-mounting to work:

- The configuration file *`path-on-host-machine/my.cnf`* must already exist, and it must contain the specification for starting the server using the user `mysql`:

  ```
  [mysqld]
  user=mysql
  ```

  You can also include other server configuration options in the file.

- The data directory *`path-on-host-machine/datadir`* must already exist. For server initialization to happen, the directory must be empty. You can also mount a directory prepopulated with data and start the server with it; however, you must make sure you start the Docker container with the same configuration as the server that created the data, and any host files or directories required are mounted when starting the container.

Running Additional Initialization Scripts

If there are any `.sh` or `.sql` scripts you want to run on the database immediately after it has been created, you can put them into a host directory and then mount the directory at `/docker-entrypoint-initdb.d/` inside the container. For example, for a MySQL Server container:

```
docker run --name=mysql1 \
--mount type=bind,src=/path-on-host-machine/scripts/,dst=/docker-entrypoint-initdb.d/ \
-d mysql/mysql-server:tag
```

Connect to MySQL from an Application in Another Docker Container

By setting up a Docker network, you can allow multiple Docker containers to communicate with each other, so that a client application in another Docker container can access the MySQL Server in the server container. First, create a Docker network:

```
docker network create my-custom-net
```

Then, when you are creating and starting the server and the client containers, use the `--network` option to put them on network you created. For example:

```
docker run --name=mysql1 --network=my-custom-net -d mysql/mysql-server
```

```
docker run --name=myapp1 --network=my-custom-net -d myapp
```

The `myapp1` container can then connect to the `mysql1` container with the `mysql1` hostname and vice versa, as Docker automatically sets up a DNS for the given container names. In the following example, we run the `mysql` client from inside the `myapp1` container to connect to host `mysql1` in its own container:

```
docker exec -it myapp1 mysql --host=mysql1 --user=myuser --password
```

For other networking techniques for containers, see the Docker container networking section in the Docker Documentation.

Server Error Log

When the MySQL Server is first started with your server container, a server error log is NOT generated if either of the following conditions is true:

- A server configuration file from the host has been mounted, but the file does not contain the system variable `log_error` (see Persisting Data and Configuration Changes on bind-mounting a server configuration file).
- A server configuration file from the host has not been mounted, but the Docker environment variable `MYSQL_LOG_CONSOLE` is `true` (the variable's default state for MySQL 5.5 server containers is `false`). The MySQL Server's error log is then redirected to `stderr`, so that the error log goes into the Docker container's log and is viewable using the `docker logs mysqld-container` command.

To make MySQL Server generate an error log when either of the two conditions is true, use the `--log-error` option to configure the server to generate the error log at a specific location inside the container. To persist the error log, mount a host file at the location of the error log inside the container as explained in Persisting Data and Configuration Changes. However, you must make sure your MySQL Server inside its container has write access to the mounted host file.

Docker Environment Variables

When you create a MySQL Server container, you can configure the MySQL instance by using the `--env` option (`-e` in short) and specifying one or more of the following environment variables.

Notes

- None of the variables below has any effect if the data directory you mount is not empty, as no server initialization is going to be attempted then (see

Persisting Data and Configuration Changes for more details). Any pre-existing contents in the folder, including any old server settings, are not modified during the container startup.

- The boolean variables including `MYSQL_RANDOM_ROOT_PASSWORD` , `MYSQL_ALLOW_EMPTY_PASSWORD`, and `MYSQL_LOG_CONSOLE` are made true by setting them with any strings of non-zero lengths. Therefore, setting them to, for example, “0”, “false”, or “no” does not make them false, but actually makes them true. This is a known issue of the MySQL Server containers.

- `MYSQL_RANDOM_ROOT_PASSWORD`: When this variable is true (which is its default state, unless `MYSQL_ROOT_PASSWORD` or `MYSQL_ALLOW_EMPTY_PASSWORD` is set to true), a random password for the server's root user is generated when the Docker container is started. The password is printed to `stdout` of the container and can be found by looking at the container’s log (see Starting a MySQL Server Instance).

- `MYSQL_DATABASE`: This variable allows you to specify the name of a database to be created on image startup. If a user name and a password are supplied with `MYSQL_USER` and `MYSQL_PASSWORD`, the user is created and granted superuser access to this database (corresponding to `GRANT ALL`). The specified database is created by a CREATE DATABASE IF NOT EXIST statement, so that the variable has no effect if the database already exists.

- `MYSQL_USER`, `MYSQL_PASSWORD`: These variables are used in conjunction to create a user and set that user's password, and the user is granted superuser permissions for the database specified by the `MYSQL_DATABASE` variable. Both `MYSQL_USER` and `MYSQL_PASSWORD` are required for a user to be created—if any of the two variables is not set, the other is ignored. If both variables are set but `MYSQL_DATABASE` is not, the user is created without any privileges.

Note

There is no need to use this mechanism to create the root superuser, which is created by default with the password set by either one of the mechanisms discussed in the descriptions for `MYSQL_ROOT_PASSWORD` and `MYSQL_RANDOM_ROOT_PASSWORD`, unless `MYSQL_ALLOW_EMPTY_PASSWORD` is true.

- `MYSQL_ROOT_HOST`: By default, MySQL creates the `'root'@'localhost'` account. This account can only be connected to from inside the container as described in Connecting to MySQL Server from within the Container. To allow root connections from other hosts, set this environment variable. For example, the value `172.17.0.1`, which is the default Docker gateway IP, allows connections from the host machine that runs the container. The option accepts only one entry, but wildcards are allowed (for example, `MYSQL_ROOT_HOST=172.*.*.*` or `MYSQL_ROOT_HOST=%`).

- `MYSQL_LOG_CONSOLE`: When the variable is true (the variable's default state for MySQL 5.5 server containers is `false`), the MySQL Server's error log is redirected to `stderr`, so that the error log goes into the Docker container's log and is viewable using the `docker logs` *`mysqld-container`* command.

Note

The variable has no effect if a server configuration file from the host has been mounted (see Persisting Data and Configuration Changes on bind-mounting a configuration file).

- `MYSQL_ROOT_PASSWORD`: This variable specifies a password that is set for the MySQL root account.

Warning

Setting the MySQL root user password on the command line is insecure. As an alternative to specifying the password explicitly, you can set the variable

with a container file path for a password file, and then mount a file from your host that contains the password at the container file path. This is still not very secure, as the location of the password file is still exposed. It is preferable to use the default settings of `MYSQL_RANDOM_ROOT_PASSWORD=true` being true.

- `MYSQL_ALLOW_EMPTY_PASSWORD`. Set it to true to allow the container to be started with a blank password for the root user.

Warning

Setting this variable to true is insecure, because it is going to leave your MySQL instance completely unprotected, allowing anyone to gain complete superuser access. It is preferable to use the default settings of `MYSQL_RANDOM_ROOT_PASSWORD=true` being true.

2.5.4 Installing MySQL on Linux Using Native Package Managers

Many Linux distributions include a version of the MySQL server, client tools, and development components in their native software repositories and can be installed with the platforms' standard package management systems. This section provides basic instructions for installing MySQL using those package management systems.

Important

Native package installations can take care of the download and dependencies required to run MySQL, but the MySQL version will often be some way behind the currently available release. You will also normally be unable to install development releases, as these are not usually made available in the native repository.

Distribution specific instructions are shown below:

- **Red Hat Linux, Fedora, CentOS**

  For Red Hat and similar distributions, the MySQL distribution is divided into a number of separate packages, `mysql` for the client tools, `mysql-server` for the server and associated tools, and `mysql-libs` for the libraries. The libraries are required if you want to provide connectivity from different languages and environments such as Perl, Python and others.

  To install, use the `yum` command to specify the packages that you want to install. For example:

```
root-shell> yum install mysql mysql-server mysql-libs mysql-server
Loaded plugins: presto, refresh-packagekit
Setting up Install Process
Resolving Dependencies
--> Running transaction check
---> Package mysql.x86_64 0:5.1.48-2.fc13 set to be updated
---> Package mysql-libs.x86_64 0:5.1.48-2.fc13 set to be updated
---> Package mysql-server.x86_64 0:5.1.48-2.fc13 set to be updated
--> Processing Dependency: perl-DBD-MySQL for package: mysql-server-5.1.48-2.fc13.x86_64
--> Running transaction check
---> Package perl-DBD-MySQL.x86_64 0:4.017-1.fc13 set to be updated
--> Finished Dependency Resolution

Dependencies Resolved

================================================================================
 Package               Arch          Version               Repository      Size
================================================================================
Installing:
 mysql                 x86_64        5.1.48-2.fc13         updates        889 k
 mysql-libs            x86_64        5.1.48-2.fc13         updates        1.2 M
 mysql-server          x86_64        5.1.48-2.fc13         updates        8.1 M
```

```
Installing for dependencies:
 perl-DBD-MySQL        x86_64        4.017-1.fc13          updates        136 k

Transaction Summary
================================================================================
Install       4 Package(s)
Upgrade       0 Package(s)

Total download size: 10 M
Installed size: 30 M
Is this ok [y/N]: y
Downloading Packages:
Setting up and reading Presto delta metadata
Processing delta metadata
Package(s) data still to download: 10 M
(1/4): mysql-5.1.48-2.fc13.x86_64.rpm                     | 889 kB     00:04
(2/4): mysql-libs-5.1.48-2.fc13.x86_64.rpm                | 1.2 MB     00:06
(3/4): mysql-server-5.1.48-2.fc13.x86_64.rpm              | 8.1 MB     00:40
(4/4): perl-DBD-MySQL-4.017-1.fc13.x86_64.rpm             | 136 kB     00:00
--------------------------------------------------------------------------------
Total                                          201 kB/s |  10 MB     00:52
Running rpm_check_debug
Running Transaction Test
Transaction Test Succeeded
Running Transaction
  Installing     : mysql-libs-5.1.48-2.fc13.x86_64                          1/4
  Installing     : mysql-5.1.48-2.fc13.x86_64                               2/4
  Installing     : perl-DBD-MySQL-4.017-1.fc13.x86_64                       3/4
  Installing     : mysql-server-5.1.48-2.fc13.x86_64                        4/4

Installed:
  mysql.x86_64 0:5.1.48-2.fc13            mysql-libs.x86_64 0:5.1.48-2.fc13
  mysql-server.x86_64 0:5.1.48-2.fc13

Dependency Installed:
  perl-DBD-MySQL.x86_64 0:4.017-1.fc13

Complete!
```

MySQL and the MySQL server should now be installed. A sample configuration file is installed into `/etc/my.cnf`. An init script, to start and stop the server, will have been installed into `/etc/init.d/mysqld`. To start the MySQL server use `service`:

```
root-shell> service mysqld start
```

To enable the server to be started and stopped automatically during boot, use `chkconfig`:

```
root-shell> chkconfig --levels 235 mysqld on
```

Which enables the MySQL server to be started (and stopped) automatically at the specified the run levels.

The database tables will have been automatically created for you, if they do not already exist. You should, however, run `mysql_secure_installation` to set the root passwords on your server.

- **Debian, Ubuntu, Kubuntu**

  On Debian and related distributions, there are two packages, `mysql-client` and `mysql-server`, for the client and server components respectively. You should specify an explicit version, for example `mysql-client-5.1`, to ensure that you install the version of MySQL that you want.

  To download and install, including any dependencies, use the `apt-get` command, specifying the packages that you want to install.

Note

Before installing, make sure that you update your `apt-get` index files to ensure you are downloading the latest available version.

A sample installation of the MySQL packages might look like this (some sections trimmed for clarity):

```
root-shell> apt-get install mysql-client-5.1 mysql-server-5.1
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  linux-headers-2.6.28-11 linux-headers-2.6.28-11-generic
Use 'apt-get autoremove' to remove them.
The following extra packages will be installed:
  bsd-mailx libdbd-mysql-perl libdbi-perl libhtml-template-perl
  libmysqlclient15off libmysqlclient16 libnet-daemon-perl libplrpc-perl mailx
  mysql-common postfix
Suggested packages:
  dbishell libipc-sharedcache-perl tinyca procmail postfix-mysql postfix-pgsql
  postfix-ldap postfix-pcre sasl2-bin resolvconf postfix-cdb
The following NEW packages will be installed
  bsd-mailx libdbd-mysql-perl libdbi-perl libhtml-template-perl
  libmysqlclient15off libmysqlclient16 libnet-daemon-perl libplrpc-perl mailx
  mysql-client-5.1 mysql-common mysql-server-5.1 postfix
0 upgraded, 13 newly installed, 0 to remove and 182 not upgraded.
Need to get 1907kB/25.3MB of archives.
After this operation, 59.5MB of additional disk space will be used.
Do you want to continue [Y/n]? Y
Get: 1 http://gb.archive.ubuntu.com jaunty-updates/main mysql-common 5.1.30really5.0.75-0ubuntu10.5 [
Get: 2 http://gb.archive.ubuntu.com jaunty-updates/main libmysqlclient15off 5.1.30really5.0.75-0ubunt
Fetched 1907kB in 9s (205kB/s)
Preconfiguring packages ...
Selecting previously deselected package mysql-common.
(Reading database ... 121260 files and directories currently installed.)
...
Processing 1 added doc-base file(s)...
Registering documents with scrollkeeper...
Setting up libnet-daemon-perl (0.43-1) ...
Setting up libplrpc-perl (0.2020-1) ...
Setting up libdbi-perl (1.607-1) ...
Setting up libmysqlclient15off (5.1.30really5.0.75-0ubuntu10.5) ...

Setting up libdbd-mysql-perl (4.008-1) ...
Setting up libmysqlclient16 (5.1.31-1ubuntu2) ...

Setting up mysql-client-5.1 (5.1.31-1ubuntu2) ...

Setting up mysql-server-5.1 (5.1.31-1ubuntu2) ...
 * Stopping MySQL database server mysqld
   ...done.
100825 11:46:15  InnoDB: Started; log sequence number 0 46409
100825 11:46:15  InnoDB: Starting shutdown...
100825 11:46:17  InnoDB: Shutdown completed; log sequence number 0 46409
100825 11:46:17 [Warning] Forcing shutdown of 1 plugins
 * Starting MySQL database server mysqld
   ...done.
 * Checking for corrupt, not cleanly closed and upgrade needing tables.
...
Processing triggers for libc6 ...
ldconfig deferred processing now taking place
```

Note

The `apt-get` command will install a number of packages, including the MySQL server, in order to provide the typical tools and application environment. This can mean that you install a large number of packages in addition to the main MySQL package.

During installation, the initial database will be created, and you will be prompted for the MySQL root password (and confirmation). A configuration file will have been created in `/etc/mysql/my.cnf`. An init script will have been created in `/etc/init.d/mysql`.

The server will already be started. You can manually start and stop the server using:

```
root-shell> service mysql [start|stop]
```

The service will automatically be added to the 2, 3 and 4 run levels, with stop scripts in the single, shutdown and restart levels.

- **Gentoo Linux**

  As a source-based distribution, installing MySQL on Gentoo involves downloading the source, patching the Gentoo specifics, and then compiling the MySQL server and installing it. This process is handled automatically by the `emerge` command.

  The MySQL server and client tools are provided within a single package, `dev-db/mysql`. You can obtain a list of the versions available to install by looking at the portage directory for the package:

  ```
  root-shell> ls /usr/portage/dev-db/mysql/mysql-5.5*
  mysql-5.5.46.ebuild
  mysql-5.5.47.ebuild
  ```

  To install a specific MySQL version, you must specify the entire atom. For example:

  ```
  root-shell> emerge =dev-db/mysql-5.5.46
  ```

  After installation, you should initialize the data directory and set the password for the MySQL *`root`* user (see Section 2.10.1, “Initializing the Data Directory”). Alternatively, use the configuration interface to perform those tasks:

  ```
  root-shell> emerge --config =dev-db/mysql-5.5.46
  ```

  During installation, a sample configuration file is created for you in `/etc/mysql/my.cnf`, and an init script is created in `/etc/init.d/mysql`.

  To enable MySQL to start automatically at the normal (default) run levels, use this command:

  ```
  root-shell> rc-update add mysql default
  ```

2.6 Installing MySQL Using Unbreakable Linux Network (ULN)

Linux supports a number of different solutions for installing MySQL, covered in Section 2.5, “Installing MySQL on Linux”. One of the methods, covered in this section, is installing from Oracle's Unbreakable Linux Network (ULN). You can find information about Oracle Linux and ULN under http://linux.oracle.com/.

To use ULN, you need to obtain a ULN login and register the machine used for installation with ULN. This is described in detail in the ULN FAQ. The page also describes how to install and update packages.The MySQL packages are in the “MySQL for Oracle Linux 6” channel for your system architecture on ULN.

Note

At the time of this writing, ULN provides MySQL 5.5 for Oracle Linux 6.

Once MySQL has been installed using ULN, you can find information on starting and stopping the server, and more, in this section, particularly under Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”.

If you're updating an existing MySQL installation to an installation using ULN, the recommended procedure is to export your data using `mysqldump`, remove the existing installation, install MySQL from ULN, and load the exported data into your freshly installed MySQL.

If the existing MySQL installation you're upgrading from is from a previous release series (prior to MySQL 5.5), make sure to read the section on upgrading MySQL, Section 2.11.1, “Upgrading MySQL”.

2.7 Installing MySQL on Solaris

Note

MySQL 5.5 supports Solaris 10 (Update 11 and later), and Solaris 11 (Update 3 and later).

MySQL on Solaris is available in a number of different formats.

- For information on installing using the native Solaris PKG format, see Section 2.7.1, “Installing MySQL on Solaris Using a Solaris PKG”.
- To use a standard `tar` binary installation, use the notes provided in Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”. Check the notes and hints at the end of this section for Solaris specific notes that you may need before or after installation.

To obtain a binary MySQL distribution for Solaris in tarball or PKG format, http://dev.mysql.com/downloads/mysql/5.5.html.

Additional notes to be aware of when installing and using MySQL on Solaris:

- If you want to use MySQL with the `mysql` user and group, use the `groupadd` and `useradd` commands:

```
groupadd mysql
useradd -g mysql -s /bin/false mysql
```

- If you install MySQL using a binary tarball distribution on Solaris, because the Solaris `tar` cannot handle long file names, use GNU `tar` (`gtar`) to unpack the distribution. If you do not have GNU `tar` on your system, install it with the following command:

```
pkg install archiver/gnu-tar
```

- You should mount any file systems on which you intend to store `InnoDB` files with the `forcedirectio` option. (By default mounting is done without this option.) Failing to do so will cause a significant drop in performance when using the `InnoDB` storage engine on this platform.
- If you would like MySQL to start automatically, you can copy `support-files/mysql.server` to `/etc/init.d` and create a symbolic link to it named `/etc/rc3.d/S99mysql.server`.
- If too many processes try to connect very rapidly to `mysqld`, you should see this error in the MySQL log:

```
Error in accept: Protocol error
```

  You might try starting the server with the `--back_log=50` option as a workaround for this.

- To configure the generation of core files on Solaris you should use the `coreadm` command. Because of the security implications of generating a core on a `setuid()` application, by default, Solaris

does not support core files on `setuid()` programs. However, you can modify this behavior using `coreadm`. If you enable `setuid()` core files for the current user, they will be generated using the mode 600 and owned by the superuser.

2.7.1 Installing MySQL on Solaris Using a Solaris PKG

You can install MySQL on Solaris using a binary package using the native Solaris PKG format instead of the binary tarball distribution.

To use this package, download the corresponding `mysql-VERSION-solaris10-PLATFORM.pkg.gz` file, then uncompress it. For example:

```
shell> gunzip mysql-5.5.60-solaris10-x86_64.pkg.gz
```

To install a new package, use `pkgadd` and follow the onscreen prompts. You must have root privileges to perform this operation:

```
shell> pkgadd -d mysql-5.5.60-solaris10-x86_64.pkg

The following packages are available:
  1  mysql     MySQL Community Server (GPL)
               (i86pc) 5.5.60

Select package(s) you wish to process (or 'all' to process
all packages). (default: all) [?,??,q]:
```

The PKG installer installs all of the files and tools needed, and then initializes your database if one does not exist. To complete the installation, you should set the root password for MySQL as provided in the instructions at the end of the installation. Alternatively, you can run the `mysql_secure_installation` script that comes with the installation.

By default, the PKG package installs MySQL under the root path `/opt/mysql`. You can change only the installation root path when using `pkgadd`, which can be used to install MySQL in a different Solaris zone. If you need to install in a specific directory, use a binary `tar` file distribution.

The `pkg` installer copies a suitable startup script for MySQL into `/etc/init.d/mysql`. To enable MySQL to startup and shutdown automatically, you should create a link between this file and the init script directories. For example, to ensure safe startup and shutdown of MySQL you could use the following commands to add the right links:

```
shell> ln /etc/init.d/mysql /etc/rc3.d/S91mysql
shell> ln /etc/init.d/mysql /etc/rc0.d/K02mysql
```

To remove MySQL, the installed package name is `mysql`. You can use this in combination with the `pkgrm` command to remove the installation.

To upgrade when using the Solaris package file format, you must remove the existing installation before installing the updated package. Removal of the package does not delete the existing database information, only the server, binaries and support files. The typical upgrade sequence is therefore:

```
shell> mysqladmin shutdown
shell> pkgrm mysql
shell> pkgadd -d mysql-5.5.60-solaris10-x86_64.pkg
shell> mysqld_safe &
shell> mysql_upgrade
```

You should check the notes in Section 2.11, “Upgrading or Downgrading MySQL” before performing any upgrade.

2.8 Installing MySQL on FreeBSD

This section provides information about installing MySQL on variants of FreeBSD Unix.

You can install MySQL on FreeBSD by using the binary distribution provided by Oracle. For more information, see Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

The easiest (and preferred) way to install MySQL is to use the `mysql-server` and `mysql-client` ports available at http://www.freebsd.org/. Using these ports gives you the following benefits:

- A working MySQL with all optimizations enabled that are known to work on your version of FreeBSD.
- Automatic configuration and build.
- Startup scripts installed in `/usr/local/etc/rc.d`.
- The ability to use `pkg_info -L` to see which files are installed.
- The ability to use `pkg_delete` to remove MySQL if you no longer want it on your machine.

The MySQL build process requires GNU make (`gmake`) to work. If GNU `make` is not available, you must install it first before compiling MySQL.

To install using the ports system:

```
# cd /usr/ports/databases/mysql55-server
# make
...
# cd /usr/ports/databases/mysql55-client
# make
...
```

The standard port installation places the server into `/usr/local/libexec/mysqld`, with the startup script for the MySQL server placed in `/usr/local/etc/rc.d/mysql-server`.

Some additional notes on the BSD implementation:

- To remove MySQL after installation using the ports system:

```
# cd /usr/ports/databases/mysql55-server
# make deinstall
...
# cd /usr/ports/databases/mysql55-client
# make deinstall
...
```

- If you get problems with the current date in MySQL, setting the `TZ` variable should help. See Section 4.9, “MySQL Program Environment Variables”.

2.9 Installing MySQL from Source

Building MySQL from the source code enables you to customize build parameters, compiler optimizations, and installation location. For a list of systems on which MySQL is known to run, see http://www.mysql.com/support/supportedplatforms/database.html.

Before you proceed with an installation from source, check whether Oracle produces a precompiled binary distribution for your platform and whether it works for you. We put a great deal of effort into ensuring that our binaries are built with the best possible options for optimal performance. Instructions for installing binary distributions are available in Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

Warning

Building MySQL with nonstandard options may lead to reduced functionality, performance, or security.

Note

This section describes how to build MySQL from source using `CMake`. Before MySQL 5.5, source builds used the GNU autotools on Unix-like systems. Source builds on Windows used `CMake`, but the process was different from that described here. For source-building instructions for older versions of MySQL, see the *MySQL 5.1 Reference Manual*. If you are familiar with autotools but not `CMake`, you might find these transition instructions helpful: Autotools to CMake Transition Guide

Source Installation Methods

There are two methods for installing MySQL from source:

- Use a standard MySQL source distribution. To obtain a standard distribution, see Section 2.1.2, “How to Get MySQL”. For instructions on building from a standard distribution, see Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”.

  Standard distributions are available as compressed `tar` files, Zip archives, or RPM packages. Distribution files have names of the form `mysql-`*`VERSION`*`.tar.gz`, `mysql-`*`VERSION`*`.zip`, or `mysql-`*`VERSION`*`.rpm`, where *`VERSION`* is a number like `5.5.60`. File names for source distributions can be distinguished from those for precompiled binary distributions in that source distribution names are generic and include no platform name, whereas binary distribution names include a platform name indicating the type of system for which the distribution is intended (for example, `pc-linux-i686` or `winx64`).

- Use a MySQL development tree. For information on building from one of the development trees, see Section 2.9.3, “Installing MySQL Using a Development Source Tree”.

Source Installation System Requirements

Installation of MySQL from source requires several development tools. Some of these tools are needed no matter whether you use a standard source distribution or a development source tree. Other tool requirements depend on which installation method you use.

To install MySQL from source, the following system requirements must be satisfied, regardless of installation method:

- `CMake`, which is used as the build framework on all platforms. `CMake` can be downloaded from http://www.cmake.org.
- A good `make` program. Although some platforms come with their own `make` implementations, it is highly recommended that you use GNU `make` 3.75 or higher. It may already be available on your system as `gmake`. GNU `make` is available from http://www.gnu.org/software/make/.
- A working ANSI C++ compiler. GCC 4.2.1 or later, Sun Studio 12 or later, Visual Studio 2008 or later, and many current vendor-supplied compilers are known to work.
- The ncurses library.
- Sufficient free memory. If you encounter problems such as “internal compiler error” when compiling large source files, it may be that you have too little memory. If compiling on a virtual machine, try increasing the memory allocation.
- Perl is needed if you intend to run test scripts. Most Unix-like systems include Perl. On Windows, you can use a version such as ActiveState Perl.

To install MySQL from a standard source distribution, one of the following tools is required to unpack the distribution file:

- For a `.tar.gz` compressed `tar` file: GNU `gunzip` to uncompress the distribution and a reasonable `tar` to unpack it. If your `tar` program supports the `z` option, it can both uncompress and unpack the file.

  GNU `tar` is known to work. The standard `tar` provided with some operating systems is not able to unpack the long file names in the MySQL distribution. You should download and install GNU `tar`, or if available, use a preinstalled version of GNU tar. Usually this is available as `gnutar`, `gtar`, or as `tar` within a GNU or Free Software directory, such as `/usr/sfw/bin` or `/usr/local/bin`. GNU `tar` is available from http://www.gnu.org/software/tar/.

- For a `.zip` Zip archive: `WinZip` or another tool that can read `.zip` files.

- For an `.rpm` RPM package: The `rpmbuild` program used to build the distribution unpacks it.

To install MySQL from a development source tree, the following additional tools are required:

- The Git revision control system is required to obtain the development source code. The GitHub Help provides instructions for downloading and installing Git on different platforms. MySQL officially joined GitHub in September, 2014. For more information about MySQL's move to GitHub, refer to the announcement on the MySQL Release Engineering blog: MySQL on GitHub

- `bison` 2.1 or higher, available from http://www.gnu.org/software/bison/. (Version 1 is no longer supported.) Use the latest version of `bison` where possible; if you experience problems, upgrade to a later version, rather than revert to an earlier one.

  `bison` is available from http://www.gnu.org/software/bison/. `bison` for Windows can be downloaded from http://gnuwin32.sourceforge.net/packages/bison.htm. Download the package labeled “Complete package, excluding sources”. On Windows, the default location for `bison` is the `C:\Program Files\GnuWin32` directory. Some utilities may fail to find `bison` because of the space in the directory name. Also, Visual Studio may simply hang if there are spaces in the path. You can resolve these problems by installing into a directory that does not contain a space; for example `C:\GnuWin32`.

- On Solaris Express, `m4` must be installed in addition to `bison`. `m4` is available from http://www.gnu.org/software/m4/.

Note

If you have to install any programs, modify your `PATH` environment variable to include any directories in which the programs are located. See Section 4.2.10, “Setting Environment Variables”.

If you run into problems and need to file a bug report, please use the instructions in Section 1.6, “How to Report Bugs or Problems”.

2.9.1 MySQL Layout for Source Installation

By default, when you install MySQL after compiling it from source, the installation step installs files under `/usr/local/mysql`. The component locations under the installation directory are the same as for binary distributions. See Table 2.3, “MySQL Installation Layout for Generic Unix/Linux Binary Package”, and Section 2.3.1, “MySQL Installation Layout on Microsoft Windows”. To configure installation locations different from the defaults, use the options described at Section 2.9.4, “MySQL Source-Configuration Options”.

2.9.2 Installing MySQL Using a Standard Source Distribution

To install MySQL from a standard source distribution:

1. Verify that your system satisfies the tool requirements listed at Section 2.9, “Installing MySQL from Source”.
2. Obtain a distribution file using the instructions in Section 2.1.2, “How to Get MySQL”.
3. Configure, build, and install the distribution using the instructions in this section.
4. Perform postinstallation procedures using the instructions in Section 2.10, “Postinstallation Setup and Testing”.

In MySQL 5.5, `CMake` is used as the build framework on all platforms. The instructions given here should enable you to produce a working installation. For additional information on using `CMake` to build MySQL, see How to Build MySQL Server with CMake.

If you start from a source RPM, use the following command to make a binary RPM that you can install. If you do not have `rpmbuild`, use `rpm` instead.

```
shell> rpmbuild --rebuild --clean MySQL-VERSION.src.rpm
```

The result is one or more binary RPM packages that you install as indicated in Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”.

The sequence for installation from a compressed `tar` file or Zip archive source distribution is similar to the process for installing from a generic binary distribution (see Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”), except that it is used on all platforms and includes steps to configure and compile the distribution. For example, with a compressed `tar` file source distribution on Unix, the basic installation command sequence looks like this:

```
# Preconfiguration setup
shell> groupadd mysql
shell> useradd -r -g mysql -s /bin/false mysql
# Beginning of source-build specific instructions
shell> tar zxvf mysql-VERSION.tar.gz
shell> cd mysql-VERSION
shell> mkdir bld
shell> cd bld
shell> cmake ..
shell> make
shell> make install
# End of source-build specific instructions
# Postinstallation setup
shell> cd /usr/local/mysql
shell> chown -R mysql .
shell> chgrp -R mysql .
shell> scripts/mysql_install_db --user=mysql
shell> chown -R root .
shell> chown -R mysql data
# Next command is optional
shell> cp support-files/my-medium.cnf /etc/my.cnf
shell> bin/mysqld_safe --user=mysql &
# Next command is optional
shell> cp support-files/mysql.server /etc/init.d/mysql.server
```

A more detailed version of the source-build specific instructions is shown following.

Note

The procedure shown here does not set up any passwords for MySQL accounts. After following the procedure, proceed to Section 2.10, “Postinstallation Setup and Testing”, for postinstallation setup and testing.

Perform Preconfiguration Setup

On Unix, set up the `mysql` user and group that will be used to run and execute the MySQL server and own the database directory. For details, see Creating a `mysql` System User and Group, in Section 2.2,

"Installing MySQL on Unix/Linux Using Generic Binaries". Then perform the following steps as the `mysql` user, except as noted.

Obtain and Unpack the Distribution

Pick the directory under which you want to unpack the distribution and change location into it.

Obtain a distribution file using the instructions in Section 2.1.2, "How to Get MySQL".

Unpack the distribution into the current directory:

- To unpack a compressed `tar` file, `tar` can uncompress and unpack the distribution if it has `z` option support:

  ```
  shell> tar zxvf mysql-VERSION.tar.gz
  ```

  If your `tar` does not have `z` option support, use `gunzip` to unpack the distribution and `tar` to unpack it:

  ```
  shell> gunzip < mysql-VERSION.tar.gz | tar xvf -
  ```

  Alternatively, `CMake` can uncompress and unpack the distribution:

  ```
  shell> cmake -E tar zxvf mysql-VERSION.tar.gz
  ```

- To unpack a Zip archive, use `WinZip` or another tool that can read `.zip` files.

Unpacking the distribution file creates a directory named `mysql-VERSION`.

Configure the Distribution

Change location into the top-level directory of the unpacked distribution:

```
shell> cd mysql-VERSION
```

Build outside of the source tree to keep the tree clean. If the top-level source directory is named `mysql-src` under your current working directory, you can build in a directory named `bld` at the same level. Create the directory and go there:

```
shell> mkdir bld
shell> cd bld
```

Configure the build directory. The minimum configuration command includes no options to override configuration defaults:

```
shell> cmake ../mysql-src
```

The build directory needs not be outside the source tree. For example, you can build in a directory named `bld` under the top-level source tree. To do this, starting with `mysql-src` as your current working directory, create the directory `bld` and then go there:

```
shell> mkdir bld
shell> cd bld
```

Configure the build directory. The minimum configuration command includes no options to override configuration defaults:

```
```

```
shell> cmake ..
```

If you have multiple source trees at the same level (for example, to build multiple versions of MySQL), the second strategy can be advantageous. The first strategy places all build directories at the same level, which requires that you choose a unique name for each. With the second strategy, you can use the same name for the build directory within each source tree. The following instructions assume this second strategy.

On Windows, specify the development environment. For example, the following commands configure MySQL for 32-bit or 64-bit builds, respectively:

```
shell> cmake .. -G "Visual Studio 9 2008"
shell> cmake .. -G "Visual Studio 9 2008 Win64"
```

On OS X, to use the Xcode IDE:

```
shell> cmake .. -G Xcode
```

When you run `cmake`, you might want to add options to the command line. Here are some examples:

- `-DBUILD_CONFIG=mysql_release`: Configure the source with the same build options used by Oracle to produce binary distributions for official MySQL releases.
- `-DCMAKE_INSTALL_PREFIX=`*`dir_name`*: Configure the distribution for installation under a particular location.
- `-DCPACK_MONOLITHIC_INSTALL=1`: Cause `make package` to generate a single installation file rather than multiple files.
- `-DWITH_DEBUG=1`: Build the distribution with debugging support.

For a more extensive list of options, see Section 2.9.4, “MySQL Source-Configuration Options”.

To list the configuration options, use one of the following commands:

```
shell> cmake .. -L   # overview
shell> cmake .. -LH  # overview with help text
shell> cmake .. -LAH # all params with help text
shell> ccmake ..     # interactive display
```

If `CMake` fails, you might need to reconfigure by running it again with different options. If you do reconfigure, take note of the following:

- If `CMake` is run after it has previously been run, it may use information that was gathered during its previous invocation. This information is stored in `CMakeCache.txt`. When `CMake` starts up, it looks for that file and reads its contents if it exists, on the assumption that the information is still correct. That assumption is invalid when you reconfigure.
- Each time you run `CMake`, you must run `make` again to recompile. However, you may want to remove old object files from previous builds first because they were compiled using different configuration options.

To prevent old object files or configuration information from being used, run these commands in the build direcotry on Unix before re-running `CMake`:

```
shell> make clean
shell> rm CMakeCache.txt
```

Or, on Windows:

```
```

```
shell> devenv MySQL.sln /clean
shell> del CMakeCache.txt
```

If you are going to send mail to a MySQL mailing list to ask for configuration assistance, first check the files in the `CMakeFiles` directory for useful information about the failure. To file a bug report, please use the instructions in Section 1.6, “How to Report Bugs or Problems”.

Build the Distribution

On Unix:

```
shell> make
shell> make VERBOSE=1
```

The second command sets `VERBOSE` to show the commands for each compiled source.

Use `gmake` instead on systems where you are using GNU `make` and it has been installed as `gmake`.

On Windows:

```
shell> devenv MySQL.sln /build RelWithDebInfo
```

If you have gotten to the compilation stage, but the distribution does not build, see Section 2.9.5, “Dealing with Problems Compiling MySQL”, for help. If that does not solve the problem, please enter it into our bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”. If you have installed the latest versions of the required tools, and they crash trying to process our configuration files, please report that also. However, if you get a `command not found` error or a similar problem for required tools, do not report it. Instead, make sure that all the required tools are installed and that your `PATH` variable is set correctly so that your shell can find them.

Install the Distribution

On Unix:

```
shell> make install
```

This installs the files under the configured installation directory (by default, `/usr/local/mysql`). You might need to run the command as `root`.

To install in a specific directory, add a `DESTDIR` parameter to the command line:

```
shell> make install DESTDIR="/opt/mysql"
```

Alternatively, generate installation package files that you can install where you like:

```
shell> make package
```

This operation produces one or more `.tar.gz` files that can be installed like generic binary distribution packages. See Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”. If you run `CMake` with `-DCPACK_MONOLITHIC_INSTALL=1`, the operation produces a single file. Otherwise, it produces multiple files.

On Windows, generate the data directory, then create a `.zip` archive installation package:

```
shell> devenv MySQL.sln /build RelWithDebInfo /project initial_database
shell> devenv MySQL.sln /build RelWithDebInfo /project package
```

You can install the resulting `.zip` archive where you like. See Section 2.3.7, “Installing MySQL on Microsoft Windows Using a `noinstall` ZIP Archive”.

Perform Postinstallation Setup

The remainder of the installation process involves setting up the configuration file, creating the core databases, and starting the MySQL server. For instructions, see Section 2.10, “Postinstallation Setup and Testing”.

Note

The accounts that are listed in the MySQL grant tables initially have no passwords. After starting the server, you should set up passwords for them using the instructions in Section 2.10, “Postinstallation Setup and Testing”.

2.9.3 Installing MySQL Using a Development Source Tree

This section describes how to install MySQL from the latest development source code, which is hosted on GitHub. To obtain the MySQL Server source code from this repository hosting service, you can set up a local MySQL Git repository.

On GitHub, MySQL Server and other MySQL projects are found on the MySQL page. The MySQL Server project is a single repository that contains branches for several MySQL series.

MySQL officially joined GitHub in September, 2014. For more information about MySQL's move to GitHub, refer to the announcement on the MySQL Release Engineering blog: MySQL on GitHub

Prerequisites for Installing from Development Source

To install MySQL from a development source tree, your system must satisfy the tool requirements outlined in Section 2.9, “Installing MySQL from Source”.

Setting Up a MySQL Git Repository

To set up a MySQL Git repository on your machine, use this procedure:

1. Clone the MySQL Git repository to your machine. The following command clones the MySQL Git repository to a directory named `mysql-server`. The initial download will take some time to complete, depending on the speed of your connection.

```
~$ git clone https://github.com/mysql/mysql-server.git
Cloning into 'mysql-server'...
remote: Counting objects: 1035465, done.
remote: Total 1035465 (delta 0), reused 0 (delta 0)
Receiving objects: 100% (1035465/1035465), 437.48 MiB | 5.10 MiB/s, done.
Resolving deltas: 100% (855607/855607), done.
Checking connectivity... done.
Checking out files: 100% (21902/21902), done.
```

2. When the clone operation completes, the contents of your local MySQL Git repository appear similar to the following:

```
~$ cd mysql-server

~/mysql-server$ ls
BUILD            COPYING             libmysqld    regex          tests
BUILD-CMAKE      dbug                libservices  scripts        unittest
client           Docs                man          sql            VERSION
cmake            extra               mysql-test   sql-bench      vio
CMakeLists.txt   include             mysys        sql-common     win
cmd-line-utils   INSTALL-SOURCE      packaging    storage        zlib
config.h.cmake   INSTALL-WIN-SOURCE  plugin       strings
configure.cmake  libmysql            README       support-files
```

3. Use the `git branch -r` command to view the remote tracking branches for the MySQL repository.

```
~/mysql-server$ git branch -r
```

```
  origin/5.5
  origin/5.6
  origin/5.7
  origin/HEAD -> origin/5.7
  origin/cluster-7.2
  origin/cluster-7.3
  origin/cluster-7.4
```

4. To view the branches that are checked out in your local repository, issue the `git branch` command. When you cloned the MySQL Git repository, the MySQL 5.7 branch was checked out automatically. The asterisk identifies the 5.7 branch as the active branch.

```
~/mysql-server$ git branch
* 5.7
```

5. To check out a different MySQL branch, run the `git checkout` command, specifying the branch name. For example, to checkout the MySQL 5.5 branch:

```
~/mysql-server$ git checkout 5.5
Branch 5.5 set up to track remote branch 5.5 from origin.
Switched to a new branch '5.5'
```

6. Run `git branch` again to verify that the MySQL 5.5 branch is present. MySQL 5.5, which is the last branch you checked out, is marked by an asterisk indicating that it is the active branch.

```
~/mysql-server$ git branch
* 5.5
  5.7
```

   The `git checkout` command is also used to switch branches. For example, to make MySQL 5.7 the active branch again, you would run `git checkout 5.7`.

7. To obtain changes made after your initial setup of the MySQL Git repository, switch to the branch you want to update and issue the `git pull` command:

```
~/mysql-server$ git checkout 5.5
~/mysql-server$ git pull
```

   To examine the commit history, use the `git log` option:

```
~/mysql-server$ git log
```

   You can also browse commit history and source code on the GitHub MySQL site.

   If you see changes or code that you have a question about, send an email to the MySQL `internals` mailing list. See Section 1.5.2, “MySQL Mailing Lists”. For information about contributing a patch, see Contributing to MySQL Server.

8. After you have cloned the MySQL Git repository and have checked out the branch you want to build, you can build MySQL Server from the source code. Instructions are provided in Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”, except that you skip the part about obtaining and unpacking the distribution.

   Be careful about installing a build from a distribution source tree on a production machine. The installation command may overwrite your live release installation. If you already have MySQL installed and do not want to overwrite it, run `CMake` with values for the `CMAKE_INSTALL_PREFIX`, `MYSQL_TCP_PORT`, and `MYSQL_UNIX_ADDR` options different from those used by your production server. For additional information about preventing multiple servers from interfering with each other, see Section 5.6, “Running Multiple MySQL Instances on One Machine”.

   Play hard with your new installation. For example, try to make new features crash. Start by running `make test`. See Section 24.1.2, “The MySQL Test Suite”.

2.9.4 MySQL Source-Configuration Options

The CMake program provides a great deal of control over how you configure a MySQL source distribution. Typically, you do this using options on the CMake command line. For information about options supported by CMake, run either of these commands in the top-level source directory:

```
shell> cmake . -LH
shell> ccmake .
```

You can also affect CMake using certain environment variables. See Section 4.9, “MySQL Program Environment Variables”.

The following table shows the available CMake options. In the Default column, PREFIX stands for the value of the CMAKE_INSTALL_PREFIX option, which specifies the installation base directory. This value is used as the parent location for several of the installation subdirectories.

Table 2.14 MySQL Source-Configuration Option Reference (CMake)

Formats	Description	Default	Introduced	Removed
BUILD_CONFIG	Use same build options as official releases		5.5.7	
CMAKE_BUILD_TYPE	Type of build to produce	RelWithDebInfo	5.5.7	
CMAKE_CXX_FLAGS	Flags for C++ Compiler			
CMAKE_C_FLAGS	Flags for C Compiler			
CMAKE_INSTALL_PREFIX	Installation base directory	/usr/local/mysql	5.5.8	
COMPILATION_COMMENT	Comment about compilation environment		5.5.7	
CPACK_MONOLITHIC_INSTALL	Whether package build produces single file	OFF	5.5.7	
DEFAULT_CHARSET	The default server character set	latin1	5.5.7	
DEFAULT_COLLATION	The default server collation	latin1_swedish_ci	5.5.7	
ENABLED_LOCAL_INFILE	Whether to enable LOCAL for LOAD DATA INFILE	OFF	5.5.7	
ENABLED_PROFILING	Whether to enable query profiling code	ON	5.5.7	
ENABLE_DEBUG_SYNC	Whether to enable Debug Sync support	ON	5.5.7	5.5.55
ENABLE_DOWNLOADS	Whether to download optional files	OFF	5.5.7	
ENABLE_DTRACE	Whether to include DTrace support		5.5.7	
ENABLE_GCOV	Whether to include gcov support		5.5.14	
IGNORE_AIO_CHECK	With -DBUILD_CONFIG=mysql_release, ignore libaio check	OFF	5.5.9	
INSTALL_BINDIR	User executables directory	PREFIX/bin	5.5.7	
INSTALL_DOCDIR	Documentation directory	PREFIX/docs	5.5.7	
INSTALL_DOCREADMEDIR	README file directory	PREFIX	5.5.7	
INSTALL_INCLUDEDIR	Header file directory	PREFIX/include	5.5.7	
INSTALL_INFODIR	Info file directory	PREFIX/docs	5.5.7	

Formats	Description	Default	Introduced	Removed
INSTALL_LAYOUT	Select predefined installation layout	STANDALONE	5.5.7	
INSTALL_LIBDIR	Library file directory	PREFIX/lib	5.5.7	
INSTALL_MANDIR	Manual page directory	PREFIX/man	5.5.7	
INSTALL_MYSQLSHAREDIR	Shared data directory	PREFIX/share	5.5.7	
INSTALL_MYSQLTESTDIR	mysql-test directory	PREFIX/mysql-test	5.5.7	
INSTALL_PLUGINDIR	Plugin directory	PREFIX/lib/plugin	5.5.7	
INSTALL_SBINDIR	Server executable directory	PREFIX/bin	5.5.7	
INSTALL_SCRIPTDIR	Scripts directory	PREFIX/scripts	5.5.7	
INSTALL_SECURE_FILE_PRIVDIR	secure_file_priv default value	platform specific	5.5.53	
INSTALL_SECURE_FILE_PRIVEMBEDDEDDIR	secure_file_priv default value for libmysqld		5.5.53	
INSTALL_SHAREDIR	aclocal/mysql.m4 installation directory	PREFIX/share	5.5.7	
INSTALL_SQLBENCHDIR	sql-bench directory	PREFIX	5.5.7	
INSTALL_SUPPORTFILESDIR	Extra support files directory	PREFIX/support-files	5.5.7	
MEMCACHED_HOME	Path to memcached	[none]	5.5.16-ndb-7.2.2	
MYSQL_DATADIR	Data directory		5.5.7	
MYSQL_MAINTAINER_MODE	Whether to enable MySQL maintainer-specific development environment	OFF	5.5.7	
MYSQL_PROJECT_NAME	Windows/OS X project name	MySQL	5.5.21	
MYSQL_TCP_PORT	TCP/IP port number	3306	5.5.7	
MYSQL_UNIX_ADDR	Unix socket file	/tmp/mysql.sock	5.5.7	
ODBC_INCLUDES	ODBC includes directory			
ODBC_LIB_DIR	ODBC library directory			
SYSCONFDIR	Option file directory		5.5.7	
TMPDIR	tmpdir default value		5.5.36	
WITHOUT_SERVER	Do not build the server	OFF		
WITHOUT_xxx_STORAGE_ENGINE	Exclude storage engine xxx from build		5.5.7	
WITH_ASAN	Enable AddressSanitizer	OFF	5.5.35	
WITH_BUNDLED_LIBEVENT	Use bundled libevent when building ndbmemcache	ON	5.5.16-ndb-7.2.2	
WITH_BUNDLED_MEMCACHED	Use bundled memcached when building ndbmemcache	ON	5.5.16-ndb-7.2.2	
WITH_CLASSPATH	Classpath to use when building MySQL Cluster			

Formats	Description	Default	Introduced	Removed
	Connector for Java. Default is an empty string.			
WITH_DEBUG	Whether to include debugging support	OFF	5.5.7	
WITH_EMBEDDED_SERVER	Whether to build embedded server	OFF	5.5.7	
WITH_EMBEDDED_SHARED_LIBRARY	Whether to build a shared embedded server library	OFF	5.5.37	
WITH_ERROR_INSERT	Enable error injection in the NDB storage engine. Should not be used for building binaries intended for production.	OFF		
WITH_EXTRA_CHARSETS	Which extra character sets to include	all	5.5.7	
WITH_LIBEDIT	Use bundled libedit library	ON	5.5.7	
WITH_LIBWRAP	Whether to include libwrap (TCP wrappers) support	OFF	5.5.7	
WITH_NDBCLUSTER	Build the NDB storage engine; alias for WITH_NDBCLUSTER_STORAGE_ENGINE	ON		
WITH_NDBCLUSTER_STORAGE_ENGINE	Build the NDB storage engine	ON		
WITH_NDBMTD	Build multi-threaded data node.	ON		
WITH_NDB_BINLOG	Enable binary logging by default by mysqld.	ON		
WITH_NDB_DEBUG	Produce a debug build for testing or troubleshooting.	OFF		
WITH_NDB_JAVA	Enable building of Java and ClusterJ support. Enabled by default. Supported in MySQL Cluster only.	ON	5.5.27-ndb-7.2.9	
WITH_NDB_PORT	Default port used by a management server built with this option. If this option was not used to build it, the management server's default port is 1186.	[none]		
WITH_NDB_TEST	Include NDB API test programs.	OFF		
WITH_READLINE	Use bundled readline library	OFF	5.5.7	
WITH_SSL	Type of SSL support	bundled	5.5.7	
WITH_UNIT_TESTS	Compile MySQL with unit tests	ON		
WITH_UNIXODBC	Enable unixODBC support	OFF		
WITH_VALGRIND	Whether to compile in Valgrind header files	OFF	5.5.6	
WITH_ZLIB	Type of zlib support	bundled	5.5.7	

Formats	Description	Default	Introduced	Removed
WITH_xxx_STORAGE_ENGINE	Compile storage engine xxx statically into server		5.5.7	

The following sections provide more information about CMake options.

- General Options
- Installation Layout Options
- Storage Engine Options
- Feature Options
- Compiler Flags
- CMake Options for Compiling NDB Cluster

For boolean options, the value may be specified as 1 or ON to enable the option, or as 0 or OFF to disable the option.

Many options configure compile-time defaults that can be overridden at server startup. For example, the CMAKE_INSTALL_PREFIX, MYSQL_TCP_PORT, and MYSQL_UNIX_ADDR options that configure the default installation base directory location, TCP/IP port number, and Unix socket file can be changed at server startup with the --basedir, --port, and --socket options for mysqld. Where applicable, configuration option descriptions indicate the corresponding mysqld startup option.

General Options

- -DBUILD_CONFIG=mysql_release

  This option configures a source distribution with the same build options used by Oracle to produce binary distributions for official MySQL releases.

- -DCMAKE_BUILD_TYPE=*type*

  The type of build to produce:

  - RelWithDebInfo: Enable optimizations and generate debugging information. This is the default MySQL build type.
  - Debug: Disable optimizations and generate debugging information. This build type is also used if the WITH_DEBUG option is enabled. That is, -DWITH_DEBUG=1 has the same effect as -DCMAKE_BUILD_TYPE=Debug.

- -DCPACK_MONOLITHIC_INSTALL=*bool*

  This option affects whether the make package operation produces multiple installation package files or a single file. If disabled, the operation produces multiple installation package files, which may be useful if you want to install only a subset of a full MySQL installation. If enabled, it produces a single file for installing everything.

Installation Layout Options

The CMAKE_INSTALL_PREFIX option indicates the base installation directory. Other options with names of the form INSTALL_*xxx* that indicate component locations are interpreted relative to the prefix and their values are relative pathnames. Their values should not include the prefix.

- -DCMAKE_INSTALL_PREFIX=*dir_name*

  The installation base directory.

  This value can be set at server startup with the --basedir option.

- `-DINSTALL_BINDIR=dir_name`

  Where to install user programs.

- `-DINSTALL_DOCDIR=dir_name`

  Where to install documentation.

- `-DINSTALL_DOCREADMEDIR=dir_name`

  Where to install `README` files.

- `-DINSTALL_INCLUDEDIR=dir_name`

  Where to install header files.

- `-DINSTALL_INFODIR=dir_name`

  Where to install Info files.

- `-DINSTALL_LAYOUT=name`

  Select a predefined installation layout:

  - `STANDALONE`: Same layout as used for `.tar.gz` and `.zip` packages. This is the default.
  - `RPM`: Layout similar to RPM packages.
  - `SVR4`: Solaris package layout.
  - `DEB`: DEB package layout (experimental).

  You can select a predefined layout but modify individual component installation locations by specifying other options. For example:

  ```
  shell> cmake . -DINSTALL_LAYOUT=SVR4 -DMYSQL_DATADIR=/var/mysql/data
  ```

- `-DINSTALL_LIBDIR=dir_name`

  Where to install library files.

- `-DINSTALL_MANDIR=dir_name`

  Where to install manual pages.

- `-DINSTALL_MYSQLSHAREDIR=dir_name`

  Where to install shared data files.

- `-DINSTALL_MYSQLTESTDIR=dir_name`

  Where to install the `mysql-test` directory. As of MySQL 5.5.32, to suppress installation of this directory, explicitly set the option to the empty value (`-DINSTALL_MYSQLTESTDIR=`).

- `-DINSTALL_PLUGINDIR=dir_name`

  The location of the plugin directory.

  This value can be set at server startup with the `--plugin_dir` option.

- `-DINSTALL_SBINDIR=dir_name`

  Where to install the `mysqld` server.

- `-DINSTALL_SCRIPTDIR=dir_name`

  Where to install `mysql_install_db`.

- `-DINSTALL_SECURE_FILE_PRIVDIR=dir_name`

  The default value for the `secure_file_priv` system variable. The default value is platform specific and depends on the value of the `INSTALL_LAYOUT` `CMake` option; see the description of the `secure_file_priv` system variable in Section 5.1.5, “Server System Variables”.

  This option was added in MySQL 5.5.53. To set the value for the `libmysqld` embedded server, use `INSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR`.

- `-DINSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR=dir_name`

  The default value for the `secure_file_priv` system variable, for the `libmysqld` embedded server. This option was added in MySQL 5.5.53.

- `-DINSTALL_SHAREDIR=dir_name`

  Where to install `aclocal/mysql.m4`.

- `-DINSTALL_SQLBENCHDIR=dir_name`

  Where to install the `sql-bench` directory. To suppress installation of this directory, explicitly set the option to the empty value (`-DINSTALL_SQLBENCHDIR=`).

- `-DINSTALL_SUPPORTFILESDIR=dir_name`

  Where to install extra support files.

- `-DMYSQL_DATADIR=dir_name`

  The location of the MySQL data directory.

  This value can be set at server startup with the `--datadir` option.

- `-DODBC_INCLUDES=dir_name`

  The location of the ODBC includes directory, and may be used while configuring Connector/ODBC.

- `-DODBC_LIB_DIR=dir_name`

  The location of the ODBC library directory, and may be used while configuring Connector/ODBC.

- `-DSYSCONFDIR=dir_name`

  The default `my.cnf` option file directory.

  This location cannot be set at server startup, but you can start the server with a given option file using the `--defaults-file=file_name` option, where *`file_name`* is the full path name to the file.

- `-DTMPDIR=dir_name`

  The default location to use for the `tmpdir` system variable. If unspecified, the value defaults to `P_tmpdir` in `<stdio.h>`. This option was added in MySQL 5.6.16.

Storage Engine Options

Storage engines are built as plugins. You can build a plugin as a static module (compiled into the server) or a dynamic module (built as a dynamic library that must be installed into the server using the `INSTALL PLUGIN` statement or the `--plugin-load` option before it can be used). Some plugins might not support static or dynamic building.

The InnoDB, MyISAM, MERGE, MEMORY, and CSV engines are mandatory (always compiled into the server) and need not be installed explicitly.

To compile a storage engine statically into the server, use -DWITH_*engine*_STORAGE_ENGINE=1. Some permissible *engine* values are ARCHIVE, BLACKHOLE, EXAMPLE, FEDERATED, NDBCLUSTER (NDB), PARTITION (partitioning support), and PERFSCHEMA (Performance Schema). Examples:

```
-DWITH_ARCHIVE_STORAGE_ENGINE=1
-DWITH_BLACKHOLE_STORAGE_ENGINE=1
-DWITH_PERFSCHEMA_STORAGE_ENGINE=1
```

Note

WITH_NDBCLUSTER_STORAGE_ENGINE is supported only when building NDB Cluster using the NDB Cluster sources. It cannot be used to enable clustering support in other MySQL source trees or distributions. In MySQL NDB Cluster 7.2 source distributions, it is enabled by default. See Section 18.2.1.4, “Building NDB Cluster from Source on Linux”, and Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”, for more information.

To exclude a storage engine from the build, use -DWITHOUT_*engine*_STORAGE_ENGINE=1. Examples:

```
-DWITHOUT_EXAMPLE_STORAGE_ENGINE=1
-DWITHOUT_FEDERATED_STORAGE_ENGINE=1
-DWITHOUT_PARTITION_STORAGE_ENGINE=1
```

If neither -DWITH_*engine*_STORAGE_ENGINE nor -DWITHOUT_*engine*_STORAGE_ENGINE are specified for a given storage engine, the engine is built as a shared module, or excluded if it cannot be built as a shared module.

Feature Options

- -DCOMPILATION_COMMENT=*string*

  A descriptive comment about the compilation environment.

- -DDEFAULT_CHARSET=*charset_name*

  The server character set. By default, MySQL uses the latin1 (cp1252 West European) character set.

  charset_name may be one of binary, armscii8, ascii, big5, cp1250, cp1251, cp1256, cp1257, cp850, cp852, cp866, cp932, dec8, eucjpms, euckr, gb2312, gbk, geostd8, greek, hebrew, hp8, keybcs2, koi8r, koi8u, latin1, latin2, latin5, latin7, macce, macroman, sjis, swe7, tis620, ucs2, ujis, utf8, utf8mb4, utf16, utf32. The permissible character sets are listed in the cmake/character_sets.cmake file as the value of CHARSETS_AVAILABLE.

  This value can be set at server startup with the --character_set_server option.

- -DDEFAULT_COLLATION=*collation_name*

  The server collation. By default, MySQL uses latin1_swedish_ci. Use the SHOW COLLATION statement to determine which collations are available for each character set.

  This value can be set at server startup with the --collation_server option.

- -DENABLE_DEBUG_SYNC=*bool*

Note

As of MySQL 5.5.55, `ENABLE_DEBUG_SYNC` is removed and enabling `WITH_DEBUG` enables Debug Sync.

Whether to compile the Debug Sync facility into the server. This facility is used for testing and debugging. This option is enabled by default, but has no effect unless MySQL is configured with debugging enabled. If debugging is enabled and you want to disable Debug Sync, use `-DENABLE_DEBUG_SYNC=0`.

When compiled in, Debug Sync is disabled by default at runtime. To enable it, start `mysqld` with the `--debug-sync-timeout=N` option, where *`N`* is a timeout value greater than 0. (The default value is 0, which disables Debug Sync.) *`N`* becomes the default timeout for individual synchronization points.

For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

- `-DENABLE_DOWNLOADS=bool`

  Whether to download optional files. For example, with this option enabled, `CMake` downloads the Google Test distribution that is used by the test suite to run unit tests.

- `-DENABLE_DTRACE=bool`

  Whether to include support for DTrace probes. For information about DTrace, wee Section 5.7, “Tracing mysqld Using DTrace”

- `-DENABLE_GCOV=bool`

  Whether to include gcov support (Linux only).

- `-DENABLED_LOCAL_INFILE=bool`

  This option controls the compiled-in default `LOCAL` capability for the MySQL client library. Clients that make no explicit arrangements therefore have `LOCAL` capability disabled or enabled according to the `ENABLED_LOCAL_INFILE` setting specified at MySQL build time.

  By default, the client library in MySQL binary distributions is compiled with `ENABLED_LOCAL_INFILE` enabled. If you compile MySQL from source, configure it with `ENABLED_LOCAL_INFILE` disabled or enabled based on whether clients that make no explicit arrangements should have `LOCAL` capability disabled or enabled, respectively.

  `ENABLED_LOCAL_INFILE` controls the default for client-side `LOCAL` capability. For the server, the `local_infile` system variable controls server-side `LOCAL` capability. To explicitly cause the server to refuse or permit `LOAD DATA LOCAL` statements (regardless of how client programs and libraries are configured at build time or runtime), start `mysqld` with `local_infile` disabled or enabled, respectively. `local_infile` can also be set at runtime. See Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

- `-DENABLED_PROFILING=bool`

  Whether to enable query profiling code (for the `SHOW PROFILE` and `SHOW PROFILES` statements).

- `-DIGNORE_AIO_CHECK=bool`

  If the `-DBUILD_CONFIG=mysql_release` option is given on Linux, the `libaio` library must be linked in by default. If you do not have `libaio` or do not want to install it, you can suppress the check for it by specifying `-DIGNORE_AIO_CHECK=1`. This option was added in MySQL 5.5.9.

- `-DMYSQL_MAINTAINER_MODE=bool`

Whether to enable a MySQL maintainer-specific development environment. If enabled, this option causes compiler warnings to become errors.

- `-DMYSQL_PROJECT_NAME=name`

  For Windows or OS X, the project name to incorporate into the project file name. This option was added in MySQL 5.5.21.

- `-DMYSQL_TCP_PORT=port_num`

  The port number on which the server listens for TCP/IP connections. The default is 3306.

  This value can be set at server startup with the `--port` option.

- `-DMYSQL_UNIX_ADDR=file_name`

  The Unix socket file path on which the server listens for socket connections. This must be an absolute path name. The default is `/tmp/mysql.sock`.

  This value can be set at server startup with the `--socket` option.

- `-DWITH_ASAN=bool`

  Whether to enable AddressSanitizer, for compilers that support it. The default is off. This option was added in MySQL 5.5.35.

- `-DWITH_DEBUG=bool`

  Whether to include debugging support.

  Configuring MySQL with debugging support enables you to use the `--debug="d,parser_debug"` option when you start the server. This causes the Bison parser that is used to process SQL statements to dump a parser trace to the server's standard error output. Typically, this output is written to the error log.

  As of MySQL 5.5.55, enabling `WITH_DEBUG` also enables Debug Sync. For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

- `-DWITH_EMBEDDED_SERVER=bool`

  Whether to build the `libmysqld` embedded server library.

- `-DWITH_EMBEDDED_SHARED_LIBRARY=bool`

  Whether to build a shared `libmysqld` embedded server library. This option was added in MySQL 5.5.37.

- `-DWITH_EXTRA_CHARSETS=name`

  Which extra character sets to include:

  - `all`: All character sets. This is the default.
  - `complex`: Complex character sets.
  - `none`: No extra character sets.

- `-DWITH_LIBEDIT=bool`

  Whether to use the `libedit` library bundled with the distribution.

- `-DWITH_LIBWRAP=bool`

Whether to include `libwrap` (TCP wrappers) support.

- `-DWITH_READLINE=bool`

  Whether to use the `readline` library bundled with the distribution.

- `-DWITH_SSL=ssl_type`

  The type of SSL support to include, if any:

  - `no`: No SSL support. This is the default before MySQL 5.5.56. As of 5.5.56, this is no longer a permitted value and the default is `bundled`.
  - `yes`: Use the system SSL library if present, else the library bundled with the distribution.
  - `bundled`: Use the SSL library bundled with the distribution. This is the default as of MySQL 5.5.56.
  - `system`: Use the system SSL library.

  For information about using SSL support, see Section 6.4, “Using Encrypted Connections”.

- `-DWITH_UNIT_TESTS={ON|OFF}`

  If enabled, compile MySQL with unit tests. The default is ON unless the server is not being compiled.

- `-DWITH_UNIXODBC=1`

  Enables unixODBC support, for Connector/ODBC.

- `-DWITH_VALGRIND=bool`

  Whether to compile in the Valgrind header files, which exposes the Valgrind API to MySQL code. The default is `OFF`.

  To generate a Valgrind-aware debug build, `-DWITH_VALGRIND=1` normally is combined with `-DWITH_DEBUG=1`. See Building Debug Configurations.

- `-DWITH_ZLIB=zlib_type`

  Some features require that the server be built with compression library support, such as the `COMPRESS()` and `UNCOMPRESS()` functions, and compression of the client/server protocol. The `WITH_ZLIB` indicates the source of `zlib` support:

  - `bundled`: Use the `zlib` library bundled with the distribution. This is the default.
  - `system`: Use the system `zlib` library.

- `-DWITHOUT_SERVER=bool`

  Whether to build without the MySQL server. The default is `OFF`, which does build the server.

Compiler Flags

- `-DCMAKE_C_FLAGS="flags"`

  Flags for the C Compiler.

- `-DCMAKE_CXX_FLAGS="flags"`

  Flags for the C++ Compiler.

To specify your own C and C++ compiler flags, for flags that do not affect optimization, use the `CMAKE_C_FLAGS` and `CMAKE_CXX_FLAGS` CMake options.

When providing your own compiler flags, you might want to specify `CMAKE_BUILD_TYPE` as well.

For example, to create a 32-bit release build on a 64-bit Linux machine, do this:

```
shell> mkdir bld
shell> cd bld
shell> cmake .. -DCMAKE_C_FLAGS=-m32 \
         -DCMAKE_CXX_FLAGS=-m32 \
         -DCMAKE_BUILD_TYPE=RelWithDebInfo
```

If you set flags that affect optimization (`-O`*`number`*), you must set the `CMAKE_C_FLAGS_`*`build_type`* and/or `CMAKE_CXX_FLAGS_`*`build_type`* options, where *`build_type`* corresponds to the `CMAKE_BUILD_TYPE` value. To specify a different optimization for the default build type (`RelWithDebInfo`) set the `CMAKE_C_FLAGS_RELWITHDEBINFO` and `CMAKE_CXX_FLAGS_RELWITHDEBINFO` options. For example, to compile on Linux with `-O3` and with debug symbols, do this:

```
shell> cmake .. -DCMAKE_C_FLAGS_RELWITHDEBINFO="-O3 -g" \
         -DCMAKE_CXX_FLAGS_RELWITHDEBINFO="-O3 -g"
```

CMake Options for Compiling NDB Cluster

The following options are for use when building MySQL NDB Cluster 7.2 or later. These options are supported only with the MySQL NDB Cluster 7.2 and later NDB Cluster sources; they are not supported when using sources from the MySQL 5.5 Server tree.

- `-DMEMCACHED_HOME=`*`dir_name`*

  Perform the build using the memcached (version 1.6 or later) installed in the system directory indicated by *`dir_name`*. Files from this installation that are used in the build include the memcached binary, header files, and libraries, as well as the `memcached_utilities` library and the header file `engine_testapp.h`.

  You must leave this option unset when building `ndbmemcache` using the bundled memcached sources (`WITH_BUNDLED_MEMCACHED` option); in other words, the bundled sources are used by default).

  This option was added in MySQL NDB Cluster 7.2.2.

  While additional `CMake` options—such as for SASL authorization and for providing `dtrace` support—are available for use when compiling `memcached` from external sources, these options are currently not enabled for the `memcached` sources bundled with NDB Cluster.

- `-DWITH_BUNDLED_LIBEVENT={ON|OFF}`

  Use the `libevent` included in the NDB Cluster sources when building NDB Cluster with ndbmemcached support (MySQL NDB Cluster 7.2.2 and later). Enabled by default. OFF causes the system's libevent to be used instead.

- `-DWITH_BUNDLED_MEMCACHED={ON|OFF}`

  Build the memcached sources included in the NDB Cluster source tree (MySQL NDB Cluster 7.2.3 and later), then use the resulting memcached server when building the ndbmemcache engine. In this case, `make install` places the `memcached` binary in the installation `bin` directory, and the ndbmemcache engine shared library file `ndb_engine.so` in the installation `lib` directory.

  This option is ON by default.

- `-DWITH_CLASSPATH=path`

  Sets the classpath for building NDB Cluster Connector for Java. The default is empty. In MySQL NDB Cluster 7.2.9 and later, this option is ignored if `-DWITH_NDB_JAVA=OFF` is used.

- `-DWITH_ERROR_INSERT={ON|OFF}`

  Enables error injection in the `NDB` kernel. For testing only; not intended for use in building production binaries. The default is `OFF`.

- `-DWITH_NDBCLUSTER_STORAGE_ENGINE={ON|OFF}`

  Build and link in support for the `NDB` (`NDBCLUSTER`) storage engine in `mysqld`. The default is `ON`.

- `-DWITH_NDBCLUSTER={ON|OFF}`

  This is an alias for `WITH_NDBCLUSTER_STORAGE_ENGINE`.

- `-DWITH_NDBMTD={ON|OFF}`

  Build the multi-threaded data node executable `ndbmtd`. The default is `ON`.

- `-DWITH_NDB_BINLOG={ON|OFF}`

  Enable binary logging by default in the `mysqld` built using this option. ON by default.

- `-DWITH_NDB_DEBUG={ON|OFF}`

  Enable building the debug versions of the NDB Cluster binaries. OFF by default.

- `-DWITH_NDB_JAVA={ON|OFF}`

  Enable building NDB Cluster with Java support, including `ClusterJ`.

  This option was added in MySQL NDB Cluster 7.2.9, and is ON by default. If you do not wish to compile NDB Cluster with Java support, you must disable it explicitly by specifying `-DWITH_NDB_JAVA=OFF` when running `CMake`. Otherwise, if Java cannot be found, configuration of the build fails.

- `-DWITH_NDB_PORT=port`

  Causes the NDB Cluster management server (`ndb_mgmd`) that is built to use this *`port`* by default. If this option is unset, the resulting management server tries to use port 1186 by default.

- `-DWITH_NDB_TEST={ON|OFF}`

  If enabled, include a set of NDB API test programs. The default is OFF.

2.9.5 Dealing with Problems Compiling MySQL

The solution to many problems involves reconfiguring. If you do reconfigure, take note of the following:

- If `CMake` is run after it has previously been run, it may use information that was gathered during its previous invocation. This information is stored in `CMakeCache.txt`. When `CMake` starts up, it looks for that file and reads its contents if it exists, on the assumption that the information is still correct. That assumption is invalid when you reconfigure.
- Each time you run `CMake`, you must run `make` again to recompile. However, you may want to remove old object files from previous builds first because they were compiled using different configuration options.

To prevent old object files or configuration information from being used, run the following commands before re-running `CMake`:

On Unix:

```
shell> make clean
shell> rm CMakeCache.txt
```

On Windows:

```
shell> devenv MySQL.sln /clean
shell> del CMakeCache.txt
```

If you build outside of the source tree, remove and recreate your build directory before re-running `CMake`. For instructions on building outside of the source tree, see How to Build MySQL Server with CMake.

On some systems, warnings may occur due to differences in system include files. The following list describes other problems that have been found to occur most often when compiling MySQL:

- To define which C and C++ compilers to use, you can define the `CC` and `CXX` environment variables. For example:

  ```
  shell> CC=gcc
  shell> CXX=g++
  shell> export CC CXX
  ```

  To specify your own C and C++ compiler flags, use the `CMAKE_C_FLAGS` and `CMAKE_CXX_FLAGS` CMake options. See Compiler Flags.

  To see what flags you might need to specify, invoke `mysql_config` with the `--cflags` option.

- To see what commands are executed during the compile stage, after using `CMake` to configure MySQL, run `make VERBOSE=1` rather than just `make`.

- If compilation fails, check whether the `MYSQL_MAINTAINER_MODE` option is enabled. This mode causes compiler warnings to become errors, so disabling it may enable compilation to proceed.

- If your compile fails with errors such as any of the following, you must upgrade your version of `make` to GNU `make`:

  ```
  make: Fatal error in reader: Makefile, line 18:
  Badly formed macro assignment
  ```

  Or:

  ```
  make: file `Makefile' line 18: Must be a separator (:
  ```

  Or:

  ```
  pthread.h: No such file or directory
  ```

  Solaris and FreeBSD are known to have troublesome `make` programs.

  GNU `make` 3.75 is known to work.

- The `sql_yacc.cc` file is generated from `sql_yacc.yy`. Normally, the build process does not need to create `sql_yacc.cc` because MySQL comes with a pregenerated copy. However, if you do need to re-create it, you might encounter this error:

  ```
  ```

```
"sql_yacc.yy", line xxx fatal: default action causes potential...
```

This is a sign that your version of `yacc` is deficient. You probably need to install a recent version of `bison` (the GNU version of `yacc`) and use that instead.

Versions of `bison` older than 1.75 may report this error:

```
sql_yacc.yy:#####: fatal error: maximum table size (32767) exceeded
```

The maximum table size is not actually exceeded; the error is caused by bugs in older versions of `bison`.

For information about acquiring or updating tools, see the system requirements in Section 2.9, “Installing MySQL from Source”.

2.9.6 MySQL Configuration and Third-Party Tools

Third-party tools that need to determine the MySQL version from the MySQL source can read the `VERSION` file in the top-level source directory. The file lists the pieces of the version separately. For example, if the version is MySQL 5.7.4-m14, the file looks like this:

```
MYSQL_VERSION_MAJOR=5
MYSQL_VERSION_MINOR=7
MYSQL_VERSION_PATCH=4
MYSQL_VERSION_EXTRA=-m14
```

If the source is not for a General Availablility (GA) release, the `MYSQL_VERSION_EXTRA` value will be nonempty. For the example, the value corresponds to Milestone 14.

To construct a five-digit number from the version components, use this formula:

```
MYSQL_VERSION_MAJOR*10000 + MYSQL_VERSION_MINOR*100 + MYSQL_VERSION_PATCH
```

2.10 Postinstallation Setup and Testing

This section discusses tasks that you should perform after installing MySQL:

- If necessary, initialize the data directory and create the MySQL grant tables. For some MySQL installation methods, data directory initialization may be done for you automatically:
  - Installation on Windows
  - Installation on Linux using a server RPM distribution.
  - Installation using the native packaging system on many platforms, including Debian Linux, Ubuntu Linux, Gentoo Linux, and others.
  - Installation on OS X using a DMG distribution.

  For other platforms and installation types, including installation from generic binary and source distributions, you must initialize the data directory yourself. For instructions, see Section 2.10.1, “Initializing the Data Directory”.
- For instructions, see Section 2.10.2, “Starting the Server”, and Section 2.10.3, “Testing the Server”.
- Assign passwords to any initial accounts in the grant tables, if that was not already done during data directory initialization. Passwords prevent unauthorized access to the MySQL server. You may also wish to restrict access to test databases. For instructions, see Section 2.10.4, “Securing the Initial MySQL Accounts”.

- Optionally, arrange for the server to start and stop automatically when your system starts and stops. For instructions, see Section 2.10.5, “Starting and Stopping MySQL Automatically”.
- Optionally, populate time zone tables to enable recognition of named time zones. For instructions, see Section 10.6, “MySQL Server Time Zone Support”.

When you are ready to create additional user accounts, you can find information on the MySQL access control system and account management in Section 6.2, “The MySQL Access Privilege System”, and Section 6.3, “MySQL User Account Management”.

2.10.1 Initializing the Data Directory

After installing MySQL, you must initialize the data directory, including the tables in the `mysql` system database. For some MySQL installation methods, data directory initialization may be done automatically, as described in Section 2.10, “Postinstallation Setup and Testing”. For other installation methods, including installation from generic binary and source distributions, you must initialize the data directory yourself.

This section describes how to initialize the data directory on Unix and Unix-like systems. (For Windows, see Section 2.3.9, “Windows Postinstallation Procedures”.) For some suggested commands that you can use to test whether the server is accessible and working properly, see Section 2.10.3, “Testing the Server”.

In the examples shown here, the server runs under the user ID of the `mysql` login account. This assumes that such an account exists. Either create the account if it does not exist, or substitute the name of a different existing login account that you plan to use for running the server. For information about creating the account, see Creating a `mysql` System User and Group, in Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”.

1. Change location into the top-level directory of your MySQL installation, represented here by *`BASEDIR`*:

   ```
   shell> cd BASEDIR
   ```

   `BASEDIR` is likely to be something like `/usr/local/mysql` or `/usr/local`. The following steps assume that you have changed location to this directory.

   You will find several files and subdirectories in the *`BASEDIR`* directory. The most important for installation purposes are the `bin` and `scripts` subdirectories, which contain the server as well as client and utility programs.

2. If necessary, ensure that the distribution contents are accessible to `mysql`. If you installed the distribution as `mysql`, no further action is required. If you installed the distribution as `root`, its contents will be owned by `root`. Change its ownership to `mysql` by executing the following commands as `root` in the installation directory. The first command changes the owner attribute of the files to the `mysql` user. The second changes the group attribute to the `mysql` group.

   ```
   shell> chown -R mysql .
   shell> chgrp -R mysql .
   ```

3. If necessary, initialize the data directory, including the `mysql` database containing the initial MySQL grant tables that determine how users are permitted to connect to the server.

   Typically, data directory initialization need be done only the first time you install MySQL. If you are upgrading an existing installation, you should run `mysql_upgrade` instead (see Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”). However, the command that initializes the data directory does not overwrite any existing privilege tables, so it should be safe to run in any circumstances.

   ```
   shell> scripts/mysql_install_db --user=mysql
   ```

It is important to make sure that the database directories and files are owned by the `mysql` login account so that the server has read and write access to them when you run it later. To ensure this if you run `mysql_install_db` as `root`, include the `--user` option as shown. Otherwise, you should execute the program while logged in as `mysql`, in which case you can omit the `--user` option from the command.

The `mysql_install_db` command creates the server's data directory. Under the data directory, it creates directories for the `mysql` database that holds the grant tables and the `test` database that you can use to test MySQL. The program also creates privilege table entries for the initial account or accounts. `test_`. For a complete listing and description of the grant tables, see Section 6.2, "The MySQL Access Privilege System".

It might be necessary to specify other options such as `--basedir` or `--datadir` if `mysql_install_db` does not identify the correct locations for the installation directory or data directory. For example:

```
shell> scripts/mysql_install_db --user=mysql \
         --basedir=/opt/mysql/mysql \
         --datadir=/opt/mysql/mysql/data
```

If you do not want to have the `test` database, you can remove it after starting the server, using the instructions in Section 2.10.4, "Securing the Initial MySQL Accounts".

If you have trouble with `mysql_install_db` at this point, see Section 2.10.1.1, "Problems Running mysql_install_db".

4. After initializing the data directory, you can establish the final installation ownership settings. To leave the installation owned by `mysql`, no action is required here. Otherwise, most of the MySQL installation can be owned by `root` if you like. The exception is that the data directory must be owned by `mysql`. To accomplish this, run the following commands as `root` in the installation directory. For some distribution types, the data directory might be named `var` rather than `data`; adjust the second command accordingly.

   ```
   shell> chown -R root .
   shell> chown -R mysql data
   ```

   If the plugin directory (the directory named by the `plugin_dir` system variable) is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making the plugin directory read only to the server or by setting the `secure_file_priv` system variable at server startup to a directory where `SELECT` writes can be performed safely.

5. If you installed MySQL using a source distribution, you may want to optionally copy one of the provided configuration files from the `support-files` directory into your `/etc` directory. There are different sample configuration files for different use cases, server types, and CPU and RAM configurations. To use one of these standard files, copy it to `/etc/my.cnf`, or `/etc/mysql/my.cnf` and edit and check the configuration before starting your MySQL server for the first time.

   You can also create `my.cnf` yourself and place into it the options the server should use at startup. See Section 5.1.2, "Server Configuration Defaults".

   If you do not copy one of the standard configuration files or create your own, the MySQL server starts with its default settings.

6. If you want MySQL to start automatically when you boot your machine, see Section 2.10.5, "Starting and Stopping MySQL Automatically".

Data directory initialization creates time zone tables in the `mysql` database but does not populate them. To do so, use the instructions in Section 10.6, "MySQL Server Time Zone Support".

2.10.1.1 Problems Running mysql_install_db

The purpose of the `mysql_install_db` program is to initialize the data directory, including the tables in the `mysql` system database. It does not overwrite existing MySQL privilege tables, and it does not affect any other data.

To re-create your privilege tables, first stop the `mysqld` server if it is running. Then rename the `mysql` directory under the data directory to save it, and run `mysql_install_db`. Suppose that your current directory is the MySQL installation directory and that `mysql_install_db` is located in the `bin` directory and the data directory is named `data`. To rename the `mysql` database and re-run `mysql_install_db`, use these commands.

```
shell> mv data/mysql data/mysql.old
shell> scripts/mysql_install_db --user=mysql
```

When you run `mysql_install_db`, you might encounter the following problems:

- **`mysql_install_db` fails to install the grant tables**

  You may find that `mysql_install_db` fails to install the grant tables and terminates after displaying the following messages:

  ```
  Starting mysqld daemon with databases from XXXXXX
  mysqld ended
  ```

  In this case, you should examine the error log file very carefully. The log should be located in the directory `XXXXXX` named by the error message and should indicate why `mysqld` did not start. If you do not understand what happened, include the log when you post a bug report. See Section 1.6, “How to Report Bugs or Problems”.

- **There is a `mysqld` process running**

  This indicates that the server is running, in which case the grant tables have probably been created already. If so, there is no need to run `mysql_install_db` at all because it needs to be run only once, when you first install MySQL.

- **Installing a second `mysqld` server does not work when one server is running**

  This can happen when you have an existing MySQL installation, but want to put a new installation in a different location. For example, you might have a production installation, but you want to create a second installation for testing purposes. Generally the problem that occurs when you try to run a second server is that it tries to use a network interface that is in use by the first server. In this case, you should see one of the following error messages:

  ```
  Can't start server: Bind on TCP/IP port:
  Address already in use
  Can't start server: Bind on unix socket...
  ```

  For instructions on setting up multiple servers, see Section 5.6, “Running Multiple MySQL Instances on One Machine”.

- **You do not have write access to the `/tmp` directory**

  If you do not have write access to create temporary files or a Unix socket file in the default location (the `/tmp` directory) or the `TMPDIR` environment variable, if it has been set, an error occurs when you run `mysql_install_db` or the `mysqld` server.

  You can specify different locations for the temporary directory and Unix socket file by executing these commands prior to starting `mysql_install_db` or `mysqld`, where *`some_tmp_dir`* is the full path name to some directory for which you have write permission:

```
shell> TMPDIR=/some_tmp_dir/
shell> MYSQL_UNIX_PORT=/some_tmp_dir/mysql.sock
shell> export TMPDIR MYSQL_UNIX_PORT
```

Then you should be able to run `mysql_install_db` and start the server with these commands:

```
shell> scripts/mysql_install_db --user=mysql
shell> bin/mysqld_safe --user=mysql &
```

If `mysql_install_db` is located in the `scripts` directory, modify the first command to `scripts/mysql_install_db`.

See Section B.5.3.6, “How to Protect or Change the MySQL Unix Socket File”, and Section 4.9, “MySQL Program Environment Variables”.

There are some alternatives to running the `mysql_install_db` program provided in the MySQL distribution:

- If you want the initial privileges to be different from the standard defaults, use account-management statements such as `CREATE USER`, `GRANT`, and `REVOKE` to change the privileges *after* the grant tables have been set up. In other words, run `mysql_install_db`, and then use `mysql -u root mysql` to connect to the server as the MySQL `root` user so that you can issue the necessary statements. (See Section 13.7.1, “Account Management Statements”.)

  To install MySQL on several machines with the same privileges, put the `CREATE USER`, `GRANT`, and `REVOKE` statements in a file and execute the file as a script using `mysql` after running `mysql_install_db`. For example:

  ```
  shell> scripts/mysql_install_db --user=mysql
  shell> bin/mysql -u root < your_script_file
  ```

  This enables you to avoid issuing the statements manually on each machine.

- It is possible to re-create the grant tables completely after they have previously been created. You might want to do this if you are just learning how to use `CREATE USER`, `GRANT`, and `REVOKE` and have made so many modifications after running `mysql_install_db` that you want to wipe out the tables and start over.

  To re-create the grant tables, stop the server if it is running and remove the `mysql` database directory. Then run `mysql_install_db` again.

2.10.2 Starting the Server

This section describes how start the server on Unix and Unix-like systems. (For Windows, see Section 2.3.7.4, “Starting the Server for the First Time”.) For some suggested commands that you can use to test whether the server is accessible and working properly, see Section 2.10.3, “Testing the Server”.

Start the MySQL server like this:

```
shell> bin/mysqld_safe --user=mysql &
```

It is important that the MySQL server be run using an unprivileged (non-`root`) login account. To ensure this if you run `mysqld_safe` as `root`, include the `--user` option as shown. Otherwise, execute the program while logged in as `mysql`, in which case you can omit the `--user` option from the command.

For further instructions for running MySQL as an unprivileged user, see Section 6.1.5, “How to Run MySQL as a Normal User”.

If the command fails immediately and prints `mysqld ended`, look for information in the error log (which by default is the *`host_name`*`.err` file in the data directory).

If the server is unable to access the data directory it starts or read the grant tables in the `mysql` database, it writes a message to its error log. Such problems can occur if you neglected to create the grant tables by initializing the data directory before proceeding to this step, or if you ran the command that initializes the data directory without the `--user` option. Remove the `data` directory and run the command with the `--user` option.

If you have other problems starting the server, see Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”. For more information about `mysqld_safe`, see Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”.

You can set up new accounts using the `bin/mysql_setpermission` script if you install the `DBI` and `DBD::mysql` Perl modules. See Section 4.6.13, “`mysql_setpermission` — Interactively Set Permissions in Grant Tables”. For Perl module installation instructions, see Section 2.12, “Perl Installation Notes”.

If you would like to use `mysqlaccess` and have the MySQL distribution in some nonstandard location, you must change the location where `mysqlaccess` expects to find the `mysql` client. Edit the `bin/mysqlaccess` script at approximately line 18. Search for a line that looks like this:

```
$MYSQL     = '/usr/local/bin/mysql';    # path to mysql executable
```

Change the path to reflect the location where `mysql` actually is stored on your system. If you do not do this, a `Broken pipe` error will occur when you run `mysqlaccess`.

2.10.2.1 Troubleshooting Problems Starting the MySQL Server

This section provides troubleshooting suggestions for problems starting the server. For additional suggestions for Windows systems, see Section 2.3.8, “Troubleshooting a Microsoft Windows MySQL Server Installation”.

If you have problems starting the server, here are some things to try:

- Check the error log to see why the server does not start.
- Specify any special options needed by the storage engines you are using.
- Make sure that the server knows where to find the data directory.
- Make sure that the server can access the data directory. The ownership and permissions of the data directory and its contents must be set such that the server can read and modify them.
- Verify that the network interfaces the server wants to use are available.

Some storage engines have options that control their behavior. You can create a `my.cnf` file and specify startup options for the engines that you plan to use. If you are going to use storage engines that support transactional tables (`InnoDB`, `NDB`), be sure that you have them configured the way you want before starting the server:

If you are using `InnoDB` tables, see Section 14.9, “InnoDB Configuration”.

Storage engines will use default option values if you specify none, but it is recommended that you review the available options and specify explicit values for those for which the defaults are not appropriate for your installation.

When the `mysqld` server starts, it changes location to the data directory. This is where it expects to find databases and where it expects to write log files. The server also writes the pid (process ID) file in the data directory.

The data directory location is hardwired in when the server is compiled. This is where the server looks for the data directory by default. If the data directory is located somewhere else on your system, the

server will not work properly. You can determine what the default path settings are by invoking `mysqld` with the `--verbose` and `--help` options.

If the default locations do not match the MySQL installation layout on your system, you can override them by specifying options to `mysqld` or `mysqld_safe` on the command line or in an option file.

To specify the location of the data directory explicitly, use the `--datadir` option. However, normally you can tell `mysqld` the location of the base directory under which MySQL is installed and it looks for the data directory there. You can do this with the `--basedir` option.

To check the effect of specifying path options, invoke `mysqld` with those options followed by the `--verbose` and `--help` options. For example, if you change location into the directory where `mysqld` is installed and then run the following command, it shows the effect of starting the server with a base directory of `/usr/local`:

```
shell> ./mysqld --basedir=/usr/local --verbose --help
```

You can specify other options such as `--datadir` as well, but `--verbose` and `--help` must be the last options.

Once you determine the path settings you want, start the server without `--verbose` and `--help`.

If `mysqld` is currently running, you can find out what path settings it is using by executing this command:

```
shell> mysqladmin variables
```

Or:

```
shell> mysqladmin -h host_name variables
```

`host_name` is the name of the MySQL server host.

If you get `Errcode 13` (which means `Permission denied`) when starting `mysqld`, this means that the privileges of the data directory or its contents do not permit server access. In this case, you change the permissions for the involved files and directories so that the server has the right to use them. You can also start the server as `root`, but this raises security issues and should be avoided.

Change location into the data directory and check the ownership of the data directory and its contents to make sure the server has access. For example, if the data directory is `/usr/local/mysql/var`, use this command:

```
shell> ls -la /usr/local/mysql/var
```

If the data directory or its files or subdirectories are not owned by the login account that you use for running the server, change their ownership to that account. If the account is named `mysql`, use these commands:

```
shell> chown -R mysql /usr/local/mysql/var
shell> chgrp -R mysql /usr/local/mysql/var
```

Even with correct ownership, MySQL might fail to start up if there is other security software running on your system that manages application access to various parts of the file system. In this case, reconfigure that software to enable `mysqld` to access the directories it uses during normal operation.

If the server fails to start up correctly, check the error log. Log files are located in the data directory (typically `C:\Program Files\MySQL\MySQL Server 5.5\data` on Windows, `/usr/local/mysql/data` for a Unix/Linux binary distribution, and `/usr/local/var` for a Unix/Linux source distribution). Look in the data directory for files with names of the form *`host_name`*`.err` and *`host_name`*`.log`, where *`host_name`* is the name of your server host. Then examine the last few lines of these files. You can use `tail` to display them:

```
shell> tail host_name.err
shell> tail host_name.log
```

The error log should contain information that indicates why the server could not start.

If either of the following errors occur, it means that some other program (perhaps another `mysqld` server) is using the TCP/IP port or Unix socket file that `mysqld` is trying to use:

```
Can't start server: Bind on TCP/IP port: Address already in use
Can't start server: Bind on unix socket...
```

Use `ps` to determine whether you have another `mysqld` server running. If so, shut down the server before starting `mysqld` again. (If another server is running, and you really want to run multiple servers, you can find information about how to do so in Section 5.6, “Running Multiple MySQL Instances on One Machine”.)

If no other server is running, try to execute the command `telnet your_host_name tcp_ip_port_number`. (The default MySQL port number is 3306.) Then press Enter a couple of times. If you do not get an error message like `telnet: Unable to connect to remote host: Connection refused`, some other program is using the TCP/IP port that `mysqld` is trying to use. You will need to track down what program this is and disable it, or else tell `mysqld` to listen to a different port with the `--port` option. In this case, you will also need to specify the port number for client programs when connecting to the server using TCP/IP.

Another reason the port might be inaccessible is that you have a firewall running that blocks connections to it. If so, modify the firewall settings to permit access to the port.

If the server starts but you cannot connect to it, you should make sure that you have an entry in `/etc/hosts` that looks like this:

```
127.0.0.1       localhost
```

If you cannot get `mysqld` to start, you can try to make a trace file to find the problem by using the `--debug` option. See Section 24.5.3, “The DBUG Package”.

2.10.3 Testing the Server

After the data directory is initialized and you have started the server, perform some simple tests to make sure that it works satisfactorily. This section assumes that your current location is the MySQL installation directory and that it has a `bin` subdirectory containing the MySQL programs used here. If that is not true, adjust the command path names accordingly.

Alternatively, add the `bin` directory to your `PATH` environment variable setting. That enables your shell (command interpreter) to find MySQL programs properly, so that you can run a program by typing only its name, not its path name. See Section 4.2.10, “Setting Environment Variables”.

Use `mysqladmin` to verify that the server is running. The following commands provide simple tests to check whether the server is up and responding to connections:

```
shell> bin/mysqladmin version
shell> bin/mysqladmin variables
```

If you cannot connect to the server, specify a `-u root` option to connect as `root`. If you have assigned a password for the `root` account already, you'll also need to specify `-p` on the command line and enter the password when prompted. For example:

```
shell> bin/mysqladmin -u root -p version
Enter password: (enter root password here)
```

The output from `mysqladmin version` varies slightly depending on your platform and version of MySQL, but should be similar to that shown here:

```
shell> bin/mysqladmin version
mysqladmin  Ver 14.12 Distrib 5.5.60, for pc-linux-gnu on i686
...

Server version          5.5.60
Protocol version        10
Connection              Localhost via UNIX socket
UNIX socket             /var/lib/mysql/mysql.sock
Uptime:                 14 days 5 hours 5 min 21 sec

Threads: 1  Questions: 366  Slow queries: 0
Opens: 0  Flush tables: 1  Open tables: 19
Queries per second avg: 0.000
```

To see what else you can do with `mysqladmin`, invoke it with the `--help` option.

Verify that you can shut down the server (include a `-p` option if the `root` account has a password already):

```
shell> bin/mysqladmin -u root shutdown
```

Verify that you can start the server again. Do this by using `mysqld_safe` or by invoking `mysqld` directly. For example:

```
shell> bin/mysqld_safe --user=mysql &
```

If `mysqld_safe` fails, see Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”.

Run some simple tests to verify that you can retrieve information from the server. The output should be similar to that shown here.

Use `mysqlshow` to see what databases exist:

```
shell> bin/mysqlshow
+--------------------+
|     Databases      |
+--------------------+
| information_schema |
| mysql              |
| performance_schema |
| test               |
+--------------------+
```

The list of installed databases may vary, but will always include the minimum of `mysql` and `information_schema`.

If you specify a database name, `mysqlshow` displays a list of the tables within the database:

```
shell> bin/mysqlshow mysql
Database: mysql
+---------------------------+
|          Tables           |
+---------------------------+
| columns_priv              |
| db                        |
| event                     |
| func                      |
| general_log               |
| help_category             |
| help_keyword              |
| help_relation             |
| help_topic                |
| host                      |
```

```
| ndb_binlog_index          |
| plugin                    |
| proc                      |
| procs_priv                |
| proxies_priv              |
| servers                   |
| slow_log                  |
| tables_priv               |
| time_zone                 |
| time_zone_leap_second     |
| time_zone_name            |
| time_zone_transition      |
| time_zone_transition_type |
| user                      |
+---------------------------+
```

Use the `mysql` program to select information from a table in the `mysql` database:

```
shell> bin/mysql -e "SELECT User, Host, plugin FROM mysql.user" mysql
+------+-----------+-----------------------+
| User | Host      | plugin                |
+------+-----------+-----------------------+
| root | localhost | mysql_native_password |
+------+-----------+-----------------------+
```

At this point, your server is running and you can access it. To tighten security if you have not yet assigned passwords to the initial account or accounts, follow the instructions in Section 2.10.4, “Securing the Initial MySQL Accounts”.

For more information about `mysql`, `mysqladmin`, and `mysqlshow`, see Section 4.5.1, “`mysql` — The MySQL Command-Line Tool”, Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”, and Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”.

2.10.4 Securing the Initial MySQL Accounts

The MySQL installation process involves initializing the data directory, including the `mysql` database containing the grant tables that define MySQL accounts. For details, see Section 2.10, “Postinstallation Setup and Testing”.

This section describes how to assign passwords to the initial accounts created during the MySQL installation procedure, if you have not already done so.

The `mysql.user` grant table defines the initial MySQL user accounts and their access privileges:

- Some accounts have the user name `root`. These are superuser accounts that have all privileges and can do anything. If these `root` accounts have empty passwords, anyone can connect to the MySQL server as `root` *without a password* and be granted all privileges.

  - On Windows, `root` accounts are created that permit connections from the local host only. Connections can be made by specifying the host name `localhost`, the IP address `127.0.0.1`, or the IPv6 address `::1`. If the user selects the **Enable root access from remote machines** option during installation, the Windows installer creates another `root` account that permits connections from any host.

  - On Unix, each `root` account permits connections from the local host. Connections can be made by specifying the host name `localhost`, the IP address `127.0.0.1`, the IPv6 address `::1`, or the actual host name or IP address.

  An attempt to connect to the host `127.0.0.1` normally resolves to the `localhost` account. However, this fails if the server is run with the `--skip-name-resolve` option, so the `127.0.0.1` account is useful in that case. The `::1` account is used for IPv6 connections.

- If accounts for anonymous users were created, these have an empty user name. The anonymous accounts have no password, so anyone can use them to connect to the MySQL server.

- On Windows, there is one anonymous account that permits connections from the local host. Connections can be made by specifying a host name of `localhost`.
- On Unix, each anonymous account permits connections from the local host. Connections can be made by specifying a host name of `localhost` for one of the accounts, or the actual host name or IP address for the other.
- The `'root'@'localhost'` account also has a row in the `mysql.proxies_priv` table that enables granting the `PROXY` privilege for `''@''`, that is, for all users and all hosts. This enables `root` to set up proxy users, as well as to delegate to other accounts the authority to set up proxy users. See Section 6.3.7, “Proxy Users”.

To display which accounts exist in the `mysql.user` table and check whether their passwords are empty, use the following statement:

```
mysql> SELECT User, Host, Password FROM mysql.user;
+------+--------------------+----------+
| User | Host               | Password |
+------+--------------------+----------+
| root | localhost          |          |
| root | myhost.example.com |          |
| root | 127.0.0.1          |          |
| root | ::1                |          |
|      | localhost          |          |
|      | myhost.example.com |          |
+------+--------------------+----------+
```

This output indicates that there are several `root` and anonymous-user accounts, none of which have passwords. The output might differ on your system, but the presence of accounts with empty passwords means that your MySQL installation is unprotected until you do something about it:

- Assign a password to each MySQL `root` account that does not have one.
- To prevent clients from connecting as anonymous users without a password, either assign a password to each anonymous account or remove the accounts.

In addition, the `mysql.db` table contains rows that permit all accounts to access the `test` database and other databases with names that start with `test_`. This is true even for accounts that otherwise have no special privileges such as the default anonymous accounts. This is convenient for testing but inadvisable on production servers. Administrators who want database access restricted only to accounts that have permissions granted explicitly for that purpose should remove these `mysql.db` table rows.

The following instructions describe how to set up passwords for the initial MySQL accounts, first for the `root` accounts, then for the anonymous accounts. The instructions also cover how to remove anonymous accounts, should you prefer not to permit anonymous access at all, and describe how to remove permissive access to test databases. Replace *`new_password`* in the examples with the password that you want to use. Replace *`host_name`* with the name of the server host. You can determine this name from the output of the preceding `SELECT` statement. For the output shown, *`host_name`* is `myhost.example.com`.

Note

For additional information about setting passwords, see Section 6.3.5, “Assigning Account Passwords”. If you forget your `root` password after setting it, see Section B.5.3.2, “How to Reset the Root Password”.

To set up additional accounts, see Section 6.3.2, “Adding User Accounts”.

You might want to defer setting the passwords until later, to avoid the need to specify them while you perform additional setup or testing. However, be sure to set them before using your installation for production purposes.

Note

On Windows, you can also perform the process described in this section using the Configuration Wizard (see Section 2.3.6.11, "The Security Options Dialog"). On all platforms, the MySQL distribution includes `mysql_secure_installation`, a command-line utility that automates much of the process of securing a MySQL installation. MySQL Workbench is available on all platforms, and also offers the ability to manage user accounts (see Chapter 26, *MySQL Workbench*).

Assigning root Account Passwords

A `root` account password can be set several ways. The following discussion demonstrates three methods:

- Use the `SET PASSWORD` statement
- Use the `UPDATE` statement
- Use the `mysqladmin` command-line client program

To assign passwords using `SET PASSWORD`, connect to the server as `root` and issue a `SET PASSWORD` statement for each `root` account listed in the `mysql.user` table.

For Windows, do this:

```
shell> mysql -u root
mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'127.0.0.1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'::1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'%' = PASSWORD('new_password');
```

The last statement is unnecessary if the `mysql.user` table has no `root` account with a host value of `%`.

For Unix, do this:

```
shell> mysql -u root
mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'127.0.0.1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'::1' = PASSWORD('new_password');
mysql> SET PASSWORD FOR 'root'@'host_name' = PASSWORD('new_password');
```

You can also use a single statement that assigns a password to all `root` accounts by using `UPDATE` to modify the `mysql.user` table directly. This method works on any platform:

```
shell> mysql -u root
mysql> UPDATE mysql.user SET Password = PASSWORD('new_password')
    ->     WHERE User = 'root';
mysql> FLUSH PRIVILEGES;
```

The `FLUSH` statement causes the server to reread the grant tables. Without it, the password change remains unnoticed by the server until you restart it.

To assign passwords to the `root` accounts using `mysqladmin`, execute the following commands:

```
shell> mysqladmin -u root password "new_password"
shell> mysqladmin -u root -h host_name password "new_password"
```

Those commands apply both to Windows and to Unix. The double quotation marks around the password are not always necessary, but you should use them if the password contains spaces or other characters that are special to your command interpreter.

The `mysqladmin` method of setting the `root` account passwords does not work for the `'root'@'127.0.0.1'` or `'root'@'::1'` account. Use the `SET PASSWORD` method shown earlier.

After the `root` passwords have been set, you must supply the appropriate password whenever you connect as `root` to the server. For example, to shut down the server with `mysqladmin`, use this command:

```
shell> mysqladmin -u root -p shutdown
Enter password: (enter root password here)
```

The `mysql` commands in the following instructions include a `-p` option based on the assumption that you have assigned the `root` account passwords using the preceding instructions and must specify that password when connecting to the server.

Assigning Anonymous Account Passwords

To assign passwords to the anonymous accounts, connect to the server as `root`, then use either `SET PASSWORD` or `UPDATE`.

To use `SET PASSWORD` on Windows, do this:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> SET PASSWORD FOR ''@'localhost' = PASSWORD('new_password');
```

To use `SET PASSWORD` on Unix, do this:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> SET PASSWORD FOR ''@'localhost' = PASSWORD('new_password');
mysql> SET PASSWORD FOR ''@'host_name' = PASSWORD('new_password');
```

To set the anonymous-user account passwords with a single `UPDATE` statement, do this (on any platform):

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> UPDATE mysql.user SET Password = PASSWORD('new_password')
    ->     WHERE User = '';
mysql> FLUSH PRIVILEGES;
```

The `FLUSH` statement causes the server to reread the grant tables. Without it, the password change remains unnoticed by the server until you restart it.

Removing Anonymous Accounts

If you prefer to remove any anonymous accounts rather than assigning them passwords, do so as follows on Windows:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DROP USER ''@'localhost';
```

On Unix, remove the anonymous accounts like this:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DROP USER ''@'localhost';
mysql> DROP USER ''@'host_name';
```

Securing Test Databases

By default, the `mysql.db` table contains rows that permit access by any user to the `test` database and other databases with names that start with `test_`. (These rows have an empty `User` column value, which for access-checking purposes matches any user name.) This means that such databases can be used even by accounts that otherwise possess no privileges. If you want to remove any-user access to test databases, do so as follows:

```
shell> mysql -u root -p
Enter password: (enter root password here)
mysql> DELETE FROM mysql.db WHERE Db LIKE 'test%';
mysql> FLUSH PRIVILEGES;
```

The `FLUSH` statement causes the server to reread the grant tables. Without it, the privilege change remains unnoticed by the server until you restart it.

With the preceding change, only users who have global database privileges or privileges granted explicitly for the `test` database can use it. However, if you prefer that the database not exist at all, drop it:

```
mysql> DROP DATABASE test;
```

2.10.5 Starting and Stopping MySQL Automatically

This section discusses methods for starting and stopping the MySQL server.

Generally, you start the `mysqld` server in one of these ways:

- Invoke `mysqld` directly. This works on any platform.
- On Windows, you can set up a MySQL service that runs automatically when Windows starts. See Section 2.3.7.7, “Starting MySQL as a Windows Service”.
- On Unix and Unix-like systems, you can invoke `mysqld_safe`, which tries to determine the proper options for `mysqld` and then runs it with those options. See Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”.
- On systems that use System V-style run directories (that is, `/etc/init.d` and run-level specific directories), invoke `mysql.server`. This script is used primarily at system startup and shutdown. It usually is installed under the name `mysql`. The `mysql.server` script starts the server by invoking `mysqld_safe`. See Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”.
- On OS X, install a launchd daemon to enable automatic MySQL startup at system startup. The daemon starts the server by invoking `mysqld_safe`. For details, see Section 2.4.3, “Installing a MySQL Launch Daemon”. A MySQL Preference Pane also provides control for starting and stopping MySQL through the System Preferences. See Section 2.4.4, “Installing and Using the MySQL Preference Pane”.
- On Solaris, use the service management framework (SMF) system to initiate and control MySQL startup.

The `mysqld_safe` and `mysql.server` scripts, Solaris SMF, and the OS X Startup Item (or MySQL Preference Pane) can be used to start the server manually, or automatically at system startup time. `mysql.server` and the Startup Item also can be used to stop the server.

The following table shows which option groups the server and startup scripts read from option files.

Table 2.15 MySQL Startup Scripts and Supported Server Option Groups

Script	Option Groups
`mysqld`	`[mysqld]`, `[server]`, `[mysqld-major_version]`
`mysqld_safe`	`[mysqld]`, `[server]`, `[mysqld_safe]`

Script	Option Groups
`mysql.server`	`[mysqld]`, `[mysql.server]`, `[server]`

`[mysqld-major_version]` means that groups with names like `[mysqld-5.1]` and `[mysqld-5.5]` are read by servers having versions 5.1.x, 5.5.x, and so forth. This feature can be used to specify options that can be read only by servers within a given release series.

For backward compatibility, `mysql.server` also reads the `[mysql_server]` group and `mysqld_safe` also reads the `[safe_mysqld]` group. However, you should update your option files to use the `[mysql.server]` and `[mysqld_safe]` groups instead.

For more information on MySQL configuration files and their structure and contents, see Section 4.2.6, “Using Option Files”.

2.11 Upgrading or Downgrading MySQL

This section describes the steps to upgrade or downgrade a MySQL installation.

Upgrading is a common procedure, as you pick up bug fixes within the same MySQL release series or significant features between major MySQL releases. You perform this procedure first on some test systems to make sure everything works smoothly, and then on the production systems.

Downgrading is less common. Typically, you undo an upgrade because of some compatibility or performance issue that occurs on a production system, and was not uncovered during initial upgrade verification on the test systems. As with the upgrade procedure, perform and verify the downgrade procedure on some test systems first, before using it on a production system.

2.11.1 Upgrading MySQL

This section describes how to upgrade to a new MySQL version.

- Upgrade Methods
- Upgrade Paths
- Before You Begin
- In-Place Upgrade
- Logical Upgrade
- Upgrade Troubleshooting

Note

In the following discussion, MySQL commands that must be run using a MySQL account with administrative privileges include `-u root` on the command line to specify the MySQL `root` user. Commands that require a password for `root` also include a `-p` option. Because `-p` is followed by no option value, such commands prompt for the password. Type the password when prompted and press Enter.

SQL statements can be executed using the `mysql` command-line client (connect as `root` to ensure that you have the necessary privileges).

Upgrade Methods

Supported upgrade methods include:

- *In-Place Upgrade*: Involves shutting down the old MySQL version, replacing the old MySQL binaries or packages with the new ones, restarting MySQL on the existing data directory, and running `mysql_upgrade`.

- *Logical Upgrade*: Involves exporting existing data from the old MySQL version using `mysqldump`, installing the new MySQL version, loading the dump file into the new MySQL version, and running `mysql_upgrade`.

Note

MySQL recommends a `mysqldump` upgrade when upgrading from a previous release. For example, use this method when upgrading from 5.1 to 5.5.

For in-place and logical upgrade procedures, see In-Place Upgrade, and Logical Upgrade.

If you run MySQL Server on Windows, see Section 2.3.10, “Upgrading MySQL on Windows”.

Upgrade Paths

- Upgrade is only supported between General Availability (GA) releases.
- Upgrade from MySQL 5.1 to 5.5 is supported. Upgrading to the latest release is recommended before upgrading to the next version. For example, upgrade to the latest MySQL 5.1 release before upgrading to MySQL 5.5.
- Upgrade that skips versions is not supported. For example, upgrading directly from MySQL 5.0 to 5.5 is not supported.
- Upgrade within a release series is supported. For example, upgrading from MySQL 5.5.*x* to 5.5.*y* is supported. Skipping a release is also supported. For example, upgrading from MySQL 5.5.*x* to 5.5.*z* is supported.

Before You Begin

Before upgrading, review the following information and perform the recommended steps:

- Before upgrading, protect your data by creating a backup of your current databases and log files. The backup should include the `mysql` system database, which contains the MySQL system tables. See Section 7.2, “Database Backup Methods”.
- Review the Release Notes which provide information about features that are new in the MySQL 5.5 or differ from those found in earlier MySQL releases. Some of these changes may result in incompatibilities.

  For a description of MySQL server features that have been removed in MySQL 5.5, see Features Removed in MySQL 5.5. An upgrade requires changes with respect to those features if you use any of them.
- Review Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”. This section describes changes that may require action before or after upgrading.
- If you use replication, review Section 17.4.3, “Upgrading a Replication Setup”.
- If you use XA transactions with `InnoDB`, run `XA RECOVER` before upgrading to check for uncommitted XA transactions. If results are returned, either commit or rollback the XA transactions by issuing an `XA COMMIT` or `XA ROLLBACK` statement.
- If your MySQL installation contains a large amount of data that might take a long time to convert after an in-place upgrade, you might find it useful to create a “dummy” database instance for assessing what conversions might be needed and the work involved to perform them. Make a copy of your MySQL instance that contains a full copy of the `mysql` database, plus all other databases without data. Run your upgrade procedure on this dummy instance to see what actions might be needed so that you can better evaluate the work involved when performing actual data conversion on your original database instance.

- Rebuilding and reinstalling MySQL language interfaces is recommended whenever you install or upgrade to a new release of MySQL. This applies to MySQL interfaces such as PHP `mysql` extensions, the Perl `DBD::mysql` module, and the Python `MySQLdb` module.

In-Place Upgrade

This section describes how to perform an in-place upgrade. Review Before you Begin before proceeding.

Note

If you upgrade an installation originally produced by installing multiple RPM packages, upgrade all the packages, not just some. For example, if you previously installed the server and client RPMs, do not upgrade just the server RPM.

To perform an in-place upgrade:

1. Review the changes described in Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5” for steps to be performed before upgrading.

2. If you use `InnoDB`, configure MySQL to perform a slow shutdown by setting `innodb_fast_shutdown` to `0`. For example:

   ```
   mysql -u root -p --execute="SET GLOBAL innodb_fast_shutdown=0"
   ```

   With a slow shutdown, `InnoDB` performs a full purge and change buffer merge before shutting down, which ensures that data files are fully prepared in case of file format differences between releases.

3. Shut down the old MySQL server. For example:

   ```
   mysqladmin -u root -p shutdown
   ```

4. Upgrade the MySQL binary installation or packages. If upgrading a binary installation, unpack the new MySQL binary distribution package. See Obtain and Unpack the Distribution. For package-based installations, replace the old packages with the new ones.

5. Start the MySQL 5.5 server, using the existing data directory. For example:

   ```
   mysqld_safe --user=mysql --datadir=/path/to/existing-datadir
   ```

6. Run `mysql_upgrade`. For example:

   ```
   mysql_upgrade -u root -p
   ```

   `mysql_upgrade` examines all tables in all databases for incompatibilities with the current version of MySQL. `mysql_upgrade` also upgrades the `mysql` system database so that you can take advantage of new privileges or capabilities.

   Note

   `mysql_upgrade` does not upgrade the contents of the help tables. For upgrade instructions, see Section 5.1.10, “Server-Side Help”.

7. Shut down and restart the MySQL server to ensure that any changes made to the system tables take effect. For example:

   ```
   mysqladmin -u root -p shutdown
   ```

```
mysqld_safe --user=mysql --datadir=/path/to/existing-datadir
```

Logical Upgrade

This section describes how to perform a logical upgrade. Review Before you Begin before proceeding.

To perform a logical upgrade:

1. Review the changes described in Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5” for steps to be performed before upgrading.
2. Export your existing data from the previous MySQL version:

```
mysqldump -u root -p
  --add-drop-table --routines --events
  --all-databases --force > data-for-upgrade.sql
```

Note

Use the `--routines` and `--events` options with `mysqldump` (as shown above) if your databases include stored programs. The `--all-databases` option includes all databases in the dump, including the `mysql` database that holds the system tables.

3. Shut down the old MySQL server. For example:

```
mysqladmin -u root -p shutdown
```

4. Install MySQL 5.5. For installation instructions, see Chapter 2, *Installing and Upgrading MySQL*.
5. Initialize a new data directory, as described at Section 2.10.1, “Initializing the Data Directory”. For example:

```
scripts/mysql_install_db --user=mysql --datadir=/path/to/5.5-datadir
```

6. Start the MySQL 5.5 server, using the new data directory. For example:

```
mysqld_safe --user=mysql --datadir=/path/to/5.5-datadir
```

7. Load the previously created dump file into the new MySQL server. For example:

```
mysql -u root -p --force < data-for-upgrade.sql
```

8. Run `mysql_upgrade`. For example:

```
mysql_upgrade -u root -p
```

`mysql_upgrade` examines all tables in all databases for incompatibilities with the current version of MySQL. `mysql_upgrade` also upgrades the `mysql` system database so that you can take advantage of new privileges or capabilities.

Note

`mysql_upgrade` does not upgrade the contents of the help tables. For upgrade instructions, see Section 5.1.10, “Server-Side Help”.

9. Shut down and restart the MySQL server to ensure that any changes made to the system tables take effect. For example:

```
mysqladmin -u root -p shutdown
mysqld_safe --user=mysql --datadir=/path/to/5.5-datadir
```

Upgrade Troubleshooting

- If problems occur, such as that the new `mysqld` server does not start or that you cannot connect without a password, verify that you do not have an old `my.cnf` file from your previous installation. You can check this with the `--print-defaults` option (for example, `mysqld --print-defaults`). If this command displays anything other than the program name, you have an active `my.cnf` file that affects server or client operation.
- If, after an upgrade, you experience problems with compiled client programs, such as `Commands out of sync` or unexpected core dumps, you probably have used old header or library files when compiling your programs. In this case, check the date for your `mysql.h` file and `libmysqlclient.a` library to verify that they are from the new MySQL distribution. If not, recompile your programs with the new headers and libraries. Recompilation might also be necessary for programs compiled against the shared client library if the library major version number has changed (for example, from `libmysqlclient.so.15` to `libmysqlclient.so.16`).
- If you have created a user-defined function (UDF) with a given name and upgrade MySQL to a version that implements a new built-in function with the same name, the UDF becomes inaccessible. To correct this, use `DROP FUNCTION` to drop the UDF, and then use `CREATE FUNCTION` to re-create the UDF with a different nonconflicting name. The same is true if the new version of MySQL implements a built-in function with the same name as an existing stored function. See Section 9.2.4, “Function Name Parsing and Resolution”, for the rules describing how the server interprets references to different kinds of functions.

2.11.1.1 Changes Affecting Upgrades to MySQL 5.5

Before upgrading to MySQL 5.5, review the changes described in this section to identify upgrade issues that apply to your current MySQL installation and applications.

Note

In addition to the changes outlined in this section, review the Release Notes and other important information outlined in Before You Begin.

Changes marked as either **Known issue** or **Incompatible change** are incompatibilities with earlier versions of MySQL, and may require your attention *before you upgrade*. Our aim is to avoid these changes, but occasionally they are necessary to correct problems that would be worse than an incompatibility between releases. If any upgrade issue applicable to your installation involves an incompatibility that requires special handling, follow the instructions given in the incompatibility description. Sometimes this involves dumping and reloading tables, or use of a statement such as `CHECK TABLE` or `REPAIR TABLE`.

For dump and reload instructions, see Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”. Any procedure that involves `REPAIR TABLE` with the `USE_FRM` option *must* be done before upgrading. Use of this statement with a version of MySQL different from the one used to create the table (that is, using it after upgrading) may damage the table. See Section 13.7.2.5, “REPAIR TABLE Syntax”.

- Configuration Changes
- Server Changes
- SQL Changes

Configuration Changes

- **Incompatible change**: The `InnoDB Plugin` is included in MySQL 5.5 releases. It becomes the built-in version of `InnoDB` in MySQL Server, replacing the version previously included as the built-in `InnoDB` engine. `InnoDB Plugin` is also available in MySQL 5.1 as of 5.1.38, but it is an optional storage engine that must be enabled explicitly using two server options:

```
[mysqld]
ignore-builtin-innodb
plugin-load=innodb=ha_innodb_plugin.so
```

If you were using `InnoDB Plugin` in MySQL 5.1 by means of those options, you must remove them after an upgrade to 5.5 or the server will fail to start.

In addition, in `InnoDB Plugin`, the `innodb_file_io_threads` system variable has been removed and replaced with `innodb_read_io_threads` and `innodb_write_io_threads`. If you upgrade from MySQL 5.1 to MySQL 5.5 and previously explicitly set `innodb_file_io_threads` at server startup, you must change your configuration. Either remove any reference to `innodb_file_io_threads` or replace it with references to `innodb_read_io_threads` and `innodb_write_io_threads`.

- **Incompatible change**: In MySQL 5.5, the server includes a plugin services interface that complements the plugin API. The services interface enables server functionality to be exposed as a “service” that plugins can access through a function-call interface. The `libmysqlservices` library provides access to the available services and dynamic plugins now must be linked against this library (use the `-lmysqlservices` flag). For an example showing how to configure for `CMake`, see Section 24.3, “MySQL Services for Plugins”.

Server Changes

- On Linux systems, the `libaio` library may be needed. Install it first, if it is not already present on your system.

- **Known issue**: As of MySQL 5.5.32, for new installations, the `url` columns in the `mysql` database help tables are now created as type `TEXT` to accommodate longer URLs. For upgrades, `mysql_upgrade` does *not* update the columns. Modify them manually using these statements:

```
ALTER TABLE mysql.help_category MODIFY url TEXT NOT NULL;
ALTER TABLE mysql.help_topic MODIFY url TEXT NOT NULL;
```

- **Incompatible change**: As of MySQL 5.5.3, due to work done for Bug #989, `FLUSH TABLES` is not permitted when there is an active `LOCK TABLES ... READ`. To provide a workaround for this restriction, `FLUSH TABLES` has a new variant, `FLUSH TABLES tbl_list WITH READ LOCK`, that enables tables to be flushed and locked in a single operation. As a result of this change, applications that previously used this statement sequence to lock and flush tables will fail:

```
LOCK TABLES tbl_list READ;
FLUSH TABLES tbl_list;
```

Such applications should now use this statement instead:

```
FLUSH TABLES tbl_list WITH READ LOCK;
```

- **Incompatible change**: As of MySQL 5.5.7, the server requires that a new grant table, `proxies_priv`, be present in the `mysql` database. If you are upgrading to 5.5.7 from a previous MySQL release rather than performing a new installation, the server will find that this table is missing and exit during startup with the following message:

```
Table 'mysql.proxies_priv' doesn't exist
```

To create the `proxies_priv` table, start the server with the `--skip-grant-tables` option to cause it to skip the normal grant table checks, then run `mysql_upgrade`. For example:

```
mysqld --skip-grant-tables &
```

```
mysql_upgrade
```

Then stop the server and restart it normally.

You can specify other options on the `mysqld` command line if necessary. Alternatively, if your installation is configured so that the server normally reads options from an option file, use the `--defaults-file` option to specify the file (enter each command on a single line):

```
mysqld --defaults-file=/usr/local/mysql/etc/my.cnf
  --skip-grant-tables &
mysql_upgrade
```

With the `--skip-grant-tables` option, the server does no password or privilege checking, so any client can connect and effectively have all privileges. For additional security, use the `--skip-networking` option as well to prevent remote clients from connecting.

Note

This problem is fixed in MySQL 5.5.8; the server treats a missing `proxies_priv` table as equivalent to an empty table. However, after starting the server, you should still run `mysql_upgrade` to create the table.

- **Incompatible change**: As of MySQL 5.5.7, `InnoDB` always uses the fast truncation technique, equivalent to `DROP TABLE` and `CREATE TABLE`. It no longer performs a row-by-row delete for tables with parent-child foreign key relationships. `TRUNCATE TABLE` returns an error for such tables. Modify your SQL to issue `DELETE FROM table_name` for such tables instead.

- **Incompatible change**: Prior to MySQL 5.5.7, if you flushed the logs using `FLUSH LOGS` or `mysqladmin flush-logs` and `mysqld` was writing the error log to a file (for example, if it was started with the `--log-error` option), it renames the current log file with the suffix `-old`, then created a new empty log file. This had the problem that a second log-flushing operation thus caused the original error log file to be lost unless you saved it under a different name. For example, you could use the following commands to save the file:

  ```
  mysqladmin flush-logs
  mv host_name.err-old backup-directory
  ```

  To avoid the preceding file-loss problem, no renaming occurs as of MySQL 5.5.7; the server merely closes and reopens the log file. To rename the file, you can do so manually before flushing. Then flushing the logs reopens a new file with the original file name. For example, you can rename the file and create a new one using the following commands:

  ```
  mv host_name.err host_name.err-old
  mysqladmin flush-logs
  mv host_name.err-old backup-directory
  ```

- **Incompatible change**: As of MySQL 5.5.6, handling of `CREATE TABLE IF NOT EXISTS ... SELECT` statements has been changed for the case that the destination table already exists:

  - Previously, for `CREATE TABLE IF NOT EXISTS ... SELECT`, MySQL produced a warning that the table exists, but inserted the rows and wrote the statement to the binary log anyway. By contrast, `CREATE TABLE ... SELECT` (without `IF NOT EXISTS`) failed with an error, but MySQL inserted no rows and did not write the statement to the binary log.

  - MySQL now handles both statements the same way when the destination table exists, in that neither statement inserts rows or is written to the binary log. The difference between them is that MySQL produces a warning when `IF NOT EXISTS` is present and an error when it is not.

  This change in handling of `IF NOT EXISTS` results in an incompatibility for statement-based replication from a MySQL 5.1 master with the original behavior and a MySQL 5.5 slave with the new

behavior. Suppose that `CREATE TABLE IF NOT EXISTS ... SELECT` is executed on the master and the destination table exists. The result is that rows are inserted on the master but not on the slave. (Row-based replication does not have this problem.)

To address this issue, statement-based binary logging for `CREATE TABLE IF NOT EXISTS ... SELECT` is changed in MySQL 5.1 as of 5.1.51:

- If the destination table does not exist, there is no change: The statement is logged as is.
- If the destination table does exist, the statement is logged as the equivalent pair of `CREATE TABLE IF NOT EXISTS` and `INSERT ... SELECT` statements. (If the `SELECT` in the original statement is preceded by `IGNORE` or `REPLACE`, the `INSERT` becomes `INSERT IGNORE` or `REPLACE`, respectively.)

This change provides forward compatibility for statement-based replication from MySQL 5.1 to 5.5 because when the destination table exists, the rows will be inserted on both the master and slave. To take advantage of this compatibility measure, the 5.1 server must be at least 5.1.51 and the 5.5 server must be at least 5.5.6.

To upgrade an existing 5.1-to-5.5 replication scenario, upgrade the master first to 5.1.51 or higher. Note that this differs from the usual replication upgrade advice of upgrading the slave first.

A workaround for applications that wish to achieve the original effect (rows inserted regardless of whether the destination table exists) is to use `CREATE TABLE IF NOT EXISTS` and `INSERT ... SELECT` statements rather than `CREATE TABLE IF NOT EXISTS ... SELECT` statements.

Along with the change just described, the following related change was made: Previously, if an existing view was named as the destination table for `CREATE TABLE IF NOT EXISTS ... SELECT`, rows were inserted into the underlying base table and the statement was written to the binary log. As of MySQL 5.1.51 and 5.5.6, nothing is inserted or logged.

- **Incompatible change**: Prior to MySQL 5.5.6, if the server was started with `character_set_server` set to `utf16`, it crashed during full-text stopword initialization. Now the stopword file is loaded and searched using `latin1` if `character_set_server` is `ucs2`, `utf16`, or `utf32`. If any table was created with `FULLTEXT` indexes while the server character set was `ucs2`, `utf16`, or `utf32`, it should be repaired using this statement:

```
REPAIR TABLE tbl_name QUICK;
```

- **Incompatible change**: As of MySQL 5.5.5, all numeric operators and functions on integer, floating-point and `DECIMAL` values throw an “out of range” error (`ER_DATA_OUT_OF_RANGE`) rather than returning an incorrect value or `NULL`, when the result is out of the supported range for the corresponding data type. See Section 11.2.6, “Out-of-Range and Overflow Handling”.

- **Incompatible change**: In very old versions of MySQL (prior to 4.1), the `TIMESTAMP` data type supported a display width, which was silently ignored beginning with MySQL 4.1. This is deprecated in MySQL 5.1, and removed altogether in MySQL 5.5. These changes in behavior can lead to two problem scenarios when trying to use `TIMESTAMP(N)` columns with a MySQL 5.5 or later server:

  - When importing a dump file (for example, one created using `mysqldump`) created in a MySQL 5.0 or earlier server into a server from a newer release series, a `CREATE TABLE` or `ALTER TABLE` statement containing `TIMESTAMP(N)` causes the import to fail with a syntax error.

    To fix this problem, edit the dump file in a text editor to replace any instances of `TIMESTAMP(N)` with `TIMESTAMP` prior to importing the file. Be sure to use a plain text editor for this, and not a word processor; otherwise, the result is almost certain to be unusable for importing into the MySQL server.

  - When trying replicate any `CREATE TABLE` or `ALTER TABLE` statement containing `TIMESTAMP(N)` from a master MySQL server that supports the `TIMESTAMP(N)` syntax to a

MySQL 5.5.3 or higher slave, the statement causes replication to fail. Similarly, when you try to restore from a binary log written by a server that supports `TIMESTAMP(N)` to a MySQL 5.5.3 or higher server, any `CREATE TABLE` or `ALTER TABLE` statement containing `TIMESTAMP(N)` causes the backup to fail. This holds true regardless of the logging format.

It may be possible to fix such issues using a hex editor, by replacing any width arguments used with `TIMESTAMP`, and the parentheses containing them, with space characters (hexadecimal `20`). Be sure to use a programmer's binary hex editor and not a regular text editor or word processor for this; otherwise, the result is almost certain to be a corrupted binary log file. To guard against accidental corruption of the binary log, you should always work on a copy of the file rather than the original.

You should try to handle potential issues of these types proactively by updating with `ALTER TABLE` any `TIMESTAMP(N)` columns in your databases so that they use `TIMESTAMP` instead, before performing any upgrades.

- **Incompatible change**: As of MySQL 5.5.3, the Unicode implementation has been extended to provide support for supplementary characters that lie outside the Basic Multilingual Plane (BMP). Noteworthy features:

  - `utf16` and `utf32` character sets have been added. These correspond to the UTF-16 and UTF-32 encodings of the Unicode character set, and they both support supplementary characters.
  - The `utf8mb4` character set has been added. This is similar to `utf8`, but its encoding allows up to four bytes per character to enable support for supplementary characters.
  - The `ucs2` character set is essentially unchanged except for the inclusion of some newer BMP characters.

  In most respects, upgrading to MySQL 5.5 should present few problems with regard to Unicode usage, although there are some potential areas of incompatibility. These are the primary areas of concern:

  - For the variable-length character data types (`VARCHAR` and the `TEXT` types), the maximum length in characters is less for `utf8mb4` columns than for `utf8` columns.
  - For all character data types (`CHAR`, `VARCHAR`, and the `TEXT` types), the maximum number of characters that can be indexed is less for `utf8mb4` columns than for `utf8` columns.

  Consequently, if you want to upgrade tables from `utf8` to `utf8mb4` to take advantage of supplementary-character support, it may be necessary to change some column or index definitions.

  For additional details about the new Unicode character sets and potential incompatibilities, see Section 10.1.9, “Unicode Support”, and Section 10.1.9.7, “Converting Between 3-Byte and 4-Byte Unicode Character Sets”.

- **Incompatible change**: As of MySQL 5.5.3, the server includes `dtoa`, a library for conversion between strings and numbers by David M. Gay. In MySQL, this library provides the basis for improved conversion between string or `DECIMAL` values and approximate-value (`FLOAT` or `DOUBLE`) numbers.

  Because the conversions produced by this library differ in some cases from previous results, the potential exists for incompatibilities in applications that rely on previous results. For example, applications that depend on a specific exact result from previous conversions might need adjustment to accommodate additional precision.

  For additional information about the properties of `dtoa` conversions, see Section 12.2, “Type Conversion in Expression Evaluation”.

- **Incompatible change**: In MySQL 5.5, several changes were made regarding the language and character set of error messages:

- The `--language` option for specifying the directory for the error message file is now deprecated. The new `lc_messages_dir` and `lc_messages` system variables should be used instead, and the server treats `--language` as an alias for `lc_messages_dir`.
- The `language` system variable has been removed and replaced with the new `lc_messages_dir` and `lc_messages` system variables. `lc_messages_dir` has only a global value and is read only. `lc_messages` has global and session values and can be modified at runtime, so the error message language can be changed while the server is running, and individual clients each can have a different error message language by changing their session `lc_messages` value to a different locale name.
- Error messages previously were constructed in a mix of character sets. This issue is resolved by constructing error messages internally within the server using UTF-8 and returning them to the client in the character set specified by the `character_set_results` system variable. The content of error messages therefore may in some cases differ from the messages returned previously.

For more information, see Section 10.2, “Setting the Error Message Language”, and Section 10.1.6, “Error Message Character Set”.

- **Incompatible change**: MySQL 5.5 implements new functions used to calculate row placement for tables partitioned by `KEY` and `LINEAR KEY`. Tables that were created using `KEY` or `LINEAR KEY` partitioning in MySQL 5.1 can be upgraded in MySQL 5.5.31 and later using `ALTER TABLE ... PARTITION BY ALGORITHM=2 [LINEAR] KEY (...)`. (Bug #14521864, Bug #66462)

SQL Changes

- **Incompatible change**: Previously, the parser accepted an `INTO` clause in nested `SELECT` statements, which is invalid because such statements must return their results to the outer context. As of MySQL 5.5.3, this syntax is no longer permitted and statements that use it must be changed.
- **Incompatible change**: In MySQL 5.5.3, several changes were made to alias resolution in multiple-table `DELETE` statements so that it is no longer possible to have inconsistent or ambiguous table aliases.
  - In MySQL 5.1.23, alias declarations outside the *`table_references`* part of the statement were disallowed for the `USING` variant of multiple-table `DELETE` syntax, to reduce the possibility of ambiguous aliases that could lead to ambiguous statements that have unexpected results such as deleting rows from the wrong table.

    As of MySQL 5.5.3, alias declarations outside *`table_references`* are disallowed for all multiple-table `DELETE` statements. Alias declarations are permitted only in the *`table_references`* part.

    Incorrect:

    ```
    DELETE FROM t1 AS a2 USING t1 AS a1 INNER JOIN t2 AS a2;
    DELETE t1 AS a2 FROM t1 AS a1 INNER JOIN t2 AS a2;
    ```

    Correct:

    ```
    DELETE FROM t1 USING t1 AS a1 INNER JOIN t2 AS a2;
    DELETE t1 FROM t1 AS a1 INNER JOIN t2 AS a2;
    ```

  - Previously, for alias references in the list of tables from which to delete rows in a multiple-table delete, the default database is used unless one is specified explicitly. For example, if the default database is `db1`, the following statement does not work because the unqualified alias reference `a2` is interpreted as having a database of `db1`:

    ```
    DELETE a1, a2 FROM db1.t1 AS a1 INNER JOIN db2.t2 AS a2
    ```

```
WHERE a1.id=a2.id;
```

To correctly match an alias that refers to a table outside the default database, you must explicitly qualify the reference with the name of the proper database:

```
DELETE a1, db2.a2 FROM db1.t1 AS a1 INNER JOIN db2.t2 AS a2
WHERE a1.id=a2.id;
```

As of MySQL 5.5.3, alias resolution does not require qualification and alias references should not be qualified with the database name. Qualified names are interpreted as referring to tables, not aliases.

Statements containing alias constructs that are no longer permitted must be rewritten.

- Some keywords may be reserved in MySQL 5.5 that were not reserved in MySQL 5.1. See Section 9.3, “Keywords and Reserved Words”. This can cause words previously used as identifiers to become illegal. To fix affected statements, use identifier quoting. See Section 9.2, “Schema Object Names”.

2.11.2 Downgrading MySQL

This section describes how to downgrade to an older MySQL version.

- Downgrade Methods
- Downgrade Paths
- Before You Begin
- In-Place Downgrade
- Logical Downgrade
- Downgrade Troubleshooting

Note

In the following discussion, MySQL commands that must be run using a MySQL account with administrative privileges include `-u root` on the command line to specify the MySQL `root` user. Commands that require a password for `root` also include a `-p` option. Because `-p` is followed by no option value, such commands prompt for the password. Type the password when prompted and press Enter.

SQL statements can be executed using the `mysql` command-line client (connect as `root` to ensure that you have the necessary privileges).

Downgrade Methods

Supported downgrade methods include:

- *In-Place Downgrade*: Involves shutting down the new MySQL version, replacing the new MySQL binaries or packages with the old ones, and restarting the old MySQL version on the new data files. In-place downgrades are supported for downgrades between GA versions within the same release series. For example, in-place downgrades are supported for downgrades from 5.5.46 to 5.5.45.
- *Logical Downgrade*: Involves using `mysqldump` to dump all tables from the new MySQL version, and then loading the dump file into the old MySQL version. Logical downgrades are supported for downgrades between GA versions within the same release series and for downgrades between release levels. For example, logical downgrades are supported for downgrades from 5.5.46 to 5.5.45 and for downgrades from 5.5 to 5.1.

For procedures, see In-Place Downgrade, and Logical Downgrade.

Downgrade Paths

- Downgrade is only supported between General Availability (GA) releases.
- Downgrade from MySQL 5.5 to 5.1 is supported using the *logical downgrade* method.
- Downgrade that skips versions is not supported. For example, downgrading directly from MySQL 5.5 to 5.0 is not supported.
- Downgrade within a release series is supported. For example, downgrading from MySQL 5.5.*z* to 5.5.*y* is supported. Skipping a release is also supported. For example, downgrading from MySQL 5.5.*z* to 5.5.*x* is supported.

Before You Begin

Before downgrading, the following steps are recommended:

- Review the Release Notes for the MySQL version you are downgrading from to ensure that there are no features or fixes that you really need.
- Review Section 2.11.2.1, “Changes Affecting Downgrades from MySQL 5.5”. This section describes changes that may require action before or after downgrading.

Note

The downgrade procedures described in the following sections assume you are downgrading with data files created or modified by the newer MySQL version. However, if you did not modify your data after upgrading, downgrading using backups taken *before* upgrading to the new MySQL version is recommended. Many of the changes described in Section 2.11.2.1, “Changes Affecting Downgrades from MySQL 5.5” that require action before or after downgrading are not applicable when downgrading using backups taken *before* upgrading to the new MySQL version.

- Always back up your current databases and log files before downgrading. The backup should include the `mysql` database, which contains the MySQL system tables. See Section 7.2, “Database Backup Methods”.
- Use of new features, new configuration options, or new configuration option values that are not supported by a previous release may cause downgrade errors or failures. Before downgrading, it is recommended that you reverse changes resulting from the use of new features and remove configuration settings that are not supported by the release you are downgrading to.
- If you use XA transactions with `InnoDB`, run `XA RECOVER` before downgrading to check for uncommitted XA transactions. If results are returned, either commit or rollback the XA transactions by issuing an `XA COMMIT` or `XA ROLLBACK` statement.

In-Place Downgrade

In-place downgrades are supported for downgrades between GA releases within the same release series. Before proceeding, review Before You Begin.

To perform an in-place downgrade:

1. Review the changes described in Section 2.11.2.1, “Changes Affecting Downgrades from MySQL 5.5” for steps to be performed before downgrading.
2. If you use `InnoDB`, configure MySQL to perform a slow shutdown by setting `innodb_fast_shutdown` to `0`. For example:

```
mysql -u root -p --execute="SET GLOBAL innodb_fast_shutdown=0"
```

With a slow shutdown, `InnoDB` performs a full purge and change buffer merge before shutting down, which ensures that data files are fully prepared in case of file format differences between releases.

3. Shut down the newer MySQL server. For example:

```
mysqladmin -u root -p shutdown
```

4. After the slow shutdown, remove the `InnoDB` redo log files (the `ib_logfile*` files) from the `data` directory to avoid downgrade issues related to redo log file format changes that may have occurred between releases.

```
rm ib_logfile*
```

5. Downgrade the MySQL binaries or packages in-place by replacing the newer binaries or packages with the older ones.

6. Start the older (downgraded) MySQL server, using the existing data directory. For example:

```
mysqld_safe --user=mysql --datadir=/path/to/existing-datadir
```

7. Run `mysql_upgrade`. For example:

```
mysql_upgrade -u root -p
```

8. Shut down and restart the MySQL server to ensure that any changes made to the system tables take effect. For example:

```
mysqladmin -u root -p shutdown
mysqld_safe --user=mysql --datadir=/path/to/existing-datadir
```

Logical Downgrade

Logical downgrades are supported for downgrades between releases within the same release series and for downgrades to the previous release level. Only downgrades between General Availability (GA) releases are supported. Before proceeding, review Before You Begin.

To perform a logical downgrade:

1. Review the changes described in Section 2.11.2.1, “Changes Affecting Downgrades from MySQL 5.5” for steps to be performed before downgrading.

2. Dump all databases. For example:

```
mysqldump -u root -p
  --add-drop-table --routines --events
  --all-databases --force > data-for-downgrade.sql
```

3. Shut down the newer MySQL server. For example:

```
mysqladmin -u root -p shutdown
```

4. Initialize an older MySQL instance, with a new data directory. For example:

```
scripts/mysql_install_db --user=mysql
```

5. Start the older MySQL server, using the new data directory. For example:

```
mysqld_safe --user=mysql --datadir=/path/to/new-datadir
```

6. Load the dump file into the older MySQL server. For example:

```
mysql -u root -p --force < data-for-upgrade.sql
```

7. Run `mysql_upgrade`. For example:

```
mysql_upgrade -u root -p
```

8. Shut down and restart the MySQL server to ensure that any changes made to the system tables take effect. For example:

```
mysqladmin -u root -p shutdown
mysqld_safe --user=mysql --datadir=/path/to/new-datadir
```

Downgrade Troubleshooting

If you downgrade from one release series to another, there may be incompatibilities in table storage formats. In this case, use `mysqldump` to dump your tables before downgrading. After downgrading, reload the dump file using `mysql` or `mysqlimport` to re-create your tables. For examples, see Section 2.11.4, “Copying MySQL Databases to Another Machine”.

A typical symptom of a downward-incompatible table format change when you downgrade is that you cannot open tables. In that case, use the following procedure:

1. Stop the older MySQL server that you are downgrading to.
2. Restart the newer MySQL server you are downgrading from.
3. Dump any tables that were inaccessible to the older server by using `mysqldump` to create a dump file.
4. Stop the newer MySQL server and restart the older one.
5. Reload the dump file into the older server. Your tables should be accessible.

2.11.2.1 Changes Affecting Downgrades from MySQL 5.5

Before downgrading from MySQL 5.5, review the changes described in this section. Some changes may require action before or after downgrading.

- **System Tables.** The `mysql.proc.comment` column definition changed between MySQL 5.1 and 5.5. After downgrading from 5.5 to 5.1, this table is seen as corrupt and in need of repair. Running `mysql_upgrade` from the version of MySQL to which you downgraded (as documented in the downgrade procedures) reverts the `mysql.proc.comment` column definition.
- **InnoDB.** MySQL 5.5 uses `InnoDB Plugin` as the built-in version of `InnoDB`. MySQL 5.1 includes `InnoDB Plugin` as of 5.1.38, but as an option that must be enabled explicitly. See the Release Notes for MySQL 5.1.38.
- **InnoDB.** In MySQL 5.5.14, the length limit for index prefix keys is increased from 767 bytes to 3072 bytes, for `InnoDB` tables using `ROW_FORMAT=DYNAMIC` or `ROW_FORMAT=COMPRESSED`. See Section 14.11.1.7, “Limits on InnoDB Tables” for details. If you downgrade from one of these releases or higher, to an earlier release with a lower length limit, the index prefix keys could be truncated at 767 bytes or the downgrade could fail. This issue could only occur if the configuration option `innodb_large_prefix` was enabled on the server being downgraded.

- **Tables partitioned by [LINEAR] KEY.** MySQL 5.5 implements new functions used to calculate row placement for tables partitioned by `KEY` and `LINEAR KEY`. Tables that were created using `KEY` or `LINEAR KEY` partitioning in MySQL 5.5 cannot be used by a MySQL 5.1 server. In MySQL 5.5.31 and later, you can downgrade such tables with `ALTER TABLE ... PARTITION BY ALGORITHM=1 [LINEAR] KEY (...)` to make them compatible with MySQL 5.1.

2.11.2.2 Downgrading from MySQL Enterprise Edition to MySQL Community Server

This section describes the steps required to downgrade from MySQL Enterprise Edition to MySQL Community Edition. This can be done at any time, and is required at the expiration of a MySQL Enterprise Edition subscription if you wish to continue using MySQL Server.

When you perform such a downgrade, all commercially licensed components of the MySQL Enterprise Edition subscription must be uninstalled. These components and related considerations are described in the rest of this section.

Note

The issues described in this section are in addition to any that may be encountered as a result of any upgrade or downgrade of the MySQL Server version (such as between MySQL 5.5 and 5.1). Information about upgrading and downgrading between MySQL release series can be found elsewhere in this chapter; see Section 2.11.1, “Upgrading MySQL”, and Section 2.11.2, “Downgrading MySQL”.

MySQL Enterprise Database Server. All commercial versions of MySQL Database Server must be uninstalled.

Commercially licensed extensions. All commercially licensed MySQL Enterprise Database Server extensions must be uninstalled. This includes the following commercial extensions:

- *MySQL External Authentication for Windows*: Following uninstallation of this plugin, existing MySQL user accounts must be re-created using local authentication. See Section 6.3, “MySQL User Account Management”, for more information.
- *MySQL External Authentication for PAM*: Following uninstallation of this plugin, existing MySQL user accounts must be re-created using local authentication. See Section 6.3, “MySQL User Account Management”, for more information.
- *MySQL Enterprise Thread Pool*: Following uninstallation of this plugin, existing MySQL servers revert to default thread and connection handling.
- *MySQL Enterprise Audit*: Following uninstallation of this plugin, no logging of user logins or query activity occurs.
- *MySQL High Availability*: Following uninstallation of this plugin, automated failover is no longer available.

MySQL Enterprise Backup. MySQL Enterprise Backup must be uninstalled. Uninstalling this application has the effects listed here:

- Automated backup scripts no longer work.
- Existing backup images taken with MySQL Enterprise Backup can no longer be used for recovery.
- Third-party integration with multimedia systems such as NetBackup, Tivoli, and Oracle Secure Backup no longer works.

MySQL Enterprise Monitor, MySQL Query Analyzer, agents. MySQL Enterprise Monitor, MySQL Query Analyzer, and all server-side agents must be uninstalled. Uninstalling these applications and agents has the following effects:

- Automated SNMP and SMTP alerts no longer work.
- All historical MySQL, OS monitoring, query, and performance metrics as well as all trending data are lost.
- All environment-specific monitoring templates, custom advisors, graphs and scripts are also lost.

2.11.3 Rebuilding or Repairing Tables or Indexes

This section describes how to rebuild or repair tables or indexes, which may be necessitated by:

- Changes to how MySQL handles data types or character sets. For example, an error in a collation might have been corrected, necessitating a table rebuild to update the indexes for character columns that use the collation.
- Required table repairs or upgrades reported by `CHECK TABLE`, `mysqlcheck`, or `mysql_upgrade`.

Methods for rebuilding a table include:

- Dump and Reload Method
- ALTER TABLE Method
- REPAIR TABLE Method

Dump and Reload Method

If you are rebuilding tables because a different version of MySQL will not handle them after a binary (in-place) upgrade or downgrade, you must use the dump-and-reload method. Dump the tables *before* upgrading or downgrading using your original version of MySQL. Then reload the tables *after* upgrading or downgrading.

If you use the dump-and-reload method of rebuilding tables only for the purpose of rebuilding indexes, you can perform the dump either before or after upgrading or downgrading. Reloading still must be done afterward.

If you need to rebuild an `InnoDB` table because a `CHECK TABLE` operation indicates that a table upgrade is required, use `mysqldump` to create a dump file and `mysql` to reload the file. If the `CHECK TABLE` operation indicates that there is a corruption or causes `InnoDB` to fail, refer to Section 14.23.2, “Forcing InnoDB Recovery” for information about using the `innodb_force_recovery` option to restart `InnoDB`. To understand the type of problem that `CHECK TABLE` may be encountering, refer to the `InnoDB` notes in Section 13.7.2.2, “CHECK TABLE Syntax”.

To rebuild a table by dumping and reloading it, use `mysqldump` to create a dump file and `mysql` to reload the file:

```
mysqldump db_name t1 > dump.sql
mysql db_name < dump.sql
```

To rebuild all the tables in a single database, specify the database name without any following table name:

```
mysqldump db_name > dump.sql
mysql db_name < dump.sql
```

To rebuild all tables in all databases, use the `--all-databases` option:

```
mysqldump --all-databases > dump.sql
mysql < dump.sql
```

ALTER TABLE Method

To rebuild a table with `ALTER TABLE`, use a “null” alteration; that is, an `ALTER TABLE` statement that “changes” the table to use the storage engine that it already has. For example, if `t1` is an `InnoDB` table, use this statement:

```
ALTER TABLE t1 ENGINE = InnoDB;
```

If you are not sure which storage engine to specify in the `ALTER TABLE` statement, use `SHOW CREATE TABLE` to display the table definition.

REPAIR TABLE Method

The `REPAIR TABLE` method is only applicable to `MyISAM`, `ARCHIVE`, and `CSV` tables.

You can use `REPAIR TABLE` if the table checking operation indicates that there is a corruption or that an upgrade is required. For example, to repair a `MyISAM` table, use this statement:

```
REPAIR TABLE t1;
```

`mysqlcheck --repair` provides command-line access to the `REPAIR TABLE` statement. This can be a more convenient means of repairing tables because you can use the `--databases` or `--all-databases` option to repair all tables in specific databases or all databases, respectively:

```
mysqlcheck --repair --databases db_name ...
mysqlcheck --repair --all-databases
```

2.11.4 Copying MySQL Databases to Another Machine

In cases where you need to transfer databases between different architectures, you can use `mysqldump` to create a file containing SQL statements. You can then transfer the file to the other machine and feed it as input to the `mysql` client.

Note

You can copy the `.frm`, `.MYI`, and `.MYD` files for `MyISAM` tables between different architectures that support the same floating-point format. (MySQL takes care of any byte-swapping issues.) See Section 15.3, “The MyISAM Storage Engine”.

Use `mysqldump --help` to see what options are available.

The easiest (although not the fastest) way to move a database between two machines is to run the following commands on the machine on which the database is located:

```
mysqladmin -h 'other_hostname' create db_name
mysqldump db_name | mysql -h 'other_hostname' db_name
```

If you want to copy a database from a remote machine over a slow network, you can use these commands:

```
mysqladmin create db_name
mysqldump -h 'other_hostname' --compress db_name | mysql db_name
```

You can also store the dump in a file, transfer the file to the target machine, and then load the file into the database there. For example, you can dump a database to a compressed file on the source machine like this:

```
```

```
mysqldump --quick db_name | gzip > db_name.gz
```

Transfer the file containing the database contents to the target machine and run these commands there:

```
mysqladmin create db_name
gunzip < db_name.gz | mysql db_name
```

You can also use `mysqldump` and `mysqlimport` to transfer the database. For large tables, this is much faster than simply using `mysqldump`. In the following commands, *`DUMPDIR`* represents the full path name of the directory you use to store the output from `mysqldump`.

First, create the directory for the output files and dump the database:

```
mkdir DUMPDIR
mysqldump --tab=DUMPDIR db_name
```

Then transfer the files in the *`DUMPDIR`* directory to some corresponding directory on the target machine and load the files into MySQL there:

```
mysqladmin create db_name           # create database
cat DUMPDIR/*.sql | mysql db_name   # create tables in database
mysqlimport db_name DUMPDIR/*.txt   # load data into tables
```

Do not forget to copy the `mysql` database because that is where the grant tables are stored. You might have to run commands as the MySQL `root` user on the new machine until you have the `mysql` database in place.

After you import the `mysql` database on the new machine, execute `mysqladmin flush-privileges` so that the server reloads the grant table information.

2.12 Perl Installation Notes

The Perl `DBI` module provides a generic interface for database access. You can write a `DBI` script that works with many different database engines without change. To use `DBI`, you must install the `DBI` module, as well as a DataBase Driver (DBD) module for each type of database server you want to access. For MySQL, this driver is the `DBD::mysql` module.

Perl, and the `DBD::MySQL` module for `DBI` must be installed if you want to run the MySQL benchmark scripts; see Section 8.13.2, “The MySQL Benchmark Suite”. They are also required for the NDB Cluster `ndb_size.pl` utility; see Section 18.4.25, “`ndb_size.pl` — NDBCLUSTER Size Requirement Estimator”.

Note

Perl support is not included with MySQL distributions. You can obtain the necessary modules from http://search.cpan.org for Unix, or by using the ActiveState `ppm` program on Windows. The following sections describe how to do this.

The `DBI`/`DBD` interface requires Perl 5.6.0, and 5.6.1 or later is preferred. DBI *does not work* if you have an older version of Perl. You should use `DBD::mysql` 4.009 or higher. Although earlier versions are available, they do not support the full functionality of MySQL 5.5.

2.12.1 Installing Perl on Unix

MySQL Perl support requires that you have installed MySQL client programming support (libraries and header files). Most installation methods install the necessary files. If you install MySQL from RPM files

on Linux, be sure to install the developer RPM as well. The client programs are in the client RPM, but client programming support is in the developer RPM.

The files you need for Perl support can be obtained from the CPAN (Comprehensive Perl Archive Network) at http://search.cpan.org.

The easiest way to install Perl modules on Unix is to use the `CPAN` module. For example:

```
shell> perl -MCPAN -e shell
cpan> install DBI
cpan> install DBD::mysql
```

The `DBD::mysql` installation runs a number of tests. These tests attempt to connect to the local MySQL server using the default user name and password. (The default user name is your login name on Unix, and `ODBC` on Windows. The default password is “no password.”) If you cannot connect to the server with those values (for example, if your account has a password), the tests fail. You can use `force install DBD::mysql` to ignore the failed tests.

`DBI` requires the `Data::Dumper` module. It may be installed; if not, you should install it before installing `DBI`.

It is also possible to download the module distributions in the form of compressed `tar` archives and build the modules manually. For example, to unpack and build a DBI distribution, use a procedure such as this:

1. Unpack the distribution into the current directory:

   ```
   shell> gunzip < DBI-VERSION.tar.gz | tar xvf -
   ```

   This command creates a directory named `DBI-VERSION`.

2. Change location into the top-level directory of the unpacked distribution:

   ```
   shell> cd DBI-VERSION
   ```

3. Build the distribution and compile everything:

   ```
   shell> perl Makefile.PL
   shell> make
   shell> make test
   shell> make install
   ```

The `make test` command is important because it verifies that the module is working. Note that when you run that command during the `DBD::mysql` installation to exercise the interface code, the MySQL server must be running or the test fails.

It is a good idea to rebuild and reinstall the `DBD::mysql` distribution whenever you install a new release of MySQL. This ensures that the latest versions of the MySQL client libraries are installed correctly.

If you do not have access rights to install Perl modules in the system directory or if you want to install local Perl modules, the following reference may be useful: http://learn.perl.org/faq/perlfaq8.html#How-do-I-keep-my-own-module-library-directory-

2.12.2 Installing ActiveState Perl on Windows

On Windows, you should do the following to install the MySQL `DBD` module with ActiveState Perl:

1. Get ActiveState Perl from http://www.activestate.com/Products/ActivePerl/ and install it.

2. Open a console window.
3. If necessary, set the `HTTP_proxy` variable. For example, you might try a setting like this:

```
C:\> set HTTP_proxy=my.proxy.com:3128
```

4. Start the PPM program:

```
C:\> C:\perl\bin\ppm.pl
```

5. If you have not previously done so, install `DBI`:

```
ppm> install DBI
```

6. If this succeeds, run the following command:

```
ppm> install DBD-mysql
```

This procedure should work with ActiveState Perl 5.6 or higher.

If you cannot get the procedure to work, you should install the ODBC driver instead and connect to the MySQL server through ODBC:

```
use DBI;
$dbh= DBI->connect("DBI:ODBC:$dsn",$user,$password) ||
  die "Got error $DBI::errstr when connecting to $dsn\n";
```

2.12.3 Problems Using the Perl DBI/DBD Interface

If Perl reports that it cannot find the `../mysql/mysql.so` module, the problem is probably that Perl cannot locate the `libmysqlclient.so` shared library. You should be able to fix this problem by one of the following methods:

- Copy `libmysqlclient.so` to the directory where your other shared libraries are located (probably `/usr/lib` or `/lib`).
- Modify the `-L` options used to compile `DBD::mysql` to reflect the actual location of `libmysqlclient.so`.
- On Linux, you can add the path name of the directory where `libmysqlclient.so` is located to the `/etc/ld.so.conf` file.
- Add the path name of the directory where `libmysqlclient.so` is located to the `LD_RUN_PATH` environment variable. Some systems use `LD_LIBRARY_PATH` instead.

Note that you may also need to modify the `-L` options if there are other libraries that the linker fails to find. For example, if the linker cannot find `libc` because it is in `/lib` and the link command specifies `-L/usr/lib`, change the `-L` option to `-L/lib` or add `-L/lib` to the existing link command.

If you get the following errors from `DBD::mysql`, you are probably using `gcc` (or using an old binary compiled with `gcc`):

```
/usr/bin/perl: can't resolve symbol '__moddi3'
/usr/bin/perl: can't resolve symbol '__divdi3'
```

Add `-L/usr/lib/gcc-lib/... -lgcc` to the link command when the `mysql.so` library gets built (check the output from `make` for `mysql.so` when you compile the Perl client). The `-L` option should specify the path name of the directory where `libgcc.a` is located on your system.

Another cause of this problem may be that Perl and MySQL are not both compiled with `gcc`. In this case, you can solve the mismatch by compiling both with `gcc`.

Chapter 3 Tutorial

Table of Contents

3.1 Connecting to and Disconnecting from the Server 217
3.2 Entering Queries 218
3.3 Creating and Using a Database 221
    3.3.1 Creating and Selecting a Database 222
    3.3.2 Creating a Table 223
    3.3.3 Loading Data into a Table 224
    3.3.4 Retrieving Information from a Table 225
3.4 Getting Information About Databases and Tables 238
3.5 Using mysql in Batch Mode 239
3.6 Examples of Common Queries 241
    3.6.1 The Maximum Value for a Column 241
    3.6.2 The Row Holding the Maximum of a Certain Column 241
    3.6.3 Maximum of Column per Group 242
    3.6.4 The Rows Holding the Group-wise Maximum of a Certain Column 242
    3.6.5 Using User-Defined Variables 243
    3.6.6 Using Foreign Keys 243
    3.6.7 Searching on Two Keys 245
    3.6.8 Calculating Visits Per Day 245
    3.6.9 Using AUTO_INCREMENT 246
3.7 Using MySQL with Apache 248

This chapter provides a tutorial introduction to MySQL by showing how to use the `mysql` client program to create and use a simple database. `mysql` (sometimes referred to as the “terminal monitor” or just “monitor”) is an interactive program that enables you to connect to a MySQL server, run queries, and view the results. `mysql` may also be used in batch mode: you place your queries in a file beforehand, then tell `mysql` to execute the contents of the file. Both ways of using `mysql` are covered here.

To see a list of options provided by `mysql`, invoke it with the `--help` option:

```
shell> mysql --help
```

This chapter assumes that `mysql` is installed on your machine and that a MySQL server is available to which you can connect. If this is not true, contact your MySQL administrator. (If *you* are the administrator, you need to consult the relevant portions of this manual, such as Chapter 5, *MySQL Server Administration*.)

This chapter describes the entire process of setting up and using a database. If you are interested only in accessing an existing database, you may want to skip over the sections that describe how to create the database and the tables it contains.

Because this chapter is tutorial in nature, many details are necessarily omitted. Consult the relevant sections of the manual for more information on the topics covered here.

3.1 Connecting to and Disconnecting from the Server

To connect to the server, you will usually need to provide a MySQL user name when you invoke `mysql` and, most likely, a password. If the server runs on a machine other than the one where you log in, you will also need to specify a host name. Contact your administrator to find out what connection parameters you should use to connect (that is, what host, user name, and password to use). Once you know the proper parameters, you should be able to connect like this:

```
shell> mysql -h host -u user -p
Enter password: ********
```

host and *user* represent the host name where your MySQL server is running and the user name of your MySQL account. Substitute appropriate values for your setup. The `********` represents your password; enter it when `mysql` displays the `Enter password:` prompt.

If that works, you should see some introductory information followed by a `mysql>` prompt:

```
shell> mysql -h host -u user -p
Enter password: ********
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 25338 to server version: 5.5.60-standard

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql>
```

The `mysql>` prompt tells you that `mysql` is ready for you to enter SQL statements.

If you are logging in on the same machine that MySQL is running on, you can omit the host, and simply use the following:

```
shell> mysql -u user -p
```

If, when you attempt to log in, you get an error message such as `ERROR 2002 (HY000): Can't connect to local MySQL server through socket '/tmp/mysql.sock' (2)`, it means that the MySQL server daemon (Unix) or service (Windows) is not running. Consult the administrator or see the section of Chapter 2, *Installing and Upgrading MySQL* that is appropriate to your operating system.

For help with other problems often encountered when trying to log in, see Section B.5.2, “Common Errors When Using MySQL Programs”.

Some MySQL installations permit users to connect as the anonymous (unnamed) user to the server running on the local host. If this is the case on your machine, you should be able to connect to that server by invoking `mysql` without any options:

```
shell> mysql
```

After you have connected successfully, you can disconnect any time by typing `QUIT` (or `\q`) at the `mysql>` prompt:

```
mysql> QUIT
Bye
```

On Unix, you can also disconnect by pressing Control+D.

Most examples in the following sections assume that you are connected to the server. They indicate this by the `mysql>` prompt.

3.2 Entering Queries

Make sure that you are connected to the server, as discussed in the previous section. Doing so does not in itself select any database to work with, but that is okay. At this point, it is more important to find out a little about how to issue queries than to jump right in creating tables, loading data into them, and retrieving data from them. This section describes the basic principles of entering queries, using several queries you can try out to familiarize yourself with how `mysql` works.

Here is a simple query that asks the server to tell you its version number and the current date. Type it in as shown here following the `mysql>` prompt and press Enter:

```
mysql> SELECT VERSION(), CURRENT_DATE;
+--------------+--------------+
| VERSION()    | CURRENT_DATE |
+--------------+--------------+
| 5.5.0-m2-log | 2009-05-04   |
+--------------+--------------+
1 row in set (0.01 sec)
mysql>
```

This query illustrates several things about `mysql`:

- A query normally consists of an SQL statement followed by a semicolon. (There are some exceptions where a semicolon may be omitted. `QUIT`, mentioned earlier, is one of them. We'll get to others later.)
- When you issue a query, `mysql` sends it to the server for execution and displays the results, then prints another `mysql>` prompt to indicate that it is ready for another query.
- `mysql` displays query output in tabular form (rows and columns). The first row contains labels for the columns. The rows following are the query results. Normally, column labels are the names of the columns you fetch from database tables. If you're retrieving the value of an expression rather than a table column (as in the example just shown), `mysql` labels the column using the expression itself.
- `mysql` shows how many rows were returned and how long the query took to execute, which gives you a rough idea of server performance. These values are imprecise because they represent wall clock time (not CPU or machine time), and because they are affected by factors such as server load and network latency. (For brevity, the “rows in set” line is sometimes not shown in the remaining examples in this chapter.)

Keywords may be entered in any lettercase. The following queries are equivalent:

```
mysql> SELECT VERSION(), CURRENT_DATE;
mysql> select version(), current_date;
mysql> SeLeCt vErSiOn(), current_DATE;
```

Here is another query. It demonstrates that you can use `mysql` as a simple calculator:

```
mysql> SELECT SIN(PI()/4), (4+1)*5;
+------------------+---------+
| SIN(PI()/4)      | (4+1)*5 |
+------------------+---------+
| 0.70710678118655 |      25 |
+------------------+---------+
1 row in set (0.02 sec)
```

The queries shown thus far have been relatively short, single-line statements. You can even enter multiple statements on a single line. Just end each one with a semicolon:

```
mysql> SELECT VERSION(); SELECT NOW();
+--------------+
| VERSION()    |
+--------------+
| 5.5.0-m2-log |
+--------------+
1 row in set (0.00 sec)

+---------------------+
| NOW()               |
+---------------------+
| 2009-05-04 15:15:00 |
+---------------------+
```

```
1 row in set (0.00 sec)
```

A query need not be given all on a single line, so lengthy queries that require several lines are not a problem. `mysql` determines where your statement ends by looking for the terminating semicolon, not by looking for the end of the input line. (In other words, `mysql` accepts free-format input: it collects input lines but does not execute them until it sees the semicolon.)

Here is a simple multiple-line statement:

```
mysql> SELECT
    -> USER()
    -> ,
    -> CURRENT_DATE;
+---------------+--------------+
| USER()        | CURRENT_DATE |
+---------------+--------------+
| jon@localhost | 2005-10-11   |
+---------------+--------------+
```

In this example, notice how the prompt changes from `mysql>` to `->` after you enter the first line of a multiple-line query. This is how `mysql` indicates that it has not yet seen a complete statement and is waiting for the rest. The prompt is your friend, because it provides valuable feedback. If you use that feedback, you can always be aware of what `mysql` is waiting for.

If you decide you do not want to execute a query that you are in the process of entering, cancel it by typing `\c`:

```
mysql> SELECT
    -> USER()
    -> \c
mysql>
```

Here, too, notice the prompt. It switches back to `mysql>` after you type `\c`, providing feedback to indicate that `mysql` is ready for a new query.

The following table shows each of the prompts you may see and summarizes what they mean about the state that `mysql` is in.

Prompt	Meaning
`mysql>`	Ready for new query
`->`	Waiting for next line of multiple-line query
`'>`	Waiting for next line, waiting for completion of a string that began with a single quote (`'`)
`">`	Waiting for next line, waiting for completion of a string that began with a double quote (`"`)
`` `> ``	Waiting for next line, waiting for completion of an identifier that began with a backtick (`` ` ``)
`/*>`	Waiting for next line, waiting for completion of a comment that began with `/*`

Multiple-line statements commonly occur by accident when you intend to issue a query on a single line, but forget the terminating semicolon. In this case, `mysql` waits for more input:

```
mysql> SELECT USER()
    ->
```

If this happens to you (you think you've entered a statement but the only response is a `->` prompt), most likely `mysql` is waiting for the semicolon. If you don't notice what the prompt is telling you, you might sit there for a while before realizing what you need to do. Enter a semicolon to complete the statement, and `mysql` executes it:

```
mysql> SELECT USER()
    -> ;
```

```
+---------------+
| USER()        |
+---------------+
| jon@localhost |
+---------------+
```

The `'>` and `">` prompts occur during string collection (another way of saying that MySQL is waiting for completion of a string). In MySQL, you can write strings surrounded by either `'` or `"` characters (for example, `'hello'` or `"goodbye"`), and `mysql` lets you enter strings that span multiple lines. When you see a `'>` or `">` prompt, it means that you have entered a line containing a string that begins with a `'` or `"` quote character, but have not yet entered the matching quote that terminates the string. This often indicates that you have inadvertently left out a quote character. For example:

```
mysql> SELECT * FROM my_table WHERE name = 'Smith AND age < 30;
    '>
```

If you enter this `SELECT` statement, then press **Enter** and wait for the result, nothing happens. Instead of wondering why this query takes so long, notice the clue provided by the `'>` prompt. It tells you that `mysql` expects to see the rest of an unterminated string. (Do you see the error in the statement? The string `'Smith` is missing the second single quotation mark.)

At this point, what do you do? The simplest thing is to cancel the query. However, you cannot just type `\c` in this case, because `mysql` interprets it as part of the string that it is collecting. Instead, enter the closing quote character (so `mysql` knows you've finished the string), then type `\c`:

```
mysql> SELECT * FROM my_table WHERE name = 'Smith AND age < 30;
    '> '\c
mysql>
```

The prompt changes back to `mysql>`, indicating that `mysql` is ready for a new query.

The `` `> `` prompt is similar to the `'>` and `">` prompts, but indicates that you have begun but not completed a backtick-quoted identifier.

It is important to know what the `'>`, `">`, and `` `> `` prompts signify, because if you mistakenly enter an unterminated string, any further lines you type appear to be ignored by `mysql`—including a line containing `QUIT`. This can be quite confusing, especially if you do not know that you need to supply the terminating quote before you can cancel the current query.

3.3 Creating and Using a Database

Once you know how to enter SQL statements, you are ready to access a database.

Suppose that you have several pets in your home (your menagerie) and you would like to keep track of various types of information about them. You can do so by creating tables to hold your data and loading them with the desired information. Then you can answer different sorts of questions about your animals by retrieving data from the tables. This section shows you how to perform the following operations:

- Create a database
- Create a table
- Load data into the table
- Retrieve data from the table in various ways
- Use multiple tables

The menagerie database is simple (deliberately), but it is not difficult to think of real-world situations in which a similar type of database might be used. For example, a database like this could be used by a farmer to keep track of livestock, or by a veterinarian to keep track of patient records. A menagerie

distribution containing some of the queries and sample data used in the following sections can be obtained from the MySQL Web site. It is available in both compressed `tar` file and Zip formats at http://dev.mysql.com/doc/.

Use the `SHOW` statement to find out what databases currently exist on the server:

```
mysql> SHOW DATABASES;
+----------+
| Database |
+----------+
| mysql    |
| test     |
| tmp      |
+----------+
```

The `mysql` database describes user access privileges. The `test` database often is available as a workspace for users to try things out.

The list of databases displayed by the statement may be different on your machine; `SHOW DATABASES` does not show databases that you have no privileges for if you do not have the `SHOW DATABASES` privilege. See Section 13.7.5.15, “SHOW DATABASES Syntax”.

If the `test` database exists, try to access it:

```
mysql> USE test
Database changed
```

`USE`, like `QUIT`, does not require a semicolon. (You can terminate such statements with a semicolon if you like; it does no harm.) The `USE` statement is special in another way, too: it must be given on a single line.

You can use the `test` database (if you have access to it) for the examples that follow, but anything you create in that database can be removed by anyone else with access to it. For this reason, you should probably ask your MySQL administrator for permission to use a database of your own. Suppose that you want to call yours `menagerie`. The administrator needs to execute a statement like this:

```
mysql> GRANT ALL ON menagerie.* TO 'your_mysql_name'@'your_client_host';
```

where `your_mysql_name` is the MySQL user name assigned to you and `your_client_host` is the host from which you connect to the server.

3.3.1 Creating and Selecting a Database

If the administrator creates your database for you when setting up your permissions, you can begin using it. Otherwise, you need to create it yourself:

```
mysql> CREATE DATABASE menagerie;
```

Under Unix, database names are case sensitive (unlike SQL keywords), so you must always refer to your database as `menagerie`, not as `Menagerie`, `MENAGERIE`, or some other variant. This is also true for table names. (Under Windows, this restriction does not apply, although you must refer to databases and tables using the same lettercase throughout a given query. However, for a variety of reasons, the recommended best practice is always to use the same lettercase that was used when the database was created.)

Note

If you get an error such as `ERROR 1044 (42000): Access denied for user 'micah'@'localhost' to database 'menagerie'` when attempting to create a database, this means that your user account does not

have the necessary privileges to do so. Discuss this with the administrator or see Section 6.2, “The MySQL Access Privilege System”.

Creating a database does not select it for use; you must do that explicitly. To make `menagerie` the current database, use this statement:

```
mysql> USE menagerie
Database changed
```

Your database needs to be created only once, but you must select it for use each time you begin a `mysql` session. You can do this by issuing a `USE` statement as shown in the example. Alternatively, you can select the database on the command line when you invoke `mysql`. Just specify its name after any connection parameters that you might need to provide. For example:

```
shell> mysql -h host -u user -p menagerie
Enter password: ********
```

Important

`menagerie` in the command just shown is **not** your password. If you want to supply your password on the command line after the `-p` option, you must do so with no intervening space (for example, as `-ppassword`, not as `-p password`). However, putting your password on the command line is not recommended, because doing so exposes it to snooping by other users logged in on your machine.

Note

You can see at any time which database is currently selected using `SELECT DATABASE()`.

3.3.2 Creating a Table

Creating the database is the easy part, but at this point it is empty, as `SHOW TABLES` tells you:

```
mysql> SHOW TABLES;
Empty set (0.00 sec)
```

The harder part is deciding what the structure of your database should be: what tables you need and what columns should be in each of them.

You want a table that contains a record for each of your pets. This can be called the `pet` table, and it should contain, as a bare minimum, each animal's name. Because the name by itself is not very interesting, the table should contain other information. For example, if more than one person in your family keeps pets, you might want to list each animal's owner. You might also want to record some basic descriptive information such as species and sex.

How about age? That might be of interest, but it is not a good thing to store in a database. Age changes as time passes, which means you'd have to update your records often. Instead, it is better to store a fixed value such as date of birth. Then, whenever you need age, you can calculate it as the difference between the current date and the birth date. MySQL provides functions for doing date arithmetic, so this is not difficult. Storing birth date rather than age has other advantages, too:

- You can use the database for tasks such as generating reminders for upcoming pet birthdays. (If you think this type of query is somewhat silly, note that it is the same question you might ask in the context of a business database to identify clients to whom you need to send out birthday greetings in the current week or month, for that computer-assisted personal touch.)
- You can calculate age in relation to dates other than the current date. For example, if you store death date in the database, you can easily calculate how old a pet was when it died.

You can probably think of other types of information that would be useful in the `pet` table, but the ones identified so far are sufficient: name, owner, species, sex, birth, and death.

Use a `CREATE TABLE` statement to specify the layout of your table:

```
mysql> CREATE TABLE pet (name VARCHAR(20), owner VARCHAR(20),
    -> species VARCHAR(20), sex CHAR(1), birth DATE, death DATE);
```

`VARCHAR` is a good choice for the `name`, `owner`, and `species` columns because the column values vary in length. The lengths in those column definitions need not all be the same, and need not be `20`. You can normally pick any length from `1` to `65535`, whatever seems most reasonable to you. If you make a poor choice and it turns out later that you need a longer field, MySQL provides an `ALTER TABLE` statement.

Several types of values can be chosen to represent sex in animal records, such as `'m'` and `'f'`, or perhaps `'male'` and `'female'`. It is simplest to use the single characters `'m'` and `'f'`.

The use of the `DATE` data type for the `birth` and `death` columns is a fairly obvious choice.

Once you have created a table, `SHOW TABLES` should produce some output:

```
mysql> SHOW TABLES;
+----------------------+
| Tables in menagerie |
+----------------------+
| pet                  |
+----------------------+
```

To verify that your table was created the way you expected, use a `DESCRIBE` statement:

```
mysql> DESCRIBE pet;
+---------+-------------+------+-----+---------+-------+
| Field   | Type        | Null | Key | Default | Extra |
+---------+-------------+------+-----+---------+-------+
| name    | varchar(20) | YES  |     | NULL    |       |
| owner   | varchar(20) | YES  |     | NULL    |       |
| species | varchar(20) | YES  |     | NULL    |       |
| sex     | char(1)     | YES  |     | NULL    |       |
| birth   | date        | YES  |     | NULL    |       |
| death   | date        | YES  |     | NULL    |       |
+---------+-------------+------+-----+---------+-------+
```

You can use `DESCRIBE` any time, for example, if you forget the names of the columns in your table or what types they have.

For more information about MySQL data types, see Chapter 11, *Data Types*.

3.3.3 Loading Data into a Table

After creating your table, you need to populate it. The `LOAD DATA` and `INSERT` statements are useful for this.

Suppose that your pet records can be described as shown here. (Observe that MySQL expects dates in `'YYYY-MM-DD'` format; this may be different from what you are used to.)

name	owner	species	sex	birth	death
Fluffy	Harold	cat	f	1993-02-04	
Claws	Gwen	cat	m	1994-03-17	
Buffy	Harold	dog	f	1989-05-13	
Fang	Benny	dog	m	1990-08-27	

name	owner	species	sex	birth	death
Bowser	Diane	dog	m	1979-08-31	1995-07-29
Chirpy	Gwen	bird	f	1998-09-11	
Whistler	Gwen	bird		1997-12-09	
Slim	Benny	snake	m	1996-04-29	

Because you are beginning with an empty table, an easy way to populate it is to create a text file containing a row for each of your animals, then load the contents of the file into the table with a single statement.

You could create a text file `pet.txt` containing one record per line, with values separated by tabs, and given in the order in which the columns were listed in the `CREATE TABLE` statement. For missing values (such as unknown sexes or death dates for animals that are still living), you can use `NULL` values. To represent these in your text file, use `\N` (backslash, capital-N). For example, the record for Whistler the bird would look like this (where the whitespace between values is a single tab character):

```
Whistler        Gwen    bird    \N      1997-12-09      \N
```

To load the text file `pet.txt` into the `pet` table, use this statement:

```
mysql> LOAD DATA LOCAL INFILE '/path/pet.txt' INTO TABLE pet;
```

If you created the file on Windows with an editor that uses `\r\n` as a line terminator, you should use this statement instead:

```
mysql> LOAD DATA LOCAL INFILE '/path/pet.txt' INTO TABLE pet
    -> LINES TERMINATED BY '\r\n';
```

(On an Apple machine running OS X, you would likely want to use `LINES TERMINATED BY '\r'`.)

You can specify the column value separator and end of line marker explicitly in the `LOAD DATA` statement if you wish, but the defaults are tab and linefeed. These are sufficient for the statement to read the file `pet.txt` properly.

If the statement fails, it is likely that your MySQL installation does not have local file capability enabled by default. See Section 6.1.6, “Security Issues with LOAD DATA LOCAL”, for information on how to change this.

When you want to add new records one at a time, the `INSERT` statement is useful. In its simplest form, you supply values for each column, in the order in which the columns were listed in the `CREATE TABLE` statement. Suppose that Diane gets a new hamster named “Puffball.” You could add a new record using an `INSERT` statement like this:

```
mysql> INSERT INTO pet
    -> VALUES ('Puffball','Diane','hamster','f','1999-03-30',NULL);
```

String and date values are specified as quoted strings here. Also, with `INSERT`, you can insert `NULL` directly to represent a missing value. You do not use `\N` like you do with `LOAD DATA`.

From this example, you should be able to see that there would be a lot more typing involved to load your records initially using several `INSERT` statements rather than a single `LOAD DATA` statement.

3.3.4 Retrieving Information from a Table

The `SELECT` statement is used to pull information from a table. The general form of the statement is:

```
SELECT what_to_select
```

```
FROM which_table
WHERE conditions_to_satisfy;
```

what_to_select indicates what you want to see. This can be a list of columns, or * to indicate “all columns.” *which_table* indicates the table from which you want to retrieve data. The WHERE clause is optional. If it is present, *conditions_to_satisfy* specifies one or more conditions that rows must satisfy to qualify for retrieval.

3.3.4.1 Selecting All Data

The simplest form of SELECT retrieves everything from a table:

```
mysql> SELECT * FROM pet;
+----------+--------+---------+------+------------+------------+
| name     | owner  | species | sex  | birth      | death      |
+----------+--------+---------+------+------------+------------+
| Fluffy   | Harold | cat     | f    | 1993-02-04 | NULL       |
| Claws    | Gwen   | cat     | m    | 1994-03-17 | NULL       |
| Buffy    | Harold | dog     | f    | 1989-05-13 | NULL       |
| Fang     | Benny  | dog     | m    | 1990-08-27 | NULL       |
| Bowser   | Diane  | dog     | m    | 1979-08-31 | 1995-07-29 |
| Chirpy   | Gwen   | bird    | f    | 1998-09-11 | NULL       |
| Whistler | Gwen   | bird    | NULL | 1997-12-09 | NULL       |
| Slim     | Benny  | snake   | m    | 1996-04-29 | NULL       |
| Puffball | Diane  | hamster | f    | 1999-03-30 | NULL       |
+----------+--------+---------+------+------------+------------+
```

This form of SELECT is useful if you want to review your entire table, for example, after you've just loaded it with your initial data set. For example, you may happen to think that the birth date for Bowser doesn't seem quite right. Consulting your original pedigree papers, you find that the correct birth year should be 1989, not 1979.

There are at least two ways to fix this:

- Edit the file pet.txt to correct the error, then empty the table and reload it using DELETE and LOAD DATA:

  ```
  mysql> DELETE FROM pet;
  mysql> LOAD DATA LOCAL INFILE '/path/pet.txt' INTO TABLE pet;
  ```

  However, if you do this, you must also re-enter the record for Puffball.

- Fix only the erroneous record with an UPDATE statement:

  ```
  mysql> UPDATE pet SET birth = '1989-08-31' WHERE name = 'Bowser';
  ```

  The UPDATE changes only the record in question and does not require you to reload the table.

3.3.4.2 Selecting Particular Rows

As shown in the preceding section, it is easy to retrieve an entire table. Just omit the WHERE clause from the SELECT statement. But typically you don't want to see the entire table, particularly when it becomes large. Instead, you're usually more interested in answering a particular question, in which case you specify some constraints on the information you want. Let's look at some selection queries in terms of questions about your pets that they answer.

You can select only particular rows from your table. For example, if you want to verify the change that you made to Bowser's birth date, select Bowser's record like this:

```
mysql> SELECT * FROM pet WHERE name = 'Bowser';
+--------+-------+---------+------+------------+------------+
| name   | owner | species | sex  | birth      | death      |
```

```
+--------+-------+---------+------+------------+------------+
| Bowser | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+-------+---------+------+------------+------------+
```

The output confirms that the year is correctly recorded as 1989, not 1979.

String comparisons normally are case-insensitive, so you can specify the name as `'bowser'`, `'BOWSER'`, and so forth. The query result is the same.

You can specify conditions on any column, not just `name`. For example, if you want to know which animals were born during or after 1998, test the `birth` column:

```
mysql> SELECT * FROM pet WHERE birth >= '1998-1-1';
+----------+-------+---------+------+------------+-------+
| name     | owner | species | sex  | birth      | death |
+----------+-------+---------+------+------------+-------+
| Chirpy   | Gwen  | bird    | f    | 1998-09-11 | NULL  |
| Puffball | Diane | hamster | f    | 1999-03-30 | NULL  |
+----------+-------+---------+------+------------+-------+
```

You can combine conditions, for example, to locate female dogs:

```
mysql> SELECT * FROM pet WHERE species = 'dog' AND sex = 'f';
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

The preceding query uses the `AND` logical operator. There is also an `OR` operator:

```
mysql> SELECT * FROM pet WHERE species = 'snake' OR species = 'bird';
+----------+-------+---------+------+------------+-------+
| name     | owner | species | sex  | birth      | death |
+----------+-------+---------+------+------------+-------+
| Chirpy   | Gwen  | bird    | f    | 1998-09-11 | NULL  |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL  |
| Slim     | Benny | snake   | m    | 1996-04-29 | NULL  |
+----------+-------+---------+------+------------+-------+
```

`AND` and `OR` may be intermixed, although `AND` has higher precedence than `OR`. If you use both operators, it is a good idea to use parentheses to indicate explicitly how conditions should be grouped:

```
mysql> SELECT * FROM pet WHERE (species = 'cat' AND sex = 'm')
    -> OR (species = 'dog' AND sex = 'f');
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

3.3.4.3 Selecting Particular Columns

If you do not want to see entire rows from your table, just name the columns in which you are interested, separated by commas. For example, if you want to know when your animals were born, select the `name` and `birth` columns:

```
mysql> SELECT name, birth FROM pet;
+----------+------------+
| name     | birth      |
+----------+------------+
| Fluffy   | 1993-02-04 |
| Claws    | 1994-03-17 |
```

```
| Buffy    | 1989-05-13 |
| Fang     | 1990-08-27 |
| Bowser   | 1989-08-31 |
| Chirpy   | 1998-09-11 |
| Whistler | 1997-12-09 |
| Slim     | 1996-04-29 |
| Puffball | 1999-03-30 |
+----------+------------+
```

To find out who owns pets, use this query:

```
mysql> SELECT owner FROM pet;
+--------+
| owner  |
+--------+
| Harold |
| Gwen   |
| Harold |
| Benny  |
| Diane  |
| Gwen   |
| Gwen   |
| Benny  |
| Diane  |
+--------+
```

Notice that the query simply retrieves the `owner` column from each record, and some of them appear more than once. To minimize the output, retrieve each unique output record just once by adding the keyword `DISTINCT`:

```
mysql> SELECT DISTINCT owner FROM pet;
+--------+
| owner  |
+--------+
| Benny  |
| Diane  |
| Gwen   |
| Harold |
+--------+
```

You can use a `WHERE` clause to combine row selection with column selection. For example, to get birth dates for dogs and cats only, use this query:

```
mysql> SELECT name, species, birth FROM pet
    -> WHERE species = 'dog' OR species = 'cat';
+--------+---------+------------+
| name   | species | birth      |
+--------+---------+------------+
| Fluffy | cat     | 1993-02-04 |
| Claws  | cat     | 1994-03-17 |
| Buffy  | dog     | 1989-05-13 |
| Fang   | dog     | 1990-08-27 |
| Bowser | dog     | 1989-08-31 |
+--------+---------+------------+
```

3.3.4.4 Sorting Rows

You may have noticed in the preceding examples that the result rows are displayed in no particular order. It is often easier to examine query output when the rows are sorted in some meaningful way. To sort a result, use an `ORDER BY` clause.

Here are animal birthdays, sorted by date:

```
mysql> SELECT name, birth FROM pet ORDER BY birth;
+----------+------------+
```

```
| name     | birth      |
+----------+------------+
| Buffy    | 1989-05-13 |
| Bowser   | 1989-08-31 |
| Fang     | 1990-08-27 |
| Fluffy   | 1993-02-04 |
| Claws    | 1994-03-17 |
| Slim     | 1996-04-29 |
| Whistler | 1997-12-09 |
| Chirpy   | 1998-09-11 |
| Puffball | 1999-03-30 |
+----------+------------+
```

On character type columns, sorting—like all other comparison operations—is normally performed in a case-insensitive fashion. This means that the order is undefined for columns that are identical except for their case. You can force a case-sensitive sort for a column by using `BINARY` like so: `ORDER BY BINARY col_name`.

The default sort order is ascending, with smallest values first. To sort in reverse (descending) order, add the `DESC` keyword to the name of the column you are sorting by:

```
mysql> SELECT name, birth FROM pet ORDER BY birth DESC;
+----------+------------+
| name     | birth      |
+----------+------------+
| Puffball | 1999-03-30 |
| Chirpy   | 1998-09-11 |
| Whistler | 1997-12-09 |
| Slim     | 1996-04-29 |
| Claws    | 1994-03-17 |
| Fluffy   | 1993-02-04 |
| Fang     | 1990-08-27 |
| Bowser   | 1989-08-31 |
| Buffy    | 1989-05-13 |
+----------+------------+
```

You can sort on multiple columns, and you can sort different columns in different directions. For example, to sort by type of animal in ascending order, then by birth date within animal type in descending order (youngest animals first), use the following query:

```
mysql> SELECT name, species, birth FROM pet
    -> ORDER BY species, birth DESC;
+----------+---------+------------+
| name     | species | birth      |
+----------+---------+------------+
| Chirpy   | bird    | 1998-09-11 |
| Whistler | bird    | 1997-12-09 |
| Claws    | cat     | 1994-03-17 |
| Fluffy   | cat     | 1993-02-04 |
| Fang     | dog     | 1990-08-27 |
| Bowser   | dog     | 1989-08-31 |
| Buffy    | dog     | 1989-05-13 |
| Puffball | hamster | 1999-03-30 |
| Slim     | snake   | 1996-04-29 |
+----------+---------+------------+
```

The `DESC` keyword applies only to the column name immediately preceding it (`birth`); it does not affect the `species` column sort order.

3.3.4.5 Date Calculations

MySQL provides several functions that you can use to perform calculations on dates, for example, to calculate ages or extract parts of dates.

To determine how many years old each of your pets is, use the `TIMESTAMPDIFF()` function. Its arguments are the unit in which you want the result expressed, and the two date for which to take the

difference. The following query shows, for each pet, the birth date, the current date, and the age in years. An *alias* (`age`) is used to make the final output column label more meaningful.

```
mysql> SELECT name, birth, CURDATE(),
    -> TIMESTAMPDIFF(YEAR,birth,CURDATE()) AS age
    -> FROM pet;
+----------+------------+------------+------+
| name     | birth      | CURDATE()  | age  |
+----------+------------+------------+------+
| Fluffy   | 1993-02-04 | 2003-08-19 |   10 |
| Claws    | 1994-03-17 | 2003-08-19 |    9 |
| Buffy    | 1989-05-13 | 2003-08-19 |   14 |
| Fang     | 1990-08-27 | 2003-08-19 |   12 |
| Bowser   | 1989-08-31 | 2003-08-19 |   13 |
| Chirpy   | 1998-09-11 | 2003-08-19 |    4 |
| Whistler | 1997-12-09 | 2003-08-19 |    5 |
| Slim     | 1996-04-29 | 2003-08-19 |    7 |
| Puffball | 1999-03-30 | 2003-08-19 |    4 |
+----------+------------+------------+------+
```

The query works, but the result could be scanned more easily if the rows were presented in some order. This can be done by adding an `ORDER BY name` clause to sort the output by name:

```
mysql> SELECT name, birth, CURDATE(),
    -> TIMESTAMPDIFF(YEAR,birth,CURDATE()) AS age
    -> FROM pet ORDER BY name;
+----------+------------+------------+------+
| name     | birth      | CURDATE()  | age  |
+----------+------------+------------+------+
| Bowser   | 1989-08-31 | 2003-08-19 |   13 |
| Buffy    | 1989-05-13 | 2003-08-19 |   14 |
| Chirpy   | 1998-09-11 | 2003-08-19 |    4 |
| Claws    | 1994-03-17 | 2003-08-19 |    9 |
| Fang     | 1990-08-27 | 2003-08-19 |   12 |
| Fluffy   | 1993-02-04 | 2003-08-19 |   10 |
| Puffball | 1999-03-30 | 2003-08-19 |    4 |
| Slim     | 1996-04-29 | 2003-08-19 |    7 |
| Whistler | 1997-12-09 | 2003-08-19 |    5 |
+----------+------------+------------+------+
```

To sort the output by `age` rather than `name`, just use a different `ORDER BY` clause:

```
mysql> SELECT name, birth, CURDATE(),
    -> TIMESTAMPDIFF(YEAR,birth,CURDATE()) AS age
    -> FROM pet ORDER BY age;
+----------+------------+------------+------+
| name     | birth      | CURDATE()  | age  |
+----------+------------+------------+------+
| Chirpy   | 1998-09-11 | 2003-08-19 |    4 |
| Puffball | 1999-03-30 | 2003-08-19 |    4 |
| Whistler | 1997-12-09 | 2003-08-19 |    5 |
| Slim     | 1996-04-29 | 2003-08-19 |    7 |
| Claws    | 1994-03-17 | 2003-08-19 |    9 |
| Fluffy   | 1993-02-04 | 2003-08-19 |   10 |
| Fang     | 1990-08-27 | 2003-08-19 |   12 |
| Bowser   | 1989-08-31 | 2003-08-19 |   13 |
| Buffy    | 1989-05-13 | 2003-08-19 |   14 |
+----------+------------+------------+------+
```

A similar query can be used to determine age at death for animals that have died. You determine which animals these are by checking whether the `death` value is `NULL`. Then, for those with non-`NULL` values, compute the difference between the `death` and `birth` values:

```
mysql> SELECT name, birth, death,
    -> TIMESTAMPDIFF(YEAR,birth,death) AS age
    -> FROM pet WHERE death IS NOT NULL ORDER BY age;
+--------+------------+------------+------+
```

```
| name   | birth      | death      | age  |
+--------+------------+------------+------+
| Bowser | 1989-08-31 | 1995-07-29 |    5 |
+--------+------------+------------+------+
```

The query uses `death IS NOT NULL` rather than `death <> NULL` because `NULL` is a special value that cannot be compared using the usual comparison operators. This is discussed later. See Section 3.3.4.6, “Working with NULL Values”.

What if you want to know which animals have birthdays next month? For this type of calculation, year and day are irrelevant; you simply want to extract the month part of the `birth` column. MySQL provides several functions for extracting parts of dates, such as `YEAR()`, `MONTH()`, and `DAYOFMONTH()`. `MONTH()` is the appropriate function here. To see how it works, run a simple query that displays the value of both `birth` and `MONTH(birth)`:

```
mysql> SELECT name, birth, MONTH(birth) FROM pet;
+----------+------------+--------------+
| name     | birth      | MONTH(birth) |
+----------+------------+--------------+
| Fluffy   | 1993-02-04 |            2 |
| Claws    | 1994-03-17 |            3 |
| Buffy    | 1989-05-13 |            5 |
| Fang     | 1990-08-27 |            8 |
| Bowser   | 1989-08-31 |            8 |
| Chirpy   | 1998-09-11 |            9 |
| Whistler | 1997-12-09 |           12 |
| Slim     | 1996-04-29 |            4 |
| Puffball | 1999-03-30 |            3 |
+----------+------------+--------------+
```

Finding animals with birthdays in the upcoming month is also simple. Suppose that the current month is April. Then the month value is `4` and you can look for animals born in May (month `5`) like this:

```
mysql> SELECT name, birth FROM pet WHERE MONTH(birth) = 5;
+-------+------------+
| name  | birth      |
+-------+------------+
| Buffy | 1989-05-13 |
+-------+------------+
```

There is a small complication if the current month is December. You cannot merely add one to the month number (`12`) and look for animals born in month `13`, because there is no such month. Instead, you look for animals born in January (month `1`).

You can write the query so that it works no matter what the current month is, so that you do not have to use the number for a particular month. `DATE_ADD()` enables you to add a time interval to a given date. If you add a month to the value of `CURDATE()`, then extract the month part with `MONTH()`, the result produces the month in which to look for birthdays:

```
mysql> SELECT name, birth FROM pet
    -> WHERE MONTH(birth) = MONTH(DATE_ADD(CURDATE(),INTERVAL 1 MONTH));
```

A different way to accomplish the same task is to add `1` to get the next month after the current one after using the modulo function (`MOD`) to wrap the month value to `0` if it is currently `12`:

```
mysql> SELECT name, birth FROM pet
    -> WHERE MONTH(birth) = MOD(MONTH(CURDATE()), 12) + 1;
```

`MONTH()` returns a number between `1` and `12`. And `MOD(something,12)` returns a number between `0` and `11`. So the addition has to be after the `MOD()`, otherwise we would go from November (`11`) to January (`1`).

3.3.4.6 Working with NULL Values

The NULL value can be surprising until you get used to it. Conceptually, NULL means “a missing unknown value” and it is treated somewhat differently from other values.

To test for NULL, use the IS NULL and IS NOT NULL operators, as shown here:

```
mysql> SELECT 1 IS NULL, 1 IS NOT NULL;
+-----------+---------------+
| 1 IS NULL | 1 IS NOT NULL |
+-----------+---------------+
|         0 |             1 |
+-----------+---------------+
```

You cannot use arithmetic comparison operators such as =, <, or <> to test for NULL. To demonstrate this for yourself, try the following query:

```
mysql> SELECT 1 = NULL, 1 <> NULL, 1 < NULL, 1 > NULL;
+----------+-----------+----------+----------+
| 1 = NULL | 1 <> NULL | 1 < NULL | 1 > NULL |
+----------+-----------+----------+----------+
|     NULL |      NULL |     NULL |     NULL |
+----------+-----------+----------+----------+
```

Because the result of any arithmetic comparison with NULL is also NULL, you cannot obtain any meaningful results from such comparisons.

In MySQL, 0 or NULL means false and anything else means true. The default truth value from a boolean operation is 1.

This special treatment of NULL is why, in the previous section, it was necessary to determine which animals are no longer alive using death IS NOT NULL instead of death <> NULL.

Two NULL values are regarded as equal in a GROUP BY.

When doing an ORDER BY, NULL values are presented first if you do ORDER BY ... ASC and last if you do ORDER BY ... DESC.

A common error when working with NULL is to assume that it is not possible to insert a zero or an empty string into a column defined as NOT NULL, but this is not the case. These are in fact values, whereas NULL means “not having a value.” You can test this easily enough by using IS [NOT] NULL as shown:

```
mysql> SELECT 0 IS NULL, 0 IS NOT NULL, '' IS NULL, '' IS NOT NULL;
+-----------+---------------+------------+----------------+
| 0 IS NULL | 0 IS NOT NULL | '' IS NULL | '' IS NOT NULL |
+-----------+---------------+------------+----------------+
|         0 |             1 |          0 |              1 |
+-----------+---------------+------------+----------------+
```

Thus it is entirely possible to insert a zero or empty string into a NOT NULL column, as these are in fact NOT NULL. See Section B.5.4.3, “Problems with NULL Values”.

3.3.4.7 Pattern Matching

MySQL provides standard SQL pattern matching as well as a form of pattern matching based on extended regular expressions similar to those used by Unix utilities such as vi, grep, and sed.

SQL pattern matching enables you to use _ to match any single character and % to match an arbitrary number of characters (including zero characters). In MySQL, SQL patterns are case-insensitive by default. Some examples are shown here. You do not use = or <> when you use SQL patterns; use the LIKE or NOT LIKE comparison operators instead.

To find names beginning with b:

```
mysql> SELECT * FROM pet WHERE name LIKE 'b%';
+--------+--------+---------+------+------------+------------+
| name   | owner  | species | sex  | birth      | death      |
+--------+--------+---------+------+------------+------------+
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL       |
| Bowser | Diane  | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+--------+---------+------+------------+------------+
```

To find names ending with `fy`:

```
mysql> SELECT * FROM pet WHERE name LIKE '%fy';
+--------+--------+---------+------+------------+-------+
| name   | owner  | species | sex  | birth      | death |
+--------+--------+---------+------+------------+-------+
| Fluffy | Harold | cat     | f    | 1993-02-04 | NULL  |
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL  |
+--------+--------+---------+------+------------+-------+
```

To find names containing a `w`:

```
mysql> SELECT * FROM pet WHERE name LIKE '%w%';
+----------+-------+---------+------+------------+------------+
| name     | owner | species | sex  | birth      | death      |
+----------+-------+---------+------+------------+------------+
| Claws    | Gwen  | cat     | m    | 1994-03-17 | NULL       |
| Bowser   | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL       |
+----------+-------+---------+------+------------+------------+
```

To find names containing exactly five characters, use five instances of the _ pattern character:

```
mysql> SELECT * FROM pet WHERE name LIKE '_____';
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

The other type of pattern matching provided by MySQL uses extended regular expressions. When you test for a match for this type of pattern, use the `REGEXP` and `NOT REGEXP` operators (or `RLIKE` and `NOT RLIKE`, which are synonyms).

The following list describes some characteristics of extended regular expressions:

- `.` matches any single character.
- A character class `[...]` matches any character within the brackets. For example, `[abc]` matches `a`, `b`, or `c`. To name a range of characters, use a dash. `[a-z]` matches any letter, whereas `[0-9]` matches any digit.
- `*` matches zero or more instances of the thing preceding it. For example, `x*` matches any number of `x` characters, `[0-9]*` matches any number of digits, and `.*` matches any number of anything.
- A `REGEXP` pattern match succeeds if the pattern matches anywhere in the value being tested. (This differs from a `LIKE` pattern match, which succeeds only if the pattern matches the entire value.)
- To anchor a pattern so that it must match the beginning or end of the value being tested, use `^` at the beginning or `$` at the end of the pattern.

To demonstrate how extended regular expressions work, the `LIKE` queries shown previously are rewritten here to use `REGEXP`.

To find names beginning with `b`, use `^` to match the beginning of the name:

```
mysql> SELECT * FROM pet WHERE name REGEXP '^b';
+--------+--------+---------+------+------------+------------+
| name   | owner  | species | sex  | birth      | death      |
+--------+--------+---------+------+------------+------------+
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL       |
| Bowser | Diane  | dog     | m    | 1989-08-31 | 1995-07-29 |
+--------+--------+---------+------+------------+------------+
```

If you really want to force a `REGEXP` comparison to be case sensitive, use the `BINARY` keyword to make one of the strings a binary string. This query matches only lowercase `b` at the beginning of a name:

```
mysql> SELECT * FROM pet WHERE name REGEXP BINARY '^b';
```

To find names ending with `fy`, use `$` to match the end of the name:

```
mysql> SELECT * FROM pet WHERE name REGEXP 'fy$';
+--------+--------+---------+------+------------+-------+
| name   | owner  | species | sex  | birth      | death |
+--------+--------+---------+------+------------+-------+
| Fluffy | Harold | cat     | f    | 1993-02-04 | NULL  |
| Buffy  | Harold | dog     | f    | 1989-05-13 | NULL  |
+--------+--------+---------+------+------------+-------+
```

To find names containing a `w`, use this query:

```
mysql> SELECT * FROM pet WHERE name REGEXP 'w';
+----------+-------+---------+------+------------+------------+
| name     | owner | species | sex  | birth      | death      |
+----------+-------+---------+------+------------+------------+
| Claws    | Gwen  | cat     | m    | 1994-03-17 | NULL       |
| Bowser   | Diane | dog     | m    | 1989-08-31 | 1995-07-29 |
| Whistler | Gwen  | bird    | NULL | 1997-12-09 | NULL       |
+----------+-------+---------+------+------------+------------+
```

Because a regular expression pattern matches if it occurs anywhere in the value, it is not necessary in the previous query to put a wildcard on either side of the pattern to get it to match the entire value like it would be if you used an SQL pattern.

To find names containing exactly five characters, use `^` and `$` to match the beginning and end of the name, and five instances of `.` in between:

```
mysql> SELECT * FROM pet WHERE name REGEXP '^.....$';
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

You could also write the previous query using the `{n}` (“repeat-*n*-times”) operator:

```
mysql> SELECT * FROM pet WHERE name REGEXP '^.{5}$';
+-------+--------+---------+------+------------+-------+
| name  | owner  | species | sex  | birth      | death |
+-------+--------+---------+------+------------+-------+
| Claws | Gwen   | cat     | m    | 1994-03-17 | NULL  |
| Buffy | Harold | dog     | f    | 1989-05-13 | NULL  |
+-------+--------+---------+------+------------+-------+
```

Section 12.5.2, “Regular Expressions”, provides more information about the syntax for regular expressions.

3.3.4.8 Counting Rows

Databases are often used to answer the question, “How often does a certain type of data occur in a table?” For example, you might want to know how many pets you have, or how many pets each owner has, or you might want to perform various kinds of census operations on your animals.

Counting the total number of animals you have is the same question as “How many rows are in the `pet` table?” because there is one record per pet. `COUNT(*)` counts the number of rows, so the query to count your animals looks like this:

```
mysql> SELECT COUNT(*) FROM pet;
+----------+
| COUNT(*) |
+----------+
|        9 |
+----------+
```

Earlier, you retrieved the names of the people who owned pets. You can use `COUNT()` if you want to find out how many pets each owner has:

```
mysql> SELECT owner, COUNT(*) FROM pet GROUP BY owner;
+--------+----------+
| owner  | COUNT(*) |
+--------+----------+
| Benny  |        2 |
| Diane  |        2 |
| Gwen   |        3 |
| Harold |        2 |
+--------+----------+
```

The preceding query uses `GROUP BY` to group all records for each `owner`. The use of `COUNT()` in conjunction with `GROUP BY` is useful for characterizing your data under various groupings. The following examples show different ways to perform animal census operations.

Number of animals per species:

```
mysql> SELECT species, COUNT(*) FROM pet GROUP BY species;
+---------+----------+
| species | COUNT(*) |
+---------+----------+
| bird    |        2 |
| cat     |        2 |
| dog     |        3 |
| hamster |        1 |
| snake   |        1 |
+---------+----------+
```

Number of animals per sex:

```
mysql> SELECT sex, COUNT(*) FROM pet GROUP BY sex;
+------+----------+
| sex  | COUNT(*) |
+------+----------+
| NULL |        1 |
| f    |        4 |
| m    |        4 |
+------+----------+
```

(In this output, `NULL` indicates that the sex is unknown.)

Number of animals per combination of species and sex:

```
mysql> SELECT species, sex, COUNT(*) FROM pet GROUP BY species, sex;
+---------+------+----------+
```

```
| species | sex  | COUNT(*) |
+---------+------+----------+
| bird    | NULL |        1 |
| bird    | f    |        1 |
| cat     | f    |        1 |
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
| hamster | f    |        1 |
| snake   | m    |        1 |
+---------+------+----------+
```

You need not retrieve an entire table when you use `COUNT()`. For example, the previous query, when performed just on dogs and cats, looks like this:

```
mysql> SELECT species, sex, COUNT(*) FROM pet
    -> WHERE species = 'dog' OR species = 'cat'
    -> GROUP BY species, sex;
+---------+------+----------+
| species | sex  | COUNT(*) |
+---------+------+----------+
| cat     | f    |        1 |
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
+---------+------+----------+
```

Or, if you wanted the number of animals per sex only for animals whose sex is known:

```
mysql> SELECT species, sex, COUNT(*) FROM pet
    -> WHERE sex IS NOT NULL
    -> GROUP BY species, sex;
+---------+------+----------+
| species | sex  | COUNT(*) |
+---------+------+----------+
| bird    | f    |        1 |
| cat     | f    |        1 |
| cat     | m    |        1 |
| dog     | f    |        1 |
| dog     | m    |        2 |
| hamster | f    |        1 |
| snake   | m    |        1 |
+---------+------+----------+
```

If you name columns to select in addition to the `COUNT()` value, a `GROUP BY` clause should be present that names those same columns. Otherwise, the following occurs:

- If the `ONLY_FULL_GROUP_BY` SQL mode is enabled, an error occurs:

  ```
  mysql> SET sql_mode = 'ONLY_FULL_GROUP_BY';
  Query OK, 0 rows affected (0.00 sec)

  mysql> SELECT owner, COUNT(*) FROM pet;
  ERROR 1140 (42000): Mixing of GROUP columns (MIN(),MAX(),COUNT()...)
  with no GROUP columns is illegal if there is no GROUP BY clause
  ```

- If `ONLY_FULL_GROUP_BY` is not enabled, the query is processed by treating all rows as a single group, but the value selected for each named column is indeterminate. The server is free to select the value from any row:

  ```
  mysql> SET sql_mode = '';
  Query OK, 0 rows affected (0.00 sec)

  mysql> SELECT owner, COUNT(*) FROM pet;
  +--------+----------+
  | owner  | COUNT(*) |
  ```

```
+--------+----------+
| Harold |        8 |
+--------+----------+
1 row in set (0.00 sec)
```

See also Section 12.16.3, “MySQL Handling of GROUP BY”. See Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions” for information about `COUNT(expr)` behavior and related optimizations.

3.3.4.9 Using More Than one Table

The `pet` table keeps track of which pets you have. If you want to record other information about them, such as events in their lives like visits to the vet or when litters are born, you need another table. What should this table look like? It needs to contain the following information:

- The pet name so that you know which animal each event pertains to.
- A date so that you know when the event occurred.
- A field to describe the event.
- An event type field, if you want to be able to categorize events.

Given these considerations, the `CREATE TABLE` statement for the `event` table might look like this:

```
mysql> CREATE TABLE event (name VARCHAR(20), date DATE,
    -> type VARCHAR(15), remark VARCHAR(255));
```

As with the `pet` table, it is easiest to load the initial records by creating a tab-delimited text file containing the following information.

name	date	type	remark
Fluffy	1995-05-15	litter	4 kittens, 3 female, 1 male
Buffy	1993-06-23	litter	5 puppies, 2 female, 3 male
Buffy	1994-06-19	litter	3 puppies, 3 female
Chirpy	1999-03-21	vet	needed beak straightened
Slim	1997-08-03	vet	broken rib
Bowser	1991-10-12	kennel	
Fang	1991-10-12	kennel	
Fang	1998-08-28	birthday	Gave him a new chew toy
Claws	1998-03-17	birthday	Gave him a new flea collar
Whistler	1998-12-09	birthday	First birthday

Load the records like this:

```
mysql> LOAD DATA LOCAL INFILE 'event.txt' INTO TABLE event;
```

Based on what you have learned from the queries that you have run on the `pet` table, you should be able to perform retrievals on the records in the `event` table; the principles are the same. But when is the `event` table by itself insufficient to answer questions you might ask?

Suppose that you want to find out the ages at which each pet had its litters. We saw earlier how to calculate ages from two dates. The litter date of the mother is in the `event` table, but to calculate her age on that date you need her birth date, which is stored in the `pet` table. This means the query requires both tables:

```
mysql> SELECT pet.name,
```

```
    -> TIMESTAMPDIFF(YEAR,birth,date) AS age,
    -> remark
    -> FROM pet INNER JOIN event
    ->   ON pet.name = event.name
    -> WHERE event.type = 'litter';
+--------+------+-----------------------------+
| name   | age  | remark                      |
+--------+------+-----------------------------+
| Fluffy |    2 | 4 kittens, 3 female, 1 male |
| Buffy  |    4 | 5 puppies, 2 female, 3 male |
| Buffy  |    5 | 3 puppies, 3 female         |
+--------+------+-----------------------------+
```

There are several things to note about this query:

- The `FROM` clause joins two tables because the query needs to pull information from both of them.
- When combining (joining) information from multiple tables, you need to specify how records in one table can be matched to records in the other. This is easy because they both have a `name` column. The query uses an `ON` clause to match up records in the two tables based on the `name` values.

  The query uses an `INNER JOIN` to combine the tables. An `INNER JOIN` permits rows from either table to appear in the result if and only if both tables meet the conditions specified in the `ON` clause. In this example, the `ON` clause specifies that the `name` column in the `pet` table must match the `name` column in the `event` table. If a name appears in one table but not the other, the row will not appear in the result because the condition in the `ON` clause fails.
- Because the `name` column occurs in both tables, you must be specific about which table you mean when referring to the column. This is done by prepending the table name to the column name.

You need not have two different tables to perform a join. Sometimes it is useful to join a table to itself, if you want to compare records in a table to other records in that same table. For example, to find breeding pairs among your pets, you can join the `pet` table with itself to produce candidate pairs of males and females of like species:

```
mysql> SELECT p1.name, p1.sex, p2.name, p2.sex, p1.species
    -> FROM pet AS p1 INNER JOIN pet AS p2
    ->   ON p1.species = p2.species AND p1.sex = 'f' AND p2.sex = 'm';
+--------+------+--------+------+---------+
| name   | sex  | name   | sex  | species |
+--------+------+--------+------+---------+
| Fluffy | f    | Claws  | m    | cat     |
| Buffy  | f    | Fang   | m    | dog     |
| Buffy  | f    | Bowser | m    | dog     |
+--------+------+--------+------+---------+
```

In this query, we specify aliases for the table name to refer to the columns and keep straight which instance of the table each column reference is associated with.

3.4 Getting Information About Databases and Tables

What if you forget the name of a database or table, or what the structure of a given table is (for example, what its columns are called)? MySQL addresses this problem through several statements that provide information about the databases and tables it supports.

You have previously seen `SHOW DATABASES`, which lists the databases managed by the server. To find out which database is currently selected, use the `DATABASE()` function:

```
mysql> SELECT DATABASE();
+------------+
| DATABASE() |
+------------+
| menagerie  |
+------------+
```

If you have not yet selected any database, the result is `NULL`.

To find out what tables the default database contains (for example, when you are not sure about the name of a table), use this statement:

```
mysql> SHOW TABLES;
+--------------------+
| Tables_in_menagerie |
+--------------------+
| event              |
| pet                |
+--------------------+
```

The name of the column in the output produced by this statement is always `Tables_in_db_name`, where *db_name* is the name of the database. See Section 13.7.5.38, “SHOW TABLES Syntax”, for more information.

If you want to find out about the structure of a table, the `DESCRIBE` statement is useful; it displays information about each of a table's columns:

```
mysql> DESCRIBE pet;
+---------+-------------+------+-----+---------+-------+
| Field   | Type        | Null | Key | Default | Extra |
+---------+-------------+------+-----+---------+-------+
| name    | varchar(20) | YES  |     | NULL    |       |
| owner   | varchar(20) | YES  |     | NULL    |       |
| species | varchar(20) | YES  |     | NULL    |       |
| sex     | char(1)     | YES  |     | NULL    |       |
| birth   | date        | YES  |     | NULL    |       |
| death   | date        | YES  |     | NULL    |       |
+---------+-------------+------+-----+---------+-------+
```

`Field` indicates the column name, `Type` is the data type for the column, `NULL` indicates whether the column can contain `NULL` values, `Key` indicates whether the column is indexed, and `Default` specifies the column's default value. `Extra` displays special information about columns: If a column was created with the `AUTO_INCREMENT` option, the value will be `auto_increment` rather than empty.

`DESC` is a short form of `DESCRIBE`. See Section 13.8.1, “DESCRIBE Syntax”, for more information.

You can obtain the `CREATE TABLE` statement necessary to create an existing table using the `SHOW CREATE TABLE` statement. See Section 13.7.5.12, “SHOW CREATE TABLE Syntax”.

If you have indexes on a table, `SHOW INDEX FROM tbl_name` produces information about them. See Section 13.7.5.23, “SHOW INDEX Syntax”, for more about this statement.

3.5 Using mysql in Batch Mode

In the previous sections, you used `mysql` interactively to enter statements and view the results. You can also run `mysql` in batch mode. To do this, put the statements you want to run in a file, then tell `mysql` to read its input from the file:

```
shell> mysql < batch-file
```

If you are running `mysql` under Windows and have some special characters in the file that cause problems, you can do this:

```
C:\> mysql -e "source batch-file"
```

If you need to specify connection parameters on the command line, the command might look like this:

```
shell> mysql -h host -u user -p < batch-file
Enter password: ********
```

When you use `mysql` this way, you are creating a script file, then executing the script.

If you want the script to continue even if some of the statements in it produce errors, you should use the `--force` command-line option.

Why use a script? Here are a few reasons:

- If you run a query repeatedly (say, every day or every week), making it a script enables you to avoid retyping it each time you execute it.
- You can generate new queries from existing ones that are similar by copying and editing script files.
- Batch mode can also be useful while you're developing a query, particularly for multiple-line statements or multiple-statement sequences. If you make a mistake, you don't have to retype everything. Just edit your script to correct the error, then tell `mysql` to execute it again.
- If you have a query that produces a lot of output, you can run the output through a pager rather than watching it scroll off the top of your screen:

```
shell> mysql < batch-file | more
```

- You can catch the output in a file for further processing:

```
shell> mysql < batch-file > mysql.out
```

- You can distribute your script to other people so that they can also run the statements.
- Some situations do not allow for interactive use, for example, when you run a query from a `cron` job. In this case, you must use batch mode.

The default output format is different (more concise) when you run `mysql` in batch mode than when you use it interactively. For example, the output of `SELECT DISTINCT species FROM pet` looks like this when `mysql` is run interactively:

```
+---------+
| species |
+---------+
| bird    |
| cat     |
| dog     |
| hamster |
| snake   |
+---------+
```

In batch mode, the output looks like this instead:

```
species
bird
cat
dog
hamster
snake
```

If you want to get the interactive output format in batch mode, use `mysql -t`. To echo to the output the statements that are executed, use `mysql -v`.

You can also use scripts from the `mysql` prompt by using the `source` command or `\.` command:

```
mysql> source filename;
mysql> \. filename
```

See Section 4.5.1.5, “Executing SQL Statements from a Text File”, for more information.

3.6 Examples of Common Queries

Here are examples of how to solve some common problems with MySQL.

Some of the examples use the table `shop` to hold the price of each article (item number) for certain traders (dealers). Supposing that each trader has a single fixed price per article, then (`article`, `dealer`) is a primary key for the records.

Start the command-line tool `mysql` and select a database:

```
shell> mysql your-database-name
```

(In most MySQL installations, you can use the database named `test`).

You can create and populate the example table with these statements:

```
CREATE TABLE shop (
    article INT(4) UNSIGNED ZEROFILL DEFAULT '0000' NOT NULL,
    dealer  CHAR(20)                 DEFAULT ''     NOT NULL,
    price   DOUBLE(16,2)             DEFAULT '0.00' NOT NULL,
    PRIMARY KEY(article, dealer));
INSERT INTO shop VALUES
    (1,'A',3.45),(1,'B',3.99),(2,'A',10.99),(3,'B',1.45),
    (3,'C',1.69),(3,'D',1.25),(4,'D',19.95);
```

After issuing the statements, the table should have the following contents:

```
SELECT * FROM shop;

+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0001 | A      |  3.45 |
|    0001 | B      |  3.99 |
|    0002 | A      | 10.99 |
|    0003 | B      |  1.45 |
|    0003 | C      |  1.69 |
|    0003 | D      |  1.25 |
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

3.6.1 The Maximum Value for a Column

“What is the highest item number?”

```
SELECT MAX(article) AS article FROM shop;

+---------+
| article |
+---------+
|       4 |
+---------+
```

3.6.2 The Row Holding the Maximum of a Certain Column

Task: Find the number, dealer, and price of the most expensive article.

This is easily done with a subquery:

```
SELECT article, dealer, price
FROM   shop
WHERE  price=(SELECT MAX(price) FROM shop);
```

```
+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

Other solutions are to use a `LEFT JOIN` or to sort all rows descending by price and get only the first row using the MySQL-specific `LIMIT` clause:

```
SELECT s1.article, s1.dealer, s1.price
FROM shop s1
LEFT JOIN shop s2 ON s1.price < s2.price
WHERE s2.article IS NULL;

SELECT article, dealer, price
FROM shop
ORDER BY price DESC
LIMIT 1;
```

Note

If there were several most expensive articles, each with a price of 19.95, the `LIMIT` solution would show only one of them.

3.6.3 Maximum of Column per Group

Task: Find the highest price per article.

```
SELECT article, MAX(price) AS price
FROM   shop
GROUP BY article;

+---------+-------+
| article | price |
+---------+-------+
|    0001 |  3.99 |
|    0002 | 10.99 |
|    0003 |  1.69 |
|    0004 | 19.95 |
+---------+-------+
```

3.6.4 The Rows Holding the Group-wise Maximum of a Certain Column

Task: For each article, find the dealer or dealers with the most expensive price.

This problem can be solved with a subquery like this one:

```
SELECT article, dealer, price
FROM   shop s1
WHERE  price=(SELECT MAX(s2.price)
              FROM shop s2
              WHERE s1.article = s2.article);

+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0001 | B      |  3.99 |
|    0002 | A      | 10.99 |
|    0003 | C      |  1.69 |
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

The preceding example uses a correlated subquery, which can be inefficient (see Section 13.2.10.7, “Correlated Subqueries”). Other possibilities for solving the problem are to use an uncorrelated subquery in the `FROM` clause or a `LEFT JOIN`.

Uncorrelated subquery:

```
SELECT s1.article, dealer, s1.price
FROM shop s1
JOIN (
  SELECT article, MAX(price) AS price
  FROM shop
  GROUP BY article) AS s2
  ON s1.article = s2.article AND s1.price = s2.price;
```

`LEFT JOIN`:

```
SELECT s1.article, s1.dealer, s1.price
FROM shop s1
LEFT JOIN shop s2 ON s1.article = s2.article AND s1.price < s2.price
WHERE s2.article IS NULL;
```

The `LEFT JOIN` works on the basis that when `s1.price` is at its maximum value, there is no `s2.price` with a greater value and the `s2` rows values will be `NULL`. See Section 13.2.9.2, “JOIN Syntax”.

3.6.5 Using User-Defined Variables

You can employ MySQL user variables to remember results without having to store them in temporary variables in the client. (See Section 9.4, “User-Defined Variables”.)

For example, to find the articles with the highest and lowest price you can do this:

```
mysql> SELECT @min_price:=MIN(price),@max_price:=MAX(price) FROM shop;
mysql> SELECT * FROM shop WHERE price=@min_price OR price=@max_price;
+---------+--------+-------+
| article | dealer | price |
+---------+--------+-------+
|    0003 | D      |  1.25 |
|    0004 | D      | 19.95 |
+---------+--------+-------+
```

Note

It is also possible to store the name of a database object such as a table or a column in a user variable and then to use this variable in an SQL statement; however, this requires the use of a prepared statement. See Section 13.5, “Prepared SQL Statement Syntax”, for more information.

3.6.6 Using Foreign Keys

In MySQL, `InnoDB` tables support checking of foreign key constraints. See Chapter 14, *The InnoDB Storage Engine*, and Section 1.7.2.3, “Foreign Key Differences”.

A foreign key constraint is not required merely to join two tables. For storage engines other than `InnoDB`, it is possible when defining a column to use a `REFERENCES` *`tbl_name(col_name)`* clause, which has no actual effect, and *serves only as a memo or comment to you that the column which you are currently defining is intended to refer to a column in another table*. It is extremely important to realize when using this syntax that:

- MySQL does not perform any sort of `CHECK` to make sure that *`col_name`* actually exists in *`tbl_name`* (or even that *`tbl_name`* itself exists).
- MySQL does not perform any sort of action on *`tbl_name`* such as deleting rows in response to actions taken on rows in the table which you are defining; in other words, this syntax induces no `ON DELETE` or `ON UPDATE` behavior whatsoever. (Although you can write an `ON DELETE` or `ON UPDATE` clause as part of the `REFERENCES` clause, it is also ignored.)

- This syntax creates a *column*; it does **not** create any sort of index or key.

You can use a column so created as a join column, as shown here:

```
CREATE TABLE person (
    id SMALLINT UNSIGNED NOT NULL AUTO_INCREMENT,
    name CHAR(60) NOT NULL,
    PRIMARY KEY (id)
);

CREATE TABLE shirt (
    id SMALLINT UNSIGNED NOT NULL AUTO_INCREMENT,
    style ENUM('t-shirt', 'polo', 'dress') NOT NULL,
    color ENUM('red', 'blue', 'orange', 'white', 'black') NOT NULL,
    owner SMALLINT UNSIGNED NOT NULL REFERENCES person(id),
    PRIMARY KEY (id)
);

INSERT INTO person VALUES (NULL, 'Antonio Paz');

SELECT @last := LAST_INSERT_ID();

INSERT INTO shirt VALUES
(NULL, 'polo', 'blue', @last),
(NULL, 'dress', 'white', @last),
(NULL, 't-shirt', 'blue', @last);

INSERT INTO person VALUES (NULL, 'Lilliana Angelovska');

SELECT @last := LAST_INSERT_ID();

INSERT INTO shirt VALUES
(NULL, 'dress', 'orange', @last),
(NULL, 'polo', 'red', @last),
(NULL, 'dress', 'blue', @last),
(NULL, 't-shirt', 'white', @last);

SELECT * FROM person;
+----+--------------------+
| id | name               |
+----+--------------------+
|  1 | Antonio Paz        |
|  2 | Lilliana Angelovska |
+----+--------------------+

SELECT * FROM shirt;
+----+---------+--------+-------+
| id | style   | color  | owner |
+----+---------+--------+-------+
|  1 | polo    | blue   |     1 |
|  2 | dress   | white  |     1 |
|  3 | t-shirt | blue   |     1 |
|  4 | dress   | orange |     2 |
|  5 | polo    | red    |     2 |
|  6 | dress   | blue   |     2 |
|  7 | t-shirt | white  |     2 |
+----+---------+--------+-------+


SELECT s.* FROM person p INNER JOIN shirt s
   ON s.owner = p.id
 WHERE p.name LIKE 'Lilliana%'
   AND s.color <> 'white';

+----+-------+--------+-------+
| id | style | color  | owner |
+----+-------+--------+-------+
|  4 | dress | orange |     2 |
|  5 | polo  | red    |     2 |
|  6 | dress | blue   |     2 |
+----+-------+--------+-------+
```

When used in this fashion, the REFERENCES clause is not displayed in the output of SHOW CREATE TABLE or DESCRIBE:

```
SHOW CREATE TABLE shirt\G
*************************** 1. row ***************************
Table: shirt
Create Table: CREATE TABLE `shirt` (
`id` smallint(5) unsigned NOT NULL auto_increment,
`style` enum('t-shirt','polo','dress') NOT NULL,
`color` enum('red','blue','orange','white','black') NOT NULL,
`owner` smallint(5) unsigned NOT NULL,
PRIMARY KEY  (`id`)
) ENGINE=MyISAM DEFAULT CHARSET=latin1
```

The use of REFERENCES in this way as a comment or “reminder” in a column definition works with MyISAM tables.

3.6.7 Searching on Two Keys

An OR using a single key is well optimized, as is the handling of AND.

The one tricky case is that of searching on two different keys combined with OR:

```
SELECT field1_index, field2_index FROM test_table
WHERE field1_index = '1' OR  field2_index = '1'
```

This case is optimized. See Section 8.2.1.3, “Index Merge Optimization”.

You can also solve the problem efficiently by using a UNION that combines the output of two separate SELECT statements. See Section 13.2.9.3, “UNION Syntax”.

Each SELECT searches only one key and can be optimized:

```
SELECT field1_index, field2_index
    FROM test_table WHERE field1_index = '1'
UNION
SELECT field1_index, field2_index
    FROM test_table WHERE field2_index = '1';
```

3.6.8 Calculating Visits Per Day

The following example shows how you can use the bit group functions to calculate the number of days per month a user has visited a Web page.

```
CREATE TABLE t1 (year YEAR(4), month INT(2) UNSIGNED ZEROFILL,
             day INT(2) UNSIGNED ZEROFILL);
INSERT INTO t1 VALUES(2000,1,1),(2000,1,20),(2000,1,30),(2000,2,2),
            (2000,2,23),(2000,2,23);
```

The example table contains year-month-day values representing visits by users to the page. To determine how many different days in each month these visits occur, use this query:

```
SELECT year,month,BIT_COUNT(BIT_OR(1<<day)) AS days FROM t1
       GROUP BY year,month;
```

Which returns:

```
+------+-------+------+
| year | month | days |
+------+-------+------+
| 2000 |    01 |    3 |
| 2000 |    02 |    2 |
```

```
+------+-------+------+
```

The query calculates how many different days appear in the table for each year/month combination, with automatic removal of duplicate entries.

3.6.9 Using AUTO_INCREMENT

The `AUTO_INCREMENT` attribute can be used to generate a unique identity for new rows:

```
CREATE TABLE animals (
     id MEDIUMINT NOT NULL AUTO_INCREMENT,
     name CHAR(30) NOT NULL,
     PRIMARY KEY (id)
);

INSERT INTO animals (name) VALUES
    ('dog'),('cat'),('penguin'),
    ('lax'),('whale'),('ostrich');

SELECT * FROM animals;
```

Which returns:

```
+----+---------+
| id | name    |
+----+---------+
|  1 | dog     |
|  2 | cat     |
|  3 | penguin |
|  4 | lax     |
|  5 | whale   |
|  6 | ostrich |
+----+---------+
```

No value was specified for the `AUTO_INCREMENT` column, so MySQL assigned sequence numbers automatically. You can also explicitly assign 0 to the column to generate sequence numbers, unless the `NO_AUTO_VALUE_ON_ZERO` SQL mode is enabled. If the column is declared `NOT NULL`, it is also possible to assign `NULL` to the column to generate sequence numbers. When you insert any other value into an `AUTO_INCREMENT` column, the column is set to that value and the sequence is reset so that the next automatically generated value follows sequentially from the largest column value.

You can retrieve the most recent automatically generated `AUTO_INCREMENT` value with the `LAST_INSERT_ID()` SQL function or the `mysql_insert_id()` C API function. These functions are connection-specific, so their return values are not affected by another connection which is also performing inserts.

Use the smallest integer data type for the `AUTO_INCREMENT` column that is large enough to hold the maximum sequence value you will need. When the column reaches the upper limit of the data type, the next attempt to generate a sequence number fails. Use the `UNSIGNED` attribute if possible to allow a greater range. For example, if you use `TINYINT`, the maximum permissible sequence number is 127. For `TINYINT UNSIGNED`, the maximum is 255. See Section 11.2.1, “Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT” for the ranges of all the integer types.

Note

For a multiple-row insert, `LAST_INSERT_ID()` and `mysql_insert_id()` actually return the `AUTO_INCREMENT` key from the *first* of the inserted rows. This enables multiple-row inserts to be reproduced correctly on other servers in a replication setup.

To start with an `AUTO_INCREMENT` value other than 1, set that value with `CREATE TABLE` or `ALTER TABLE`, like this:

```
mysql> ALTER TABLE tbl AUTO_INCREMENT = 100;
```

InnoDB Notes

For information about AUTO_INCREMENT usage specific to InnoDB, see Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”.

MyISAM Notes

- For MyISAM tables, you can specify AUTO_INCREMENT on a secondary column in a multiple-column index. In this case, the generated value for the AUTO_INCREMENT column is calculated as MAX(*auto_increment_column*) + 1 WHERE prefix=*given-prefix*. This is useful when you want to put data into ordered groups.

  ```
  CREATE TABLE animals (
      grp ENUM('fish','mammal','bird') NOT NULL,
      id MEDIUMINT NOT NULL AUTO_INCREMENT,
      name CHAR(30) NOT NULL,
      PRIMARY KEY (grp,id)
  ) ENGINE=MyISAM;

  INSERT INTO animals (grp,name) VALUES
      ('mammal','dog'),('mammal','cat'),
      ('bird','penguin'),('fish','lax'),('mammal','whale'),
      ('bird','ostrich');

  SELECT * FROM animals ORDER BY grp,id;
  ```

  Which returns:

  ```
  +--------+----+---------+
  | grp    | id | name    |
  +--------+----+---------+
  | fish   |  1 | lax     |
  | mammal |  1 | dog     |
  | mammal |  2 | cat     |
  | mammal |  3 | whale   |
  | bird   |  1 | penguin |
  | bird   |  2 | ostrich |
  +--------+----+---------+
  ```

  In this case (when the AUTO_INCREMENT column is part of a multiple-column index), AUTO_INCREMENT values are reused if you delete the row with the biggest AUTO_INCREMENT value in any group. This happens even for MyISAM tables, for which AUTO_INCREMENT values normally are not reused.

- If the AUTO_INCREMENT column is part of multiple indexes, MySQL generates sequence values using the index that begins with the AUTO_INCREMENT column, if there is one. For example, if the animals table contained indexes PRIMARY KEY (grp, id) and INDEX (id), MySQL would ignore the PRIMARY KEY for generating sequence values. As a result, the table would contain a single sequence, not a sequence per grp value.

Further Reading

More information about AUTO_INCREMENT is available here:

- How to assign the AUTO_INCREMENT attribute to a column: Section 13.1.17, “CREATE TABLE Syntax”, and Section 13.1.7, “ALTER TABLE Syntax”.
- How AUTO_INCREMENT behaves depending on the NO_AUTO_VALUE_ON_ZERO SQL mode: Section 5.1.8, “Server SQL Modes”.
- How to use the LAST_INSERT_ID() function to find the row that contains the most recent AUTO_INCREMENT value: Section 12.14, “Information Functions”.

- Setting the `AUTO_INCREMENT` value to be used: Section 5.1.5, “Server System Variables”.
- Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
- `AUTO_INCREMENT` and replication: Section 17.4.1.1, “Replication and AUTO_INCREMENT”.
- Server-system variables related to `AUTO_INCREMENT` (`auto_increment_increment` and `auto_increment_offset`) that can be used for replication: Section 5.1.5, “Server System Variables”.

3.7 Using MySQL with Apache

There are programs that let you authenticate your users from a MySQL database and also let you write your log files into a MySQL table.

You can change the Apache logging format to be easily readable by MySQL by putting the following into the Apache configuration file:

```
LogFormat \
        "\"%h\",%{%Y%m%d%H%M%S}t,%>s,\"%b\",\"%{Content-Type}o\",  \
        \"%U\",\"%{Referer}i\",\"%{User-Agent}i\""
```

To load a log file in that format into MySQL, you can use a statement something like this:

```
LOAD DATA INFILE '/local/access_log' INTO TABLE tbl_name
FIELDS TERMINATED BY ',' OPTIONALLY ENCLOSED BY '"' ESCAPED BY '\\'
```

The named table should be created to have columns that correspond to those that the `LogFormat` line writes to the log file.

Chapter 4 MySQL Programs

Table of Contents

4.1 Overview of MySQL Programs 250
4.2 Using MySQL Programs 254
4.2.1 Invoking MySQL Programs 254
4.2.2 Connecting to the MySQL Server 255
4.2.3 Specifying Program Options 258
4.2.4 Using Options on the Command Line 259
4.2.5 Program Option Modifiers 261
4.2.6 Using Option Files 261
4.2.7 Command-Line Options that Affect Option-File Handling 266
4.2.8 Using Options to Set Program Variables 267
4.2.9 Option Defaults, Options Expecting Values, and the = Sign 268
4.2.10 Setting Environment Variables 271
4.3 MySQL Server and Server-Startup Programs 272
4.3.1 `mysqld` — The MySQL Server 272
4.3.2 `mysqld_safe` — MySQL Server Startup Script 273
4.3.3 `mysql.server` — MySQL Server Startup Script 278
4.3.4 `mysqld_multi` — Manage Multiple MySQL Servers 280
4.4 MySQL Installation-Related Programs 283
4.4.1 `comp_err` — Compile MySQL Error Message File 283
4.4.2 `mysqlbug` — Generate Bug Report 284
4.4.3 `mysql_install_db` — Initialize MySQL Data Directory 285
4.4.4 `mysql_plugin` — Configure MySQL Server Plugins 287
4.4.5 `mysql_secure_installation` — Improve MySQL Installation Security 289
4.4.6 `mysql_tzinfo_to_sql` — Load the Time Zone Tables 289
4.4.7 `mysql_upgrade` — Check and Upgrade MySQL Tables 290
4.5 MySQL Client Programs 295
4.5.1 `mysql` — The MySQL Command-Line Tool 295
4.5.2 `mysqladmin` — Client for Administering a MySQL Server 317
4.5.3 `mysqlcheck` — A Table Maintenance Program 324
4.5.4 `mysqldump` — A Database Backup Program 331
4.5.5 `mysqlimport` — A Data Import Program 350
4.5.6 `mysqlshow` — Display Database, Table, and Column Information 355
4.5.7 `mysqlslap` — Load Emulation Client 359
4.6 MySQL Administrative and Utility Programs 367
4.6.1 `innochecksum` — Offline InnoDB File Checksum Utility 367
4.6.2 `myisam_ftdump` — Display Full-Text Index information 367
4.6.3 `myisamchk` — MyISAM Table-Maintenance Utility 369
4.6.4 `myisamlog` — Display MyISAM Log File Contents 385
4.6.5 `myisampack` — Generate Compressed, Read-Only MyISAM Tables 386
4.6.6 `mysqlaccess` — Client for Checking Access Privileges 392
4.6.7 `mysqlbinlog` — Utility for Processing Binary Log Files 394
4.6.8 `mysqldumpslow` — Summarize Slow Query Log Files 409
4.6.9 `mysqlhotcopy` — A Database Backup Program 411
4.6.10 `mysql_convert_table_format` — Convert Tables to Use a Given Storage Engine 414
4.6.11 `mysql_find_rows` — Extract SQL Statements from Files 415
4.6.12 `mysql_fix_extensions` — Normalize Table File Name Extensions 415
4.6.13 `mysql_setpermission` — Interactively Set Permissions in Grant Tables 416
4.6.14 `mysql_waitpid` — Kill Process and Wait for Its Termination 416
4.6.15 `mysql_zap` — Kill Processes That Match a Pattern 417
4.7 MySQL Program Development Utilities 417
4.7.1 `msql2mysql` — Convert mSQL Programs for Use with MySQL 418

4.7.2 mysql_config — Display Options for Compiling Clients 418
4.7.3 my_print_defaults — Display Options from Option Files 419
4.7.4 resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols 420
4.8 Miscellaneous Programs 421
4.8.1 perror — Explain Error Codes 421
4.8.2 replace — A String-Replacement Utility 422
4.8.3 resolveip — Resolve Host name to IP Address or Vice Versa 422
4.9 MySQL Program Environment Variables 423

This chapter provides a brief overview of the MySQL command-line programs provided by Oracle Corporation. It also discusses the general syntax for specifying options when you run these programs. Most programs have options that are specific to their own operation, but the option syntax is similar for all of them. Finally, the chapter provides more detailed descriptions of individual programs, including which options they recognize.

4.1 Overview of MySQL Programs

There are many different programs in a MySQL installation. This section provides a brief overview of them. Later sections provide a more detailed description of each one, with the exception of NDB Cluster programs. Each program's description indicates its invocation syntax and the options that it supports. Chapter 18, *MySQL NDB Cluster 7.2*, describes programs specific to NDB Cluster.

Most MySQL distributions include all of these programs, except for those programs that are platform-specific. (For example, the server startup scripts are not used on Windows.) The exception is that RPM distributions are more specialized. There is one RPM for the server, another for client programs, and so forth. If you appear to be missing one or more programs, see Chapter 2, *Installing and Upgrading MySQL*, for information on types of distributions and what they contain. It may be that you have a distribution that does not include all programs and you need to install an additional package.

Each MySQL program takes many different options. Most programs provide a `--help` option that you can use to get a description of the program's different options. For example, try `mysql --help`.

You can override default option values for MySQL programs by specifying options on the command line or in an option file. See Section 4.2, “Using MySQL Programs”, for general information on invoking programs and specifying program options.

The MySQL server, `mysqld`, is the main program that does most of the work in a MySQL installation. The server is accompanied by several related scripts that assist you in starting and stopping the server:

- `mysqld`

  The SQL daemon (that is, the MySQL server). To use client programs, `mysqld` must be running, because clients gain access to databases by connecting to the server. See Section 4.3.1, “`mysqld` — The MySQL Server”.

- `mysqld_safe`

  A server startup script. `mysqld_safe` attempts to start `mysqld`. See Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”.

- `mysql.server`

  A server startup script. This script is used on systems that use System V-style run directories containing scripts that start system services for particular run levels. It invokes `mysqld_safe` to start the MySQL server. See Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”.

- `mysqld_multi`

  A server startup script that can start or stop multiple servers installed on the system. See Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”.

Several programs perform setup operations during MySQL installation or upgrading:

- `comp_err`

  This program is used during the MySQL build/installation process. It compiles error message files from the error source files. See Section 4.4.1, “`comp_err` — Compile MySQL Error Message File”.

- `mysql_install_db`

  This program initializes the MySQL data directory, creates the `mysql` database, and initializes its grant tables with default privileges. It is usually executed only once, when first installing MySQL on a system. See Section 4.4.3, “`mysql_install_db` — Initialize MySQL Data Directory”, and Section 2.10, “Postinstallation Setup and Testing”.

- `mysql_plugin`

  This program configures MySQL server plugins. See Section 4.4.4, “`mysql_plugin` — Configure MySQL Server Plugins”.

- `mysql_secure_installation`

  This program enables you to improve the security of your MySQL installation. See Section 4.4.5, “`mysql_secure_installation` — Improve MySQL Installation Security”.

- `mysql_tzinfo_to_sql`

  This program loads the time zone tables in the `mysql` database using the contents of the host system *zoneinfo* database (the set of files describing time zones). See Section 4.4.6, “`mysql_tzinfo_to_sql` — Load the Time Zone Tables”.

- `mysql_upgrade`

  This program is used after a MySQL upgrade operation. It checks tables for incompatibilities and repairs them if necessary, and updates the grant tables with any changes that have been made in newer versions of MySQL. See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

MySQL client programs that connect to the MySQL server:

- `mysql`

  The command-line tool for interactively entering SQL statements or executing them from a file in batch mode. See Section 4.5.1, “`mysql` — The MySQL Command-Line Tool”.

- `mysqladmin`

  A client that performs administrative operations, such as creating or dropping databases, reloading the grant tables, flushing tables to disk, and reopening log files. `mysqladmin` can also be used to retrieve version, process, and status information from the server. See Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”.

- `mysqlcheck`

  A table-maintenance client that checks, repairs, analyzes, and optimizes tables. See Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”.

- `mysqldump`

  A client that dumps a MySQL database into a file as SQL, text, or XML. See Section 4.5.4, “`mysqldump` — A Database Backup Program”.

- `mysqlimport`

A client that imports text files into their respective tables using `LOAD DATA INFILE`. See Section 4.5.5, “`mysqlimport` — A Data Import Program”.

- `mysqlshow`

  A client that displays information about databases, tables, columns, and indexes. See Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”.

- `mysqlslap`

  A client that is designed to emulate client load for a MySQL server and report the timing of each stage. It works as if multiple clients are accessing the server. See Section 4.5.7, “`mysqlslap` — Load Emulation Client”.

MySQL administrative and utility programs:

- `innochecksum`

  An offline `InnoDB` offline file checksum utility. See Section 4.6.1, “`innochecksum` — Offline InnoDB File Checksum Utility”.

- `myisam_ftdump`

  A utility that displays information about full-text indexes in `MyISAM` tables. See Section 4.6.2, “`myisam_ftdump` — Display Full-Text Index information”.

- `myisamchk`

  A utility to describe, check, optimize, and repair `MyISAM` tables. See Section 4.6.3, “`myisamchk` — MyISAM Table-Maintenance Utility”.

- `myisamlog`

  A utility that processes the contents of a `MyISAM` log file. See Section 4.6.4, “`myisamlog` — Display MyISAM Log File Contents”.

- `myisampack`

  A utility that compresses `MyISAM` tables to produce smaller read-only tables. See Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”.

- `mysqlaccess`

  A script that checks the access privileges for a host name, user name, and database combination. See Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”.

- `mysqlbinlog`

  A utility for reading statements from a binary log. The log of executed statements contained in the binary log files can be used to help recover from a crash. See Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”.

- `mysqldumpslow`

  A utility to read and summarize the contents of a slow query log. See Section 4.6.8, “`mysqldumpslow` — Summarize Slow Query Log Files”.

- `mysqlhotcopy`

  A utility that quickly makes backups of `MyISAM` tables while the server is running. See Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”.

- `mysql_convert_table_format`

A utility that converts tables in a database to use a given storage engine. See Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”.

- mysql_find_rows

  A utility that reads files containing SQL statements (such as update logs) and extracts statements that match a given regular expression. See Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”.

- mysql_fix_extensions

  A utility that converts the extensions for MyISAM table files to lowercase. This can be useful after transferring the files from a system with case-insensitive file names to a system with case-sensitive file names. See Section 4.6.12, “mysql_fix_extensions — Normalize Table File Name Extensions”.

- mysql_setpermission

  A utility for interactively setting permissions in the MySQL grant tables. See Section 4.6.13, “mysql_setpermission — Interactively Set Permissions in Grant Tables”.

- mysql_waitpid

  A utility that kills the process with a given process ID. See Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”.

- mysql_zap

  A utility that kills processes that match a pattern. See Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”.

MySQL program-development utilities:

- msql2mysql

  A shell script that converts mSQL programs to MySQL. It doesn't handle every case, but it gives a good start when converting. See Section 4.7.1, “msql2mysql — Convert mSQL Programs for Use with MySQL”.

- mysql_config

  A shell script that produces the option values needed when compiling MySQL programs. See Section 4.7.2, “mysql_config — Display Options for Compiling Clients”.

- my_print_defaults

  A utility that shows which options are present in option groups of option files. See Section 4.7.3, “my_print_defaults — Display Options from Option Files”.

- resolve_stack_dump

  A utility program that resolves a numeric stack trace dump to symbols. See Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”.

Miscellaneous utilities:

- perror

  A utility that displays the meaning of system or MySQL error codes. See Section 4.8.1, “perror — Explain Error Codes”.

- replace

A utility program that performs string replacement in the input text. See Section 4.8.2, “`replace` — A String-Replacement Utility”.

- `resolveip`

  A utility program that resolves a host name to an IP address or vice versa. See Section 4.8.3, “`resolveip` — Resolve Host name to IP Address or Vice Versa”.

Oracle Corporation also provides the MySQL Workbench GUI tool, which is used to administer MySQL servers and databases, to create, execute, and evaluate queries, and to migrate schemas and data from other relational database management systems for use with MySQL. Additional GUI tools include MySQL Notifier MySQL for Excel.

MySQL client programs that communicate with the server using the MySQL client/server library use the following environment variables.

Environment Variable	Meaning
`MYSQL_UNIX_PORT`	The default Unix socket file; used for connections to `localhost`
`MYSQL_TCP_PORT`	The default port number; used for TCP/IP connections
`MYSQL_PWD`	The default password
`MYSQL_DEBUG`	Debug trace options when debugging
`TMPDIR`	The directory where temporary tables and files are created

For a full list of environment variables used by MySQL programs, see Section 4.9, “MySQL Program Environment Variables”.

Use of `MYSQL_PWD` is insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

4.2 Using MySQL Programs

4.2.1 Invoking MySQL Programs

To invoke a MySQL program from the command line (that is, from your shell or command prompt), enter the program name followed by any options or other arguments needed to instruct the program what you want it to do. The following commands show some sample program invocations. `shell>` represents the prompt for your command interpreter; it is not part of what you type. The particular prompt you see depends on your command interpreter. Typical prompts are `$` for `sh`, `ksh`, or `bash`, `%` for `csh` or `tcsh`, and `C:\>` for the Windows `command.com` or `cmd.exe` command interpreters.

```
shell> mysql --user=root test
shell> mysqladmin extended-status variables
shell> mysqlshow --help
shell> mysqldump -u root personnel
```

Arguments that begin with a single or double dash (`-`, `--`) specify program options. Options typically indicate the type of connection a program should make to the server or affect its operational mode. Option syntax is described in Section 4.2.3, “Specifying Program Options”.

Nonoption arguments (arguments with no leading dash) provide additional information to the program. For example, the `mysql` program interprets the first nonoption argument as a database name, so the command `mysql --user=root test` indicates that you want to use the `test` database.

Later sections that describe individual programs indicate which options a program supports and describe the meaning of any additional nonoption arguments.

Some options are common to a number of programs. The most frequently used of these are the `--host` (or `-h`), `--user` (or `-u`), and `--password` (or `-p`) options that specify connection parameters. They indicate the host where the MySQL server is running, and the user name and password of your

MySQL account. All MySQL client programs understand these options; they enable you to specify which server to connect to and the account to use on that server. Other connection options are `--port` (or `-P`) to specify a TCP/IP port number and `--socket` (or `-S`) to specify a Unix socket file on Unix (or named pipe name on Windows). For more information on options that specify connection options, see Section 4.2.2, “Connecting to the MySQL Server”.

You may find it necessary to invoke MySQL programs using the path name to the `bin` directory in which they are installed. This is likely to be the case if you get a “program not found” error whenever you attempt to run a MySQL program from any directory other than the `bin` directory. To make it more convenient to use MySQL, you can add the path name of the `bin` directory to your `PATH` environment variable setting. That enables you to run a program by typing only its name, not its entire path name. For example, if `mysql` is installed in `/usr/local/mysql/bin`, you can run the program by invoking it as `mysql`, and it is not necessary to invoke it as `/usr/local/mysql/bin/mysql`.

Consult the documentation for your command interpreter for instructions on setting your `PATH` variable. The syntax for setting environment variables is interpreter-specific. (Some information is given in Section 4.2.10, “Setting Environment Variables”.) After modifying your `PATH` setting, open a new console window on Windows or log in again on Unix so that the setting goes into effect.

4.2.2 Connecting to the MySQL Server

This section describes how to establish a connection to the MySQL server. For additional information if you are unable to connect, see Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”.

For a client program to be able to connect to the MySQL server, it must use the proper connection parameters, such as the name of the host where the server is running and the user name and password of your MySQL account. Each connection parameter has a default value, but you can override them as necessary using program options specified either on the command line or in an option file.

The examples here use the `mysql` client program, but the principles apply to other clients such as `mysqldump`, `mysqladmin`, or `mysqlshow`.

This command invokes `mysql` without specifying any connection parameters explicitly:

```
shell> mysql
```

Because there are no parameter options, the default values apply:

- The default host name is `localhost`. On Unix, this has a special meaning, as described later.
- The default user name is `ODBC` on Windows or your Unix login name on Unix.
- No password is sent if neither `-p` nor `--password` is given.
- For `mysql`, the first nonoption argument is taken as the name of the default database. If there is no such option, `mysql` does not select a default database.

To specify the host name and user name explicitly, as well as a password, supply appropriate options on the command line:

```
shell> mysql --host=localhost --user=myname --password=password mydb
shell> mysql -h localhost -u myname -ppassword mydb
```

For password options, the password value is optional:

- If you use a `-p` or `--password` option and specify the password value, there must be *no space* between `-p` or `--password=` and the password following it.
- If you use a `-p` or `--password` option but do not specify the password value, the client program prompts you to enter the password. The password is not displayed as you enter it. This is more

secure than giving the password on the command line. Other users on your system may be able to see a password specified on the command line by executing a command such as `ps auxw`. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

As just mentioned, including the password value on the command line can be a security risk. To avoid this problem, specify the `--password` or `-p` option without any following password value:

```
shell> mysql --host=localhost --user=myname --password mydb
shell> mysql -h localhost -u myname -p mydb
```

When the password option has no password value, the client program prints a prompt and waits for you to enter the password. (In these examples, `mydb` is *not* interpreted as a password because it is separated from the preceding password option by a space.)

On some systems, the library routine that MySQL uses to prompt for a password automatically limits the password to eight characters. That is a problem with the system library, not with MySQL. Internally, MySQL does not have any limit for the length of the password. To work around the problem, change your MySQL password to a value that is eight or fewer characters long, or put your password in an option file.

On Unix, MySQL programs treat the host name `localhost` specially, in a way that is likely different from what you expect compared to other network-based programs. For connections to `localhost`, MySQL programs attempt to connect to the local server by using a Unix socket file. This occurs even if a `--port` or `-P` option is given to specify a port number. To ensure that the client makes a TCP/IP connection to the local server, use `--host` or `-h` to specify a host name value of `127.0.0.1`, or the IP address or name of the local server. You can also specify the connection protocol explicitly, even for `localhost`, by using the `--protocol=TCP` option. For example:

```
shell> mysql --host=127.0.0.1
shell> mysql --protocol=TCP
```

The `--protocol` option enables you to establish a particular type of connection even when the other options would normally default to some other protocol.

If the server is configured to accept IPv6 connections, clients can connect over IPv6 using `--host=::1`. See Section 5.1.9, “IPv6 Support”.

On Windows, you can force a MySQL client to use a named-pipe connection by specifying the `--pipe` or `--protocol=PIPE` option, or by specifying `.` (period) as the host name. If named-pipe connections are not enabled, an error occurs. Use the `--socket` option to specify the name of the pipe if you do not want to use the default pipe name.

Connections to remote servers always use TCP/IP. This command connects to the server running on `remote.example.com` using the default port number (3306):

```
shell> mysql --host=remote.example.com
```

To specify a port number explicitly, use the `--port` or `-P` option:

```
shell> mysql --host=remote.example.com --port=13306
```

You can specify a port number for connections to a local server, too. However, as indicated previously, connections to `localhost` on Unix will use a socket file by default. You will need to force a TCP/IP connection as already described or any option that specifies a port number will be ignored.

For this command, the program uses a socket file on Unix and the `--port` option is ignored:

```
shell> mysql --port=13306 --host=localhost
```

To cause the port number to be used, invoke the program in either of these ways:

```
shell> mysql --port=13306 --host=127.0.0.1
shell> mysql --port=13306 --protocol=TCP
```

The following list summarizes the options that can be used to control how client programs connect to the server:

- `--host=host_name`, `-h host_name`

  The host where the server is running. The default value is `localhost`.

- `--password[=pass_val]`, `-p[pass_val]`

  The password of the MySQL account. As described earlier, the password value is optional, but if given, there must be *no space* between `-p` or `--password=` and the password following it. The default is to send no password.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. The server must be started with the `--enable-named-pipe` option to enable named-pipe connections.

- `--port=port_num`, `-P port_num`

  The port number to use for the connection, for connections made using TCP/IP. The default port number is 3306.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  This option explicitly specifies a protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For example, connections on Unix to `localhost` are made using a Unix socket file by default:

  ```
  shell> mysql --host=localhost
  ```

  To force a TCP/IP connection to be used instead, specify a `--protocol` option:

  ```
  shell> mysql --host=localhost --protocol=TCP
  ```

  The following table shows the permissible `--protocol` option values and indicates the platforms on which each value may be used. The values are not case sensitive.

`--protocol` Value	**Connection Protocol**	**Permissible Operating Systems**
`TCP`	TCP/IP connection to local or remote server	All
`SOCKET`	Unix socket file connection to local server	Unix only
`PIPE`	Named-pipe connection to local or remote server	Windows only
`MEMORY`	Shared-memory connection to local server	Windows only

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--socket=file_name`, `-S file_name`

On Unix, the name of the Unix socket file to use, for connections made using a named pipe to a local server. The default Unix socket file name is `/tmp/mysql.sock`.

On Windows, the name of the named pipe to use, for connections to a local server. The default Windows pipe name is `MySQL`. The pipe name is not case sensitive.

The server must be started with the `--enable-named-pipe` option to enable named-pipe connections.

- `--ssl*`

  Options that begin with `--ssl` are used for establishing a secure connection to the server using SSL, if the server is configured with SSL support. For details, see Section 6.4.2, “Command Options for Encrypted Connections”.

- `--user=user_name`, `-u user_name`

  The user name of the MySQL account you want to use. The default user name is `ODBC` on Windows or your Unix login name on Unix.

It is possible to specify different default values to be used when you make a connection so that you need not enter them on the command line each time you invoke a client program. This can be done in a couple of ways:

- You can specify connection parameters in the `[client]` section of an option file. The relevant section of the file might look like this:

  ```
  [client]
  host=host_name
  user=user_name
  password=your_pass
  ```

  Section 4.2.6, “Using Option Files”, discusses option files further.

- You can specify some connection parameters using environment variables. The host can be specified for `mysql` using `MYSQL_HOST`. The MySQL user name can be specified using `USER` (this is for Windows only). The password can be specified using `MYSQL_PWD`, although this is insecure; see Section 6.1.2.1, “End-User Guidelines for Password Security”. For a list of variables, see Section 4.9, “MySQL Program Environment Variables”.

4.2.3 Specifying Program Options

There are several ways to specify options for MySQL programs:

- List the options on the command line following the program name. This is common for options that apply to a specific invocation of the program.
- List the options in an option file that the program reads when it starts. This is common for options that you want the program to use each time it runs.
- List the options in environment variables (see Section 4.2.10, “Setting Environment Variables”). This method is useful for options that you want to apply each time the program runs. In practice, option files are used more commonly for this purpose, but Section 5.6.3, “Running Multiple MySQL Instances on Unix”, discusses one situation in which environment variables can be very helpful. It describes a handy technique that uses such variables to specify the TCP/IP port number and Unix socket file for the server and for client programs.

Options are processed in order, so if an option is specified multiple times, the last occurrence takes precedence. The following command causes `mysql` to connect to the server running on `localhost`:

```
shell> mysql -h example.com -h localhost
```

If conflicting or related options are given, later options take precedence over earlier options. The following command runs `mysql` in “no column names” mode:

```
shell> mysql --column-names --skip-column-names
```

MySQL programs determine which options are given first by examining environment variables, then by processing option files, and then by checking the command line. This means that environment variables have the lowest precedence and command-line options the highest.

You can take advantage of the way that MySQL programs process options by specifying default option values for a program in an option file. That enables you to avoid typing them each time you run the program while enabling you to override the defaults if necessary by using command-line options.

An option can be specified by writing it in full or as any unambiguous prefix. For example, the `--compress` option can be given to `mysqldump` as `--compr`, but not as `--comp` because the latter is ambiguous:

```
shell> mysqldump --comp
mysqldump: ambiguous option '--comp' (compatible, compress)
```

Be aware that the use of option prefixes can cause problems in the event that new options are implemented for a program. A prefix that is unambiguous now might become ambiguous in the future.

Note

As of MySQL 5.5.33, unambiguous prefixes are deprecated. If an unambiguous prefix is given, a warning occurs to provide feedback. Option prefixes are no longer supported as of MySQL 5.7; only full options are accepted.

4.2.4 Using Options on the Command Line

Program options specified on the command line follow these rules:

- Options are given after the command name.
- An option argument begins with one dash or two dashes, depending on whether it is a short form or long form of the option name. Many options have both short and long forms. For example, `-?` and `--help` are the short and long forms of the option that instructs a MySQL program to display its help message.
- Option names are case sensitive. `-v` and `-V` are both legal and have different meanings. (They are the corresponding short forms of the `--verbose` and `--version` options.)
- Some options take a value following the option name. For example, `-h localhost` or `--host=localhost` indicate the MySQL server host to a client program. The option value tells the program the name of the host where the MySQL server is running.
- For a long option that takes a value, separate the option name and the value by an `=` sign. For a short option that takes a value, the option value can immediately follow the option letter, or there can be a space between: `-hlocalhost` and `-h localhost` are equivalent. An exception to this rule is the option for specifying your MySQL password. This option can be given in long form as `--password=pass_val` or as `--password`. In the latter case (with no password value given), the program prompts you for the password. The password option also may be given in short form as `-ppass_val` or as `-p`. However, for the short form, if the password value is given, it must follow the option letter with *no intervening space*. The reason for this is that if a space follows the option letter, the program has no way to tell whether a following argument is supposed to be the password value or some other kind of argument. Consequently, the following two commands have two completely different meanings:

```
shell> mysql -ptest
shell> mysql -p test
```

The first command instructs `mysql` to use a password value of `test`, but specifies no default database. The second instructs `mysql` to prompt for the password value and to use `test` as the default database.

- Within option names, dash (`-`) and underscore (_) may be used interchangeably. For example, `--skip-grant-tables` and `--skip_grant_tables` are equivalent. (However, the leading dashes cannot be given as underscores.)
- For options that take a numeric value, the value can be given with a suffix of `K`, `M`, or `G` (either uppercase or lowercase) to indicate a multiplier of 1024, 1024^2 or 1024^3. For example, the following command tells `mysqladmin` to ping the server 1024 times, sleeping 10 seconds between each ping:

```
shell> mysqladmin --count=1K --sleep=10 ping
```

- When specifying file names as option values, avoid the use of the `~` shell metacharacter because it might not be interpreted as you expect.

Option values that contain spaces must be quoted when given on the command line. For example, the `--execute` (or `-e`) option can be used with `mysql` to pass SQL statements to the server. When this option is used, `mysql` executes the statements in the option value and exits. The statements must be enclosed by quotation marks. For example, you can use the following command to obtain a list of user accounts:

```
shell> mysql -u root -p --execute="SELECT User, Host FROM mysql.user"
Enter password: ******
+------+-----------+
| User | Host      |
+------+-----------+
|      | gigan     |
| root | gigan     |
|      | localhost |
| jon  | localhost |
| root | localhost |
+------+-----------+
shell>
```

Note

The long form (`--execute`) is followed by an equals sign (`=`).

If you wish to use quoted values within a statement, you will either need to escape the inner quotation marks, or use a different type of quotation marks within the statement from those used to quote the statement itself. The capabilities of your command processor dictate your choices for whether you can use single or double quotation marks and the syntax for escaping quote characters. For example, if your command processor supports quoting with single or double quotation marks, you can use double quotation marks around the statement, and single quotation marks for any quoted values within the statement.

Multiple SQL statements may be passed in the option value on the command line, separated by semicolons:

```
shell> mysql -u root -p -e "SELECT VERSION();SELECT NOW()"
Enter password: ******
+------------------+
| VERSION()        |
+------------------+
| 5.5.46-debug-log |
```

```
+-----------------+
+---------------------+
| NOW()               |
+---------------------+
| 2015-11-05 20:02:49 |
+---------------------+
```

4.2.5 Program Option Modifiers

Some options are “boolean” and control behavior that can be turned on or off. For example, the `mysql` client supports a `--column-names` option that determines whether or not to display a row of column names at the beginning of query results. By default, this option is enabled. However, you may want to disable it in some instances, such as when sending the output of `mysql` into another program that expects to see only data and not an initial header line.

To disable column names, you can specify the option using any of these forms:

```
--disable-column-names
--skip-column-names
--column-names=0
```

The `--disable` and `--skip` prefixes and the `=0` suffix all have the same effect: They turn the option off.

The “enabled” form of the option may be specified in any of these ways:

```
--column-names
--enable-column-names
--column-names=1
```

As of MySQL 5.5.10, the values `ON`, `TRUE`, `OFF`, and `FALSE` are also recognized for boolean options (not case sensitive).

If an option is prefixed by `--loose`, a program does not exit with an error if it does not recognize the option, but instead issues only a warning:

```
shell> mysql --loose-no-such-option
mysql: WARNING: unknown option '--loose-no-such-option'
```

The `--loose` prefix can be useful when you run programs from multiple installations of MySQL on the same machine and list options in an option file. An option that may not be recognized by all versions of a program can be given using the `--loose` prefix (or `loose` in an option file). Versions of the program that recognize the option process it normally, and versions that do not recognize it issue a warning and ignore it.

The `--maximum` prefix is available for `mysqld` only and permits a limit to be placed on how large client programs can set session system variables. To do this, use a `--maximum` prefix with the variable name. For example, `--maximum-max_heap_table_size=32M` prevents any client from making the heap table size limit larger than 32M.

The `--maximum` prefix is intended for use with system variables that have a session value. If applied to a system variable that has only a global value, an error occurs. For example, with `--maximum-back_log=200`, the server produces this error:

```
Maximum value of 'back_log' cannot be set
```

4.2.6 Using Option Files

Most MySQL programs can read startup options from option files (sometimes called configuration files). Option files provide a convenient way to specify commonly used options so that they need not be

entered on the command line each time you run a program. For the MySQL server, MySQL provides a number of preconfigured option files.

To determine whether a program reads option files, invoke it with the `--help` option. (For `mysqld`, use `--verbose` and `--help`.) If the program reads option files, the help message indicates which files it looks for and which option groups it recognizes.

Note

A MySQL program started with the `--no-defaults` option reads no option files.

Option files are plain text files, created using any text editor.

MySQL looks for option files in the order described in the following discussion and reads any that exist. If an option file you want to use does not exist, create it with a plain text editor.

Note

Option files used with NDB Cluster programs are covered in Section 18.3, “Configuration of NDB Cluster”.

On Windows, MySQL programs read startup options from the files shown in the following table, in the specified order (top files are read first, files read later take precedence).

Table 4.1 Option Files Read on Windows Systems

File Name	Purpose
`%PROGRAMDATA%\MySQL\MySQL Server 5.5\my.ini`, `%PROGRAMDATA%\MySQL\MySQL Server 5.5\my.cnf`	Global options
`%WINDIR%\my.ini`, `%WINDIR%\my.cnf`	Global options
`C:\my.ini`, `C:\my.cnf`	Global options
`BASEDIR``\my.ini`, *`BASEDIR`*`\my.cnf`	Global options
`defaults-extra-file`	The file specified with `--defaults-extra-file`, if any

In the preceding table, `%PROGRAMDATA%` represents the file system directory that contains application data for all users on the host. This path defaults to `C:\ProgramData` on Microsoft Windows Vista and greater, and `C:\Documents and Settings\All Users\Application Data` on older versions of Microsoft Windows.

`%WINDIR%` represents the location of your Windows directory. This is commonly `C:\WINDOWS`. Use the following command to determine its exact location from the value of the `WINDIR` environment variable:

```
C:\> echo %WINDIR%
```

`%APPDATA%` represents the value of the Windows application data directory. Use the following command to determine its exact location from the value of the `APPDATA` environment variable:

```
C:\> echo %APPDATA%
```

`BASEDIR` represents the MySQL base installation directory. When MySQL 5.5 has been installed using MySQL Installer, this is typically `C:\`*`PROGRAMDIR`*`\MySQL\MySQL 5.5 Server` where

PROGRAMDIR represents the programs directory (usually `Program Files` on English-language versions of Windows), See Section 2.3.3, “MySQL Installer for Windows”.

On Unix and Unix-like systems, MySQL programs read startup options from the files shown in the following table, in the specified order (top files are read first, files read later take precedence).

Note

On Unix platforms, MySQL ignores configuration files that are world-writable. This is intentional as a security measure.

Table 4.2 Option Files Read on Unix and Unix-Like Systems

File Name	Purpose
`/etc/my.cnf`	Global options
`/etc/mysql/my.cnf`	Global options
SYSCONFDIR`/my.cnf`	Global options
`$MYSQL_HOME/my.cnf`	Server-specific options (server only)
`defaults-extra-file`	The file specified with `--defaults-extra-file`, if any
`~/.my.cnf`	User-specific options

In the preceding table, `~` represents the current user's home directory (the value of `$HOME`).

SYSCONFDIR represents the directory specified with the `SYSCONFDIR` option to `CMake` when MySQL was built. By default, this is the `etc` directory located under the compiled-in installation directory.

`MYSQL_HOME` is an environment variable containing the path to the directory in which the server-specific `my.cnf` file resides. If `MYSQL_HOME` is not set and you start the server using the `mysqld_safe` program, `mysqld_safe` attempts to set `MYSQL_HOME` as follows:

- Let *BASEDIR* and *DATADIR* represent the path names of the MySQL base directory and data directory, respectively.
- If there is a `my.cnf` file in *DATADIR* but not in *BASEDIR*, `mysqld_safe` sets `MYSQL_HOME` to *DATADIR*.
- Otherwise, if `MYSQL_HOME` is not set and there is no `my.cnf` file in *DATADIR*, `mysqld_safe` sets `MYSQL_HOME` to *BASEDIR*.

In MySQL 5.5, use of *DATADIR* as the location for `my.cnf` is deprecated.

DATADIR is commonly `/usr/local/mysql/data`, although this can vary per platform or installation method. The value is the data directory location built in when MySQL was compiled, not the location specified with the `--datadir` option when `mysqld` starts. Use of `--datadir` at runtime has no effect on where the server looks for option files that it reads before processing any options.

If multiple instances of a given option are found, the last instance takes precedence, with one exception: For `mysqld`, the *first* instance of the `--user` option is used as a security precaution, to prevent a user specified in an option file from being overridden on the command line.

The following description of option file syntax applies to files that you edit manually. This excludes `.mylogin.cnf`, which is created using `mysql_config_editor` and is encrypted.

Any long option that may be given on the command line when running a MySQL program can be given in an option file as well. To get the list of available options for a program, run it with the `--help` option. (For `mysqld`, use `--verbose` and `--help`.)

The syntax for specifying options in an option file is similar to command-line syntax (see Section 4.2.4, “Using Options on the Command Line”). However, in an option file, you omit the leading two dashes

from the option name and you specify only one option per line. For example, `--quick` and `--host=localhost` on the command line should be specified as `quick` and `host=localhost` on separate lines in an option file. To specify an option of the form `--loose-opt_name` in an option file, write it as `loose-opt_name`.

Empty lines in option files are ignored. Nonempty lines can take any of the following forms:

- `#comment`, `;comment`

  Comment lines start with `#` or `;`. A `#` comment can start in the middle of a line as well.

- `[group]`

  `group` is the name of the program or group for which you want to set options. After a group line, any option-setting lines apply to the named group until the end of the option file or another group line is given. Option group names are not case sensitive.

- `opt_name`

  This is equivalent to `--opt_name` on the command line.

- `opt_name=value`

  This is equivalent to `--opt_name=value` on the command line. In an option file, you can have spaces around the `=` character, something that is not true on the command line. The value optionally can be enclosed within single quotation marks or double quotation marks, which is useful if the value contains a `#` comment character.

Leading and trailing spaces are automatically deleted from option names and values.

You can use the escape sequences `\b`, `\t`, `\n`, `\r`, `\\`, and `\s` in option values to represent the backspace, tab, newline, carriage return, backslash, and space characters. In option files, these escaping rules apply:

- A backslash followed by a valid escape sequence character is converted to the character represented by the sequence. For example, `\s` is converted to a space.
- A backslash not followed by a valid escape sequence character remains unchanged. For example, `\S` is retained as is.

The preceding rules mean that a literal backslash can be given as `\\`, or as `\` if it is not followed by a valid escape sequence character.

The rules for escape sequences in option files differ slightly from the rules for escape sequences in string literals in SQL statements. In the latter context, if "*x*" is not a valid escape sequence character, `\x` becomes "*x*" rather than `\x`. See Section 9.1.1, "String Literals".

The escaping rules for option file values are especially pertinent for Windows path names, which use `\` as a path name separator. A separator in a Windows path name must be written as `\\` if it is followed by an escape sequence character. It can be written as `\\` or `\` if it is not. Alternatively, `/` may be used in Windows path names and will be treated as `\`. Suppose that you want to specify a base directory of `C:\Program Files\MySQL\MySQL Server 5.5` in an option file. This can be done several ways. Some examples:

```
basedir="C:\Program Files\MySQL\MySQL Server 5.5"
basedir="C:\\Program Files\\MySQL\\MySQL Server 5.5"
basedir="C:/Program Files/MySQL/MySQL Server 5.5"
basedir=C:\\Program\sFiles\\MySQL\\MySQL\sServer\s5.5
```

If an option group name is the same as a program name, options in the group apply specifically to that program. For example, the `[mysqld]` and `[mysql]` groups apply to the `mysqld` server and the `mysql` client program, respectively.

The [client] option group is read by all client programs provided in MySQL distributions (but *not* by mysqld). To understand how third-party client programs that use the C API can use option files, see the C API documentation at Section 23.8.7.49, “mysql_options()”.

The [client] group enables you to specify options that apply to all clients. For example, [client] is the appropriate group to use to specify the password for connecting to the server. (But make sure that the option file is accessible only by yourself, so that other people cannot discover your password.) Be sure not to put an option in the [client] group unless it is recognized by *all* client programs that you use. Programs that do not understand the option quit after displaying an error message if you try to run them.

List more general option groups first and more specific groups later. For example, a [client] group is more general because it is read by all client programs, whereas a [mysqldump] group is read only by mysqldump. Options specified later override options specified earlier, so putting the option groups in the order [client], [mysqldump] enables mysqldump-specific options to override [client] options.

Here is a typical global option file:

```
[client]
port=3306
socket=/tmp/mysql.sock

[mysqld]
port=3306
socket=/tmp/mysql.sock
key_buffer_size=16M
max_allowed_packet=8M

[mysqldump]
quick
```

Here is a typical user option file:

```
[client]
# The following password will be sent to all standard MySQL clients
password="my password"

[mysql]
no-auto-rehash
connect_timeout=2

[mysqlhotcopy]
interactive-timeout
```

To create option groups to be read only by mysqld servers from specific MySQL release series, use groups with names of [mysqld-5.1], [mysqld-5.5], and so forth. The following group indicates that the sql_mode setting should be used only by MySQL servers with 5.5.x version numbers:

```
[mysqld-5.5]
sql_mode=TRADITIONAL
```

It is possible to use !include directives in option files to include other option files and !includedir to search specific directories for option files. For example, to include the /home/mydir/myopt.cnf file, use the following directive:

```
!include /home/mydir/myopt.cnf
```

To search the /home/mydir directory and read option files found there, use this directive:

```
!includedir /home/mydir
```

MySQL makes no guarantee about the order in which option files in the directory will be read.

Note

Any files to be found and included using the `!includedir` directive on Unix operating systems *must* have file names ending in `.cnf`. On Windows, this directive checks for files with the `.ini` or `.cnf` extension.

Write the contents of an included option file like any other option file. That is, it should contain groups of options, each preceded by a `[group]` line that indicates the program to which the options apply.

While an included file is being processed, only those options in groups that the current program is looking for are used. Other groups are ignored. Suppose that a `my.cnf` file contains this line:

```
!include /home/mydir/myopt.cnf
```

And suppose that `/home/mydir/myopt.cnf` looks like this:

```
[mysqladmin]
force

[mysqld]
key_buffer_size=16M
```

If `my.cnf` is processed by `mysqld`, only the `[mysqld]` group in `/home/mydir/myopt.cnf` is used. If the file is processed by `mysqladmin`, only the `[mysqladmin]` group is used. If the file is processed by any other program, no options in `/home/mydir/myopt.cnf` are used.

The `!includedir` directive is processed similarly except that all option files in the named directory are read.

If an option file contains `!include` or `!includedir` directives, files named by those directives are processed whenever the option file is processed, no matter where they appear in the file.

4.2.7 Command-Line Options that Affect Option-File Handling

Most MySQL programs that support option files handle the following options. Because these options affect option-file handling, they must be given on the command line and not in an option file. To work properly, each of these options must be given before other options, with these exceptions:

- `--print-defaults` may be used immediately after `--defaults-file` or `--defaults-extra-file`.
- On Windows, if the server is started with the `--defaults-file` and `--install` options, `--install` must be first. See Section 2.3.7.7, “Starting MySQL as a Windows Service”.

When specifying file names as option values, avoid the use of the `~` shell metacharacter because it might not be interpreted as you expect.

- `--defaults-extra-file=`*`file_name`*

  Read this option file after the global option file but (on Unix) before the user option file. (For information about the order in which option files are used, see Section 4.2.6, “Using Option Files”.) If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is interpreted relative to the current directory if given as a relative path name rather than a full path name.

- `--defaults-file=`*`file_name`*

  Read only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is interpreted relative to the current directory if given as a relative path name rather than a full path name.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, the `mysql` client normally reads the `[client]` and `[mysql]` groups. If the `--defaults-group-suffix=_other` option is given, `mysql` also reads the `[client_other]` and `[mysql_other]` groups.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

4.2.8 Using Options to Set Program Variables

Many MySQL programs have internal variables that can be set at runtime using the `SET` statement. See Section 13.7.4.1, “SET Syntax for Variable Assignment”, and Section 5.1.6, “Using System Variables”.

Most of these program variables also can be set at server startup by using the same syntax that applies to specifying program options. For example, `mysql` has a `max_allowed_packet` variable that controls the maximum size of its communication buffer. To set the `max_allowed_packet` variable for `mysql` to a value of 16MB, use either of the following commands:

```
shell> mysql --max_allowed_packet=16777216
shell> mysql --max_allowed_packet=16M
```

The first command specifies the value in bytes. The second specifies the value in megabytes. For variables that take a numeric value, the value can be given with a suffix of `K`, `M`, or `G` (either uppercase or lowercase) to indicate a multiplier of 1024, 1024^2 or 1024^3. (For example, when used to set `max_allowed_packet`, the suffixes indicate units of kilobytes, megabytes, or gigabytes.)

In an option file, variable settings are given without the leading dashes:

```
[mysql]
max_allowed_packet=16777216
```

Or:

```
[mysql]
max_allowed_packet=16M
```

If you like, underscores in a variable name can be specified as dashes. The following option groups are equivalent. Both set the size of the server's key buffer to 512MB:

```
[mysqld]
key_buffer_size=512M

[mysqld]
key-buffer-size=512M
```

A variable can be specified by writing it in full or as any unambiguous prefix. For example, the `max_allowed_packet` variable can be set for `mysql` as `--max_a`, but not as `--max` because the latter is ambiguous:

```
shell> mysql --max=1000000
mysql: ambiguous option '--max=1000000' (max_allowed_packet, max_join_size)
```

Be aware that the use of variable prefixes can cause problems in the event that new variables are implemented for a program. A prefix that is unambiguous now might become ambiguous in the future.

Suffixes for specifying a value multiplier can be used when setting a variable at server startup, but not to set the value with `SET` at runtime. On the other hand, with `SET`, you can assign a variable's value using an expression, which is not true when you set a variable at server startup. For example, the first of the following lines is legal at server startup, but the second is not:

```
shell> mysql --max_allowed_packet=16M
shell> mysql --max_allowed_packet=16*1024*1024
```

Conversely, the second of the following lines is legal at runtime, but the first is not:

```
mysql> SET GLOBAL max_allowed_packet=16M;
mysql> SET GLOBAL max_allowed_packet=16*1024*1024;
```

4.2.9 Option Defaults, Options Expecting Values, and the = Sign

By convention, long forms of options that assign a value are written with an equals (`=`) sign, like this:

```
shell> mysql --host=tonfisk --user=jon
```

For options that require a value (that is, not having a default value), the equal sign is not required, and so the following is also valid:

```
shell> mysql --host tonfisk --user jon
```

In both cases, the `mysql` client attempts to connect to a MySQL server running on the host named “tonfisk” using an account with the user name “jon”.

Due to this behavior, problems can occasionally arise when no value is provided for an option that expects one. Consider the following example, where a user connects to a MySQL server running on host `tonfisk` as user `jon`:

```
shell> mysql --host 85.224.35.45 --user jon
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 3
Server version: 5.5.60 Source distribution

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT CURRENT_USER();
+----------------+
| CURRENT_USER() |
+----------------+
| jon@%          |
+----------------+
1 row in set (0.00 sec)
```

Omitting the required value for one of these option yields an error, such as the one shown here:

```
shell> mysql --host 85.224.35.45 --user
mysql: option '--user' requires an argument
```

In this case, `mysql` was unable to find a value following the `--user` option because nothing came after it on the command line. However, if you omit the value for an option that is *not* the last option to be used, you obtain a different error that you may not be expecting:

```
shell> mysql --host --user jon
ERROR 2005 (HY000): Unknown MySQL server host '--user' (1)
```

Because `mysql` assumes that any string following `--host` on the command line is a host name, `--host --user` is interpreted as `--host=--user`, and the client attempts to connect to a MySQL server running on a host named “--user”.

Options having default values always require an equal sign when assigning a value; failing to do so causes an error. For example, the MySQL server `--log-error` option has the default value *`host_name`*`.err`, where *`host_name`* is the name of the host on which MySQL is running. Assume that you are running MySQL on a computer whose host name is “tonfisk”, and consider the following invocation of `mysqld_safe`:

```
shell> mysqld_safe &
[1] 11699
shell> 080112 12:53:40 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
080112 12:53:40 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
shell>
```

After shutting down the server, restart it as follows:

```
shell> mysqld_safe --log-error &
[1] 11699
shell> 080112 12:53:40 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
080112 12:53:40 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
shell>
```

The result is the same, since `--log-error` is not followed by anything else on the command line, and it supplies its own default value. (The `&` character tells the operating system to run MySQL in the background; it is ignored by MySQL itself.) Now suppose that you wish to log errors to a file named `my-errors.err`. You might try starting the server with `--log-error my-errors`, but this does not have the intended effect, as shown here:

```
shell> mysqld_safe --log-error my-errors &
[1] 31357
shell> 080111 22:53:31 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
080111 22:53:32 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var
080111 22:53:34 mysqld_safe mysqld from pid file /usr/local/mysql/var/tonfisk.pid ended

[1]+  Done                    ./mysqld_safe --log-error my-errors
```

The server attempted to start using `/usr/local/mysql/var/tonfisk.err` as the error log, but then shut down. Examining the last few lines of this file shows the reason:

```
shell> tail /usr/local/mysql/var/tonfisk.err
080111 22:53:32  InnoDB: Started; log sequence number 0 46409
/usr/local/mysql/libexec/mysqld: Too many arguments (first extra is 'my-errors').
Use --verbose --help to get a list of available options
080111 22:53:32 [ERROR] Aborting

080111 22:53:32  InnoDB: Starting shutdown...
080111 22:53:34  InnoDB: Shutdown completed; log sequence number 0 46409
080111 22:53:34 [Note] /usr/local/mysql/libexec/mysqld: Shutdown complete

080111 22:53:34 mysqld_safe mysqld from pid file /usr/local/mysql/var/tonfisk.pid ended
```

Because the `--log-error` option supplies a default value, you must use an equal sign to assign a different value to it, as shown here:

```
shell> mysqld_safe --log-error=my-errors &
[1] 31437
shell> 080111 22:54:15 mysqld_safe Logging to '/usr/local/mysql/var/my-errors.err'.
080111 22:54:15 mysqld_safe Starting mysqld daemon with databases from /usr/local/mysql/var

shell>
```

Now the server has been started successfully, and is logging errors to the file `/usr/local/mysql/var/my-errors.err`.

Similar issues can arise when specifying option values in option files. For example, consider a `my.cnf` file that contains the following:

```
[mysql]

host
user
```

When the `mysql` client reads this file, these entries are parsed as `--host --user` or `--host=--user`, with the result shown here:

```
shell> mysql
ERROR 2005 (HY000): Unknown MySQL server host '--user' (1)
```

However, in option files, an equal sign is not assumed. Suppose the `my.cnf` file is as shown here:

```
[mysql]

user jon
```

Trying to start `mysql` in this case causes a different error:

```
shell> mysql
mysql: unknown option '--user jon'
```

A similar error would occur if you were to write `host tonfisk` in the option file rather than `host=tonfisk`. Instead, you must use the equal sign:

```
[mysql]

user=jon
```

Now the login attempt succeeds:

```
shell> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 5
Server version: 5.5.60 Source distribution

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT USER();
+---------------+
| USER()        |
+---------------+
| jon@localhost |
+---------------+
1 row in set (0.00 sec)
```

This is not the same behavior as with the command line, where the equals sign is not required:

```
shell> mysql --user jon --host tonfisk
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 6
Server version: 5.5.60 Source distribution

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT USER();
+---------------+
```

```
| USER()        |
+---------------+
| jon@tonfisk   |
+---------------+
1 row in set (0.00 sec)
```

Specifying an option requiring a value without a value in an option file causes the server to abort with an error. Suppose that `my.cnf` contains the following:

```
[mysqld]
log_error
relay_log
relay_log_index
```

This causes the server to fail on startup, as shown here:

```
shell> mysqld_safe &

090514 09:48:39 mysqld_safe Logging to '/home/jon/bin/mysql/var/tonfisk.err'.
090514 09:48:39 mysqld_safe Starting mysqld daemon with databases from /home/jon/bin/mysql/var
090514 09:48:39 mysqld_safe mysqld from pid file /home/jon/bin/mysql/var/tonfisk.pid ended
```

The `--log-error` option does not require an argument; however, the `--relay-log` option requires one, as shown in the error log (which in the absence of a specified value, defaults to *`datadir/hostname`*`.err`):

```
shell> tail -n 3 ../var/tonfisk.err

090514 09:48:39 mysqld_safe Starting mysqld daemon with databases from /home/jon/bin/mysql/var
090514  9:48:39 [ERROR] /home/jon/bin/mysql/libexec/mysqld: option '--relay-log' requires an argument
090514  9:48:39 [ERROR] Aborting
```

This is a change from previous behavior, where the server would have interpreted the last two lines in the example `my.cnf` file as `--relay-log=relay_log_index` and created a relay log file using “relay_log_index” as the base name. (Bug #25192)

4.2.10 Setting Environment Variables

Environment variables can be set at the command prompt to affect the current invocation of your command processor, or set permanently to affect future invocations. To set a variable permanently, you can set it in a startup file or by using the interface provided by your system for this purpose. Consult the documentation for your command interpreter for specific details. Section 4.9, “MySQL Program Environment Variables”, lists all environment variables that affect MySQL program operation.

To specify a value for an environment variable, use the syntax appropriate for your command processor. For example, on Windows, you can set the `USER` variable to specify your MySQL account name. To do so, use this syntax:

```
SET USER=your_name
```

The syntax on Unix depends on your shell. Suppose that you want to specify the TCP/IP port number using the `MYSQL_TCP_PORT` variable. Typical syntax (such as for `sh`, `ksh`, `bash`, `zsh`, and so on) is as follows:

```
MYSQL_TCP_PORT=3306
export MYSQL_TCP_PORT
```

The first command sets the variable, and the `export` command exports the variable to the shell environment so that its value becomes accessible to MySQL and other processes.

For `csh` and `tcsh`, use `setenv` to make the shell variable available to the environment:

```
setenv MYSQL_TCP_PORT 3306
```

The commands to set environment variables can be executed at your command prompt to take effect immediately, but the settings persist only until you log out. To have the settings take effect each time you log in, use the interface provided by your system or place the appropriate command or commands in a startup file that your command interpreter reads each time it starts.

On Windows, you can set environment variables using the System Control Panel (under Advanced).

On Unix, typical shell startup files are `.bashrc` or `.bash_profile` for `bash`, or `.tcshrc` for `tcsh`.

Suppose that your MySQL programs are installed in `/usr/local/mysql/bin` and that you want to make it easy to invoke these programs. To do this, set the value of the `PATH` environment variable to include that directory. For example, if your shell is `bash`, add the following line to your `.bashrc` file:

```
PATH=${PATH}:/usr/local/mysql/bin
```

`bash` uses different startup files for login and nonlogin shells, so you might want to add the setting to `.bashrc` for login shells and to `.bash_profile` for nonlogin shells to make sure that `PATH` is set regardless.

If your shell is `tcsh`, add the following line to your `.tcshrc` file:

```
setenv PATH ${PATH}:/usr/local/mysql/bin
```

If the appropriate startup file does not exist in your home directory, create it with a text editor.

After modifying your `PATH` setting, open a new console window on Windows or log in again on Unix so that the setting goes into effect.

4.3 MySQL Server and Server-Startup Programs

This section describes `mysqld`, the MySQL server, and several programs that are used to start the server.

4.3.1 `mysqld` — The MySQL Server

`mysqld`, also known as MySQL Server, is the main program that does most of the work in a MySQL installation. MySQL Server manages access to the MySQL data directory that contains databases and tables. The data directory is also the default location for other information such as log files and status files.

When MySQL server starts, it listens for network connections from client programs and manages access to databases on behalf of those clients.

The `mysqld` program has many options that can be specified at startup. For a complete list of options, run this command:

```
shell> mysqld --verbose --help
```

MySQL Server also has a set of system variables that affect its operation as it runs. System variables can be set at server startup, and many of them can be changed at runtime to effect dynamic server reconfiguration. MySQL Server also has a set of status variables that provide information about its operation. You can monitor these status variables to access runtime performance characteristics.

For a full description of MySQL Server command options, system variables, and status variables, see Section 5.1, “The MySQL Server”. For information about installing MySQL and setting up the initial configuration, see Chapter 2, *Installing and Upgrading MySQL*.

4.3.2 mysqld_safe — MySQL Server Startup Script

mysqld_safe is the recommended way to start a mysqld server on Unix. mysqld_safe adds some safety features such as restarting the server when an error occurs and logging runtime information to an error log. A description of error logging is given later in this section.

mysqld_safe tries to start an executable named mysqld. To override the default behavior and specify explicitly the name of the server you want to run, specify a --mysqld or --mysqld-version option to mysqld_safe. You can also use --ledir to indicate the directory where mysqld_safe should look for the server.

Many of the options to mysqld_safe are the same as the options to mysqld. See Section 5.1.4, “Server Command Options”.

Options unknown to mysqld_safe are passed to mysqld if they are specified on the command line, but ignored if they are specified in the [mysqld_safe] group of an option file. See Section 4.2.6, “Using Option Files”.

mysqld_safe reads all options from the [mysqld], [server], and [mysqld_safe] sections in option files. For example, if you specify a [mysqld] section like this, mysqld_safe will find and use the --log-error option:

```
[mysqld]
log-error=error.log
```

For backward compatibility, mysqld_safe also reads [safe_mysqld] sections, but to be current you should rename such sections to [mysqld_safe].

mysqld_safe supports the following options. It also reads option files and supports the options for processing them described at Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

Table 4.3 mysqld_safe Options

Format	Description	Introduced
--basedir	Path to MySQL installation directory	
--core-file-size	Size of core file that mysqld should be able to create	
--datadir	Path to data directory	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--help	Display help message and exit	
--ledir	Path to directory where server is located	
--log-error	Write error log to named file	
--malloc-lib	Alternative malloc library to use for mysqld	
--mysqld	Name of server program to start (in ledir directory)	
--mysqld-version	Suffix for server program name	
--nice	Use nice program to set server scheduling priority	
--no-defaults	Read no option files	
--open-files-limit	Number of files that mysqld should be able to open	
--pid-file	Path name of server process ID file	
--plugin-dir	Directory where plugins are installed	5.5.3
--port	Port number on which to listen for TCP/IP connections	
--skip-kill-mysqld	Do not try to kill stray mysqld processes	
--skip-syslog	Do not write error messages to syslog; use error log file	

Format	Description	Introduced
--socket	Socket file on which to listen for Unix socket connections	
--syslog	Write error messages to syslog	
--syslog-tag	Tag suffix for messages written to syslog	
--timezone	Set TZ time zone environment variable to named value	
--user	Run mysqld as user having name user_name or numeric user ID user_id	

- `--help`

  Display a help message and exit.

- `--basedir=dir_name`

  The path to the MySQL installation directory.

- `--core-file-size=size`

  The size of the core file that `mysqld` should be able to create. The option value is passed to `ulimit -c`.

- `--datadir=dir_name`

  The path to the data directory.

- `--defaults-extra-file=file_name`

  Read this option file in addition to the usual option files. If the file does not exist or is otherwise inaccessible, the server will exit with an error. *`file_name`* is interpreted relative to the current directory if given as a relative path name rather than a full path name. This must be the first option on the command line if it is used.

  For additional information about this option, see Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, the server will exit with an error. *`file_name`* is interpreted relative to the current directory if given as a relative path name rather than a full path name. This must be the first option on the command line if it is used.

  For additional information about this option, see Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- `--ledir=dir_name`

  If `mysqld_safe` cannot find the server, use this option to indicate the path name to the directory where the server is located.

  As of MySQL 5.5.54, this option is accepted only on the command line, not in option files.

- `--log-error=file_name`

  Write the error log to the given file. See Section 5.4.2, “The Error Log”.

- `--malloc-lib=[lib_name]`

  The name of the library to use for memory allocation instead of the system `malloc()` library. As of MySQL 5.5.52, the option value must be one of the directories `/usr/lib`, `/usr/lib64`, `/usr/lib/i386-linux-gnu`, or `/usr/lib/x86_64-linux-gnu`. Prior to MySQL 5.5.52, any library

can be used by specifying its path name, but there is a shortcut form to enable use of the tcmalloc library that is shipped with binary MySQL distributions for Linux in MySQL 5.5. It is possible that the shortcut form will not work under certain configurations, in which case you should specify a path name instead.

Note

As of MySQL 5.5.50, MySQL distributions no longer include a tcmalloc library.

The --malloc-lib option works by modifying the LD_PRELOAD environment value to affect dynamic linking to enable the loader to find the memory-allocation library when mysqld runs:

- If the option is not given, or is given without a value (--malloc-lib=), LD_PRELOAD is not modified and no attempt is made to use tcmalloc.
- If the option is given as --malloc-lib=tcmalloc, mysqld_safe looks for a tcmalloc library in /usr/lib and then in the MySQL pkglibdir location (for example, /usr/local/mysql/lib or whatever is appropriate). If tmalloc is found, its path name is added to the beginning of the LD_PRELOAD value for mysqld. If tcmalloc is not found, mysqld_safe aborts with an error.
- If the option is given as --malloc-lib=*/path/to/some/library*, that full path is added to the beginning of the LD_PRELOAD value. If the full path points to a nonexistent or unreadable file, mysqld_safe aborts with an error.
- For cases where mysqld_safe adds a path name to LD_PRELOAD, it adds the path to the beginning of any existing value the variable already has.

Linux users can use the libtcmalloc_minimal.so included in binary packages by adding these lines to the my.cnf file:

```
[mysqld_safe]
malloc-lib=tcmalloc
```

Those lines also suffice for users on any platform who have installed a tcmalloc package in /usr/lib. To use a specific tcmalloc library, specify its full path name. Example:

```
[mysqld_safe]
malloc-lib=/opt/lib/libtcmalloc_minimal.so
```

- --mysqld=*prog_name*

  The name of the server program (in the ledir directory) that you want to start. This option is needed if you use the MySQL binary distribution but have the data directory outside of the binary distribution. If mysqld_safe cannot find the server, use the --ledir option to indicate the path name to the directory where the server is located.

  As of MySQL 5.5.52, this option is accepted only on the command line, not in option files.

- --mysqld-version=*suffix*

  This option is similar to the --mysqld option, but you specify only the suffix for the server program name. The base name is assumed to be mysqld. For example, if you use --mysqld-version=debug, mysqld_safe starts the mysqld-debug program in the ledir directory. If the argument to --mysqld-version is empty, mysqld_safe uses mysqld in the ledir directory.

  As of MySQL 5.5.52, this option is accepted only on the command line, not in option files.

- --nice=*priority*

  Use the nice program to set the server's scheduling priority to the given value.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read. This must be the first option on the command line if it is used.

  For additional information about this option, see Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- `--open-files-limit=`*`count`*

  The number of files that `mysqld` should be able to open. The option value is passed to `ulimit -n`.

  Note

  You must start `mysqld_safe` as `root` for this to function properly.

- `--pid-file=`*`file_name`*

  The path name that `mysqld` should use for its process ID file.

- `--plugin-dir=`*`dir_name`*

  The path name of the plugin directory. This option was added in MySQL 5.5.3.

- `--port=`*`port_num`*

  The port number that the server should use when listening for TCP/IP connections. The port number must be 1024 or higher unless the server is started by the `root` system user.

- `--skip-kill-mysqld`

  Do not try to kill stray `mysqld` processes at startup. This option works only on Linux.

- `--socket=`*`path`*

  The Unix socket file that the server should use when listening for local connections.

- `--syslog`, `--skip-syslog`

  `--syslog` causes error messages to be sent to `syslog` on systems that support the `logger` program. `--skip-syslog` suppresses the use of `syslog`; messages are written to an error log file.

  When `syslog` is used, the `daemon.err` syslog facility/severity is used for all log messages.

  `mysqld_safe` ignores `--syslog` if `--log-error` is also given.

- `--syslog-tag=`*`tag`*

  For logging to `syslog`, messages from `mysqld_safe` and `mysqld` are written with identifiers of `mysqld_safe` and `mysqld`, respectively. To specify a suffix for the identifiers, use `--syslog-tag=`*`tag`*, which modifies the identifiers to be `mysqld_safe-`*`tag`* and `mysqld-`*`tag`*.

- `--timezone=`*`timezone`*

  Set the `TZ` time zone environment variable to the given option value. Consult your operating system documentation for legal time zone specification formats.

- `--user={`*`user_name`*`|`*`user_id`*`}`

  Run the `mysqld` server as the user having the name *`user_name`* or the numeric user ID *`user_id`*. (“User” in this context refers to a system login account, not a MySQL user listed in the grant tables.)

If you execute mysqld_safe with the --defaults-file or --defaults-extra-file option to name an option file, the option must be the first one given on the command line or the option file will not be used. For example, this command will not use the named option file:

```
mysql> mysqld_safe --port=port_num --defaults-file=file_name
```

Instead, use the following command:

```
mysql> mysqld_safe --defaults-file=file_name --port=port_num
```

The mysqld_safe script is written so that it normally can start a server that was installed from either a source or a binary distribution of MySQL, even though these types of distributions typically install the server in slightly different locations. (See Section 2.1.4, “Installation Layouts”.) mysqld_safe expects one of the following conditions to be true:

- The server and databases can be found relative to the working directory (the directory from which mysqld_safe is invoked). For binary distributions, mysqld_safe looks under its working directory for bin and data directories. For source distributions, it looks for libexec and var directories. This condition should be met if you execute mysqld_safe from your MySQL installation directory (for example, /usr/local/mysql for a binary distribution).
- If the server and databases cannot be found relative to the working directory, mysqld_safe attempts to locate them by absolute path names. Typical locations are /usr/local/libexec and /usr/local/var. The actual locations are determined from the values configured into the distribution at the time it was built. They should be correct if MySQL is installed in the location specified at configuration time.

Because mysqld_safe tries to find the server and databases relative to its own working directory, you can install a binary distribution of MySQL anywhere, as long as you run mysqld_safe from the MySQL installation directory:

```
shell> cd mysql_installation_directory
shell> bin/mysqld_safe &
```

If mysqld_safe fails, even when invoked from the MySQL installation directory, specify the --ledir and --datadir options to indicate the directories in which the server and databases are located on your system.

Beginning with MySQL 5.5.21, mysqld_safe tries to use the sleep and date system utilities to determine how many times it has attempted to start this second, and—if these are present and this is greater than 5 times—is forced to wait 1 full second before starting again. This is intended to prevent excessive CPU usage in the event of repeated failures. (Bug #11761530, Bug #54035)

When you use mysqld_safe to start mysqld, mysqld_safe arranges for error (and notice) messages from itself and from mysqld to go to the same destination.

There are several mysqld_safe options for controlling the destination of these messages:

- --log-error=*file_name*: Write error messages to the named error file.
- --syslog: Write error messages to syslog on systems that support the logger program.
- --skip-syslog: Do not write error messages to syslog. Messages are written to the default error log file (*host_name*.err in the data directory), or to a named file if the --log-error option is given.

If none of these options is given, the default is --skip-syslog.

If --log-error and --syslog are both given, a warning is issued and --log-error takes precedence.

When mysqld_safe writes a message, notices go to the logging destination (syslog or the error log file) and stdout. Errors go to the logging destination and stderr.

Normally, you should not edit the mysqld_safe script. Instead, configure mysqld_safe by using command-line options or options in the [mysqld_safe] section of a my.cnf option file. In rare cases, it might be necessary to edit mysqld_safe to get it to start the server properly. However, if you do this, your modified version of mysqld_safe might be overwritten if you upgrade MySQL in the future, so you should make a copy of your edited version that you can reinstall.

4.3.3 mysql.server — MySQL Server Startup Script

MySQL distributions on Unix and Unix-like system include a script named mysql.server, which starts the MySQL server using mysqld_safe. It can be used on systems such as Linux and Solaris that use System V-style run directories to start and stop system services. It is also used by the macOS Startup Item for MySQL.

mysql.server is the script name as used within the MySQL source tree. The installed name might be different; for example, mysqld or mysql. In the following discussion, adjust the name mysql.server as appropriate for your system.

To start or stop the server manually using the mysql.server script, invoke it from the command line with start or stop arguments:

```
shell> mysql.server start
shell> mysql.server stop
```

mysql.server changes location to the MySQL installation directory, then invokes mysqld_safe. To run the server as some specific user, add an appropriate user option to the [mysqld] group of the global /etc/my.cnf option file, as shown later in this section. (It is possible that you must edit mysql.server if you've installed a binary distribution of MySQL in a nonstandard location. Modify it to change location into the proper directory before it runs mysqld_safe. If you do this, your modified version of mysql.server may be overwritten if you upgrade MySQL in the future; make a copy of your edited version that you can reinstall.)

mysql.server stop stops the server by sending a signal to it. You can also stop the server manually by executing mysqladmin shutdown.

To start and stop MySQL automatically on your server, you must add start and stop commands to the appropriate places in your /etc/rc* files:

- If you use the Linux server RPM package (MySQL-server-*VERSION*.rpm), or a native Linux package installation, the mysql.server script may be installed in the /etc/init.d directory with the name mysqld or mysql. See Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”, for more information on the Linux RPM packages.
- If you install MySQL from a source distribution or using a binary distribution format that does not install mysql.server automatically, you can install the script manually. It can be found in the support-files directory under the MySQL installation directory or in a MySQL source tree. Copy the script to the /etc/init.d directory with the name mysql and make it executable:

  ```
  shell> cp mysql.server /etc/init.d/mysql
  shell> chmod +x /etc/init.d/mysql
  ```

  After installing the script, the commands needed to activate it to run at system startup depend on your operating system. On Linux, you can use chkconfig:

  ```
  shell> chkconfig --add mysql
  ```

  On some Linux systems, the following command also seems to be necessary to fully enable the mysql script:

```
shell> chkconfig --level 345 mysql on
```

- On FreeBSD, startup scripts generally should go in /usr/local/etc/rc.d/. Install the mysql.server script as /usr/local/etc/rc.d/mysql.server.sh to enable automatic startup. The rc(8) manual page states that scripts in this directory are executed only if their base name matches the *.sh shell file name pattern. Any other files or directories present within the directory are silently ignored.
- As an alternative to the preceding setup, some operating systems also use /etc/rc.local or /etc/init.d/boot.local to start additional services on startup. To start up MySQL using this method, append a command like the one following to the appropriate startup file:

```
/bin/sh -c 'cd /usr/local/mysql; ./bin/mysqld_safe --user=mysql &'
```

- For other systems, consult your operating system documentation to see how to install startup scripts.

mysql.server reads options from the [mysql.server] and [mysqld] sections of option files. For backward compatibility, it also reads [mysql_server] sections, but to be current you should rename such sections to [mysql.server].

You can add options for mysql.server in a global /etc/my.cnf file. A typical my.cnf file might look like this:

```
[mysqld]
datadir=/usr/local/mysql/var
socket=/var/tmp/mysql.sock
port=3306
user=mysql

[mysql.server]
basedir=/usr/local/mysql
```

The mysql.server script supports the options shown in the following table. If specified, they *must* be placed in an option file, not on the command line. mysql.server supports only start and stop as command-line arguments.

Table 4.4 mysql.server Option-File Options

Option Name	Description	Type
basedir	Path to MySQL installation directory	directory name
datadir	Path to MySQL data directory	directory name
pid-file	File in which server should write its process ID	file name
service-startup-timeout	How long to wait for server startup	integer

- basedir=*dir_name*

  The path to the MySQL installation directory.

- datadir=*dir_name*

  The path to the MySQL data directory.

- pid-file=*file_name*

  The path name of the file in which the server should write its process ID.

If this option is not given, mysql.server uses a default value of *host_name*.pid. The PID file value passed to mysqld_safe overrides any value specified in the [mysqld_safe] option file group. Because mysql.server reads the [mysqld] option file group but not the [mysqld_safe] group, you can ensure that mysqld_safe gets the same value when invoked from mysql.server as when invoked manually by putting the same pid-file setting in both the [mysqld_safe] and [mysqld] groups.

- service-startup-timeout=*seconds*

  How long in seconds to wait for confirmation of server startup. If the server does not start within this time, mysql.server exits with an error. The default value is 900. A value of 0 means not to wait at all for startup. Negative values mean to wait forever (no timeout).

4.3.4 mysqld_multi — Manage Multiple MySQL Servers

mysqld_multi is designed to manage several mysqld processes that listen for connections on different Unix socket files and TCP/IP ports. It can start or stop servers, or report their current status.

mysqld_multi searches for groups named [mysqld*N*] in my.cnf (or in the file named by the --defaults-file option). *N* can be any positive integer. This number is referred to in the following discussion as the option group number, or *GNR*. Group numbers distinguish option groups from one another and are used as arguments to mysqld_multi to specify which servers you want to start, stop, or obtain a status report for. Options listed in these groups are the same that you would use in the [mysqld] group used for starting mysqld. (See, for example, Section 2.10.5, “Starting and Stopping MySQL Automatically”.) However, when using multiple servers, it is necessary that each one use its own value for options such as the Unix socket file and TCP/IP port number. For more information on which options must be unique per server in a multiple-server environment, see Section 5.6, “Running Multiple MySQL Instances on One Machine”.

To invoke mysqld_multi, use the following syntax:

```
shell> mysqld_multi [options] {start|stop|report} [GNR[,GNR] ...]
```

start, stop, and report indicate which operation to perform. You can perform the designated operation for a single server or multiple servers, depending on the *GNR* list that follows the option name. If there is no list, mysqld_multi performs the operation for all servers in the option file.

Each *GNR* value represents an option group number or range of group numbers. The value should be the number at the end of the group name in the option file. For example, the *GNR* for a group named [mysqld17] is 17. To specify a range of numbers, separate the first and last numbers by a dash. The *GNR* value 10-13 represents groups [mysqld10] through [mysqld13]. Multiple groups or group ranges can be specified on the command line, separated by commas. There must be no whitespace characters (spaces or tabs) in the *GNR* list; anything after a whitespace character is ignored.

This command starts a single server using option group [mysqld17]:

```
shell> mysqld_multi start 17
```

This command stops several servers, using option groups [mysqld8] and [mysqld10] through [mysqld13]:

```
shell> mysqld_multi stop 8,10-13
```

For an example of how you might set up an option file, use this command:

```
shell> mysqld_multi --example
```

mysqld_multi searches for option files as follows:

- With --no-defaults, no option files are read.
- With --defaults-file=*file_name*, only the named file is read.
- Otherwise, option files in the standard list of locations are read, including any file named by the --defaults-extra-file=*file_name* option, if one is given. (If the option is given multiple times, the last value is used.)

Option files read are searched for [mysqld_multi] and [mysqld*N*] option groups. The [mysqld_multi] group can be used for options to mysqld_multi itself. [mysqld*N*] groups can be used for options passed to specific mysqld instances.

The [mysqld] or [mysqld_safe] groups can be used for common options read by all instances of mysqld or mysqld_safe. You can specify a --defaults-file=*file_name* option to use a different configuration file for that instance, in which case the [mysqld] or [mysqld_safe] groups from that file will be used for that instance.

mysqld_multi supports the following options.

- --help

  Display a help message and exit.

- --config-file=*file_name*

  This option is deprecated. If given, it is treated the same way as --defaults-extra-file, described earlier. --config-file was removed in MySQL 5.5.3.

- --example

  Display a sample option file.

- --log=*file_name*

  Specify the name of the log file. If the file exists, log output is appended to it.

- --mysqladmin=*prog_name*

  The mysqladmin binary to be used to stop servers.

- --mysqld=*prog_name*

  The mysqld binary to be used. Note that you can specify mysqld_safe as the value for this option also. If you use mysqld_safe to start the server, you can include the mysqld or ledir options in the corresponding [mysqld*N*] option group. These options indicate the name of the server that mysqld_safe should start and the path name of the directory where the server is located. (See the descriptions for these options in Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”.) Example:

  ```
  [mysqld38]
  mysqld = mysqld-debug
  ledir  = /opt/local/mysql/libexec
  ```

- --no-log

  Print log information to stdout rather than to the log file. By default, output goes to the log file.

- --password=*password*

  The password of the MySQL account to use when invoking mysqladmin. The password value is not optional for this option, unlike for other MySQL programs.

- `--silent`

  Silent mode; disable warnings.

- `--tcp-ip`

  Connect to each MySQL server through the TCP/IP port instead of the Unix socket file. (If a socket file is missing, the server might still be running, but accessible only through the TCP/IP port.) By default, connections are made using the Unix socket file. This option affects `stop` and `report` operations.

- `--user=user_name`

  The user name of the MySQL account to use when invoking `mysqladmin`.

- `--verbose`

  Be more verbose.

- `--version`

  Display version information and exit.

Some notes about `mysqld_multi`:

- **Most important**: Before using `mysqld_multi` be sure that you understand the meanings of the options that are passed to the `mysqld` servers and *why* you would want to have separate `mysqld` processes. Beware of the dangers of using multiple `mysqld` servers with the same data directory. Use separate data directories, unless you *know* what you are doing. Starting multiple servers with the same data directory does *not* give you extra performance in a threaded system. See Section 5.6, “Running Multiple MySQL Instances on One Machine”.

  Important

  Make sure that the data directory for each server is fully accessible to the Unix account that the specific `mysqld` process is started as. *Do not* use the Unix *`root`* account for this, unless you *know* what you are doing. See Section 6.1.5, “How to Run MySQL as a Normal User”.

- Make sure that the MySQL account used for stopping the `mysqld` servers (with the `mysqladmin` program) has the same user name and password for each server. Also, make sure that the account has the `SHUTDOWN` privilege. If the servers that you want to manage have different user names or passwords for the administrative accounts, you might want to create an account on each server that has the same user name and password. For example, you might set up a common `multi_admin` account by executing the following commands for each server:

  ```
  shell> mysql -u root -S /tmp/mysql.sock -p
  Enter password:
  mysql> CREATE USER 'multi_admin'@'localhost' IDENTIFIED BY 'multipass';
  mysql> GRANT SHUTDOWN ON *.* TO 'multi_admin'@'localhost';
  ```

  See Section 6.2, “The MySQL Access Privilege System”. You have to do this for each `mysqld` server. Change the connection parameters appropriately when connecting to each one. Note that the host name part of the account name must permit you to connect as `multi_admin` from the host where you want to run `mysqld_multi`.

- The Unix socket file and the TCP/IP port number must be different for every `mysqld`. (Alternatively, if the host has multiple network addresses, you can use `--bind-address` to cause different servers to listen to different interfaces.)

- The `--pid-file` option is very important if you are using `mysqld_safe` to start `mysqld` (for example, `--mysqld=mysqld_safe`) Every `mysqld` should have its own process ID file. The

advantage of using `mysqld_safe` instead of `mysqld` is that `mysqld_safe` monitors its `mysqld` process and restarts it if the process terminates due to a signal sent using `kill -9` or for other reasons, such as a segmentation fault.

- You might want to use the `--user` option for `mysqld`, but to do this you need to run the `mysqld_multi` script as the Unix superuser (`root`). Having the option in the option file doesn't matter; you just get a warning if you are not the superuser and the `mysqld` processes are started under your own Unix account.

The following example shows how you might set up an option file for use with `mysqld_multi`. The order in which the `mysqld` programs are started or stopped depends on the order in which they appear in the option file. Group numbers need not form an unbroken sequence. The first and fifth `[mysqldN]` groups were intentionally omitted from the example to illustrate that you can have “gaps” in the option file. This gives you more flexibility.

```
# This is an example of a my.cnf file for mysqld_multi.
# Usually this file is located in home dir ~/.my.cnf or /etc/my.cnf

[mysqld_multi]
mysqld     = /usr/local/mysql/bin/mysqld_safe
mysqladmin = /usr/local/mysql/bin/mysqladmin
user       = multi_admin
password   = my_password

[mysqld2]
socket     = /tmp/mysql.sock2
port       = 3307
pid-file   = /usr/local/mysql/data2/hostname.pid2
datadir    = /usr/local/mysql/data2
language   = /usr/local/mysql/share/mysql/english
user       = unix_user1

[mysqld3]
mysqld     = /path/to/mysqld_safe
ledir      = /path/to/mysqld-binary/
mysqladmin = /path/to/mysqladmin
socket     = /tmp/mysql.sock3
port       = 3308
pid-file   = /usr/local/mysql/data3/hostname.pid3
datadir    = /usr/local/mysql/data3
language   = /usr/local/mysql/share/mysql/swedish
user       = unix_user2

[mysqld4]
socket     = /tmp/mysql.sock4
port       = 3309
pid-file   = /usr/local/mysql/data4/hostname.pid4
datadir    = /usr/local/mysql/data4
language   = /usr/local/mysql/share/mysql/estonia
user       = unix_user3

[mysqld6]
socket     = /tmp/mysql.sock6
port       = 3311
pid-file   = /usr/local/mysql/data6/hostname.pid6
datadir    = /usr/local/mysql/data6
language   = /usr/local/mysql/share/mysql/japanese
user       = unix_user4
```

See Section 4.2.6, “Using Option Files”.

4.4 MySQL Installation-Related Programs

The programs in this section are used when installing or upgrading MySQL.

4.4.1 `comp_err` — Compile MySQL Error Message File

comp_err creates the errmsg.sys file that is used by mysqld to determine the error messages to display for different error codes. comp_err normally is run automatically when MySQL is built. It compiles the errmsg.sys file from the text file located at sql/share/errmsg-utf8.txt in MySQL source distributions.

comp_err also generates mysqld_error.h, mysqld_ername.h, and sql_state.h header files.

For more information about how error messages are defined, see the MySQL Internals Manual.

Invoke comp_err like this:

```
shell> comp_err [options]
```

comp_err supports the following options.

- --help, -?

  Display a help message and exit.

- --charset=*dir_name*, -C *dir_name*

  The character set directory. The default is ../sql/share/charsets.

- --debug=*debug_options*, -# *debug_options*

  Write a debugging log. A typical *debug_options* string is d:t:O,*file_name*. The default is d:t:O,/tmp/comp_err.trace.

- --debug-info, -T

  Print some debugging information when the program exits.

- --header_file=*file_name*, -H *file_name*

  The name of the error header file. The default is mysqld_error.h.

- --in_file=*file_name*, -F *file_name*

  The name of the input file. The default is ../sql/share/errmsg-utf8.txt.

- --name_file=*file_name*, -N *file_name*

  The name of the error name file. The default is mysqld_ername.h.

- --out_dir=*dir_name*, -D *dir_name*

  The name of the output base directory. The default is ../sql/share/.

- --out_file=*file_name*, -O *file_name*

  The name of the output file. The default is errmsg.sys.

- --statefile=*file_name*, -S *file_name*

  The name for the SQLSTATE header file. The default is sql_state.h.

- --version, -V

  Display version information and exit.

4.4.2 mysqlbug — Generate Bug Report

This program is obsolete.

The normal way to report bugs is to visit http://bugs.mysql.com/, which is the address for our bugs database. This database is public and can be browsed and searched by anyone. If you log in to the system, you can enter new reports.

4.4.3 mysql_install_db — Initialize MySQL Data Directory

`mysql_install_db` initializes the MySQL data directory and creates the system tables that it contains, if they do not exist. `mysql_install_db` is a shell script and is available only on Unix platforms. (As of MySQL 5.6, `mysql_install_db` is a Perl script and can be used on any system with Perl installed.)

To invoke `mysql_install_db`, use the following syntax:

```
shell> mysql_install_db [options]
```

Because the MySQL server, `mysqld`, must access the data directory when it runs later, you should either run `mysql_install_db` from the same system account that will be used for running `mysqld`, or run it as `root` and specify the `--user` option to indicate the user name that `mysqld` will run as. It might be necessary to specify other options such as `--basedir` or `--datadir` if `mysql_install_db` does not use the correct locations for the installation directory or data directory. For example:

```
shell> scripts/mysql_install_db --user=mysql \
         --basedir=/opt/mysql/mysql \
         --datadir=/opt/mysql/mysql/data
```

Note

If you have set a custom `TMPDIR` environment variable when performing the installation, and the specified directory is not accessible, `mysql_install_db` may fail. If so, unset `TMPDIR` or set `TMPDIR` to point to the system temporary directory (usually `/tmp`).

`mysql_install_db` supports the following options, which can be specified on the command line or in the `[mysql_install_db]` group of an option file. (Options that are common to `mysqld` can also be specified in the `[mysqld]` group.) Other options are passed to `mysqld`. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.5 mysql_install_db Options

Format	Description
--basedir	Path to base directory
--builddir	Path to build directory (for out-of-source builds)
--cross-bootstrap	For internal use
--datadir	Path to data directory
--defaults-extra-file	Read named option file in addition to usual option files
--defaults-file	Read only named option file
--force	Run even if DNS does not work
--help	Display help message and exit
--ldata	Synonym for --datadir
--no-defaults	Read no option files
--rpm	For internal use

Format	Description
--skip-name-resolve	Use IP addresses rather than host names in grant tables
--srcdir	For internal use
--user	System login user under which to execute mysqld
--verbose	Verbose mode
--windows	For internal use

- `--help`

  Display a help message and exit.

- `--basedir=dir_name`

  The path to the MySQL installation directory.

- `--builddir=dir_name`

  For use with `--srcdir` and out-of-source builds. Set this to the location of the directory where the built files reside.

- `--cross-bootstrap`

  For internal use. This option is used for building system tables on one host intended for another.

- `--datadir=dir_name`

  The path to the MySQL data directory.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is interpreted relative to the current directory if given as a relative path name rather than a full path name.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *`file_name`* is interpreted relative to the current directory if given as a relative path name rather than a full path name.

- `--force`

  Cause `mysql_install_db` to run even if DNS does not work. Grant table entries normally created using host names will use IP addresses instead.

- `--ldata=dir_name`

  A synonym for `--datadir`.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--rpm`

  For internal use. This option is used during the MySQL installation process for install operations performed using RPM packages.

- `--skip-name-resolve`

Use IP addresses rather than host names when creating grant table entries. This option can be useful if your DNS does not work.

- `--srcdir=dir_name`

  For internal use. This option specifies the directory under which `mysql_install_db` looks for support files such as the error message file and the file for populating the help tables.

- `--user=user_name`

  The system (login) user name to use for running `mysqld`. Files and directories created by `mysqld` will be owned by this user. You must be the system `root` user to use this option. By default, `mysqld` runs using your current login name and files and directories that it creates will be owned by you.

- `--verbose`

  Verbose mode. Print more information about what the program does.

- `--windows`

  For internal use. This option is used for creating Windows distributions.

4.4.4 `mysql_plugin` — Configure MySQL Server Plugins

The `mysql_plugin` utility enables MySQL administrators to manage which plugins a MySQL server loads. It provides an alternative to manually specifying the `--plugin-load` option at server startup or using the `INSTALL PLUGIN` and `UNINSTALL PLUGIN` statements at runtime. `mysql_plugin` is available as of MySQL 5.5.16.

Depending on whether `mysql_plugin` is invoked to enable or disable plugins, it inserts or deletes rows in the `mysql.plugin` table that serves as a plugin registry. (To perform this operation, `mysql_plugin` invokes the MySQL server in bootstrap mode. This means that the server must not already be running.) For normal server startups, the server loads and enables plugins listed in `mysql.plugin` automatically. For additional control over plugin activation, use `--plugin_name` options named for specific plugins, as described in Section 5.5.1, “Installing and Uninstalling Plugins”.

Each invocation of `mysql_plugin` reads a configuration file to determine how to configure the plugins contained in a single plugin library file. To invoke `mysql_plugin`, use this syntax:

```
mysql_plugin [options] plugin {ENABLE|DISABLE}
```

`plugin` is the name of the plugin to configure. `ENABLE` or `DISABLE` (not case sensitive) specify whether to enable or disable components of the plugin library named in the configuration file. The order of the *`plugin`* and `ENABLE` or `DISABLE` arguments does not matter.

For example, to configure components of a plugin library file named `myplugins.so` on Linux or `myplugins.dll` on Windows, specify a *`plugin`* value of `myplugins`. Suppose that this plugin library contains three plugins, `plugin1`, `plugin2`, and `plugin3`, all of which should be configured under `mysql_plugin` control. By convention, configuration files have a suffix of `.ini` and the same base name as the plugin library, so the default configuration file name for this plugin library is `myplugins.ini`. The configuration file contents look like this:

```
myplugins
plugin1
plugin2
plugin3
```

The first line in the `myplugins.ini` file is the name of the library file, without any extension such as `.so` or `.dll`. The remaining lines are the names of the components to be enabled or disabled. Each

value in the file should be on a separate line. Lines on which the first character is '#' are taken as comments and ignored.

To enable the plugins listed in the configuration file, invoke mysql_plugin this way:

```
shell> mysql_plugin myplugins ENABLE
```

To disable the plugins, use DISABLE rather than ENABLE.

An error occurs if mysql_plugin cannot find the configuration file or plugin library file, or if mysql_plugin cannot start the MySQL server.

mysql_plugin supports the following options, which can be specified on the command line or in the [mysqld] group of any option file. For options specified in a [mysqld] group, mysql_plugin recognizes the --basedir, --datadir, and --plugin-dir options and ignores others. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.6 mysql_plugin Options

Format	Description
--basedir	The server base directory
--datadir	The server data directory
--help	Display help message and exit
--my-print-defaults	Path to my_print_defaults
--mysqld	Path to server
--no-defaults	Do not read configuration file
--plugin-dir	Directory where plugins are installed
--plugin-ini	The plugin configuration file
--print-defaults	Show configuration file defaults
--verbose	Verbose mode
--version	Display version information and exit

- --help, -?

  Display a help message and exit.

- --basedir=*dir_name*, -b *dir_name*

  The server base directory.

- --datadir=*dir_name*, -d *dir_name*

  The server data directory.

- --my-print-defaults=*file_name*, -b *file_name*

  The path to the my_print_defaults program.

- --mysqld=*file_name*, -b *file_name*

  The path to the mysqld server.

- --no-defaults, -p

  Do not read values from the configuration file. This option enables an administrator to skip reading defaults from the configuration file.

With mysql_plugin, this option need not be given first on the command line, unlike most other MySQL programs that support --no-defaults.

- --plugin-dir=*dir_name*, -p *dir_name*

  The server plugin directory.

- --plugin-ini=*file_name*, -i *file_name*

  The mysql_plugin configuration file. Relative path names are interpreted relative to the current directory. If this option is not given, the default is *plugin*.ini in the plugin directory, where *plugin* is the *plugin* argument on the command line.

- --print-defaults, -P

  Display the default values from the configuration file. This option causes mysql_plugin to print the defaults for --basedir, --datadir, and --plugin-dir if they are found in the configuration file. If no value for a variable is found, nothing is shown.

  With mysql_plugin, this option need not be given first on the command line, unlike most other MySQL programs that support --print-defaults.

- --verbose, -v

  Verbose mode. Print more information about what the program does. This option can be used multiple times to increase the amount of information.

- --version, -V

  Display version information and exit.

4.4.5 mysql_secure_installation — Improve MySQL Installation Security

This program enables you to improve the security of your MySQL installation in the following ways:

- You can set a password for root accounts.
- You can remove root accounts that are accessible from outside the local host.
- You can remove anonymous-user accounts.
- You can remove the test database (which by default can be accessed by all users, even anonymous users), and privileges that permit anyone to access databases with names that start with test_.

mysql_secure_installation helps you implement security recommendations similar to those described at Section 2.10.4, “Securing the Initial MySQL Accounts”.

Invoke mysql_secure_installation without arguments:

```
shell> mysql_secure_installation
```

When executed, the script prompts you to determine which actions to perform.

4.4.6 mysql_tzinfo_to_sql — Load the Time Zone Tables

The mysql_tzinfo_to_sql program loads the time zone tables in the mysql database. It is used on systems that have a *zoneinfo* database (the set of files describing time zones). Examples of such

systems are Linux, FreeBSD, Solaris, and OS X. One likely location for these files is the /usr/share/zoneinfo directory (/usr/share/lib/zoneinfo on Solaris). If your system does not have a zoneinfo database, you can use the downloadable package described in Section 10.6, "MySQL Server Time Zone Support".

mysql_tzinfo_to_sql can be invoked several ways:

```
shell> mysql_tzinfo_to_sql tz_dir
shell> mysql_tzinfo_to_sql tz_file tz_name
shell> mysql_tzinfo_to_sql --leap tz_file
```

For the first invocation syntax, pass the zoneinfo directory path name to mysql_tzinfo_to_sql and send the output into the mysql program. For example:

```
shell> mysql_tzinfo_to_sql /usr/share/zoneinfo | mysql -u root mysql
```

mysql_tzinfo_to_sql reads your system's time zone files and generates SQL statements from them. mysql processes those statements to load the time zone tables.

The second syntax causes mysql_tzinfo_to_sql to load a single time zone file *tz_file* that corresponds to a time zone name *tz_name*:

```
shell> mysql_tzinfo_to_sql tz_file tz_name | mysql -u root mysql
```

If your time zone needs to account for leap seconds, invoke mysql_tzinfo_to_sql using the third syntax, which initializes the leap second information. *tz_file* is the name of your time zone file:

```
shell> mysql_tzinfo_to_sql --leap tz_file | mysql -u root mysql
```

After running mysql_tzinfo_to_sql, it is best to restart the server so that it does not continue to use any previously cached time zone data.

4.4.7 mysql_upgrade — Check and Upgrade MySQL Tables

mysql_upgrade examines all tables in all databases for incompatibilities with the current version of MySQL Server. mysql_upgrade also upgrades the system tables so that you can take advantage of new privileges or capabilities that might have been added.

If mysql_upgrade finds that a table has a possible incompatibility, it performs a table check and, if problems are found, attempts a table repair. If the table cannot be repaired, see Section 2.11.3, "Rebuilding or Repairing Tables or Indexes" for manual table repair strategies.

You should execute mysql_upgrade each time you upgrade MySQL.

If you install MySQL from RPM packages on Linux, you must install the server and client RPMs. mysql_upgrade is included in the server RPM but requires the client RPM because the latter includes mysqlcheck. (See Section 2.5.1, "Installing MySQL on Linux Using RPM Packages".)

Note

On Windows Server 2008, Vista, and newer, you must run mysql_upgrade with administrator privileges. You can do this by running a Command Prompt as Administrator and running the command. Failure to do so may result in the upgrade failing to execute correctly.

Caution

You should always back up your current MySQL installation *before* performing an upgrade. See Section 7.2, "Database Backup Methods".

> Some upgrade incompatibilities may require special handling before you upgrade your MySQL installation and run mysql_upgrade. See Section 2.11.1, “Upgrading MySQL”, for instructions on determining whether any such incompatibilities apply to your installation and how to handle them.

To use mysql_upgrade, make sure that the server is running. Then invoke it like this:

```
shell> mysql_upgrade [options]
```

After running mysql_upgrade, stop the server and restart it so that any changes made to the system tables take effect.

If you have multiple MySQL server instances running, invoke mysql_upgrade with connection parameters appropriate for connecting to the desired server. For example, with servers running on the local host on parts 3306 through 3308, upgrade each of them by connecting to the appropriate port:

```
shell> mysql_upgrade --protocol=tcp -P 3306 [other_options]
shell> mysql_upgrade --protocol=tcp -P 3307 [other_options]
shell> mysql_upgrade --protocol=tcp -P 3308 [other_options]
```

For local host connections on Unix, the --protocol=tcp option forces a connection using TCP/IP rather than the Unix socket file.

mysql_upgrade executes the following commands to check and repair tables and to upgrade the system tables:

```
mysqlcheck --no-defaults --all-databases
 --fix-db-names --fix-table-names
mysqlcheck --no-defaults --check-upgrade --all-databases
 --auto-repair
mysql < fix_priv_tables
```

Notes about the preceding commands:

- mysql_upgrade also adds --write-binlog or --skip-write-binlog to the mysqlcheck commands, depending on whether the --write-binlog option was specified on the mysql_upgrade command.
- Because mysql_upgrade invokes mysqlcheck with the --all-databases option, it processes all tables in all databases, which might take a long time to complete. Each table is locked and therefore unavailable to other sessions while it is being processed. Check and repair operations can be time-consuming, particularly for large tables.
- For details about what checks the --check-upgrade option entails, see the description of the FOR UPGRADE option of the CHECK TABLE statement (see Section 13.7.2.2, “CHECK TABLE Syntax”).
- *fix_priv_tables* represents a script generated internally by mysql_upgrade that contains SQL statements to upgrade the tables in the mysql database.

All checked and repaired tables are marked with the current MySQL version number. This ensures that next time you run mysql_upgrade with the same version of the server, it can tell whether there is any need to check or repair the table again.

mysql_upgrade also saves the MySQL version number in a file named mysql_upgrade_info in the data directory. This is used to quickly check whether all tables have been checked for this release so that table-checking can be skipped. To ignore this file and perform the check regardless, use the --force option.

mysql_upgrade does not upgrade the contents of the help tables. For upgrade instructions, see Section 5.1.10, “Server-Side Help”.

mysql_upgrade supports the following options, which can be specified on the command line or in the [mysql_upgrade] and [client] groups of an option file. Unrecognized options are passed to mysqlcheck. For information about option files, see Section 4.2.6, “Using Option Files”.

Table 4.7 mysql_upgrade Options

Format	Description	Introduced
--basedir	Not used	
--character-sets-dir	Directory where character sets are installed	
--compress	Compress all information sent between client and server	
--datadir	Not used	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	
--debug-info	Print debugging information, memory, and CPU statistics when program exits	
--default-auth	Authentication plugin to use	5.5.10
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--force	Force execution even if mysql_upgrade has already been executed for current version of MySQL	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--no-defaults	Read no option files	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--plugin-dir	Directory where plugins are installed	5.5.10
--port	TCP/IP port number for connection	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable encrypted connection	
--ssl-ca	File that contains list of trusted SSL Certificate Authorities	
--ssl-capath	Directory that contains trusted SSL Certificate Authority certificate files	
--ssl-cert	File that contains X509 certificate	
--ssl-cipher	List of permitted ciphers for connection encryption	
--ssl-key	File that contains X509 key	
--ssl-mode	Security state of connection to server	5.5.49
--ssl-verify-server-cert	Verify host name against server certificate Common Name identity	
--tmpdir	Directory for temporary files	

Format	Description	Introduced
--upgrade-system-tables	Update only system tables, not data	
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version-check	Check for proper server version	5.5.32
--write-binlog	Write all statements to binary log	

- `--help`

  Display a short help message and exit.

- `--basedir=dir_name`

  The path to the MySQL installation directory. This option is accepted for backward compatibility but ignored. It is removed in MySQL 5.7.

- `--character-sets-dir=dir_name`

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- `--compress`

  Compress all information sent between the client and the server if both support compression.

- `--datadir=dir_name`

  The path to the data directory. This option is accepted for backward compatibility but ignored. It is removed in MySQL 5.7.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical `debug_options` string is `d:t:o,file_name`. The default is `d:t:O,/tmp/mysql_upgrade.trace`.

- `--debug-check`

  Print some debugging information when the program exits.

- `--debug-info`, `-T`

  Print debugging information and memory and CPU usage statistics when the program exits.

- `--default-auth=plugin`

  A hint about the client-side authentication plugin to use. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- `--default-character-set=charset_name`

  Use `charset_name` as the default character set. See Section 10.5, “Character Set Configuration”.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, `file_name` must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-file=file_name`

Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *file_name* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of *str*. For example, `mysql_upgrade` normally reads the `[client]` and `[mysql_upgrade]` groups. If the `--defaults-group-suffix=_other` option is given, `mysql_upgrade` also reads the `[client_other]` and `[mysql_upgrade_other]` groups.

- `--force`

  Ignore the `mysql_upgrade_info` file and force execution even if `mysql_upgrade` has already been executed for the current version of MySQL.

- `--host=host_name`, `-h host_name`

  Connect to the MySQL server on the given host.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *password* value following the `--password` or `-p` option on the command line, `mysql_upgrade` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--plugin-dir=dir_name`

  The directory in which to look for plugins. Specify this option if the `--default-auth` option is used to specify an authentication plugin but `mysql_upgrade` does not find it. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, “Connecting to the MySQL Server”.

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--socket=path`, `-S path`

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- `--tmpdir=dir_name`, `-t dir_name`

  The path name of the directory to use for creating temporary files.

- `--upgrade-system-tables`, `-s`

  Upgrade only the system tables, do not upgrade data.

- `--user=user_name`, `-u user_name`

  The MySQL user name to use when connecting to the server. The default user name is `root`.

- `--verbose`

  Verbose mode. Print more information about what the program does.

- `--version-check`, `-k`

  Check the version of the server to which `mysql_upgrade` is connecting to verify that it is the same as the version for which `mysql_upgrade` was built. If not, `mysql_upgrade` exits. This option is enabled by default; to disable the check, use `--skip-version-check`. This option was added in MySQL 5.5.32.

- `--write-binlog`

  Cause binary logging to be enabled while `mysql_upgrade` runs. This is the default behavior; to disable binary logging during the upgrade, use the inverse of this option (that is, start the program with `--skip-write-binlog`).

4.5 MySQL Client Programs

This section describes client programs that connect to the MySQL server.

4.5.1 `mysql` — The MySQL Command-Line Tool

`mysql` is a simple SQL shell with input line editing capabilities. It supports interactive and noninteractive use. When used interactively, query results are presented in an ASCII-table format. When used noninteractively (for example, as a filter), the result is presented in tab-separated format. The output format can be changed using command options.

If you have problems due to insufficient memory for large result sets, use the `--quick` option. This forces `mysql` to retrieve results from the server a row at a time rather than retrieving the entire result set and buffering it in memory before displaying it. This is done by returning the

result set using the mysql_use_result() C API function in the client/server library rather than mysql_store_result().

Using mysql is very easy. Invoke it from the prompt of your command interpreter as follows:

```
shell> mysql db_name
```

Or:

```
shell> mysql --user=user_name --password db_name
Enter password: your_password
```

Then type an SQL statement, end it with ;, \g, or \G and press Enter.

Typing **Control+C** causes mysql to attempt to kill the current statement. If this cannot be done, or **Control+C** is typed again before the statement is killed, mysql exits.

You can execute SQL statements in a script file (batch file) like this:

```
shell> mysql db_name < script.sql > output.tab
```

On Unix, the mysql client logs statements executed interactively to a history file. See Section 4.5.1.3, “mysql Logging”.

4.5.1.1 mysql Options

mysql supports the following options, which can be specified on the command line or in the [mysql] and [client] groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.8 mysql Options

Format	Description	Introduced	Removed
--auto-rehash	Enable automatic rehashing		
--auto-vertical-output	Enable automatic vertical result set display	5.5.3	
--batch	Do not use history file		
--binary-as-hex	Display binary values in hexadecimal notation	5.5.57	
--character-sets-dir	Directory where character sets are installed		
--column-names	Write column names in results		
--column-type-info	Display result set metadata		
--comments	Whether to retain or strip comments in statements sent to the server		
--compress	Compress all information sent between client and server		
--connect_timeout	Number of seconds before connection timeout		
--database	The database to use		
--debug	Write debugging log; supported only if MySQL was built with debugging support		
--debug-check	Print debugging information when program exits		
--debug-info	Print debugging information, memory, and CPU statistics when program exits		
--default-auth	Authentication plugin to use	5.5.7	
--default-character-set	Specify default character set		

Format	Description	Introduced	Removed
--defaults-extra-file	Read named option file in addition to usual option files		
--defaults-file	Read only named option file		
--defaults-group-suffix	Option group suffix value		
--delimiter	Set the statement delimiter		
--enable-cleartext-plugin	Enable cleartext authentication plugin	5.5.27	
--execute	Execute the statement and quit		
--force	Continue even if an SQL error occurs		
--help	Display help message and exit		
--host	Connect to MySQL server on given host		
--html	Produce HTML output		
--ignore-spaces	Ignore spaces after function names		
--init-command	SQL statement to execute after connecting		
--line-numbers	Write line numbers for errors		
--local-infile	Enable or disable for LOCAL capability for LOAD DATA INFILE		
--max_allowed_packet	Maximum packet length to send to or receive from server		
--max_join_size	The automatic limit for rows in a join when using --safe-updates		
--named-commands	Enable named mysql commands		
--net_buffer_length	Buffer size for TCP/IP and socket communication		
--no-auto-rehash	Disable automatic rehashing		
--no-beep	Do not beep when errors occur		
--no-defaults	Read no option files		
--no-named-commands	Disable named mysql commands		5.5.3
--no-pager	Deprecated form of --skip-pager		5.5.3
--no-tee	Do not copy output to a file		5.5.3
--one-database	Ignore statements except those for the default database named on the command line		
--pager	Use the given command for paging query output		
--password	Password to use when connecting to server		
--pipe	On Windows, connect to server using named pipe		
--plugin-dir	Directory where plugins are installed	5.5.7	
--port	TCP/IP port number for connection		
--print-defaults	Print default options		
--prompt	Set the prompt to the specified format		
--protocol	Connection protocol to use		
--quick	Do not cache each query result		
--raw	Write column values without escape conversion		
--reconnect	If the connection to the server is lost, automatically try to reconnect		

Format	Description	Introduced	Removed
--i-am-a-dummy, --safe-updates	Allow only UPDATE and DELETE statements that specify key values		
--secure-auth	Do not send passwords to server in old (pre-4.1) format		
--select_limit	The automatic limit for SELECT statements when using --safe-updates		
--shared-memory-base-name	The name of shared memory to use for shared-memory connections		
--show-warnings	Show warnings after each statement if there are any		
--sigint-ignore	Ignore SIGINT signals (typically the result of typing Control+C)		
--silent	Silent mode		
--skip-auto-rehash	Disable automatic rehashing		
--skip-column-names	Do not write column names in results		
--skip-line-numbers	Skip line numbers for errors		
--skip-named-commands	Disable named mysql commands		
--skip-pager	Disable paging		
--skip-reconnect	Disable reconnecting		
--socket	For connections to localhost, the Unix socket file or Windows named pipe to use		
--ssl	Enable encrypted connection		
--ssl-ca	File that contains list of trusted SSL Certificate Authorities		
--ssl-capath	Directory that contains trusted SSL Certificate Authority certificate files		
--ssl-cert	File that contains X509 certificate		
--ssl-cipher	List of permitted ciphers for connection encryption		
--ssl-key	File that contains X509 key		
--ssl-mode	Security state of connection to server	5.5.49	
--ssl-verify-server-cert	Verify host name against server certificate Common Name identity		
--table	Display output in tabular format		
--tee	Append a copy of output to named file		
--unbuffered	Flush the buffer after each query		
--user	MySQL user name to use when connecting to server		
--verbose	Verbose mode		
--version	Display version information and exit		
--vertical	Print query output rows vertically (one line per column value)		
--wait	If the connection cannot be established, wait and retry instead of aborting		
--xml	Produce XML output		

- `--help`, `-?`

  Display a help message and exit.

- `--auto-rehash`

  Enable automatic rehashing. This option is on by default, which enables database, table, and column name completion. Use `--disable-auto-rehash` to disable rehashing. That causes `mysql` to start faster, but you must issue the `rehash` command or its `\#` shortcut if you want to use name completion.

  To complete a name, enter the first part and press Tab. If the name is unambiguous, `mysql` completes it. Otherwise, you can press Tab again to see the possible names that begin with what you have typed so far. Completion does not occur if there is no default database.

  Note

  This feature requires a MySQL client that is compiled with the **readline** library. Typically, the **readline** library is not available on Windows.

- `--auto-vertical-output`

  Cause result sets to be displayed vertically if they are too wide for the current window, and using normal tabular format otherwise. (This applies to statements terminated by `;` or `\G`.) This option was added in MySQL 5.5.3.

- `--batch`, `-B`

  Print results using tab as the column separator, with each row on a new line. With this option, `mysql` does not use the history file.

  Batch mode results in nontabular output format and escaping of special characters. Escaping may be disabled by using raw mode; see the description for the `--raw` option.

- `--binary-as-hex`, `-b`

  When this option is given, `mysql` displays binary data using hexadecimal notation (`0x`*`value`*). This occurs whether the overall output dislay format is tabular, vertical, HTML, or XML.

  This option was added in MySQL 5.5.57.

- `--bind-address=`*`ip_address`*

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported only in the version of the `mysql` client that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- `--character-sets-dir=`*`dir_name`*

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- `--column-names`

  Write column names in results.

- `--column-type-info`

  Display result set metadata.

- `--comments`, `-c`

Whether to strip or preserve comments in statements sent to the server. The default is `--skip-comments` (strip comments), enable with `--comments` (preserve comments).

- `--compress`, `-C`

  Compress all information sent between the client and the server if both support compression.

- `--database=db_name`, `-D db_name`

  The database to use. This is useful primarily in an option file.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical *`debug_options`* string is `d:t:o,file_name`. The default is `d:t:o,/tmp/mysql.trace`.

  This option is available only if MySQL was built using `WITH_DEBUG`. MySQL release binaries provided by Oracle are *not* built using this option.

- `--debug-check`

  Print some debugging information when the program exits.

- `--debug-info`, `-T`

  Print debugging information and memory and CPU usage statistics when the program exits.

- `--default-auth=plugin`

  A hint about the client-side authentication plugin to use. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.7.

- `--default-character-set=charset_name`

  Use *`charset_name`* as the default character set for the client and connection.

  This option can be useful if the operating system uses one character set and the `mysql` client by default uses another. In this case, output may be formatted incorrectly. You can usually fix such issues by using this option to force the client to use the system character set instead.

  For more information, see Section 10.1.4, “Connection Character Sets and Collations”, and Section 10.5, “Character Set Configuration”.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysql` normally reads the `[client]` and `[mysql]` groups. If the `--defaults-group-`

suffix=_other option is given, mysql also reads the [client_other] and [mysql_other] groups.

- --delimiter=*str*

  Set the statement delimiter. The default is the semicolon character (;).

- --disable-named-commands

  Disable named commands. Use the * form only, or use named commands only at the beginning of a line ending with a semicolon (;). mysql starts with this option *enabled* by default. However, even with this option, long-format commands still work from the first line. See Section 4.5.1.2, “mysql Commands”.

- --enable-cleartext-plugin

  Enable the mysql_clear_password cleartext authentication plugin. (See Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”.) This option was added in MySQL 5.5.27.

- --execute=*statement*, -e *statement*

  Execute the statement and quit. The default output format is like that produced with --batch. See Section 4.2.4, “Using Options on the Command Line”, for some examples. With this option, mysql does not use the history file.

- --force, -f

  Continue even if an SQL error occurs.

- --host=*host_name*, -h *host_name*

  Connect to the MySQL server on the given host.

- --html, -H

  Produce HTML output.

- --ignore-spaces, -i

  Ignore spaces after function names. The effect of this is described in the discussion for the IGNORE_SPACE SQL mode (see Section 5.1.8, “Server SQL Modes”).

- --init-command=str

  SQL statement to execute after connecting to the server. If auto-reconnect is enabled, the statement is executed again after reconnection occurs.

- --line-numbers

  Write line numbers for errors. Disable this with --skip-line-numbers.

- --local-infile[={0|1}]

  Enable or disable LOCAL capability for LOAD DATA INFILE. For mysql, this capability is disabled by default. With no value, the option enables LOCAL. The option may be given as --local-infile=0 or --local-infile=1 to explicitly disable or enable LOCAL. Enabling local data loading also requires that the server permits it; see Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

- --named-commands, -G

  Enable named mysql commands. Long-format commands are permitted, not just short-format commands. For example, quit and \q both are recognized. Use --skip-named-commands to disable named commands. See Section 4.5.1.2, “mysql Commands”.

- `--no-auto-rehash`, `-A`

  This has the same effect as `--skip-auto-rehash`. See the description for `--auto-rehash`.

- `--no-beep`, `-b`

  Do not beep when errors occur.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--no-named-commands`, `-g`

  Deprecated, use `--disable-named-commands` instead. `--no-named-commands` was removed in MySQL 5.5.3.

- `--no-pager`

  Deprecated form of `--skip-pager`. See the `--pager` option. `--no-pager` was removed in MySQL 5.5.3.

- `--no-tee`

  Deprecated form of `--skip-tee`. See the `--tee` option. `--no-tee` is removed in MySQL 5.5.3.

- `--one-database`, `-o`

  Ignore statements except those that occur while the default database is the one named on the command line. This option is rudimentary and should be used with care. Statement filtering is based only on `USE` statements.

  Initially, `mysql` executes statements in the input because specifying a database *`db_name`* on the command line is equivalent to inserting `USE` *`db_name`* at the beginning of the input. Then, for each `USE` statement encountered, `mysql` accepts or rejects following statements depending on whether the database named is the one on the command line. The content of the statements is immaterial.

  Suppose that `mysql` is invoked to process this set of statements:

  ```
  DELETE FROM db2.t2;
  USE db2;
  DROP TABLE db1.t1;
  CREATE TABLE db1.t1 (i INT);
  USE db1;
  INSERT INTO t1 (i) VALUES(1);
  CREATE TABLE db2.t1 (j INT);
  ```

  If the command line is `mysql --force --one-database db1`, `mysql` handles the input as follows:

  - The `DELETE` statement is executed because the default database is `db1`, even though the statement names a table in a different database.
  - The `DROP TABLE` and `CREATE TABLE` statements are not executed because the default database is not `db1`, even though the statements name a table in `db1`.
  - The `INSERT` and `CREATE TABLE` statements are executed because the default database is `db1`, even though the `CREATE TABLE` statement names a table in a different database.

- `--pager[=`*`command`*`]`

Use the given command for paging query output. If the command is omitted, the default pager is the value of your PAGER environment variable. Valid pagers are less, more, cat [> filename], and so forth. This option works only on Unix and only in interactive mode. To disable paging, use --skip-pager. Section 4.5.1.2, “mysql Commands”, discusses output paging further.

- --password[=*password*], -p[*password*]

  The password to use when connecting to the server. If you use the short option form (-p), you *cannot* have a space between the option and the password. If you omit the *password* value following the --password or -p option on the command line, mysql prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line.

- --pipe, -W

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- --plugin-dir=*dir_name*

  The directory in which to look for plugins. Specify this option if the --default-auth option is used to specify an authentication plugin but mysql does not find it. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.7.

- --port=*port_num*, -P *port_num*

  The TCP/IP port number to use for the connection.

- --print-defaults

  Print the program name and all options that it gets from option files.

- --prompt=*format_str*

  Set the prompt to the specified format. The default is mysql>. The special sequences that the prompt can contain are described in Section 4.5.1.2, “mysql Commands”.

- --protocol={TCP|SOCKET|PIPE|MEMORY}

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, “Connecting to the MySQL Server”.

- --quick, -q

  Do not cache each query result, print each row as it is received. This may slow down the server if the output is suspended. With this option, mysql does not use the history file.

- --raw, -r

  For tabular output, the “boxing” around columns enables one column value to be distinguished from another. For nontabular output (such as is produced in batch mode or when the --batch or --silent option is given), special characters are escaped in the output so they can be identified easily. Newline, tab, NUL, and backslash are written as \n, \t, \0, and \\. The --raw option disables this character escaping.

  The following example demonstrates tabular versus nontabular output and the use of raw mode to disable escaping:

```
% mysql
mysql> SELECT CHAR(92);
+----------+
| CHAR(92) |
+----------+
| \        |
+----------+

% mysql -s
mysql> SELECT CHAR(92);
CHAR(92)
\\

% mysql -s -r
mysql> SELECT CHAR(92);
CHAR(92)
\
```

- `--reconnect`

  If the connection to the server is lost, automatically try to reconnect. A single reconnect attempt is made each time the connection is lost. To suppress reconnection behavior, use `--skip-reconnect`.

- `--safe-updates`, `--i-am-a-dummy`, `-U`

  Permit only those `UPDATE` and `DELETE` statements that specify which rows to modify by using key values. If you have set this option in an option file, you can override it by using `--safe-updates` on the command line. See Section 4.5.1.6, “mysql Tips”, for more information about this option.

- `--secure-auth`

  Do not send passwords to the server in old (pre-4.1) format. This prevents connections except for servers that use the newer password format.

  Note

  Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

- `--shared-memory-base-name=`*name*

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--show-warnings`

  Cause warnings to be shown after each statement if there are any. This option applies to interactive and batch mode.

- `--sigint-ignore`

  Ignore `SIGINT` signals (typically the result of typing **Control+C**).

- `--silent`, `-s`

  Silent mode. Produce less output. This option can be given multiple times to produce less and less output.

This option results in nontabular output format and escaping of special characters. Escaping may be disabled by using raw mode; see the description for the `--raw` option.

- `--skip-column-names`, `-N`

  Do not write column names in results.

- `--skip-line-numbers`, `-L`

  Do not write line numbers for errors. Useful when you want to compare result files that include error messages.

- `--socket=`*`path`*, `-S` *`path`*

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- `--table`, `-t`

  Display output in table format. This is the default for interactive use, but can be used to produce table output in batch mode.

- `--tee=`*`file_name`*

  Append a copy of output to the given file. This option works only in interactive mode. Section 4.5.1.2, “mysql Commands”, discusses tee files further.

- `--unbuffered`, `-n`

  Flush the buffer after each query.

- `--user=`*`user_name`*, `-u` *`user_name`*

  The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

  Verbose mode. Produce more output about what the program does. This option can be given multiple times to produce more and more output. (For example, `-v -v -v` produces table output format even in batch mode.)

- `--version`, `-V`

  Display version information and exit.

- `--vertical`, `-E`

  Print query output rows vertically (one line per column value). Without this option, you can specify vertical output for individual statements by terminating them with `\G`.

- `--wait`, `-w`

  If the connection cannot be established, wait and retry instead of aborting.

- `--xml`, `-X`

  Produce XML output.

```
<field name="column_name">NULL</field>
```

The output when `--xml` is used with `mysql` matches that of `mysqldump --xml`. See Section 4.5.4, “mysqldump — A Database Backup Program”, for details.

The XML output also uses an XML namespace, as shown here:

```
shell> mysql --xml -uroot -e "SHOW VARIABLES LIKE 'version%'"
<?xml version="1.0"?>

<resultset statement="SHOW VARIABLES LIKE 'version%'" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instanc
<row>
<field name="Variable_name">version</field>
<field name="Value">5.0.40-debug</field>
</row>

<row>
<field name="Variable_name">version_comment</field>
<field name="Value">Source distribution</field>
</row>

<row>
<field name="Variable_name">version_compile_machine</field>
<field name="Value">i686</field>
</row>

<row>
<field name="Variable_name">version_compile_os</field>
<field name="Value">suse-linux-gnu</field>
</row>
</resultset>
```

(See Bug #25946.)

You can also set the following variables by using `--var_name=value`. The `--set-variable` format is deprecated and was removed in MySQL 5.5.3.

- `connect_timeout`

  The number of seconds before connection timeout. (Default value is `0`.)

- `max_allowed_packet`

  The maximum size of the buffer for client/server communication. The default is 16MB, the maximum is 1GB.

- `max_join_size`

  The automatic limit for rows in a join when using `--safe-updates`. (Default value is 1,000,000.)

- `net_buffer_length`

  The buffer size for TCP/IP and socket communication. (Default value is 16KB.)

- `select_limit`

  The automatic limit for `SELECT` statements when using `--safe-updates`. (Default value is 1,000.)

4.5.1.2 mysql Commands

`mysql` sends each SQL statement that you issue to the server to be executed. There is also a set of commands that `mysql` itself interprets. For a list of these commands, type `help` or `\h` at the `mysql>` prompt:

```
mysql> help

List of all MySQL commands:
Note that all text commands must be first on line and end with ';'
?         (\?) Synonym for `help'.
clear     (\c) Clear command.
connect   (\r) Reconnect to the server. Optional arguments are db and host.
delimiter (\d) Set statement delimiter.
edit      (\e) Edit command with $EDITOR.
ego       (\G) Send command to mysql server, display result vertically.
exit      (\q) Exit mysql. Same as quit.
go        (\g) Send command to mysql server.
help      (\h) Display this help.
nopager   (\n) Disable pager, print to stdout.
notee     (\t) Don't write into outfile.
pager     (\P) Set PAGER [to_pager]. Print the query results via PAGER.
print     (\p) Print current command.
prompt    (\R) Change your mysql prompt.
quit      (\q) Quit mysql.
rehash    (\#) Rebuild completion hash.
source    (\.) Execute an SQL script file. Takes a file name as an argument.
status    (\s) Get status information from the server.
system    (\!) Execute a system shell command.
tee       (\T) Set outfile [to_outfile]. Append everything into given
               outfile.
use       (\u) Use another database. Takes database name as argument.
charset   (\C) Switch to another charset. Might be needed for processing
               binlog with multi-byte charsets.
warnings  (\W) Show warnings after every statement.
nowarning (\w) Don't show warnings after every statement.

For server side help, type 'help contents'
```

Each command has both a long and short form. The long form is not case sensitive; the short form is. The long form can be followed by an optional semicolon terminator, but the short form should not.

The use of short-form commands within multiple-line `/* ... */` comments is not supported.

- `help [arg]`, `\h [arg]`, `\? [arg]`, `? [arg]`

  Display a help message listing the available `mysql` commands.

  If you provide an argument to the `help` command, `mysql` uses it as a search string to access server-side help from the contents of the MySQL Reference Manual. For more information, see Section 4.5.1.4, “mysql Server-Side Help”.

- `charset charset_name`, `\C charset_name`

  Change the default character set and issue a `SET NAMES` statement. This enables the character set to remain synchronized on the client and server if `mysql` is run with auto-reconnect enabled (which is not recommended), because the specified character set is used for reconnects.

- `clear`, `\c`

  Clear the current input. Use this if you change your mind about executing the statement that you are entering.

- `connect [db_name host_name]]`, `\r [db_name host_name]]`

  Reconnect to the server. The optional database name and host name arguments may be given to specify the default database or the host where the server is running. If omitted, the current values are used.

- `delimiter str`, `\d str`

  Change the string that `mysql` interprets as the separator between SQL statements. The default is the semicolon character (`;`).

The delimiter string can be specified as an unquoted or quoted argument on the delimiter command line. Quoting can be done with either single quote ('), double quote ("), or backtick (`) characters. To include a quote within a quoted string, either quote the string with a different quote character or escape the quote with a backslash (\) character. Backslash should be avoided outside of quoted strings because it is the escape character for MySQL. For an unquoted argument, the delimiter is read up to the first space or end of line. For a quoted argument, the delimiter is read up to the matching quote on the line.

mysql interprets instances of the delimiter string as a statement delimiter anywhere it occurs, except within quoted strings. Be careful about defining a delimiter that might occur within other words. For example, if you define the delimiter as X, you will be unable to use the word INDEX in statements. mysql interprets this as INDE followed by the delimiter X.

When the delimiter recognized by mysql is set to something other than the default of ;, instances of that character are sent to the server without interpretation. However, the server itself still interprets ; as a statement delimiter and processes statements accordingly. This behavior on the server side comes into play for multiple-statement execution (see Section 23.8.16, “C API Multiple Statement Execution Support”), and for parsing the body of stored procedures and functions, triggers, and events (see Section 20.1, “Defining Stored Programs”).

- edit, \e

  Edit the current input statement. mysql checks the values of the EDITOR and VISUAL environment variables to determine which editor to use. The default editor is vi if neither variable is set.

  The edit command works only in Unix.

- ego, \G

  Send the current statement to the server to be executed and display the result using vertical format.

- exit, \q

  Exit mysql.

- go, \g

  Send the current statement to the server to be executed.

- nopager, \n

  Disable output paging. See the description for pager.

  The nopager command works only in Unix.

- notee, \t

  Disable output copying to the tee file. See the description for tee.

- nowarning, \w

  Disable display of warnings after each statement.

- pager [*command*], \P [*command*]

  Enable output paging. By using the --pager option when you invoke mysql, it is possible to browse or search query results in interactive mode with Unix programs such as less, more, or any other similar program. If you specify no value for the option, mysql checks the value of the PAGER environment variable and sets the pager to that. Pager functionality works only in interactive mode.

  Output paging can be enabled interactively with the pager command and disabled with nopager. The command takes an optional argument; if given, the paging program is set to that. With no

argument, the pager is set to the pager that was set on the command line, or stdout if no pager was specified.

Output paging works only in Unix because it uses the popen() function, which does not exist on Windows. For Windows, the tee option can be used instead to save query output, although it is not as convenient as pager for browsing output in some situations.

- print, \p

  Print the current input statement without executing it.

- prompt [*str*], \R [*str*]

  Reconfigure the mysql prompt to the given string. The special character sequences that can be used in the prompt are described later in this section.

  If you specify the prompt command with no argument, mysql resets the prompt to the default of mysql>.

- quit, \q

  Exit mysql.

- rehash, \#

  Rebuild the completion hash that enables database, table, and column name completion while you are entering statements. (See the description for the --auto-rehash option.)

- source *file_name*, \. *file_name*

  Read the named file and executes the statements contained therein. On Windows, you can specify path name separators as / or \\.

- status, \s

  Provide status information about the connection and the server you are using. If you are running in --safe-updates mode, status also prints the values for the mysql variables that affect your queries.

- system *command*, \! *command*

  Execute the given command using your default command interpreter.

  The system command works only in Unix.

- tee [*file_name*], \T [*file_name*]

  By using the --tee option when you invoke mysql, you can log statements and their output. All the data displayed on the screen is appended into a given file. This can be very useful for debugging purposes also. mysql flushes results to the file after each statement, just before it prints its next prompt. Tee functionality works only in interactive mode.

  You can enable this feature interactively with the tee command. Without a parameter, the previous file is used. The tee file can be disabled with the notee command. Executing tee again re-enables logging.

- use *db_name*, \u *db_name*

  Use *db_name* as the default database.

- warnings, \W

  Enable display of warnings after each statement (if there are any).

Here are a few tips about the pager command:

- You can use it to write to a file and the results go only to the file:

```
mysql> pager cat > /tmp/log.txt
```

  You can also pass any options for the program that you want to use as your pager:

```
mysql> pager less -n -i -S
```

- In the preceding example, note the -S option. You may find it very useful for browsing wide query results. Sometimes a very wide result set is difficult to read on the screen. The -S option to less can make the result set much more readable because you can scroll it horizontally using the left-arrow and right-arrow keys. You can also use -S interactively within less to switch the horizontal-browse mode on and off. For more information, read the less manual page:

```
shell> man less
```

- The -F and -X options may be used with less to cause it to exit if output fits on one screen, which is convenient when no scrolling is necessary:

```
mysql> pager less -n -i -S -F -X
```

- You can specify very complex pager commands for handling query output:

```
mysql> pager cat | tee /dr1/tmp/res.txt \
         | tee /dr2/tmp/res2.txt | less -n -i -S
```

  In this example, the command would send query results to two files in two different directories on two different file systems mounted on /dr1 and /dr2, yet still display the results onscreen using less.

You can also combine the tee and pager functions. Have a tee file enabled and pager set to less, and you are able to browse the results using the less program and still have everything appended into a file the same time. The difference between the Unix tee used with the pager command and the mysql built-in tee command is that the built-in tee works even if you do not have the Unix tee available. The built-in tee also logs everything that is printed on the screen, whereas the Unix tee used with pager does not log quite that much. Additionally, tee file logging can be turned on and off interactively from within mysql. This is useful when you want to log some queries to a file, but not others.

The prompt command reconfigures the default mysql> prompt. The string for defining the prompt can contain the following special sequences.

Option	Description
\c	A counter that increments for each statement you issue
\D	The full current date
\d	The default database
\h	The server host
\l	The current delimiter
\m	Minutes of the current time
\n	A newline character
\O	The current month in three-letter format (Jan, Feb, …)
\o	The current month in numeric format

Option	Description
\P	am/pm
\p	The current TCP/IP port or socket file
\R	The current time, in 24-hour military time (0–23)
\r	The current time, standard 12-hour time (1–12)
\S	Semicolon
\s	Seconds of the current time
\t	A tab character
\U	Your full *user_name@host_name* account name
\u	Your user name
\v	The server version
\w	The current day of the week in three-letter format (Mon, Tue, …)
\Y	The current year, four digits
\y	The current year, two digits
_	A space
\	A space (a space follows the backslash)
\'	Single quote
\"	Double quote
\\	A literal \ backslash character
\x	*x*, for any "*x*" not listed above

You can set the prompt in several ways:

- *Use an environment variable.* You can set the MYSQL_PS1 environment variable to a prompt string. For example:

```
shell> export MYSQL_PS1="(\u@\h) [\d]> "
```

- *Use a command-line option.* You can set the --prompt option on the command line to mysql. For example:

```
shell> mysql --prompt="(\u@\h) [\d]> "
(user@host) [database]>
```

- *Use an option file.* You can set the prompt option in the [mysql] group of any MySQL option file, such as /etc/my.cnf or the .my.cnf file in your home directory. For example:

```
[mysql]
prompt=(\\u@\\h) [\\d]>\\_
```

  In this example, note that the backslashes are doubled. If you set the prompt using the prompt option in an option file, it is advisable to double the backslashes when using the special prompt options. There is some overlap in the set of permissible prompt options and the set of special escape sequences that are recognized in option files. (The rules for escape sequences in option files are listed in Section 4.2.6, "Using Option Files".) The overlap may cause you problems if you use single backslashes. For example, \s is interpreted as a space rather than as the current seconds value. The following example shows how to define a prompt within an option file to include the current time in HH:MM:SS> format:

```
[mysql]
prompt="\\r:\\m:\\s> "
```

- *Set the prompt interactively.* You can change your prompt interactively by using the `prompt` (or `\R`) command. For example:

```
mysql> prompt (\u@\h) [\d]>\_
PROMPT set to '(\u@\h) [\d]>\_'
(user@host) [database]>
(user@host) [database]> prompt
Returning to default PROMPT of mysql>
mysql>
```

4.5.1.3 mysql Logging

On Unix, the `mysql` client logs statements executed interactively to a history file. By default, this file is named `.mysql_history` in your home directory. To specify a different file, set the value of the `MYSQL_HISTFILE` environment variable.

How Logging Occurs

Statement logging occurs as follows:

- Statements are logged only when executed interactively. Statements are noninteractive, for example, when read from a file or a pipe. It is also possible to suppress statement logging by using the `--batch` or `--execute` option.
- `mysql` logs each nonempty statement line individually.
- If a statement spans multiple lines (not including the terminating delimiter), `mysql` concatenates the lines to form the complete statement, maps newlines to spaces, and logs the result, plus a delimiter.

Consequently, an input statement that spans multiple lines can be logged twice. Consider this input:

```
mysql> SELECT
    -> 'Today is'
    -> ,
    -> CURDATE()
    -> ;
```

In this case, `mysql` logs the “SELECT”, “'Today is'”, “,”, “CURDATE()”, and “;” lines as it reads them. It also logs the complete statement, after mapping `SELECT\n'Today is'\n,\nCURDATE()` to `SELECT 'Today is' , CURDATE()`, plus a delimiter. Thus, these lines appear in logged output:

```
SELECT
'Today is'
,
CURDATE()
;
SELECT 'Today is' , CURDATE();
```

Controlling the History File

The `.mysql_history` file should be protected with a restrictive access mode because sensitive information might be written to it, such as the text of SQL statements that contain passwords. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

If you do not want to maintain a history file, first remove `.mysql_history` if it exists. Then use either of the following techniques to prevent it from being created again:

- Set the `MYSQL_HISTFILE` environment variable to `/dev/null`. To cause this setting to take effect each time you log in, put it in one of your shell's startup files.
- Create `.mysql_history` as a symbolic link to `/dev/null`; this need be done only once:

```
shell> ln -s /dev/null $HOME/.mysql_history
```

4.5.1.4 mysql Server-Side Help

```
mysql> help search_string
```

If you provide an argument to the `help` command, `mysql` uses it as a search string to access server-side help from the contents of the MySQL Reference Manual. The proper operation of this command requires that the help tables in the `mysql` database be initialized with help topic information (see Section 5.1.10, “Server-Side Help”).

If there is no match for the search string, the search fails:

```
mysql> help me

Nothing found
Please try to run 'help contents' for a list of all accessible topics
```

Use `help contents` to see a list of the help categories:

```
mysql> help contents
You asked for help about help category: "Contents"
For more information, type 'help <item>', where <item> is one of the
following categories:
   Account Management
   Administration
   Data Definition
   Data Manipulation
   Data Types
   Functions
   Functions and Modifiers for Use with GROUP BY
   Geographic Features
   Language Structure
   Plugins
   Storage Engines
   Stored Routines
   Table Maintenance
   Transactions
   Triggers
```

If the search string matches multiple items, `mysql` shows a list of matching topics:

```
mysql> help logs
Many help items for your request exist.
To make a more specific request, please type 'help <item>',
where <item> is one of the following topics:
   SHOW
   SHOW BINARY LOGS
   SHOW ENGINE
   SHOW LOGS
```

Use a topic as the search string to see the help entry for that topic:

```
mysql> help show binary logs
Name: 'SHOW BINARY LOGS'
Description:
Syntax:
SHOW BINARY LOGS
SHOW MASTER LOGS

Lists the binary log files on the server. This statement is used as
part of the procedure described in [purge-binary-logs], that shows how
```

```
to determine which logs can be purged.

mysql> SHOW BINARY LOGS;
+---------------+-----------+
| Log_name      | File_size |
+---------------+-----------+
| binlog.000015 |    724935 |
| binlog.000016 |    733481 |
+---------------+-----------+
```

The search string can contain the wildcard characters `%` and `_`. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator. For example, `HELP rep%` returns a list of topics that begin with `rep`:

```
mysql> HELP rep%
Many help items for your request exist.
To make a more specific request, please type 'help <item>',
where <item> is one of the following
topics:
   REPAIR TABLE
   REPEAT FUNCTION
   REPEAT LOOP
   REPLACE
   REPLACE FUNCTION
```

4.5.1.5 Executing SQL Statements from a Text File

The `mysql` client typically is used interactively, like this:

```
shell> mysql db_name
```

However, it is also possible to put your SQL statements in a file and then tell `mysql` to read its input from that file. To do so, create a text file *`text_file`* that contains the statements you wish to execute. Then invoke `mysql` as shown here:

```
shell> mysql db_name < text_file
```

If you place a `USE db_name` statement as the first statement in the file, it is unnecessary to specify the database name on the command line:

```
shell> mysql < text_file
```

If you are already running `mysql`, you can execute an SQL script file using the `source` command or `\.` command:

```
mysql> source file_name
mysql> \. file_name
```

Sometimes you may want your script to display progress information to the user. For this you can insert statements like this:

```
SELECT '<info_to_display>' AS ' ';
```

The statement shown outputs `<info_to_display>`.

You can also invoke `mysql` with the `--verbose` option, which causes each statement to be displayed before the result that it produces.

`mysql` ignores Unicode byte order mark (BOM) characters at the beginning of input files. Previously, it read them and sent them to the server, resulting in a syntax error. Presence of a BOM does not

cause mysql to change its default character set. To do that, invoke mysql with an option such as --default-character-set=utf8.

For more information about batch mode, see Section 3.5, “Using mysql in Batch Mode”.

4.5.1.6 mysql Tips

This section describes some techniques that can help you use mysql more effectively.

Input-Line Editing

mysql supports input-line editing, which enables you to modify the current input line in place or recall previous input lines. For example, the **left-arrow** and **right-arrow** keys move horizontally within the current input line, and the **up-arrow** and **down-arrow** keys move up and down through the set of previously entered lines. **Backspace** deletes the character before the cursor and typing new characters enters them at the cursor position. To enter the line, press **Enter**.

On Windows, the editing key sequences are the same as supported for command editing in console windows. On Unix, the key sequences depend on the input library used to build mysql (for example, the libedit or readline library).

Documentation for the libedit and readline libraries is available online. To change the set of key sequences permitted by a given input library, define key bindings in the library startup file. This is a file in your home directory: .editrc for libedit and .inputrc for readline.

For example, in libedit, **Control+W** deletes everything before the current cursor position and **Control+U** deletes the entire line. In readline, **Control+W** deletes the word before the cursor and **Control+U** deletes everything before the current cursor position. If mysql was built using libedit, a user who prefers the readline behavior for these two keys can put the following lines in the .editrc file (creating the file if necessary):

```
bind "^W" ed-delete-prev-word
bind "^U" vi-kill-line-prev
```

To see the current set of key bindings, temporarily put a line that says only bind at the end of .editrc. mysql will show the bindings when it starts.

Displaying Query Results Vertically

Some query results are much more readable when displayed vertically, instead of in the usual horizontal table format. Queries can be displayed vertically by terminating the query with \G instead of a semicolon. For example, longer text values that include newlines often are much easier to read with vertical output:

```
mysql> SELECT * FROM mails WHERE LENGTH(txt) < 300 LIMIT 300,1\G
*************************** 1. row ***************************
  msg_nro: 3068
     date: 2000-03-01 23:29:50
time_zone: +0200
mail_from: Monty
    reply: monty@no.spam.com
  mail_to: "Thimble Smith" <tim@no.spam.com>
      sbj: UTF-8
      txt: >>>>> "Thimble" == Thimble Smith writes:

Thimble> Hi.  I think this is a good idea.  Is anyone familiar
Thimble> with UTF-8 or Unicode? Otherwise, I'll put this on my
Thimble> TODO list and see what happens.

Yes, please do that.

Regards,
Monty
```

```
     file: inbox-jani-1
     hash: 190402944
1 row in set (0.09 sec)
```

Using the --safe-updates Option

For beginners, a useful startup option is `--safe-updates` (or `--i-am-a-dummy`, which has the same effect). It is helpful for cases when you might have issued a `DELETE FROM tbl_name` statement but forgotten the `WHERE` clause. Normally, such a statement deletes all rows from the table. With `--safe-updates`, you can delete rows only by specifying the key values that identify them. This helps prevent accidents.

When you use the `--safe-updates` option, `mysql` issues the following statement when it connects to the MySQL server:

```
SET sql_safe_updates=1, sql_select_limit=1000, sql_max_join_size=1000000;
```

See Section 5.1.5, “Server System Variables”.

The `SET` statement has the following effects:

- You are not permitted to execute an `UPDATE` or `DELETE` statement unless you specify a key constraint in the `WHERE` clause or provide a `LIMIT` clause (or both). For example:

  ```
  UPDATE tbl_name SET not_key_column=val WHERE key_column=val;

  UPDATE tbl_name SET not_key_column=val LIMIT 1;
  ```

- The server limits all large `SELECT` results to 1,000 rows unless the statement includes a `LIMIT` clause.
- The server aborts multiple-table `SELECT` statements that probably need to examine more than 1,000,000 row combinations.

To specify limits different from 1,000 and 1,000,000, you can override the defaults by using the `--select_limit` and `--max_join_size` options:

```
shell> mysql --safe-updates --select_limit=500 --max_join_size=10000
```

Disabling mysql Auto-Reconnect

If the `mysql` client loses its connection to the server while sending a statement, it immediately and automatically tries to reconnect once to the server and send the statement again. However, even if `mysql` succeeds in reconnecting, your first connection has ended and all your previous session objects and settings are lost: temporary tables, the autocommit mode, and user-defined and session variables. Also, any current transaction rolls back. This behavior may be dangerous for you, as in the following example where the server was shut down and restarted between the first and second statements without you knowing it:

```
mysql> SET @a=1;
Query OK, 0 rows affected (0.05 sec)

mysql> INSERT INTO t VALUES(@a);
ERROR 2006: MySQL server has gone away
No connection. Trying to reconnect...
Connection id:    1
Current database: test

Query OK, 1 row affected (1.30 sec)

mysql> SELECT * FROM t;
+------+
```

```
| a    |
+------+
| NULL |
+------+
1 row in set (0.05 sec)
```

The @a user variable has been lost with the connection, and after the reconnection it is undefined. If it is important to have mysql terminate with an error if the connection has been lost, you can start the mysql client with the --skip-reconnect option.

For more information about auto-reconnect and its effect on state information when a reconnection occurs, see Section 23.8.20, “C API Automatic Reconnection Control”.

4.5.2 mysqladmin — Client for Administering a MySQL Server

mysqladmin is a client for performing administrative operations. You can use it to check the server's configuration and current status, to create and drop databases, and more.

Invoke mysqladmin like this:

```
shell> mysqladmin [options] command [command-arg] [command [command-arg]] ...
```

mysqladmin supports the following commands. Some of the commands take an argument following the command name.

- create *db_name*

  Create a new database named *db_name*.

- debug

  Tell the server to write debug information to the error log. The connected user must have the SUPER privilege. Format and content of this information is subject to change.

  This includes information about the Event Scheduler. See Section 20.4.5, “Event Scheduler Status”.

- drop *db_name*

  Delete the database named *db_name* and all its tables.

- extended-status

  Display the server status variables and their values.

- flush-hosts

  Flush all information in the host cache.

- flush-logs

  Flush all logs.

- flush-privileges

  Reload the grant tables (same as reload).

- flush-status

  Clear status variables.

- flush-tables

  Flush all tables.

- `flush-threads`

  Flush the thread cache.

- `kill id,id,...`

  Kill server threads. If multiple thread ID values are given, there must be no spaces in the list.

  To kill threads belonging to other users, the connected user must have the `SUPER` privilege.

- `old-password new_password`

  This is like the `password` command but stores the password using the old (pre-4.1) password-hashing format. (See Section 6.1.2.4, “Password Hashing in MySQL”.)

- `password new_password`

  Set a new password. This changes the password to *`new_password`* for the account that you use with `mysqladmin` for connecting to the server. Thus, the next time you invoke `mysqladmin` (or any other client program) using the same account, you will need to specify the new password.

  Warning

  Setting a password using `mysqladmin` should be considered *insecure*. On some systems, your password becomes visible to system status programs such as `ps` that may be invoked by other users to display command lines. MySQL clients typically overwrite the command-line password argument with zeros during their initialization sequence. However, there is still a brief interval during which the value is visible. Also, on some systems this overwriting strategy is ineffective and the password remains visible to `ps`. (SystemV Unix systems and perhaps others are subject to this problem.)

  If the *`new_password`* value contains spaces or other characters that are special to your command interpreter, you need to enclose it within quotation marks. On Windows, be sure to use double quotation marks rather than single quotation marks; single quotation marks are not stripped from the password, but rather are interpreted as part of the password. For example:

```
shell> mysqladmin password "my new password"
```

  As of MySQL 5.5.3, the new password can be omitted following the `password` command. In this case, `mysqladmin` prompts for the password value, which enables you to avoid specifying the password on the command line. Omitting the password value should be done only if `password` is the final command on the `mysqladmin` command line. Otherwise, the next argument is taken as the password.

  Caution

  Do not use this command used if the server was started with the `--skip-grant-tables` option. No password change will be applied. This is true even if you precede the `password` command with `flush-privileges` on the same command line to re-enable the grant tables because the flush operation occurs after you connect. However, you can use `mysqladmin flush-privileges` to re-enable the grant table and then use a separate `mysqladmin password` command to change the password.

- `ping`

  Check whether the server is available. The return status from `mysqladmin` is 0 if the server is running, 1 if it is not. This is 0 even in case of an error such as `Access denied`, because this means that the server is running but refused the connection, which is different from the server not running.

- `processlist`

  Show a list of active server threads. This is like the output of the `SHOW PROCESSLIST` statement. If the `--verbose` option is given, the output is like that of `SHOW FULL PROCESSLIST`. (See Section 13.7.5.30, “SHOW PROCESSLIST Syntax”.)

- `reload`

  Reload the grant tables.

- `refresh`

  Flush all tables and close and open log files.

- `shutdown`

  Stop the server.

- `start-slave`

  Start replication on a slave server.

- `status`

  Display a short server status message.

- `stop-slave`

  Stop replication on a slave server.

- `variables`

  Display the server system variables and their values.

- `version`

  Display version information from the server.

All commands can be shortened to any unique prefix. For example:

```
shell> mysqladmin proc stat
+----+-------+-----------+----+---------+------+-------+------------------+
| Id | User  | Host      | db | Command | Time | State | Info             |
+----+-------+-----------+----+---------+------+-------+------------------+
| 51 | monty | localhost |    | Query   | 0    |       | show processlist |
+----+-------+-----------+----+---------+------+-------+------------------+
Uptime: 1473624  Threads: 1  Questions: 39487
Slow queries: 0  Opens: 541  Flush tables: 1
Open tables: 19  Queries per second avg: 0.0268
```

The `mysqladmin status` command result displays the following values:

- `Uptime`

  The number of seconds the MySQL server has been running.

- `Threads`

  The number of active threads (clients).

- `Questions`

  The number of questions (queries) from clients since the server was started.

- `Slow queries`

The number of queries that have taken more than `long_query_time` seconds. See Section 5.4.5, "The Slow Query Log".

- `Opens`

  The number of tables the server has opened.

- `Flush tables`

  The number of `flush-*`, `refresh`, and `reload` commands the server has executed.

- `Open tables`

  The number of tables that currently are open.

- `Memory in use`

  The amount of memory allocated directly by `mysqld`. This value is displayed only when MySQL has been compiled with `safemalloc`, which is available only before MySQL 5.5.6.

- `Maximum memory used`

  The maximum amount of memory allocated directly by `mysqld`. This value is displayed only when MySQL has been compiled with `safemalloc`, which is available only before MySQL 5.5.6.

If you execute `mysqladmin shutdown` when connecting to a local server using a Unix socket file, `mysqladmin` waits until the server's process ID file has been removed, to ensure that the server has stopped properly.

`mysqladmin` supports the following options, which can be specified on the command line or in the `[mysqladmin]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, "Using Option Files".

Table 4.9 `mysqladmin` Options

Format	Description	Introduced
--compress	Compress all information sent between client and server	
--connect_timeout	Number of seconds before connection timeout	
--count	Number of iterations to make for repeated command execution	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	
--debug-info	Print debugging information, memory, and CPU statistics when program exits	
--default-auth	Authentication plugin to use	5.5.9
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--enable-cleartext-plugin	Enable cleartext authentication plugin	5.5.27
--force	Continue even if an SQL error occurs	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--no-beep	Do not beep when errors occur	

Format	Description	Introduced
--no-defaults	Read no option files	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--plugin-dir	Directory where plugins are installed	5.5.9
--port	TCP/IP port number for connection	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--relative	Show the difference between the current and previous values when used with the --sleep option	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--shutdown_timeout	The maximum number of seconds to wait for server shutdown	
--silent	Silent mode	
--sleep	Execute commands repeatedly, sleeping for delay seconds in between	
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable encrypted connection	
--ssl-ca	File that contains list of trusted SSL Certificate Authorities	
--ssl-capath	Directory that contains trusted SSL Certificate Authority certificate files	
--ssl-cert	File that contains X509 certificate	
--ssl-cipher	List of permitted ciphers for connection encryption	
--ssl-key	File that contains X509 key	
--ssl-mode	Security state of connection to server	5.5.49
--ssl-verify-server-cert	Verify host name against server certificate Common Name identity	
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	
--vertical	Print query output rows vertically (one line per column value)	
--wait	If the connection cannot be established, wait and retry instead of aborting	

- `--help`, `-?`

  Display a help message and exit.

- `--bind-address=`*`ip_address`*

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported only in the version of `mysqladmin` that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- `--character-sets-dir=dir_name`

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- `--compress`, `-C`

  Compress all information sent between the client and the server if both support compression.

- `--count=N`, `-c N`

  The number of iterations to make for repeated command execution if the `--sleep` option is given.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical *`debug_options`* string is `d:t:o,file_name`. The default is `d:t:o,/tmp/mysqladmin.trace`.

- `--debug-check`

  Print some debugging information when the program exits.

- `--debug-info`

  Print debugging information and memory and CPU usage statistics when the program exits.

- `--default-auth=plugin`

  A hint about the client-side authentication plugin to use. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.9.

- `--default-character-set=charset_name`

  Use *`charset_name`* as the default character set. See Section 10.5, “Character Set Configuration”.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysqladmin` normally reads the `[client]` and `[mysqladmin]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqladmin` also reads the `[client_other]` and `[mysqladmin_other]` groups.

- `--enable-cleartext-plugin`

  Enable the `mysql_clear_password` cleartext authentication plugin. (See Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”.) This option was added in MySQL 5.5.27.

- `--force`, `-f`

Do not ask for confirmation for the `drop db_name` command. With multiple commands, continue even if an error occurs.

- `--host=host_name`, `-h host_name`

  Connect to the MySQL server on the given host.

- `--no-beep`, `-b`

  Suppress the warning beep that is emitted by default for errors such as a failure to connect to the server.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysqladmin` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--plugin-dir=dir_name`

  The directory in which to look for plugins. Specify this option if the `--default-auth` option is used to specify an authentication plugin but `mysqladmin` does not find it. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.9.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, “Connecting to the MySQL Server”.

- `--relative`, `-r`

  Show the difference between the current and previous values when used with the `--sleep` option. This option works only with the `extended-status` command.

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--silent`, `-s`

  Exit silently if a connection to the server cannot be established.

- `--sleep=delay`, `-i delay`

  Execute commands repeatedly, sleeping for *`delay`* seconds in between. The `--count` option determines the number of iterations. If `--count` is not given, `mysqladmin` executes commands indefinitely until interrupted.

- `--socket=path`, `-S path`

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- `--user=user_name`, `-u user_name`

  The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does.

- `--version`, `-V`

  Display version information and exit.

- `--vertical`, `-E`

  Print output vertically. This is similar to `--relative`, but prints output vertically.

- `--wait[=count]`, `-w[count]`

  If the connection cannot be established, wait and retry instead of aborting. If a *`count`* value is given, it indicates the number of times to retry. The default is one time.

You can also set the following variables by using `--var_name=value` The `--set-variable` format is deprecated and was removed in MySQL 5.5.3. syntax:

- `connect_timeout`

  The maximum number of seconds before connection timeout. The default value is 43200 (12 hours).

- `shutdown_timeout`

  The maximum number of seconds to wait for server shutdown. The default value is 3600 (1 hour).

4.5.3 `mysqlcheck` — A Table Maintenance Program

The `mysqlcheck` client performs table maintenance: It checks, repairs, optimizes, or analyzes tables.

Each table is locked and therefore unavailable to other sessions while it is being processed, although for check operations, the table is locked with a `READ` lock only (see Section 13.3.5, “LOCK

TABLES and UNLOCK TABLES Syntax", for more information about READ and WRITE locks). Table maintenance operations can be time-consuming, particularly for large tables. If you use the --databases or --all-databases option to process all tables in one or more databases, an invocation of mysqlcheck might take a long time. (This is also true for mysql_upgrade because that program invokes mysqlcheck to check all tables and repair them if necessary.)

mysqlcheck is similar in function to myisamchk, but works differently. The main operational difference is that mysqlcheck must be used when the mysqld server is running, whereas myisamchk should be used when it is not. The benefit of using mysqlcheck is that you do not have to stop the server to perform table maintenance.

mysqlcheck uses the SQL statements CHECK TABLE, REPAIR TABLE, ANALYZE TABLE, and OPTIMIZE TABLE in a convenient way for the user. It determines which statements to use for the operation you want to perform, and then sends the statements to the server to be executed. For details about which storage engines each statement works with, see the descriptions for those statements in Section 13.7.2, "Table Maintenance Statements".

The MyISAM storage engine supports all four maintenance operations, so mysqlcheck can be used to perform any of them on MyISAM tables. Other storage engines do not necessarily support all operations. In such cases, an error message is displayed. For example, if test.t is a MEMORY table, an attempt to check it produces this result:

```
shell> mysqlcheck test t
test.t
note     : The storage engine for the table doesn't support check
```

If mysqlcheck is unable to repair a table, see Section 2.11.3, "Rebuilding or Repairing Tables or Indexes" for manual table repair strategies. This will be the case, for example, for InnoDB tables, which can be checked with CHECK TABLE, but not repaired with REPAIR TABLE.

Caution

It is best to make a backup of a table before performing a table repair operation; under some circumstances the operation might cause data loss. Possible causes include but are not limited to file system errors.

There are three general ways to invoke mysqlcheck:

```
shell> mysqlcheck [options] db_name [tbl_name ...]
shell> mysqlcheck [options] --databases db_name ...
shell> mysqlcheck [options] --all-databases
```

If you do not name any tables following *db_name* or if you use the --databases or --all-databases option, entire databases are checked.

mysqlcheck has a special feature compared to other client programs. The default behavior of checking tables (--check) can be changed by renaming the binary. If you want to have a tool that repairs tables by default, you should just make a copy of mysqlcheck named mysqlrepair, or make a symbolic link to mysqlcheck named mysqlrepair. If you invoke mysqlrepair, it repairs tables.

The names shown in the following table can be used to change mysqlcheck default behavior.

Command	Meaning
mysqlrepair	The default option is --repair
mysqlanalyze	The default option is --analyze
mysqloptimize	The default option is --optimize

mysqlcheck supports the following options, which can be specified on the command line or in the [mysqlcheck] and [client] groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.10 mysqlcheck Options

Format	Description	Introduced
--all-databases	Check all tables in all databases	
--all-in-1	Execute a single statement for each database that names all the tables from that database	
--analyze	Analyze the tables	
--auto-repair	If a checked table is corrupted, automatically fix it	
--character-sets-dir	Directory where character sets are installed	
--check	Check the tables for errors	
--check-only-changed	Check only tables that have changed since the last check	
--check-upgrade	Invoke CHECK TABLE with the FOR UPGRADE option	
--compress	Compress all information sent between client and server	
--databases	Interpret all arguments as database names	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	
--debug-info	Print debugging information, memory, and CPU statistics when program exits	
--default-auth	Authentication plugin to use	5.5.10
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--enable-cleartext-plugin	Enable cleartext authentication plugin	5.5.47
--extended	Check and repair tables	
--fast	Check only tables that have not been closed properly	
--fix-db-names	Convert database names to 5.1 format	
--fix-table-names	Convert table names to 5.1 format	
--force	Continue even if an SQL error occurs	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--medium-check	Do a check that is faster than an --extended operation	
--no-defaults	Read no option files	
--optimize	Optimize the tables	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--plugin-dir	Directory where plugins are installed	5.5.10
--port	TCP/IP port number for connection	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--quick	The fastest method of checking	

Format	Description	Introduced
--repair	Perform a repair that can fix almost anything except unique keys that are not unique	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--silent	Silent mode	
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable encrypted connection	
--ssl-ca	File that contains list of trusted SSL Certificate Authorities	
--ssl-capath	Directory that contains trusted SSL Certificate Authority certificate files	
--ssl-cert	File that contains X509 certificate	
--ssl-cipher	List of permitted ciphers for connection encryption	
--ssl-key	File that contains X509 key	
--ssl-mode	Security state of connection to server	5.5.49
--ssl-verify-server-cert	Verify host name against server certificate Common Name identity	
--tables	Overrides the --databases or -B option	
--use-frm	For repair operations on MyISAM tables	
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	
--write-binlog	Log ANALYZE, OPTIMIZE, REPAIR statements to binary log. --skip-write-binlog adds NO_WRITE_TO_BINLOG to these statements.	

- `--help`, `-?`

  Display a help message and exit.

- `--all-databases`, `-A`

  Check all tables in all databases. This is the same as using the `--databases` option and naming all the databases on the command line, except that the `INFORMATION_SCHEMA` and `performace_schema` databases are not checked. They can be checked by explicitly naming them with the `--databases` option.

- `--all-in-1`, `-1`

  Instead of issuing a statement for each table, execute a single statement for each database that names all the tables from that database to be processed.

- `--analyze`, `-a`

  Analyze the tables.

- `--auto-repair`

  If a checked table is corrupted, automatically fix it. Any necessary repairs are done after all tables have been checked.

- `--bind-address=`*`ip_address`*

On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

This option is supported only in the version of mysqlcheck that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- --character-sets-dir=*dir_name*

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- --check, -c

  Check the tables for errors. This is the default operation.

- --check-only-changed, -C

  Check only tables that have changed since the last check or that have not been closed properly.

- --check-upgrade, -g

  Invoke CHECK TABLE with the FOR UPGRADE option to check tables for incompatibilities with the current version of the server. This option automatically enables the --fix-db-names and --fix-table-names options.

- --compress

  Compress all information sent between the client and the server if both support compression.

- --databases, -B

  Process all tables in the named databases. Normally, mysqlcheck treats the first name argument on the command line as a database name and any following names as table names. With this option, it treats all name arguments as database names.

- --debug[=*debug_options*], -# [*debug_options*]

  Write a debugging log. A typical *debug_options* string is d:t:o,*file_name*. The default is d:t:o.

- --debug-check

  Print some debugging information when the program exits.

- --debug-info

  Print debugging information and memory and CPU usage statistics when the program exits.

- --default-character-set=*charset_name*

  Use *charset_name* as the default character set. See Section 10.5, “Character Set Configuration”.

- --defaults-extra-file=*file_name*

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *file_name* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- --defaults-file=*file_name*

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *file_name* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysqlcheck` normally reads the `[client]` and `[mysqlcheck]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqlcheck` also reads the `[client_other]` and `[mysqlcheck_other]` groups.

- `--extended`, `-e`

  If you are using this option to check tables, it ensures that they are 100% consistent but takes a long time.

  If you are using this option to repair tables, it runs an extended repair that may not only take a long time to execute, but may produce a lot of garbage rows also!

- `--default-auth=plugin`

  A hint about the client-side authentication plugin to use. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- `--enable-cleartext-plugin`

  Enable the `mysql_clear_password` cleartext authentication plugin. (See Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”.)

  This option was added in MySQL 5.5.47.

- `--fast`, `-F`

  Check only tables that have not been closed properly.

- `--fix-db-names`

  Convert database names to 5.1 format. Only database names that contain special characters are affected.

- `--fix-table-names`

  Convert table names to 5.1 format. Only table names that contain special characters are affected. This option also applies to views.

- `--force`, `-f`

  Continue even if an SQL error occurs.

- `--host=host_name`, `-h host_name`

  Connect to the MySQL server on the given host.

- `--medium-check`, `-m`

  Do a check that is faster than an `--extended` operation. This finds only 99.99% of all errors, which should be good enough in most cases.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--optimize`, `-o`

  Optimize the tables.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysqlcheck` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--plugin-dir=dir_name`

  The directory in which to look for plugins. Specify this option if the `--default-auth` option is used to specify an authentication plugin but `mysqlcheck` does not find it. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, “Connecting to the MySQL Server”.

- `--quick`, `-q`

  If you are using this option to check tables, it prevents the check from scanning the rows to check for incorrect links. This is the fastest check method.

  If you are using this option to repair tables, it tries to repair only the index tree. This is the fastest repair method.

- `--repair`, `-r`

  Perform a repair that can fix almost anything except unique keys that are not unique.

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--silent`, `-s`

  Silent mode. Print only error messages.

- `--socket=path`, `-S path`

For connections to localhost, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- --ssl*

  Options that begin with --ssl specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- --tables

  Override the --databases or -B option. All name arguments following the option are regarded as table names.

- --use-frm

  For repair operations on MyISAM tables, get the table structure from the .frm file so that the table can be repaired even if the .MYI header is corrupted.

- --user=*user_name*, -u *user_name*

  The MySQL user name to use when connecting to the server.

- --verbose, -v

  Verbose mode. Print information about the various stages of program operation.

- --version, -V

  Display version information and exit.

- --write-binlog

  This option is enabled by default, so that ANALYZE TABLE, OPTIMIZE TABLE, and REPAIR TABLE statements generated by mysqlcheck are written to the binary log. Use --skip-write-binlog to cause NO_WRITE_TO_BINLOG to be added to the statements so that they are not logged. Use the --skip-write-binlog when these statements should not be sent to replication slaves or run when using the binary logs for recovery from backup.

4.5.4 mysqldump — A Database Backup Program

- Performance and Scalability Considerations
- Invocation Syntax
- Option Syntax - Alphabetical Summary

The mysqldump client utility performs logical backups, producing a set of SQL statements that can be executed to reproduce the original database object definitions and table data. It dumps one or more MySQL databases for backup or transfer to another SQL server. The mysqldump command can also generate output in CSV, other delimited text, or XML format.

mysqldump requires at least the SELECT privilege for dumped tables, SHOW VIEW for dumped views, TRIGGER for dumped triggers, and LOCK TABLES if the --single-transaction option is not used. Certain options might require other privileges as noted in the option descriptions.

To reload a dump file, you must have the privileges required to execute the statements that it contains, such as the appropriate CREATE privileges for objects created by those statements.

mysqldump output can include ALTER DATABASE statements that change the database collation. These may be used when dumping stored programs to preserve their character encodings. To reload a dump file containing such statements, the ALTER privilege for the affected database is required.

If you are performing a backup on the server and your tables all are MyISAM tables, you can also use mysqlhotcopy for this purpose.

Note

A dump made using PowerShell on Windows with output redirection creates a file that has UTF-16 encoding:

```
shell> mysqldump [options] > dump.sql
```

However, UTF-16 is not permitted as a connection character set (see Section 10.1.4, “Connection Character Sets and Collations”), so the dump file will not load correctly. To work around this issue, use the --result-file option, which creates the output in ASCII format:

```
shell> mysqldump [options] --result-file=dump.sql
```

Performance and Scalability Considerations

mysqldump advantages include the convenience and flexibility of viewing or even editing the output before restoring. You can clone databases for development and DBA work, or produce slight variations of an existing database for testing. It is not intended as a fast or scalable solution for backing up substantial amounts of data. With large data sizes, even if the backup step takes a reasonable time, restoring the data can be very slow because replaying the SQL statements involves disk I/O for insertion, index creation, and so on.

For large-scale backup and restore, a physical backup is more appropriate, to copy the data files in their original format that can be restored quickly:

- If your tables are primarily InnoDB tables, or if you have a mix of InnoDB and MyISAM tables, consider using the mysqlbackup command of the MySQL Enterprise Backup product. (Available as part of the Enterprise subscription.) It provides the best performance for InnoDB backups with minimal disruption; it can also back up tables from MyISAM and other storage engines; and it provides a number of convenient options to accommodate different backup scenarios. See Section 25.2, “MySQL Enterprise Backup Overview”.
- If your tables are primarily MyISAM tables, consider using the mysqlhotcopy instead, for better performance than mysqldump of backup and restore operations. See Section 4.6.9, “mysqlhotcopy — A Database Backup Program”.

mysqldump can retrieve and dump table contents row by row, or it can retrieve the entire content from a table and buffer it in memory before dumping it. Buffering in memory can be a problem if you are dumping large tables. To dump tables row by row, use the --quick option (or --opt, which enables --quick). The --opt option (and hence --quick) is enabled by default, so to enable memory buffering, use --skip-quick.

If you are using a recent version of mysqldump to generate a dump to be reloaded into a very old MySQL server, use the --skip-opt option instead of the --opt or --extended-insert option.

For additional information about mysqldump, see Section 7.4, “Using mysqldump for Backups”.

Invocation Syntax

There are in general three ways to use mysqldump—in order to dump a set of one or more tables, a set of one or more complete databases, or an entire MySQL server—as shown here:

```
shell> mysqldump [options] db_name [tbl_name ...]
shell> mysqldump [options] --databases db_name ...
shell> mysqldump [options] --all-databases
```

To dump entire databases, do not name any tables following *db_name*, or use the `--databases` or `--all-databases` option.

`mysqldump` does not dump the `INFORMATION_SCHEMA` or `performance_schema` database by default. To dump either of these, name it explicitly on the command line and also use the `--skip-lock-tables` option. You can also name them with the `--databases` option. Before MySQL 5.5 `mysqldump` silently ignores `INFORMATION_SCHEMA` even if you name it explicitly on the command line.

`mysqldump` does not dump the `performance_schema` database.

Before MySQL 5.5.25, `mysqldump` does not dump the `general_log` or `slow_query_log` tables for dumps of the `mysql` database. As of 5.5.25, the dump includes statements to recreate those tables so that they are not missing after reloading the dump file. Log table contents are not dumped.

`mysqldump` also does not dump the NDB Cluster `ndbinfo` information database.

To see a list of the options your version of `mysqldump` supports, execute `mysqldump --help`.

Some `mysqldump` options are shorthand for groups of other options:

- Use of `--opt` is the same as specifying `--add-drop-table`, `--add-locks`, `--create-options`, `--disable-keys`, `--extended-insert`, `--lock-tables`, `--quick`, and `--set-charset`. All of the options that `--opt` stands for also are on by default because `--opt` is on by default.
- Use of `--compact` is the same as specifying `--skip-add-drop-table`, `--skip-add-locks`, `--skip-comments`, `--skip-disable-keys`, and `--skip-set-charset` options.

To reverse the effect of a group option, uses its `--skip-xxx` form (`--skip-opt` or `--skip-compact`). It is also possible to select only part of the effect of a group option by following it with options that enable or disable specific features. Here are some examples:

- To select the effect of `--opt` except for some features, use the `--skip` option for each feature. To disable extended inserts and memory buffering, use `--opt --skip-extended-insert --skip-quick`. (Actually, `--skip-extended-insert --skip-quick` is sufficient because `--opt` is on by default.)
- To reverse `--opt` for all features except index disabling and table locking, use `--skip-opt --disable-keys --lock-tables`.

When you selectively enable or disable the effect of a group option, order is important because options are processed first to last. For example, `--disable-keys --lock-tables --skip-opt` would not have the intended effect; it is the same as `--skip-opt` by itself.

`mysqldump` can retrieve and dump table contents row by row, or it can retrieve the entire content from a table and buffer it in memory before dumping it. Buffering in memory can be a problem if you are dumping large tables. To dump tables row by row, use the `--quick` option (or `--opt`, which enables `--quick`). The `--opt` option (and hence `--quick`) is enabled by default, so to enable memory buffering, use `--skip-quick`.

If you are using a recent version of `mysqldump` to generate a dump to be reloaded into a very old MySQL server, you should not use the `--opt` or `--extended-insert` option. Use `--skip-opt` instead.

For additional information about `mysqldump`, see Section 7.4, “Using mysqldump for Backups”.

Option Syntax - Alphabetical Summary

`mysqldump` supports the following options, which can be specified on the command line or in the `[mysqldump]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.11 mysqldump Options

Format	Description	Introduced	Removed
--add-drop-database	Add DROP DATABASE statement before each CREATE DATABASE statement		
--add-drop-table	Add DROP TABLE statement before each CREATE TABLE statement		
--add-locks	Surround each table dump with LOCK TABLES and UNLOCK TABLES statements		
--all-databases	Dump all tables in all databases		
--allow-keywords	Allow creation of column names that are keywords		
--apply-slave-statements	Include STOP SLAVE prior to CHANGE MASTER statement and START SLAVE at end of output	5.5.3	
--bind-address	Use specified network interface to connect to MySQL Server	5.5.8	
--character-sets-dir	Directory where character sets are installed		
--comments	Add comments to dump file		
--compact	Produce more compact output		
--compatible	Produce output that is more compatible with other database systems or with older MySQL servers		
--complete-insert	Use complete INSERT statements that include column names		
--compress	Compress all information sent between client and server		
--create-options	Include all MySQL-specific table options in CREATE TABLE statements		
--databases	Interpret all name arguments as database names		
--debug	Write debugging log		
--debug-check	Print debugging information when program exits		
--debug-info	Print debugging information, memory, and CPU statistics when program exits		
--default-auth	Authentication plugin to use	5.5.9	
--default-character-set	Specify default character set		
--defaults-extra-file	Read named option file in addition to usual option files		
--defaults-file	Read only named option file		
--defaults-group-suffix	Option group suffix value		
--delayed-insert	Write INSERT DELAYED statements rather than INSERT statements		
--delete-master-logs	On a master replication server, delete the binary logs after performing the dump operation		
--disable-keys	For each table, surround INSERT statements with statements to disable and enable keys		
--dump-date	Include dump date as "Dump completed on" comment if --comments is given		
--dump-slave	Include CHANGE MASTER statement that lists binary log coordinates of slave's master	5.5.3	

Format	Description	Introduced	Removed
--enable-cleartext-plugin	Enable cleartext authentication plugin	5.5.47	
--events	Dump events from dumped databases		
--extended-insert	Use multiple-row INSERT syntax		
--fields-enclosed-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE		
--fields-escaped-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE		
--fields-optionally-enclosed-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE		
--fields-terminated-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE		
--first-slave	Deprecated; use --lock-all-tables instead		5.5.3
--flush-logs	Flush MySQL server log files before starting dump		
--flush-privileges	Emit a FLUSH PRIVILEGES statement after dumping mysql database		
--force	Continue even if an SQL error occurs during a table dump		
--help	Display help message and exit		
--hex-blob	Dump binary columns using hexadecimal notation		
--host	Host to connect to (IP address or hostname)		
--ignore-table	Do not dump given table		
--include-master-host-port	Include MASTER_HOST/MASTER_PORT options in CHANGE MASTER statement produced with --dump-slave	5.5.3	
--insert-ignore	Write INSERT IGNORE rather than INSERT statements		
--lines-terminated-by	This option is used with the --tab option and has the same meaning as the corresponding clause for LOAD DATA INFILE		
--lock-all-tables	Lock all tables across all databases		
--lock-tables	Lock all tables before dumping them		
--log-error	Append warnings and errors to named file		
--master-data	Write the binary log file name and position to the output		
--max_allowed_packet	Maximum packet length to send to or receive from server		
--net_buffer_length	Buffer size for TCP/IP and socket communication		
--no-autocommit	Enclose the INSERT statements for each dumped table within SET autocommit = 0 and COMMIT statements		
--no-create-db	Do not write CREATE DATABASE statements		

Format	Description	Introduced	Removed
--no-create-info	Do not write CREATE TABLE statements that re-create each dumped table		
--no-data	Do not dump table contents		
--no-defaults	Read no option files		
--no-set-names	Same as --skip-set-charset		
--no-tablespaces	Do not write any CREATE LOGFILE GROUP or CREATE TABLESPACE statements in output		
--opt	Shorthand for --add-drop-table --add-locks --create-options --disable-keys --extended-insert --lock-tables --quick --set-charset.		
--order-by-primary	Dump each table's rows sorted by its primary key, or by its first unique index		
--password	Password to use when connecting to server		
--pipe	On Windows, connect to server using named pipe		
--plugin-dir	Directory where plugins are installed	5.5.9	
--port	TCP/IP port number for connection		
--print-defaults	Print default options		
--protocol	Connection protocol to use		
--quick	Retrieve rows for a table from the server a row at a time		
--quote-names	Quote identifiers within backtick characters		
--replace	Write REPLACE statements rather than INSERT statements		
--result-file	Direct output to a given file		
--routines	Dump stored routines (procedures and functions) from dumped databases		
--set-charset	Add SET NAMES default_character_set to output		
--shared-memory-base-name	The name of shared memory to use for shared-memory connections		
--single-transaction	Issue a BEGIN SQL statement before dumping data from server		
--skip-add-drop-table	Do not add a DROP TABLE statement before each CREATE TABLE statement		
--skip-add-locks	Do not add locks		
--skip-comments	Do not add comments to dump file		
--skip-compact	Do not produce more compact output		
--skip-disable-keys	Do not disable keys		
--skip-extended-insert	Turn off extended-insert		
--skip-opt	Turn off options set by --opt		
--skip-quick	Do not retrieve rows for a table from the server a row at a time		
--skip-quote-names	Do not quote identifiers		
--skip-set-charset	Do not write SET NAMES statement		
--skip-triggers	Do not dump triggers		

Format	Description	Introduced	Removed
--skip-tz-utc	Turn off tz-utc		
--socket	For connections to localhost, the Unix socket file to use		
--ssl	Enable encrypted connection		
--ssl-ca	File that contains list of trusted SSL Certificate Authorities		
--ssl-capath	Directory that contains trusted SSL Certificate Authority certificate files		
--ssl-cert	File that contains X509 certificate		
--ssl-cipher	List of permitted ciphers for connection encryption		
--ssl-key	File that contains X509 key		
--ssl-mode	Security state of connection to server	5.5.49	
--ssl-verify-server-cert	Verify host name against server certificate Common Name identity		
--tab	Produce tab-separated data files		
--tables	Override --databases or -B option		
--triggers	Dump triggers for each dumped table		
--tz-utc	Add SET TIME_ZONE='+00:00' to dump file		
--user	MySQL user name to use when connecting to server		
--verbose	Verbose mode		
--version	Display version information and exit		
--where	Dump only rows selected by given WHERE condition		
--xml	Produce XML output		

- `--help`, `-?`

  Display a help message and exit.

- `--add-drop-database`

  Write a `DROP DATABASE` statement before each `CREATE DATABASE` statement. This option is typically used in conjunction with the `--all-databases` or `--databases` option because no `CREATE DATABASE` statements are written unless one of those options is specified.

- `--add-drop-table`

  Write a `DROP TABLE` statement before each `CREATE TABLE` statement.

- `--add-drop-trigger`

  Write a `DROP TRIGGER` statement before each `CREATE TRIGGER` statement.

  Note

  This option is supported only by `mysqldump` as supplied with NDB Cluster. It is not available when using MySQL Server 5.5.

- `--add-locks`

Surround each table dump with LOCK TABLES and UNLOCK TABLES statements. This results in faster inserts when the dump file is reloaded. See Section 8.2.4.1, “Optimizing INSERT Statements”.

- --all-databases, -A

  Dump all tables in all databases. This is the same as using the --databases option and naming all the databases on the command line.

- --all-tablespaces, -Y

  Adds to a table dump all SQL statements needed to create any tablespaces used by an NDBCLUSTER table. This information is not otherwise included in the output from mysqldump. This option is currently relevant only to NDB Cluster tables.

- --allow-keywords

  Permit creation of column names that are keywords. This works by prefixing each column name with the table name.

- --apply-slave-statements

  For a slave dump produced with the --dump-slave option, add a STOP SLAVE statement before the CHANGE MASTER TO statement and a START SLAVE statement at the end of the output. This option was added in MySQL 5.5.3.

- --bind-address=*ip_address*

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported only in the version of mysqldump that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- --character-sets-dir=*dir_name*

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- --comments, -i

  Write additional information in the dump file such as program version, server version, and host. This option is enabled by default. To suppress this additional information, use --skip-comments.

- --compact

  Produce more compact output. This option enables the --skip-add-drop-table, --skip-add-locks, --skip-comments, --skip-disable-keys, and --skip-set-charset options.

- --compatible=*name*

  Produce output that is more compatible with other database systems or with older MySQL servers. The value of *name* can be ansi, mysql323, mysql40, postgresql, oracle, mssql, db2, maxdb, no_key_options, no_table_options, or no_field_options. To use several values, separate them by commas. These values have the same meaning as the corresponding options for setting the server SQL mode. See Section 5.1.8, “Server SQL Modes”.

  This option does not guarantee compatibility with other servers. It only enables those SQL mode values that are currently available for making dump output more compatible. For example, --compatible=oracle does not map data types to Oracle types or use Oracle comment syntax.

  This option requires a server version of 4.1.0 or higher. With older servers, it does nothing.

- --complete-insert, -c

Use complete INSERT statements that include column names.

- --compress, -C

  Compress all information sent between the client and the server if both support compression.

- --create-options

  Include all MySQL-specific table options in the CREATE TABLE statements.

- --databases, -B

  Dump several databases. Normally, mysqldump treats the first name argument on the command line as a database name and following names as table names. With this option, it treats all name arguments as database names. CREATE DATABASE and USE statements are included in the output before each new database.

  This option may be used to dump the INFORMATION_SCHEMA and performace_schema databases, which normally are not dumped even with the --all-databases option. (Also use the --skip-lock-tables option.)

- --debug[=*debug_options*], -# [*debug_options*]

  Write a debugging log. A typical *debug_options* string is d:t:o,*file_name*. The default value is d:t:o,/tmp/mysqldump.trace.

- --debug-check

  Print some debugging information when the program exits.

- --debug-info

  Print debugging information and memory and CPU usage statistics when the program exits.

- --default-auth=*plugin*

  A hint about the client-side authentication plugin to use. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.9.

- --default-character-set=*charset_name*

  Use *charset_name* as the default character set. See Section 10.5, “Character Set Configuration”. If no character set is specified, mysqldump uses utf8.

- --defaults-extra-file=*file_name*

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *file_name* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- --defaults-file=*file_name*

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *file_name* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- --defaults-group-suffix=*str*

  Read not only the usual option groups, but also groups with the usual names and a suffix of *str*. For example, mysqldump normally reads the [client] and [mysqldump] groups. If the --

defaults-group-suffix=_other option is given, mysqldump also reads the [client_other] and [mysqldump_other] groups.

- --delayed-insert

  Write INSERT DELAYED statements rather than INSERT statements.

- --delete-master-logs

  On a master replication server, delete the binary logs by sending a PURGE BINARY LOGS statement to the server after performing the dump operation. This option automatically enables --master-data.

- --disable-keys, -K

  For each table, surround the INSERT statements with /*!40000 ALTER TABLE *tbl_name* DISABLE KEYS */; and /*!40000 ALTER TABLE *tbl_name* ENABLE KEYS */; statements. This makes loading the dump file faster because the indexes are created after all rows are inserted. This option is effective only for nonunique indexes of MyISAM tables. It has no effect for other tables.

- --dump-date

  If the --comments option is given, mysqldump produces a comment at the end of the dump of the following form:

  ```
  -- Dump completed on DATE
  ```

  However, the date causes dump files taken at different times to appear to be different, even if the data are otherwise identical. --dump-date and --skip-dump-date control whether the date is added to the comment. The default is --dump-date (include the date in the comment). --skip-dump-date suppresses date printing.

- --dump-slave[=*value*]

  This option is similar to --master-data except that it is used to dump a replication slave server to produce a dump file that can be used to set up another server as a slave that has the same master as the dumped server. It causes the dump output to include a CHANGE MASTER TO statement that indicates the binary log coordinates (file name and position) of the dumped slave's master. These are the master server coordinates from which the slave should start replicating.

  --dump-slave causes the coordinates from the master to be used rather than those of the dumped server, as is done by the --master-data option. In addition, specfiying this option causes the --master-data option to be overridden, if used, and effectively ignored.

  The option value is handled the same way as for --master-data (setting no value or 1 causes a CHANGE MASTER TO statement to be written to the dump, setting 2 causes the statement to be written but encased in SQL comments) and has the same effect as --master-data in terms of enabling or disabling other options and in how locking is handled.

  This option causes mysqldump to stop the slave SQL thread before the dump and restart it again after.

  In conjunction with --dump-slave, the --apply-slave-statements and --include-master-host-port options can also be used.

  This option was added in MySQL 5.5.3.

- --events, -E

  Include Event Scheduler events for the dumped databases in the output. This option requires the EVENT privileges for those databases.

- `--extended-insert`, `-e`

  Write `INSERT` statements using multiple-row syntax that includes several `VALUES` lists. This results in a smaller dump file and speeds up inserts when the file is reloaded.

- `--fields-terminated-by=...`, `--fields-enclosed-by=...`, `--fields-optionally-enclosed-by=...`, `--fields-escaped-by=...`

  These options are used with the `--tab` option and have the same meaning as the corresponding `FIELDS` clauses for `LOAD DATA INFILE`. See Section 13.2.6, “LOAD DATA INFILE Syntax”.

- `--first-slave`

  Deprecated. Use `--lock-all-tables` instead. `--first-slave` was removed in MySQL 5.5.3.

- `--flush-logs`, `-F`

  Flush the MySQL server log files before starting the dump. This option requires the `RELOAD` privilege. If you use this option in combination with the `--all-databases` option, the logs are flushed *for each database dumped*. The exception is when using `--lock-all-tables`, `--master-data`, or (as of MySQL 5.5.21) `--single-transaction`: In this case, the logs are flushed only once, corresponding to the moment that all tables are locked by `FLUSH TABLES WITH READ LOCK`. If you want your dump and the log flush to happen at exactly the same moment, you should use `--flush-logs` together with `--lock-all-tables`, `--master-data`, or `--single-transaction`.

- `--flush-privileges`

  Add a `FLUSH PRIVILEGES` statement to the dump output after dumping the `mysql` database. This option should be used any time the dump contains the `mysql` database and any other database that depends on the data in the `mysql` database for proper restoration.

- `--force`, `-f`

  Continue even if an SQL error occurs during a table dump.

  One use for this option is to cause `mysqldump` to continue executing even when it encounters a view that has become invalid because the definition refers to a table that has been dropped. Without `--force`, `mysqldump` exits with an error message. With `--force`, `mysqldump` prints the error message, but it also writes an SQL comment containing the view definition to the dump output and continues executing.

- `--enable-cleartext-plugin`

  Enable the `mysql_clear_password` cleartext authentication plugin. (See Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”.)

  This option was added in MySQL 5.5.47.

- `--host=`*`host_name`*, `-h` *`host_name`*

  Dump data from the MySQL server on the given host. The default host is `localhost`.

- `--hex-blob`

  Dump binary columns using hexadecimal notation (for example, `'abc'` becomes `0x616263`). The affected data types are `BINARY`, `VARBINARY`, the `BLOB` types, and `BIT`.

- `--include-master-host-port`

  For the `CHANGE MASTER TO` statement in a slave dump produced with the `--dump-slave` option, add `MASTER_HOST` and `MASTER_PORT` options for the host name and TCP/IP port number of the slave's master. This option was added in MySQL 5.5.3.

- `--ignore-table=db_name.tbl_name`

  Do not dump the given table, which must be specified using both the database and table names. To ignore multiple tables, use this option multiple times. This option also can be used to ignore views.

- `--insert-ignore`

  Write `INSERT IGNORE` statements rather than `INSERT` statements.

- `--lines-terminated-by=...`

  This option is used with the `--tab` option and has the same meaning as the corresponding `LINES` clause for `LOAD DATA INFILE`. See Section 13.2.6, “LOAD DATA INFILE Syntax”.

- `--lock-all-tables`, `-x`

  Lock all tables across all databases. This is achieved by acquiring a global read lock for the duration of the whole dump. This option automatically turns off `--single-transaction` and `--lock-tables`.

- `--lock-tables`, `-l`

  For each dumped database, lock all tables to be dumped before dumping them. The tables are locked with `READ LOCAL` to permit concurrent inserts in the case of `MyISAM` tables. For transactional tables such as `InnoDB`, `--single-transaction` is a much better option than `--lock-tables` because it does not need to lock the tables at all.

  Because `--lock-tables` locks tables for each database separately, this option does not guarantee that the tables in the dump file are logically consistent between databases. Tables in different databases may be dumped in completely different states.

  Some options, such as `--opt`, automatically enable `--lock-tables`. If you want to override this, use `--skip-lock-tables` at the end of the option list.

- `--log-error=file_name`

  Log warnings and errors by appending them to the named file. The default is to do no logging.

- `--master-data[=value]`

  Use this option to dump a master replication server to produce a dump file that can be used to set up another server as a slave of the master. It causes the dump output to include a `CHANGE MASTER TO` statement that indicates the binary log coordinates (file name and position) of the dumped server. These are the master server coordinates from which the slave should start replicating after you load the dump file into the slave.

  If the option value is 2, the `CHANGE MASTER TO` statement is written as an SQL comment, and thus is informative only; it has no effect when the dump file is reloaded. If the option value is 1, the statement is not written as a comment and takes effect when the dump file is reloaded. If no option value is specified, the default value is 1.

  This option requires the `RELOAD` privilege and the binary log must be enabled.

  The `--master-data` option automatically turns off `--lock-tables`. It also turns on `--lock-all-tables`, unless `--single-transaction` also is specified, in which case, a global read lock is acquired only for a short time at the beginning of the dump (see the description for `--single-transaction`). In all cases, any action on logs happens at the exact moment of the dump.

  It is also possible to set up a slave by dumping an existing slave of the master. In MySQL 5.5.3 and higher, you can create such a dump using the `--dump-slave` option, which overrides `--master-data` and causes it to be ignored if both options are used.

Before MySQL 5.5.3, use the following procedure on the existing slave:

1. Stop the slave's SQL thread and get its current status:

```
mysql> STOP SLAVE SQL_THREAD;
mysql> SHOW SLAVE STATUS;
```

2. From the output of the SHOW SLAVE STATUS statement, the binary log coordinates of the master server from which the new slave should start replicating are the values of the Relay_Master_Log_File and Exec_Master_Log_Pos fields. Denote those values as *file_name* and *file_pos*.

3. Dump the slave server:

```
shell> mysqldump --master-data=2 --all-databases > dumpfile
```

Using --master-data=2 works only if binary logging has been enabled on the slave. Otherwise, mysqldump fails with the error Binlogging on server not active. In this case you must handle any locking issues in another manner, using one or more of --add-locks, --lock-tables, --lock-all-tables, or --single-transaction, as required by your application and environment.

4. Restart the slave:

```
mysql> START SLAVE;
```

5. On the new slave, load the dump file:

```
shell> mysql < dumpfile
```

6. On the new slave, set the replication coordinates to those of the master server obtained earlier:

```
mysql> CHANGE MASTER TO
    -> MASTER_LOG_FILE = 'file_name', MASTER_LOG_POS = file_pos;
```

The CHANGE MASTER TO statement might also need other parameters, such as MASTER_HOST to point the slave to the correct master server host. Add any such parameters as necessary.

- --no-autocommit

Enclose the INSERT statements for each dumped table within SET autocommit = 0 and COMMIT statements.

- --no-create-db, -n

Suppress the CREATE DATABASE statements that are otherwise included in the output if the --databases or --all-databases option is given.

- --no-create-info, -t

Do not write CREATE TABLE statements that create each dumped table.

Note

This option does *not* exclude statements creating log file groups or tablespaces from mysqldump output; however, you can use the --no-tablespaces option for this purpose.

- --no-data, -d

Do not write any table row information (that is, do not dump table contents). This is useful if you want to dump only the CREATE TABLE statement for the table (for example, to create an empty copy of the table by loading the dump file).

- --no-defaults

  Do not read any option files. If program startup fails due to reading unknown options from an option file, --no-defaults can be used to prevent them from being read.

- --no-set-names, -N

  This has the same effect as --skip-set-charset.

- --no-tablespaces, -y

  This option suppresses all CREATE LOGFILE GROUP and CREATE TABLESPACE statements in the output of mysqldump.

- --opt

  This option is shorthand. It is the same as specifying --add-drop-table --add-locks --create-options --disable-keys --extended-insert --lock-tables --quick --set-charset. It should give you a fast dump operation and produce a dump file that can be reloaded into a MySQL server quickly.

  The --opt option is enabled by default. Use --skip-opt to disable it. See the discussion at the beginning of this section for information about selectively enabling or disabling a subset of the options affected by --opt.

- --order-by-primary

  Dump each table's rows sorted by its primary key, or by its first unique index, if such an index exists. This is useful when dumping a MyISAM table to be loaded into an InnoDB table, but will make the dump operation take considerably longer.

- --password[=*password*], -p[*password*]

  The password to use when connecting to the server. If you use the short option form (-p), you *cannot* have a space between the option and the password. If you omit the *password* value following the --password or -p option on the command line, mysqldump prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line.

- --pipe, -W

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- --plugin-dir=*dir_name*

  The directory in which to look for plugins. Specify this option if the --default-auth option is used to specify an authentication plugin but mysqldump does not find it. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.9.

- --port=*port_num*, -P *port_num*

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, “Connecting to the MySQL Server”.

- `--quick`, `-q`

  This option is useful for dumping large tables. It forces `mysqldump` to retrieve rows for a table from the server a row at a time rather than retrieving the entire row set and buffering it in memory before writing it out.

- `--quote-names`, `-Q`

  Quote identifiers (such as database, table, and column names) within ` characters. If the `ANSI_QUOTES` SQL mode is enabled, identifiers are quoted within " characters. This option is enabled by default. It can be disabled with `--skip-quote-names`, but this option should be given after any option such as `--compatible` that may enable `--quote-names`.

- `--replace`

  Write `REPLACE` statements rather than `INSERT` statements.

- `--result-file=`*`file_name`*, `-r` *`file_name`*

  Direct output to the named file. The result file is created and its previous contents overwritten, even if an error occurs while generating the dump.

  This option should be used on Windows to prevent newline `\n` characters from being converted to `\r\n` carriage return/newline sequences.

- `--routines`, `-R`

  Include stored routines (procedures and functions) for the dumped databases in the output. This option requires the `SELECT` privilege for the `mysql.proc` table.

  The output generated by using `--routines` contains `CREATE PROCEDURE` and `CREATE FUNCTION` statements to create the routines. However, these statements do not include attributes such as the routine creation and modification timestamps, so when the routines are reloaded, they are created with timestamps equal to the reload time.

  If you require routines to be created with their original timestamp attributes, do not use `--routines`. Instead, dump and reload the contents of the `mysql.proc` table directly, using a MySQL account that has appropriate privileges for the `mysql` database.

  Prior to MySQL 5.5.21, this option had no effect when used together with the `--xml` option. (Bug #11760384, Bug #52792)

- `--set-charset`

  Write `SET NAMES` *`default_character_set`* to the output. This option is enabled by default. To suppress the `SET NAMES` statement, use `--skip-set-charset`.

- `--shared-memory-base-name=`*`name`*

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

The server must be started with the --shared-memory option to enable shared-memory connections.

- --single-transaction

  This option sets the transaction isolation mode to REPEATABLE READ and sends a START TRANSACTION SQL statement to the server before dumping data. It is useful only with transactional tables such as InnoDB, because then it dumps the consistent state of the database at the time when START TRANSACTION was issued without blocking any applications.

  When using this option, you should keep in mind that only InnoDB tables are dumped in a consistent state. For example, any MyISAM or MEMORY tables dumped while using this option may still change state.

  While a --single-transaction dump is in process, to ensure a valid dump file (correct table contents and binary log coordinates), no other connection should use the following statements: ALTER TABLE, CREATE TABLE, DROP TABLE, RENAME TABLE, TRUNCATE TABLE. A consistent read is not isolated from those statements, so use of them on a table to be dumped can cause the SELECT that is performed by mysqldump to retrieve the table contents to obtain incorrect contents or fail.

  The --single-transaction option and the --lock-tables option are mutually exclusive because LOCK TABLES causes any pending transactions to be committed implicitly.

  This option is not supported for NDB Cluster tables; the results cannot be guaranteed to be consistent due to the fact that the NDBCLUSTER storage engine supports only the READ_COMMITTED transaction isolation level. You should always use NDB backup and restore instead.

  To dump large tables, combine the --single-transaction option with the --quick option.

- --skip-comments

  See the description for the --comments option.

- --skip-opt

  See the description for the --opt option.

- --socket=*path*, -S *path*

  For connections to localhost, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- --ssl*

  Options that begin with --ssl specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- --tab=*dir_name*, -T *dir_name*

  Produce tab-separated text-format data files. For each dumped table, mysqldump creates a *tbl_name*.sql file that contains the CREATE TABLE statement that creates the table, and the server writes a *tbl_name*.txt file that contains its data. The option value is the directory in which to write the files.

Note

This option should be used only when mysqldump is run on the same machine as the mysqld server. Because the server creates *.txt files in the directory that you specify, the directory must be writable by the server

> and the MySQL account that you use must have the FILE privilege. Because mysqldump creates *.sql in the same directory, it must be writable by your system login account.

By default, the .txt data files are formatted using tab characters between column values and a newline at the end of each line. The format can be specified explicitly using the --fields-*xxx* and --lines-terminated-by options.

Column values are converted to the character set specified by the --default-character-set option.

- --tables

  Override the --databases or -B option. mysqldump regards all name arguments following the option as table names.

- --triggers

  Include triggers for each dumped table in the output. This option is enabled by default; disable it with --skip-triggers.

  To be able to dump a table's triggers, you must have the TRIGGER privilege for the table.

- --tz-utc

  This option enables TIMESTAMP columns to be dumped and reloaded between servers in different time zones. mysqldump sets its connection time zone to UTC and adds SET TIME_ZONE='+00:00' to the dump file. Without this option, TIMESTAMP columns are dumped and reloaded in the time zones local to the source and destination servers, which can cause the values to change if the servers are in different time zones. --tz-utc also protects against changes due to daylight saving time. --tz-utc is enabled by default. To disable it, use --skip-tz-utc.

- --user=*user_name*, -u *user_name*

  The MySQL user name to use when connecting to the server.

- --verbose, -v

  Verbose mode. Print more information about what the program does.

- --version, -V

  Display version information and exit.

- --where='*where_condition*', -w '*where_condition*'

  Dump only rows selected by the given WHERE condition. Quotes around the condition are mandatory if it contains spaces or other characters that are special to your command interpreter.

  Examples:

```
--where="user='jimf'"
-w"userid>1"
-w"userid<1"
```

- --xml, -X

  Write dump output as well-formed XML.

  NULL, 'NULL', and Empty Values: For a column named *column_name*, the NULL value, an empty string, and the string value 'NULL' are distinguished from one another in the output generated by this option as follows.

Value:	XML Representation:
NULL (*unknown value*)	<field name="*column_name*" xsi:nil="true" />
'' (*empty string*)	<field name="*column_name*"></field>
'NULL' (*string value*)	<field name="*column_name*">NULL</field>

The output from the mysql client when run using the --xml option also follows the preceding rules. (See Section 4.5.1.1, “mysql Options”.)

XML output from mysqldump includes the XML namespace, as shown here:

```
shell> mysqldump --xml -u root world City
<?xml version="1.0"?>
<mysqldump xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
<database name="world">
<table_structure name="City">
<field Field="ID" Type="int(11)" Null="NO" Key="PRI" Extra="auto_increment" />
<field Field="Name" Type="char(35)" Null="NO" Key="" Default="" Extra="" />
<field Field="CountryCode" Type="char(3)" Null="NO" Key="" Default="" Extra="" />
<field Field="District" Type="char(20)" Null="NO" Key="" Default="" Extra="" />
<field Field="Population" Type="int(11)" Null="NO" Key="" Default="0" Extra="" />
<key Table="City" Non_unique="0" Key_name="PRIMARY" Seq_in_index="1" Column_name="ID"
Collation="A" Cardinality="4079" Null="" Index_type="BTREE" Comment="" />
<options Name="City" Engine="MyISAM" Version="10" Row_format="Fixed" Rows="4079"
Avg_row_length="67" Data_length="273293" Max_data_length="18858823439613951"
Index_length="43008" Data_free="0" Auto_increment="4080"
Create_time="2007-03-31 01:47:01" Update_time="2007-03-31 01:47:02"
Collation="latin1_swedish_ci" Create_options="" Comment="" />
</table_structure>
<table_data name="City">
<row>
<field name="ID">1</field>
<field name="Name">Kabul</field>
<field name="CountryCode">AFG</field>
<field name="District">Kabol</field>
<field name="Population">1780000</field>
</row>

...

<row>
<field name="ID">4079</field>
<field name="Name">Rafah</field>
<field name="CountryCode">PSE</field>
<field name="District">Rafah</field>
<field name="Population">92020</field>
</row>
</table_data>
</database>
</mysqldump>
```

Prior to MySQL 5.5.21, this option prevented the --routines option from working correctly—that is, no stored routines, triggers, or events could be dumped in XML format. (Bug #11760384, Bug #52792)

You can also set the following variables by using --*var_name*=*value* syntax:

- max_allowed_packet

  The maximum size of the buffer for client/server communication. The default is 24MB, the maximum is 1GB.

- net_buffer_length

The initial size of the buffer for client/server communication. When creating multiple-row INSERT statements (as with the --extended-insert or --opt option), mysqldump creates rows up to net_buffer_length bytes long. If you increase this variable, ensure that the MySQL server net_buffer_length system variable has a value at least this large.

A common use of mysqldump is for making a backup of an entire database:

```
shell> mysqldump db_name > backup-file.sql
```

You can load the dump file back into the server like this:

```
shell> mysql db_name < backup-file.sql
```

Or like this:

```
shell> mysql -e "source /path-to-backup/backup-file.sql" db_name
```

mysqldump is also very useful for populating databases by copying data from one MySQL server to another:

```
shell> mysqldump --opt db_name | mysql --host=remote_host -C db_name
```

It is possible to dump several databases with one command:

```
shell> mysqldump --databases db_name1 [db_name2 ...] > my_databases.sql
```

To dump all databases, use the --all-databases option:

```
shell> mysqldump --all-databases > all_databases.sql
```

For InnoDB tables, mysqldump provides a way of making an online backup:

```
shell> mysqldump --all-databases --master-data --single-transaction > all_databases.sql
```

This backup acquires a global read lock on all tables (using FLUSH TABLES WITH READ LOCK) at the beginning of the dump. As soon as this lock has been acquired, the binary log coordinates are read and the lock is released. If long updating statements are running when the FLUSH statement is issued, the MySQL server may get stalled until those statements finish. After that, the dump becomes lock free and does not disturb reads and writes on the tables. If the update statements that the MySQL server receives are short (in terms of execution time), the initial lock period should not be noticeable, even with many updates.

For point-in-time recovery (also known as “roll-forward,” when you need to restore an old backup and replay the changes that happened since that backup), it is often useful to rotate the binary log (see Section 5.4.4, “The Binary Log”) or at least know the binary log coordinates to which the dump corresponds:

```
shell> mysqldump --all-databases --master-data=2 > all_databases.sql
```

Or:

```
shell> mysqldump --all-databases --flush-logs --master-data=2
            > all_databases.sql
```

The --master-data and --single-transaction options can be used simultaneously, which provides a convenient way to make an online backup suitable for use prior to point-in-time recovery if tables are stored using the InnoDB storage engine.

For more information on making backups, see Section 7.2, “Database Backup Methods”, and Section 7.3, “Example Backup and Recovery Strategy”.

If you encounter problems backing up views, please read the section that covers restrictions on views which describes a workaround for backing up views when this fails due to insufficient privileges. See Section C.5, “Restrictions on Views”.

4.5.5 mysqlimport — A Data Import Program

The mysqlimport client provides a command-line interface to the LOAD DATA INFILE SQL statement. Most options to mysqlimport correspond directly to clauses of LOAD DATA INFILE syntax. See Section 13.2.6, “LOAD DATA INFILE Syntax”.

Invoke mysqlimport like this:

```
shell> mysqlimport [options] db_name textfile1 [textfile2 ...]
```

For each text file named on the command line, mysqlimport strips any extension from the file name and uses the result to determine the name of the table into which to import the file's contents. For example, files named patient.txt, patient.text, and patient all would be imported into a table named patient.

mysqlimport supports the following options, which can be specified on the command line or in the [mysqlimport] and [client] groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.12 mysqlimport Options

Format	Description	Introduced
--columns	This option takes a comma-separated list of column names as its value	
--compress	Compress all information sent between client and server	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	
--debug-info	Print debugging information, memory, and CPU statistics when program exits	
--default-auth	Authentication plugin to use	5.5.10
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--delete	Empty the table before importing the text file	
--enable-cleartext-plugin	Enable cleartext authentication plugin	5.5.47
--fields-enclosed-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--fields-escaped-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--fields-optionally-enclosed-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--fields-terminated-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--force	Continue even if an SQL error occurs	
--help	Display help message and exit	

Format	Description	Introduced
--host	Connect to MySQL server on given host	
--ignore	See the description for the --replace option	
--ignore-lines	Ignore the first N lines of the data file	
--lines-terminated-by	This option has the same meaning as the corresponding clause for LOAD DATA INFILE	
--local	Read input files locally from the client host	
--lock-tables	Lock all tables for writing before processing any text files	
--low-priority	Use LOW_PRIORITY when loading the table.	
--no-defaults	Read no option files	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--plugin-dir	Directory where plugins are installed	5.5.10
--port	TCP/IP port number for connection	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--replace	The --replace and --ignore options control handling of input rows that duplicate existing rows on unique key values	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--silent	Produce output only when errors occur	
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable encrypted connection	
--ssl-ca	File that contains list of trusted SSL Certificate Authorities	
--ssl-capath	Directory that contains trusted SSL Certificate Authority certificate files	
--ssl-cert	File that contains X509 certificate	
--ssl-cipher	List of permitted ciphers for connection encryption	
--ssl-key	File that contains X509 key	
--ssl-mode	Security state of connection to server	5.5.49
--ssl-verify-server-cert	Verify host name against server certificate Common Name identity	
--use-threads	Number of threads for parallel file-loading	
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	

- `--help`, `-?`

  Display a help message and exit.

  The output generated by using `--events` contains `CREATE EVENT` statements to create the events. However, these statements do not include attributes such as the event creation and modification timestamps, so when the events are reloaded, they are created with timestamps equal to the reload time.

If you require events to be created with their original timestamp attributes, do not use `--events`. Instead, dump and reload the contents of the `mysql.event` table directly, using a MySQL account that has appropriate privileges for the `mysql` database.

- `--bind-address=ip_address`

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported only in the version of `mysqlimport` that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- `--character-sets-dir=dir_name`

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- `--columns=column_list`, `-c column_list`

  This option takes a comma-separated list of column names as its value. The order of the column names indicates how to match data file columns with table columns.

- `--compress`, `-C`

  Compress all information sent between the client and the server if both support compression.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical *`debug_options`* string is `d:t:o,file_name`. The default is `d:t:o`.

- `--debug-check`

  Print some debugging information when the program exits.

- `--debug-info`

  Print debugging information and memory and CPU usage statistics when the program exits.

- `--default-character-set=charset_name`

  Use *`charset_name`* as the default character set. See Section 10.5, “Character Set Configuration”.

- `--default-auth=plugin`

  A hint about the client-side authentication plugin to use. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-group-suffix=str`

Read not only the usual option groups, but also groups with the usual names and a suffix of *str*. For example, mysqlimport normally reads the [client] and [mysqlimport] groups. If the --defaults-group-suffix=_other option is given, mysqlimport also reads the [client_other] and [mysqlimport_other] groups.

- --delete, -D

  Empty the table before importing the text file.

- --enable-cleartext-plugin

  Enable the mysql_clear_password cleartext authentication plugin. (See Section 6.5.1.3, "Client-Side Cleartext Pluggable Authentication".)

  This option was added in MySQL 5.5.47.

- --fields-terminated-by=..., --fields-enclosed-by=..., --fields-optionally-enclosed-by=..., --fields-escaped-by=...

  These options have the same meaning as the corresponding clauses for LOAD DATA INFILE. See Section 13.2.6, "LOAD DATA INFILE Syntax".

- --force, -f

  Ignore errors. For example, if a table for a text file does not exist, continue processing any remaining files. Without --force, mysqlimport exits if a table does not exist.

- --host=*host_name*, -h *host_name*

  Import data to the MySQL server on the given host. The default host is localhost.

- --ignore, -i

  See the description for the --replace option.

- --ignore-lines=*N*

  Ignore the first *N* lines of the data file.

- --lines-terminated-by=...

  This option has the same meaning as the corresponding clause for LOAD DATA INFILE. For example, to import Windows files that have lines terminated with carriage return/linefeed pairs, use --lines-terminated-by="\r\n". (You might have to double the backslashes, depending on the escaping conventions of your command interpreter.) See Section 13.2.6, "LOAD DATA INFILE Syntax".

- --local, -L

  By default, files are read by the server on the server host. With this option, mysqlimport reads input files locally on the client host. Enabling local data loading also requires that the server permits it; see Section 6.1.6, "Security Issues with LOAD DATA LOCAL"

- --lock-tables, -l

  Lock *all* tables for writing before processing any text files. This ensures that all tables are synchronized on the server.

- --low-priority

  Use LOW_PRIORITY when loading the table. This affects only storage engines that use only table-level locking (such as MyISAM, MEMORY, and MERGE).

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysqlimport` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--plugin-dir=dir_name`

  The directory in which to look for plugins. Specify this option if the `--default-auth` option is used to specify an authentication plugin but `mysqlimport` does not find it. See Section 6.3.6, "Pluggable Authentication".

  This option was added in MySQL 5.5.10.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, "Connecting to the MySQL Server".

- `--replace`, `-r`

  The `--replace` and `--ignore` options control handling of input rows that duplicate existing rows on unique key values. If you specify `--replace`, new rows replace existing rows that have the same unique key value. If you specify `--ignore`, input rows that duplicate an existing row on a unique key value are skipped. If you do not specify either option, an error occurs when a duplicate key value is found, and the rest of the text file is ignored.

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--silent`, `-s`

  Silent mode. Produce output only when errors occur.

- `--socket=path`, `-S path`

For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- `--user=user_name`, `-u user_name`

  The MySQL user name to use when connecting to the server.

- `--use-threads=N`

  Load files in parallel using `N` threads.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does.

- `--version`, `-V`

  Display version information and exit.

Here is a sample session that demonstrates use of `mysqlimport`:

```
shell> mysql -e 'CREATE TABLE imptest(id INT, n VARCHAR(30))' test
shell> ed
a
100     Max Sydow
101     Count Dracula
.
w imptest.txt
32
q
shell> od -c imptest.txt
0000000   1   0   0  \t   M   a   x       S   y   d   o   w  \n   1   0
0000020   1  \t   C   o   u   n   t       D   r   a   c   u   l   a  \n
0000040
shell> mysqlimport --local test imptest.txt
test.imptest: Records: 2  Deleted: 0  Skipped: 0  Warnings: 0
shell> mysql -e 'SELECT * FROM imptest' test
+------+--------------+
| id   | n            |
+------+--------------+
|  100 | Max Sydow    |
|  101 | Count Dracula |
+------+--------------+
```

4.5.6 `mysqlshow` — Display Database, Table, and Column Information

The `mysqlshow` client can be used to quickly see which databases exist, their tables, or a table's columns or indexes.

`mysqlshow` provides a command-line interface to several SQL `SHOW` statements. See Section 13.7.5, “SHOW Syntax”. The same information can be obtained by using those statements directly. For example, you can issue them from the `mysql` client program.

Invoke `mysqlshow` like this:

```
shell> mysqlshow [options] [db_name [tbl_name [col_name]]]
```

- If no database is given, a list of database names is shown.

- If no table is given, all matching tables in the database are shown.
- If no column is given, all matching columns and column types in the table are shown.

The output displays only the names of those databases, tables, or columns for which you have some privileges.

If the last argument contains shell or SQL wildcard characters (*, ?, %, or _), only those names that are matched by the wildcard are shown. If a database name contains any underscores, those should be escaped with a backslash (some Unix shells require two) to get a list of the proper tables or columns. * and ? characters are converted into SQL % and _ wildcard characters. This might cause some confusion when you try to display the columns for a table with a _ in the name, because in this case, mysqlshow shows you only the table names that match the pattern. This is easily fixed by adding an extra % last on the command line as a separate argument.

mysqlshow supports the following options, which can be specified on the command line or in the [mysqlshow] and [client] groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.13 mysqlshow Options

Format	Description	Introduced
--bind-address	Use specified network interface to connect to MySQL Server	5.5.8
--compress	Compress all information sent between client and server	
--count	Show the number of rows per table	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	
--debug-info	Print debugging information, memory, and CPU statistics when program exits	
--default-auth	Authentication plugin to use	5.5.10
--default-character-set	Specify default character set	
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--enable-cleartext-plugin	Enable cleartext authentication plugin	5.5.47
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--keys	Show table indexes	
--no-defaults	Read no option files	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--plugin-dir	Directory where plugins are installed	5.5.10
--port	TCP/IP port number for connection	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--show-table-type	Show a column indicating the table type	
--socket	For connections to localhost, the Unix socket file to use	

Format	Description	Introduced
--ssl	Enable encrypted connection	
--ssl-ca	File that contains list of trusted SSL Certificate Authorities	
--ssl-capath	Directory that contains trusted SSL Certificate Authority certificate files	
--ssl-cert	File that contains X509 certificate	
--ssl-cipher	List of permitted ciphers for connection encryption	
--ssl-key	File that contains X509 key	
--ssl-mode	Security state of connection to server	5.5.49
--ssl-verify-server-cert	Verify host name against server certificate Common Name identity	
--status	Display extra information about each table	
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	

- `--help`, `-?`

  Display a help message and exit.

- `--bind-address=`*`ip_address`*

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported only in the version of `mysqlshow` that is supplied with NDB Cluster. It is not available in standard MySQL Server 5.5 releases.

- `--character-sets-dir=`*`dir_name`*

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- `--compress`, `-C`

  Compress all information sent between the client and the server if both support compression.

- `--count`

  Show the number of rows per table. This can be slow for non-`MyISAM` tables.

- `--debug[=`*`debug_options`*`]`, `-# [`*`debug_options`*`]`

  Write a debugging log. A typical *`debug_options`* string is `d:t:o,`*`file_name`*. The default is `d:t:o`.

- `--debug-check`

  Print some debugging information when the program exits.

- `--debug-info`

  Print debugging information and memory and CPU usage statistics when the program exits.

- `--default-character-set=`*`charset_name`*

  Use *`charset_name`* as the default character set. See Section 10.5, “Character Set Configuration”.

- `--default-auth=plugin`

  A hint about the client-side authentication plugin to use. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysqlshow` normally reads the `[client]` and `[mysqlshow]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqlshow` also reads the `[client_other]` and `[mysqlshow_other]` groups.

- `--enable-cleartext-plugin`

  Enable the `mysql_clear_password` cleartext authentication plugin. (See Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”.)

  This option was added in MySQL 5.5.47.

- `--host=host_name`, `-h host_name`

  Connect to the MySQL server on the given host.

- `--keys`, `-k`

  Show table indexes.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysqlshow` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--plugin-dir=dir_name`

The directory in which to look for plugins. Specify this option if the `--default-auth` option is used to specify an authentication plugin but `mysqlshow` does not find it. See Section 6.3.6, “Pluggable Authentication”.

This option was added in MySQL 5.5.10.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use for the connection.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, “Connecting to the MySQL Server”.

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--show-table-type`, `-t`

  Show a column indicating the table type, as in `SHOW FULL TABLES`. The type is `BASE TABLE` or `VIEW`.

- `--socket=path`, `-S path`

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- `--status`, `-i`

  Display extra information about each table.

- `--user=user_name`, `-u user_name`

  The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does. This option can be used multiple times to increase the amount of information.

- `--version`, `-V`

  Display version information and exit.

4.5.7 `mysqlslap` — Load Emulation Client

mysqlslap is a diagnostic program designed to emulate client load for a MySQL server and to report the timing of each stage. It works as if multiple clients are accessing the server.

Invoke mysqlslap like this:

```
shell> mysqlslap [options]
```

Some options such as --create or --query enable you to specify a string containing an SQL statement or a file containing statements. If you specify a file, by default it must contain one statement per line. (That is, the implicit statement delimiter is the newline character.) Use the --delimiter option to specify a different delimiter, which enables you to specify statements that span multiple lines or place multiple statements on a single line. You cannot include comments in a file; mysqlslap does not understand them.

mysqlslap runs in three stages:

1. Create schema, table, and optionally any stored programs or data to use for the test. This stage uses a single client connection.
2. Run the load test. This stage can use many client connections.
3. Clean up (disconnect, drop table if specified). This stage uses a single client connection.

Examples:

Supply your own create and query SQL statements, with 50 clients querying and 200 selects for each (enter the command on a single line):

```
mysqlslap --delimiter=";"
  --create="CREATE TABLE a (b int);INSERT INTO a VALUES (23)"
  --query="SELECT * FROM a" --concurrency=50 --iterations=200
```

Let mysqlslap build the query SQL statement with a table of two INT columns and three VARCHAR columns. Use five clients querying 20 times each. Do not create the table or insert the data (that is, use the previous test's schema and data):

```
mysqlslap --concurrency=5 --iterations=20
  --number-int-cols=2 --number-char-cols=3
  --auto-generate-sql
```

Tell the program to load the create, insert, and query SQL statements from the specified files, where the create.sql file has multiple table creation statements delimited by ';' and multiple insert statements delimited by ';'. The --query file will have multiple queries delimited by ';'. Run all the load statements, then run all the queries in the query file with five clients (five times each):

```
mysqlslap --concurrency=5
  --iterations=5 --query=query.sql --create=create.sql
  --delimiter=";"
```

mysqlslap supports the following options, which can be specified on the command line or in the [mysqlslap] and [client] groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.14 mysqlslap Options

Format	Description	Introduced
--auto-generate-sql	Generate SQL statements automatically when they are not supplied in files or using command options	
--auto-generate-sql-add-autoincrement	Add AUTO_INCREMENT column to automatically generated tables	

Format	Description	Introduced
--auto-generate-sql-execute-number	Specify how many queries to generate automatically	
--auto-generate-sql-guid-primary	Add a GUID-based primary key to automatically generated tables	
--auto-generate-sql-load-type	Specify the test load type	
--auto-generate-sql-secondary-indexes	Specify how many secondary indexes to add to automatically generated tables	
--auto-generate-sql-unique-query-number	How many different queries to generate for automatic tests.	
--auto-generate-sql-unique-write-number	How many different queries to generate for --auto-generate-sql-write-number	
--auto-generate-sql-write-number	How many row inserts to perform on each thread	
--commit	How many statements to execute before committing.	
--compress	Compress all information sent between client and server	
--concurrency	Number of clients to simulate when issuing the SELECT statement	
--create	File or string containing the statement to use for creating the table	
--create-schema	Schema in which to run the tests	
--csv	Generate output in comma-separated values format	
--debug	Write debugging log	
--debug-check	Print debugging information when program exits	
--debug-info	Print debugging information, memory, and CPU statistics when program exits	
--default-auth	Authentication plugin to use	5.5.10
--defaults-extra-file	Read named option file in addition to usual option files	
--defaults-file	Read only named option file	
--defaults-group-suffix	Option group suffix value	
--delimiter	Delimiter to use in SQL statements	
--detach	Detach (close and reopen) each connection after each N statements	
--enable-cleartext-plugin	Enable cleartext authentication plugin	5.5.27
--engine	Storage engine to use for creating the table	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--iterations	Number of times to run the tests	
--no-defaults	Read no option files	
--no-drop	Do not drop any schema created during the test run	5.5.12
--number-char-cols	Number of VARCHAR columns to use if --auto-generate-sql is specified	
--number-int-cols	Number of INT columns to use if --auto-generate-sql is specified	
--number-of-queries	Limit each client to approximately this number of queries	

Format	Description	Introduced
--only-print	Do not connect to databases. mysqlslap only prints what it would have done	
--password	Password to use when connecting to server	
--pipe	On Windows, connect to server using named pipe	
--plugin-dir	Directory where plugins are installed	5.5.10
--port	TCP/IP port number for connection	
--post-query	File or string containing the statement to execute after the tests have completed	
--post-system	String to execute using system() after the tests have completed	
--pre-query	File or string containing the statement to execute before running the tests	
--pre-system	String to execute using system() before running the tests	
--print-defaults	Print default options	
--protocol	Connection protocol to use	
--query	File or string containing the SELECT statement to use for retrieving data	
--shared-memory-base-name	The name of shared memory to use for shared-memory connections	
--silent	Silent mode	
--socket	For connections to localhost, the Unix socket file to use	
--ssl	Enable encrypted connection	
--ssl-ca	File that contains list of trusted SSL Certificate Authorities	
--ssl-capath	Directory that contains trusted SSL Certificate Authority certificate files	
--ssl-cert	File that contains X509 certificate	
--ssl-cipher	List of permitted ciphers for connection encryption	
--ssl-key	File that contains X509 key	
--ssl-mode	Security state of connection to server	5.5.49
--ssl-verify-server-cert	Verify host name against server certificate Common Name identity	
--user	MySQL user name to use when connecting to server	
--verbose	Verbose mode	
--version	Display version information and exit	

- `--help`, `-?`

  Display a help message and exit.

- `--auto-generate-sql`, `-a`

  Generate SQL statements automatically when they are not supplied in files or using command options.

- `--auto-generate-sql-add-autoincrement`

  Add an `AUTO_INCREMENT` column to automatically generated tables.

- `--auto-generate-sql-execute-number=N`

  Specify how many queries to generate automatically.

- `--auto-generate-sql-guid-primary`

  Add a GUID-based primary key to automatically generated tables.

- `--auto-generate-sql-load-type=type`

  Specify the test load type. The permissible values are `read` (scan tables), `write` (insert into tables), `key` (read primary keys), `update` (update primary keys), or `mixed` (half inserts, half scanning selects). The default is `mixed`.

- `--auto-generate-sql-secondary-indexes=N`

  Specify how many secondary indexes to add to automatically generated tables. By default, none are added.

- `--auto-generate-sql-unique-query-number=N`

  How many different queries to generate for automatic tests. For example, if you run a `key` test that performs 1000 selects, you can use this option with a value of 1000 to run 1000 unique queries, or with a value of 50 to perform 50 different selects. The default is 10.

- `--auto-generate-sql-unique-write-number=N`

  How many different queries to generate for `--auto-generate-sql-write-number`. The default is 10.

- `--auto-generate-sql-write-number=N`

  How many row inserts to perform. The default is 100.

- `--commit=N`

  How many statements to execute before committing. The default is 0 (no commits are done).

- `--compress`, `-C`

  Compress all information sent between the client and the server if both support compression.

- `--concurrency=N`, `-c N`

  The number of parallel clients to simulate.

- `--create=value`

  The file or string containing the statement to use for creating the table.

- `--create-schema=value`

  The schema in which to run the tests.

  Note

  If the `--auto-generate-sql` option is also given, `mysqlslap` drops the schema at the end of the test run. To avoid this, use the `--no-drop` option as well.

- `--csv[=file_name]`

  Generate output in comma-separated values format. The output goes to the named file, or to the standard output if no file is given.

- `--debug[=debug_options]`, `-# [debug_options]`

  Write a debugging log. A typical *`debug_options`* string is `d:t:o,file_name`. The default is `d:t:o,/tmp/mysqlslap.trace`.

- `--debug-check`

  Print some debugging information when the program exits.

- `--debug-info`, `-T`

  Print debugging information and memory and CPU usage statistics when the program exits.

- `--default-auth=plugin`

  A hint about the client-side authentication plugin to use. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- `--defaults-extra-file=file_name`

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysqlslap` normally reads the `[client]` and `[mysqlslap]` groups. If the `--defaults-group-suffix=_other` option is given, `mysqlslap` also reads the `[client_other]` and `[mysqlslap_other]` groups.

- `--delimiter=str`, `-F str`

  The delimiter to use in SQL statements supplied in files or using command options.

- `--detach=N`

  Detach (close and reopen) each connection after each *`N`* statements. The default is 0 (connections are not detached).

- `--enable-cleartext-plugin`

  Enable the `mysql_clear_password` cleartext authentication plugin. (See Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”.) This option was added in MySQL 5.5.27.

- `--engine=engine_name`, `-e engine_name`

  The storage engine to use for creating tables.

- `--host=host_name`, `-h host_name`

  Connect to the MySQL server on the given host.

- `--iterations=N`, `-i N`

The number of times to run the tests.

- `--no-drop`

  Prevent `mysqlslap` from dropping any schema it creates during the test run. This option was added in MySQL 5.5.12.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--number-char-cols=N`, `-x N`

  The number of `VARCHAR` columns to use if `--auto-generate-sql` is specified.

- `--number-int-cols=N`, `-y N`

  The number of `INT` columns to use if `--auto-generate-sql` is specified.

- `--number-of-queries=N`

  Limit each client to approximately this many queries. Query counting takes into account the statement delimiter. For example, if you invoke `mysqlslap` as follows, the `;` delimiter is recognized so that each instance of the query string counts as two queries. As a result, 5 rows (not 10) are inserted.

  ```
  shell> mysqlslap --delimiter=";" --number-of-queries=10
           --query="use test;insert into t values(null)"
  ```

- `--only-print`

  Do not connect to databases. `mysqlslap` only prints what it would have done.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you use the short option form (`-p`), you *cannot* have a space between the option and the password. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysqlslap` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line.

- `--pipe`, `-W`

  On Windows, connect to the server using a named pipe. This option applies only if the server supports named-pipe connections.

- `--plugin-dir=dir_name`

  The directory in which to look for plugins. Specify this option if the `--default-auth` option is used to specify an authentication plugin but `mysqlslap` does not find it. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- `--port=port_num`, `-P port_num`

  The TCP/IP port number to use for the connection.

- `--post-query=value`

The file or string containing the statement to execute after the tests have completed. This execution is not counted for timing purposes.

- `--post-system=str`

  The string to execute using `system()` after the tests have completed. This execution is not counted for timing purposes.

- `--pre-query=value`

  The file or string containing the statement to execute before running the tests. This execution is not counted for timing purposes.

- `--pre-system=str`

  The string to execute using `system()` before running the tests. This execution is not counted for timing purposes.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, “Connecting to the MySQL Server”.

- `--query=value`, `-q value`

  The file or string containing the `SELECT` statement to use for retrieving data.

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. This option applies only if the server supports shared-memory connections.

- `--silent`, `-s`

  Silent mode. No output.

- `--socket=path`, `-S path`

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

  Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- `--user=user_name`, `-u user_name`

  The MySQL user name to use when connecting to the server.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does. This option can be used multiple times to increase the amount of information.

- `--version`, `-V`

Display version information and exit.

4.6 MySQL Administrative and Utility Programs

This section describes administrative programs and programs that perform miscellaneous utility operations.

4.6.1 `innochecksum` — Offline InnoDB File Checksum Utility

`innochecksum` prints checksums for `InnoDB` files. This tool reads an `InnoDB` tablespace file, calculates the checksum for each page, compares the calculated checksum to the stored checksum, and reports mismatches, which indicate damaged pages. It was originally developed to speed up verifying the integrity of tablespace files after power outages but can also be used after file copies. Because checksum mismatches cause `InnoDB` to deliberately shut down a running server, it may be preferable to use this tool rather than waiting for an in-production server to encounter the damaged pages. `innochecksum` supports files up to 2GB in size.

`innochecksum` does not support tablespaces that contain compressed pages.

`innochecksum` cannot be used on tablespace files that the server already has open. For such files, you should use `CHECK TABLE` to check tables within the tablespace.

If checksum mismatches are found, you would normally restore the tablespace from backup or start the server and attempt to use `mysqldump` to make a backup of the tables within the tablespace.

Invoke `innochecksum` like this:

```
shell> innochecksum [options] file_name
```

`innochecksum` supports the following options. For options that refer to page numbers, the numbers are zero-based.

- `-c`

  Print a count of the number of pages in the file.

- `-d`

  Debug mode; prints checksums for each page.

- `-e num`

  End at this page number.

- `-p num`

  Check only this page number.

- `-s num`

  Start at this page number.

- `-v`

  Verbose mode; print a progress indicator every five seconds.

4.6.2 `myisam_ftdump` — Display Full-Text Index information

`myisam_ftdump` displays information about `FULLTEXT` indexes in `MyISAM` tables. It reads the `MyISAM` index file directly, so it must be run on the server host where the table is located. Before using `myisam_ftdump`, be sure to issue a `FLUSH TABLES` statement first if the server is running.

myisam_ftdump scans and dumps the entire index, which is not particularly fast. On the other hand, the distribution of words changes infrequently, so it need not be run often.

Invoke myisam_ftdump like this:

```
shell> myisam_ftdump [options] tbl_name index_num
```

The *tbl_name* argument should be the name of a MyISAM table. You can also specify a table by naming its index file (the file with the .MYI suffix). If you do not invoke myisam_ftdump in the directory where the table files are located, the table or index file name must be preceded by the path name to the table's database directory. Index numbers begin with 0.

Example: Suppose that the test database contains a table named mytexttable that has the following definition:

```
CREATE TABLE mytexttable
(
  id   INT NOT NULL,
  txt  TEXT NOT NULL,
  PRIMARY KEY (id),
  FULLTEXT (txt)
) ENGINE=MyISAM;
```

The index on id is index 0 and the FULLTEXT index on txt is index 1. If your working directory is the test database directory, invoke myisam_ftdump as follows:

```
shell> myisam_ftdump mytexttable 1
```

If the path name to the test database directory is /usr/local/mysql/data/test, you can also specify the table name argument using that path name. This is useful if you do not invoke myisam_ftdump in the database directory:

```
shell> myisam_ftdump /usr/local/mysql/data/test/mytexttable 1
```

You can use myisam_ftdump to generate a list of index entries in order of frequency of occurrence like this on Unix-like systems:

```
shell> myisam_ftdump -c mytexttable 1 | sort -r
```

On Windows, use:

```
shell> myisam_ftdump -c mytexttable 1 | sort /R
```

myisam_ftdump supports the following options:

- --help, -h -?

  Display a help message and exit.

- --count, -c

  Calculate per-word statistics (counts and global weights).

- --dump, -d

  Dump the index, including data offsets and word weights.

- --length, -l

  Report the length distribution.

- --stats, -s

Report global index statistics. This is the default operation if no other operation is specified.

- `--verbose`, `-v`

  Verbose mode. Print more output about what the program does.

4.6.3 myisamchk — MyISAM Table-Maintenance Utility

The `myisamchk` utility gets information about your database tables or checks, repairs, or optimizes them. `myisamchk` works with `MyISAM` tables (tables that have `.MYD` and `.MYI` files for storing data and indexes).

You can also use the `CHECK TABLE` and `REPAIR TABLE` statements to check and repair `MyISAM` tables. See Section 13.7.2.2, “CHECK TABLE Syntax”, and Section 13.7.2.5, “REPAIR TABLE Syntax”.

The use of `myisamchk` with partitioned tables is not supported.

Caution

It is best to make a backup of a table before performing a table repair operation; under some circumstances the operation might cause data loss. Possible causes include but are not limited to file system errors.

Invoke `myisamchk` like this:

```
shell> myisamchk [options] tbl_name ...
```

The *`options`* specify what you want `myisamchk` to do. They are described in the following sections. You can also get a list of options by invoking `myisamchk --help`.

With no options, `myisamchk` simply checks your table as the default operation. To get more information or to tell `myisamchk` to take corrective action, specify options as described in the following discussion.

`tbl_name` is the database table you want to check or repair. If you run `myisamchk` somewhere other than in the database directory, you must specify the path to the database directory, because `myisamchk` has no idea where the database is located. In fact, `myisamchk` does not actually care whether the files you are working on are located in a database directory. You can copy the files that correspond to a database table into some other location and perform recovery operations on them there.

You can name several tables on the `myisamchk` command line if you wish. You can also specify a table by naming its index file (the file with the `.MYI` suffix). This enables you to specify all tables in a directory by using the pattern `*.MYI`. For example, if you are in a database directory, you can check all the `MyISAM` tables in that directory like this:

```
shell> myisamchk *.MYI
```

If you are not in the database directory, you can check all the tables there by specifying the path to the directory:

```
shell> myisamchk /path/to/database_dir/*.MYI
```

You can even check all tables in all databases by specifying a wildcard with the path to the MySQL data directory:

```
shell> myisamchk /path/to/datadir/*/*.MYI
```

The recommended way to quickly check all `MyISAM` tables is:

```
shell> myisamchk --silent --fast /path/to/datadir/*/*.MYI
```

If you want to check all MyISAM tables and repair any that are corrupted, you can use the following command:

```
shell> myisamchk --silent --force --fast --update-state \
          --key_buffer_size=64M --myisam_sort_buffer_size=64M \
          --read_buffer_size=1M --write_buffer_size=1M \
          /path/to/datadir/*/*.MYI
```

This command assumes that you have more than 64MB free. For more information about memory allocation with myisamchk, see Section 4.6.3.6, “myisamchk Memory Usage”.

For additional information about using myisamchk, see Section 7.6, “MyISAM Table Maintenance and Crash Recovery”.

Important

You must ensure that no other program is using the tables while you are running myisamchk. The most effective means of doing so is to shut down the MySQL server while running myisamchk, or to lock all tables that myisamchk is being used on.

Otherwise, when you run myisamchk, it may display the following error message:

```
warning: clients are using or haven't closed the table properly
```

This means that you are trying to check a table that has been updated by another program (such as the mysqld server) that hasn't yet closed the file or that has died without closing the file properly, which can sometimes lead to the corruption of one or more MyISAM tables.

If mysqld is running, you must force it to flush any table modifications that are still buffered in memory by using FLUSH TABLES. You should then ensure that no one is using the tables while you are running myisamchk

However, the easiest way to avoid this problem is to use CHECK TABLE instead of myisamchk to check tables. See Section 13.7.2.2, “CHECK TABLE Syntax”.

myisamchk supports the following options, which can be specified on the command line or in the [myisamchk] group of an option file. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.15 myisamchk Options

Format	Description	Introduced	Deprecated
--analyze	Analyze the distribution of key values		
--backup	Make a backup of the .MYD file as file_name-time.BAK		
--block-search	Find the record that a block at the given offset belongs to		
--check	Check the table for errors		
--check-only-changed	Check only tables that have changed since the last check		
--correct-checksum	Correct the checksum information for the table		
--data-file-length	Maximum length of the data file (when re-creating data file when it is full)		

Format	Description	Introduced	Deprecated
--debug	Write debugging log		
--decode_bits	Decode_bits		
--defaults-extra-file	Read named option file in addition to usual option files		
--defaults-file	Read only named option file		
--defaults-group-suffix	Option group suffix value		
--description	Print some descriptive information about the table		
--extend-check	Do very thorough table check or repair that tries to recover every possible row from the data file		
--fast	Check only tables that haven't been closed properly		
--force	Do a repair operation automatically if myisamchk finds any errors in the table		
--force	Overwrite old temporary files. For use with the -r or -o option		
--ft_max_word_len	Maximum word length for FULLTEXT indexes		
--ft_min_word_len	Minimum word length for FULLTEXT indexes		
--ft_stopword_file	Use stopwords from this file instead of built-in list		
--HELP	Display help message and exit		
--help	Display help message and exit		
--information	Print informational statistics about the table that is checked		
--key_buffer_size	Size of buffer used for index blocks for MyISAM tables		
--keys-used	A bit-value that indicates which indexes to update		
--max-record-length	Skip rows larger than the given length if myisamchk cannot allocate memory to hold them		
--medium-check	Do a check that is faster than an --extend-check operation		
--myisam_block_size	Block size to be used for MyISAM index pages		
--myisam_sort_buffer_size	The buffer that is allocated when sorting the index when doing a REPAIR or when creating indexes with CREATE INDEX or ALTER TABLE	5.5.29	
--no-defaults	Read no option files		
--parallel-recover	Uses the same technique as -r and -n, but creates all the keys in parallel, using different threads (beta)		
--print-defaults	Print default options		
--quick	Achieve a faster repair by not modifying the data file.		
--read_buffer_size	Each thread that does a sequential scan allocates a buffer of this size for each table it scans		
--read-only	Do not mark the table as checked		
--recover	Do a repair that can fix almost any problem except unique keys that aren't unique		

Format	Description	Introduced	Deprecated
--safe-recover	Do a repair using an old recovery method that reads through all rows in order and updates all index trees based on the rows found		
--set-auto-increment	Force AUTO_INCREMENT numbering for new records to start at the given value		
--set-collation	Specify the collation to use for sorting table indexes		
--silent	Silent mode		
--sort_buffer_size	The buffer that is allocated when sorting the index when doing a REPAIR or when creating indexes with CREATE INDEX or ALTER TABLE		5.5.29
--sort-index	Sort the index tree blocks in high-low order		
--sort_key_blocks	sort_key_blocks		
--sort-records	Sort records according to a particular index		
--sort-recover	Force myisamchk to use sorting to resolve the keys even if the temporary files would be very large		
--stats_method	Specifies how MyISAM index statistics collection code should treat NULLs		
--tmpdir	Directory to be used for storing temporary files		
--unpack	Unpack a table that was packed with myisampack		
--update-state	Store information in the .MYI file to indicate when the table was checked and whether the table crashed		
--verbose	Verbose mode		
--version	Display version information and exit		
--write_buffer_size	Write buffer size		

4.6.3.1 myisamchk General Options

The options described in this section can be used for any type of table maintenance operation performed by `myisamchk`. The sections following this one describe options that pertain only to specific operations, such as table checking or repairing.

- `--help`, `-?`

  Display a help message and exit. Options are grouped by type of operation.

- `--HELP`, `-H`

  Display a help message and exit. Options are presented in a single list.

- `--debug=`*`debug_options`*, `-#` *`debug_options`*

  Write a debugging log. A typical *`debug_options`* string is `d:t:o,`*`file_name`*. The default is `d:t:o,/tmp/myisamchk.trace`.

- `--defaults-extra-file=`*`file_name`*

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-file=file_name`

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *`file_name`* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `myisamchk` normally reads the `[myisamchk]` group. If the `--defaults-group-suffix=_other` option is given, `myisamchk` also reads the `[myisamchk_other]` group.

- `--no-defaults`

  Do not read any option files. If program startup fails due to reading unknown options from an option file, `--no-defaults` can be used to prevent them from being read.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--silent`, `-s`

  Silent mode. Write output only when errors occur. You can use `-s` twice (`-ss`) to make `myisamchk` very silent.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does. This can be used with `-d` and `-e`. Use `-v` multiple times (`-vv`, `-vvv`) for even more output.

- `--version`, `-V`

  Display version information and exit.

- `--wait`, `-w`

  Instead of terminating with an error if the table is locked, wait until the table is unlocked before continuing. If you are running `mysqld` with external locking disabled, the table can be locked only by another `myisamchk` command.

You can also set the following variables by using `--var_name=value` syntax:

Variable	Default Value
`decode_bits`	9
`ft_max_word_len`	version-dependent
`ft_min_word_len`	4
`ft_stopword_file`	built-in list
`key_buffer_size`	523264
`myisam_block_size`	1024
`myisam_sort_key_blocks`	16
`read_buffer_size`	262136
`sort_buffer_size`	2097144
`sort_key_blocks`	16
`stats_method`	nulls_unequal
`write_buffer_size`	262136

The possible myisamchk variables and their default values can be examined with myisamchk --help:

sort_buffer_size is used when the keys are repaired by sorting keys, which is the normal case when you use --recover. As of MySQL 5.5.29, myisam_sort_buffer_size is available as an alternative name to sort_buffer_size. myisam_sort_buffer_size is preferable to sort_buffer_size because its name corresponds to the myisam_sort_buffer_size server system variable that has a similar meaning. sort_buffer_size should be considered deprecated.

key_buffer_size is used when you are checking the table with --extend-check or when the keys are repaired by inserting keys row by row into the table (like when doing normal inserts). Repairing through the key buffer is used in the following cases:

- You use --safe-recover.
- The temporary files needed to sort the keys would be more than twice as big as when creating the key file directly. This is often the case when you have large key values for CHAR, VARCHAR, or TEXT columns, because the sort operation needs to store the complete key values as it proceeds. If you have lots of temporary space and you can force myisamchk to repair by sorting, you can use the --sort-recover option.

Repairing through the key buffer takes much less disk space than using sorting, but is also much slower.

If you want a faster repair, set the key_buffer_size and myisam_sort_buffer_size variables to about 25% of your available memory. You can set both variables to large values, because only one of them is used at a time.

myisam_block_size is the size used for index blocks.

stats_method influences how NULL values are treated for index statistics collection when the --analyze option is given. It acts like the myisam_stats_method system variable. For more information, see the description of myisam_stats_method in Section 5.1.5, “Server System Variables”, and Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”.

ft_min_word_len and ft_max_word_len indicate the minimum and maximum word length for FULLTEXT indexes. ft_stopword_file names the stopword file. These need to be set under the following circumstances.

If you use myisamchk to perform an operation that modifies table indexes (such as repair or analyze), the FULLTEXT indexes are rebuilt using the default full-text parameter values for minimum and maximum word length and the stopword file unless you specify otherwise. This can result in queries failing.

The problem occurs because these parameters are known only by the server. They are not stored in MyISAM index files. To avoid the problem if you have modified the minimum or maximum word length or the stopword file in the server, specify the same ft_min_word_len, ft_max_word_len, and ft_stopword_file values to myisamchk that you use for mysqld. For example, if you have set the minimum word length to 3, you can repair a table with myisamchk like this:

```
shell> myisamchk --recover --ft_min_word_len=3 tbl_name.MYI
```

To ensure that myisamchk and the server use the same values for full-text parameters, you can place each one in both the [mysqld] and [myisamchk] sections of an option file:

```
[mysqld]
ft_min_word_len=3

[myisamchk]
```

```
ft_min_word_len=3
```

An alternative to using myisamchk is to use the REPAIR TABLE, ANALYZE TABLE, OPTIMIZE TABLE, or ALTER TABLE. These statements are performed by the server, which knows the proper full-text parameter values to use.

4.6.3.2 myisamchk Check Options

myisamchk supports the following options for table checking operations:

- --check, -c

  Check the table for errors. This is the default operation if you specify no option that selects an operation type explicitly.

- --check-only-changed, -C

  Check only tables that have changed since the last check.

- --extend-check, -e

  Check the table very thoroughly. This is quite slow if the table has many indexes. This option should only be used in extreme cases. Normally, myisamchk or myisamchk --medium-check should be able to determine whether there are any errors in the table.

  If you are using --extend-check and have plenty of memory, setting the key_buffer_size variable to a large value helps the repair operation run faster.

  See also the description of this option under table repair options.

  For a description of the output format, see Section 4.6.3.5, “Obtaining Table Information with myisamchk”.

- --fast, -F

  Check only tables that haven't been closed properly.

- --force, -f

  Do a repair operation automatically if myisamchk finds any errors in the table. The repair type is the same as that specified with the --recover or -r option.

- --information, -i

  Print informational statistics about the table that is checked.

- --medium-check, -m

  Do a check that is faster than an --extend-check operation. This finds only 99.99% of all errors, which should be good enough in most cases.

- --read-only, -T

  Do not mark the table as checked. This is useful if you use myisamchk to check a table that is in use by some other application that does not use locking, such as mysqld when run with external locking disabled.

- --update-state, -U

  Store information in the .MYI file to indicate when the table was checked and whether the table crashed. This should be used to get full benefit of the --check-only-changed option, but you shouldn't use this option if the mysqld server is using the table and you are running it with external locking disabled.

4.6.3.3 myisamchk Repair Options

myisamchk supports the following options for table repair operations (operations performed when an option such as --recover or --safe-recover is given):

- --backup, -B

  Make a backup of the .MYD file as *file_name-time*.BAK

- --character-sets-dir=*dir_name*

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- --correct-checksum

  Correct the checksum information for the table.

- --data-file-length=*len*, -D *len*

  The maximum length of the data file (when re-creating data file when it is “full”).

- --extend-check, -e

  Do a repair that tries to recover every possible row from the data file. Normally, this also finds a lot of garbage rows. Do not use this option unless you are desperate.

  See also the description of this option under table checking options.

  For a description of the output format, see Section 4.6.3.5, “Obtaining Table Information with myisamchk”.

- --force, -f

  Overwrite old intermediate files (files with names like *tbl_name*.TMD) instead of aborting.

- --keys-used=*val*, -k *val*

  For myisamchk, the option value is a bit value that indicates which indexes to update. Each binary bit of the option value corresponds to a table index, where the first index is bit 0. An option value of 0 disables updates to all indexes, which can be used to get faster inserts. Deactivated indexes can be reactivated by using myisamchk -r.

- --no-symlinks, -l

  Do not follow symbolic links. Normally myisamchk repairs the table that a symlink points to. This option does not exist as of MySQL 4.0 because versions from 4.0 on do not remove symlinks during repair operations.

- --max-record-length=*len*

  Skip rows larger than the given length if myisamchk cannot allocate memory to hold them.

- --parallel-recover, -p

  Use the same technique as -r and -n, but create all the keys in parallel, using different threads. *This is beta-quality code. Use at your own risk!*

- --quick, -q

  Achieve a faster repair by modifying only the index file, not the data file. You can specify this option twice to force myisamchk to modify the original data file in case of duplicate keys.

- --recover, -r

Do a repair that can fix almost any problem except unique keys that are not unique (which is an extremely unlikely error with MyISAM tables). If you want to recover a table, this is the option to try first. You should try --safe-recover only if myisamchk reports that the table cannot be recovered using --recover. (In the unlikely case that --recover fails, the data file remains intact.)

If you have lots of memory, you should increase the value of myisam_sort_buffer_size.

- --safe-recover, -o

  Do a repair using an old recovery method that reads through all rows in order and updates all index trees based on the rows found. This is an order of magnitude slower than --recover, but can handle a couple of very unlikely cases that --recover cannot. This recovery method also uses much less disk space than --recover. Normally, you should repair first using --recover, and then with --safe-recover only if --recover fails.

  If you have lots of memory, you should increase the value of key_buffer_size.

- --set-collation=*name*

  Specify the collation to use for sorting table indexes. The character set name is implied by the first part of the collation name.

- --sort-recover, -n

  Force myisamchk to use sorting to resolve the keys even if the temporary files would be very large.

- --tmpdir=*dir_name*, -t *dir_name*

  The path of the directory to be used for storing temporary files. If this is not set, myisamchk uses the value of the TMPDIR environment variable. --tmpdir can be set to a list of directory paths that are used successively in round-robin fashion for creating temporary files. The separator character between directory names is the colon (:) on Unix and the semicolon (;) on Windows.

- --unpack, -u

  Unpack a table that was packed with myisampack.

4.6.3.4 Other myisamchk Options

myisamchk supports the following options for actions other than table checks and repairs:

- --analyze, -a

  Analyze the distribution of key values. This improves join performance by enabling the join optimizer to better choose the order in which to join the tables and which indexes it should use. To obtain information about the key distribution, use a myisamchk --description --verbose *tbl_name* command or the SHOW INDEX FROM *tbl_name* statement.

- --block-search=*offset*, -b *offset*

  Find the record that a block at the given offset belongs to.

- --description, -d

  Print some descriptive information about the table. Specifying the --verbose option once or twice produces additional information. See Section 4.6.3.5, “Obtaining Table Information with myisamchk”.

- --set-auto-increment[=*value*], -A[*value*]

  Force AUTO_INCREMENT numbering for new records to start at the given value (or higher, if there are existing records with AUTO_INCREMENT values this large). If *value* is not specified,

AUTO_INCREMENT numbers for new records begin with the largest value currently in the table, plus one.

- --sort-index, -S

  Sort the index tree blocks in high-low order. This optimizes seeks and makes table scans that use indexes faster.

- --sort-records=N, -R N

  Sort records according to a particular index. This makes your data much more localized and may speed up range-based SELECT and ORDER BY operations that use this index. (The first time you use this option to sort a table, it may be very slow.) To determine a table's index numbers, use SHOW INDEX, which displays a table's indexes in the same order that myisamchk sees them. Indexes are numbered beginning with 1.

  If keys are not packed (PACK_KEYS=0), they have the same length, so when myisamchk sorts and moves records, it just overwrites record offsets in the index. If keys are packed (PACK_KEYS=1), myisamchk must unpack key blocks first, then re-create indexes and pack the key blocks again. (In this case, re-creating indexes is faster than updating offsets for each index.)

4.6.3.5 Obtaining Table Information with myisamchk

To obtain a description of a MyISAM table or statistics about it, use the commands shown here. The output from these commands is explained later in this section.

- myisamchk -d *tbl_name*

  Runs myisamchk in "describe mode" to produce a description of your table. If you start the MySQL server with external locking disabled, myisamchk may report an error for a table that is updated while it runs. However, because myisamchk does not change the table in describe mode, there is no risk of destroying data.

- myisamchk -dv *tbl_name*

  Adding -v runs myisamchk in verbose mode so that it produces more information about the table. Adding -v a second time produces even more information.

- myisamchk -eis *tbl_name*

  Shows only the most important information from a table. This operation is slow because it must read the entire table.

- myisamchk -eiv *tbl_name*

  This is like -eis, but tells you what is being done.

The *tbl_name* argument can be either the name of a MyISAM table or the name of its index file, as described in Section 4.6.3, "myisamchk — MyISAM Table-Maintenance Utility". Multiple *tbl_name* arguments can be given.

Suppose that a table named person has the following structure. (The MAX_ROWS table option is included so that in the example output from myisamchk shown later, some values are smaller and fit the output format more easily.)

```
CREATE TABLE person
(
  id         INT NOT NULL AUTO_INCREMENT,
  last_name  VARCHAR(20) NOT NULL,
  first_name VARCHAR(20) NOT NULL,
  birth      DATE,
  death      DATE,
```

```
  PRIMARY KEY (id),
  INDEX (last_name, first_name),
  INDEX (birth)
) MAX_ROWS = 1000000 ENGINE=MYISAM;
```

Suppose also that the table has these data and index file sizes:

```
-rw-rw----  1 mysql  mysql  9347072 Aug 19 11:47 person.MYD
-rw-rw----  1 mysql  mysql  6066176 Aug 19 11:47 person.MYI
```

Example of `myisamchk -dvv` output:

```
MyISAM file:         person
Record format:       Packed
Character set:       latin1_swedish_ci (8)
File-version:        1
Creation time:       2009-08-19 16:47:41
Recover time:        2009-08-19 16:47:56
Status:              checked,analyzed,optimized keys
Auto increment key:              1  Last value:               306688
Data records:               306688  Deleted blocks:                0
Datafile parts:             306688  Deleted data:                  0
Datafile pointer (bytes):        4  Keyfile pointer (bytes):       3
Datafile length:           9347072  Keyfile length:           6066176
Max datafile length:    4294967294  Max keyfile length:   17179868159
Recordlength:                   54

table description:
Key Start Len Index   Type                 Rec/key         Root  Blocksize
1   2     4   unique  long                       1        99328       1024
2   6     20  multip. varchar prefix           512      3563520       1024
    27    20          varchar                  512
3   48    3   multip. uint24 NULL           306688      6065152       1024

Field Start Length Nullpos Nullbit Type
1     1     1
2     2     4                    no zeros
3     6     21                   varchar
4     27    21                   varchar
5     48    3      1       1     no zeros
6     51    3      1       2     no zeros
```

Explanations for the types of information `myisamchk` produces are given here. “Keyfile” refers to the index file. “Record” and “row” are synonymous, as are “field” and “column.”

The initial part of the table description contains these values:

- `MyISAM file`

  Name of the `MyISAM` (index) file.

- `Record format`

  The format used to store table rows. The preceding examples use `Fixed length`. Other possible values are `Compressed` and `Packed`. (`Packed` corresponds to what `SHOW TABLE STATUS` reports as `Dynamic`.)

- `Chararacter set`

  The table default character set.

- `File-version`

  Version of `MyISAM` format. Always 1.

- `Creation time`

When the data file was created.

- `Recover time`

  When the index/data file was last reconstructed.

- `Status`

  Table status flags. Possible values are `crashed`, `open`, `changed`, `analyzed`, `optimized keys`, and `sorted index pages`.

- `Auto increment key`, `Last value`

  The key number associated the table's `AUTO_INCREMENT` column, and the most recently generated value for this column. These fields do not appear if there is no such column.

- `Data records`

  The number of rows in the table.

- `Deleted blocks`

  How many deleted blocks still have reserved space. You can optimize your table to minimize this space. See Section 7.6.4, “MyISAM Table Optimization”.

- `Datafile parts`

  For dynamic-row format, this indicates how many data blocks there are. For an optimized table without fragmented rows, this is the same as `Data records`.

- `Deleted data`

  How many bytes of unreclaimed deleted data there are. You can optimize your table to minimize this space. See Section 7.6.4, “MyISAM Table Optimization”.

- `Datafile pointer`

  The size of the data file pointer, in bytes. It is usually 2, 3, 4, or 5 bytes. Most tables manage with 2 bytes, but this cannot be controlled from MySQL yet. For fixed tables, this is a row address. For dynamic tables, this is a byte address.

- `Keyfile pointer`

  The size of the index file pointer, in bytes. It is usually 1, 2, or 3 bytes. Most tables manage with 2 bytes, but this is calculated automatically by MySQL. It is always a block address.

- `Max datafile length`

  How long the table data file can become, in bytes.

- `Max keyfile length`

  How long the table index file can become, in bytes.

- `Recordlength`

  How much space each row takes, in bytes.

The `table description` part of the output includes a list of all keys in the table. For each key, `myisamchk` displays some low-level information:

- `Key`

This key's number. This value is shown only for the first column of the key. If this value is missing, the line corresponds to the second or later column of a multiple-column key. For the table shown in the example, there are two `table description` lines for the second index. This indicates that it is a multiple-part index with two parts.

- `Start`

  Where in the row this portion of the index starts.

- `Len`

  How long this portion of the index is. For packed numbers, this should always be the full length of the column. For strings, it may be shorter than the full length of the indexed column, because you can index a prefix of a string column. The total length of a multiple-part key is the sum of the `Len` values for all key parts.

- `Index`

  Whether a key value can exist multiple times in the index. Possible values are `unique` or `multip.` (multiple).

- `Type`

  What data type this portion of the index has. This is a `MyISAM` data type with the possible values `packed`, `stripped`, or `empty`.

- `Root`

  Address of the root index block.

- `Blocksize`

  The size of each index block. By default this is 1024, but the value may be changed at compile time when MySQL is built from source.

- `Rec/key`

  This is a statistical value used by the optimizer. It tells how many rows there are per value for this index. A unique index always has a value of 1. This may be updated after a table is loaded (or greatly changed) with `myisamchk -a`. If this is not updated at all, a default value of 30 is given.

The last part of the output provides information about each column:

- `Field`

  The column number.

- `Start`

  The byte position of the column within table rows.

- `Length`

  The length of the column in bytes.

- `Nullpos`, `Nullbit`

  For columns that can be `NULL`, `MyISAM` stores `NULL` values as a flag in a byte. Depending on how many nullable columns there are, there can be one or more bytes used for this purpose. The `Nullpos` and `Nullbit` values, if nonempty, indicate which byte and bit contains that flag indicating whether the column is `NULL`.

The position and number of bytes used to store `NULL` flags is shown in the line for field 1. This is why there are six `Field` lines for the `person` table even though it has only five columns.

- `Type`

  The data type. The value may contain any of the following descriptors:

  - `constant`

    All rows have the same value.

  - `no endspace`

    Do not store endspace.

  - `no endspace, not_always`

    Do not store endspace and do not do endspace compression for all values.

  - `no endspace, no empty`

    Do not store endspace. Do not store empty values.

  - `table-lookup`

    The column was converted to an `ENUM`.

  - `zerofill(N)`

    The most significant *`N`* bytes in the value are always 0 and are not stored.

  - `no zeros`

    Do not store zeros.

  - `always zero`

    Zero values are stored using one bit.

- `Huff tree`

  The number of the Huffman tree associated with the column.

- `Bits`

  The number of bits used in the Huffman tree.

The `Huff tree` and `Bits` fields are displayed if the table has been compressed with `myisampack`. See Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”, for an example of this information.

Example of `myisamchk -eiv` output:

```
Checking MyISAM file: person
Data records:  306688   Deleted blocks:       0
- check file-size
- check record delete-chain
No recordlinks
- check key delete-chain
block_size 1024:
- check index reference
- check data record references index: 1
Key:  1:  Keyblocks used:  98%  Packed:    0%  Max levels:  3
```

```
- check data record references index: 2
Key:  2:  Keyblocks used:  99%  Packed:   97%  Max levels:  3
- check data record references index: 3
Key:  3:  Keyblocks used:  98%  Packed:  -14%  Max levels:  3
Total:    Keyblocks used:  98%  Packed:   89%

- check records and index references
*** LOTS OF ROW NUMBERS DELETED ***

Records:            306688  M.recordlength:       25  Packed:            83%
Recordspace used:       97% Empty space:           2% Blocks/Record:   1.00
Record blocks:      306688  Delete blocks:         0
Record data:       7934464  Deleted data:          0
Lost space:         256512  Linkdata:        1156096

User time 43.08, System time 1.68
Maximum resident set size 0, Integral resident set size 0
Non-physical pagefaults 0, Physical pagefaults 0, Swaps 0
Blocks in 0 out 7, Messages in 0 out 0, Signals 0
Voluntary context switches 0, Involuntary context switches 0
Maximum memory usage: 1046926 bytes (1023k)
```

`myisamchk -eiv` output includes the following information:

- `Data records`

  The number of rows in the table.

- `Deleted blocks`

  How many deleted blocks still have reserved space. You can optimize your table to minimize this space. See Section 7.6.4, “MyISAM Table Optimization”.

- `Key`

  The key number.

- `Keyblocks used`

  What percentage of the keyblocks are used. When a table has just been reorganized with `myisamchk`, the values are very high (very near theoretical maximum).

- `Packed`

  MySQL tries to pack key values that have a common suffix. This can only be used for indexes on `CHAR` and `VARCHAR` columns. For long indexed strings that have similar leftmost parts, this can significantly reduce the space used. In the preceding example, the second key is 40 bytes long and a 97% reduction in space is achieved.

- `Max levels`

  How deep the B-tree for this key is. Large tables with long key values get high values.

- `Records`

  How many rows are in the table.

- `M.recordlength`

  The average row length. This is the exact row length for tables with fixed-length rows, because all rows have the same length.

- `Packed`

  MySQL strips spaces from the end of strings. The `Packed` value indicates the percentage of savings achieved by doing this.

- `Recordspace used`

  What percentage of the data file is used.

- `Empty space`

  What percentage of the data file is unused.

- `Blocks/Record`

  Average number of blocks per row (that is, how many links a fragmented row is composed of). This is always 1.0 for fixed-format tables. This value should stay as close to 1.0 as possible. If it gets too large, you can reorganize the table. See Section 7.6.4, “MyISAM Table Optimization”.

- `Recordblocks`

  How many blocks (links) are used. For fixed-format tables, this is the same as the number of rows.

- `Deleteblocks`

  How many blocks (links) are deleted.

- `Recorddata`

  How many bytes in the data file are used.

- `Deleted data`

  How many bytes in the data file are deleted (unused).

- `Lost space`

  If a row is updated to a shorter length, some space is lost. This is the sum of all such losses, in bytes.

- `Linkdata`

  When the dynamic table format is used, row fragments are linked with pointers (4 to 7 bytes each). `Linkdata` is the sum of the amount of storage used by all such pointers.

4.6.3.6 myisamchk Memory Usage

Memory allocation is important when you run `myisamchk`. `myisamchk` uses no more memory than its memory-related variables are set to. If you are going to use `myisamchk` on very large tables, you should first decide how much memory you want it to use. The default is to use only about 3MB to perform repairs. By using larger values, you can get `myisamchk` to operate faster. For example, if you have more than 512MB RAM available, you could use options such as these (in addition to any other options you might specify):

```
shell> myisamchk --myisam_sort_buffer_size=256M \
           --key_buffer_size=512M \
           --read_buffer_size=64M \
           --write_buffer_size=64M ...
```

Using `--myisam_sort_buffer_size=16M` is probably enough for most cases.

Be aware that `myisamchk` uses temporary files in `TMPDIR`. If `TMPDIR` points to a memory file system, out of memory errors can easily occur. If this happens, run `myisamchk` with the `--tmpdir=dir_name` option to specify a directory located on a file system that has more space.

When performing repair operations, `myisamchk` also needs a lot of disk space:

- Twice the size of the data file (the original file and a copy). This space is not needed if you do a repair with `--quick`; in this case, only the index file is re-created. *This space must be available on the same file system as the original data file*, as the copy is created in the same directory as the original.
- Space for the new index file that replaces the old one. The old index file is truncated at the start of the repair operation, so you usually ignore this space. This space must be available on the same file system as the original data file.
- When using `--recover` or `--sort-recover` (but not when using `--safe-recover`), you need space on disk for sorting. This space is allocated in the temporary directory (specified by `TMPDIR` or `--tmpdir=dir_name`). The following formula yields the amount of space required:

  ```
  (largest_key + row_pointer_length) * number_of_rows * 2
  ```

  You can check the length of the keys and the *`row_pointer_length`* with `myisamchk -dv tbl_name` (see Section 4.6.3.5, “Obtaining Table Information with myisamchk”). The *`row_pointer_length`* and *`number_of_rows`* values are the `Datafile pointer` and `Data records` values in the table description. To determine the *`largest_key`* value, check the `Key` lines in the table description. The `Len` column indicates the number of bytes for each key part. For a multiple-column index, the key size is the sum of the `Len` values for all key parts.

If you have a problem with disk space during repair, you can try `--safe-recover` instead of `--recover`.

4.6.4 `myisamlog` — Display MyISAM Log File Contents

`myisamlog` processes the contents of a `MyISAM` log file. To create such a file, start the server with a `--log-isam=log_file` option.

Invoke `myisamlog` like this:

```
shell> myisamlog [options] [file_name [tbl_name] ...]
```

The default operation is update (`-u`). If a recovery is done (`-r`), all writes and possibly updates and deletes are done and errors are only counted. The default log file name is `myisam.log` if no *`log_file`* argument is given. If tables are named on the command line, only those tables are updated.

`myisamlog` supports the following options:

- `-?`, `-I`

  Display a help message and exit.

- `-c N`

  Execute only *`N`* commands.

- `-f N`

  Specify the maximum number of open files.

- `-i`

  Display extra information before exiting.

- `-o offset`

  Specify the starting offset.

- `-p N`

Remove *N* components from path.

- `-r`

  Perform a recovery operation.

- `-R record_pos_file record_pos`

  Specify record position file and record position.

- `-u`

  Perform an update operation.

- `-v`

  Verbose mode. Print more output about what the program does. This option can be given multiple times to produce more and more output.

- `-w write_file`

  Specify the write file.

- `-V`

  Display version information.

4.6.5 myisampack — Generate Compressed, Read-Only MyISAM Tables

The `myisampack` utility compresses `MyISAM` tables. `myisampack` works by compressing each column in the table separately. Usually, `myisampack` packs the data file 40% to 70%.

When the table is used later, the server reads into memory the information needed to decompress columns. This results in much better performance when accessing individual rows, because you only have to uncompress exactly one row.

MySQL uses `mmap()` when possible to perform memory mapping on compressed tables. If `mmap()` does not work, MySQL falls back to normal read/write file operations.

Please note the following:

- If the `mysqld` server was invoked with external locking disabled, it is not a good idea to invoke `myisampack` if the table might be updated by the server during the packing process. It is safest to compress tables with the server stopped.
- After packing a table, it becomes read only. This is generally intended (such as when accessing packed tables on a CD).
- `myisampack` does not support partitioned tables.

Invoke `myisampack` like this:

```
shell> myisampack [options] file_name ...
```

Each file name argument should be the name of an index (`.MYI`) file. If you are not in the database directory, you should specify the path name to the file. It is permissible to omit the `.MYI` extension.

After you compress a table with `myisampack`, use `myisamchk -rq` to rebuild its indexes. Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”.

myisampack supports the following options. It also reads option files and supports the options for processing them described at Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- --help, -?

  Display a help message and exit.

- --backup, -b

  Make a backup of each table's data file using the name *tbl_name*.OLD.

- --character-sets-dir=*dir_name*

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- --debug[=*debug_options*], -# [*debug_options*]

  Write a debugging log. A typical *debug_options* string is d:t:o,*file_name*. The default is d:t:o.

- --force, -f

  Produce a packed table even if it becomes larger than the original or if the intermediate file from an earlier invocation of myisampack exists. (myisampack creates an intermediate file named *tbl_name*.TMD in the database directory while it compresses the table. If you kill myisampack, the .TMD file might not be deleted.) Normally, myisampack exits with an error if it finds that *tbl_name*.TMD exists. With --force, myisampack packs the table anyway.

- --join=*big_tbl_name*, -j *big_tbl_name*

  Join all tables named on the command line into a single packed table *big_tbl_name*. All tables that are to be combined *must* have identical structure (same column names and types, same indexes, and so forth).

  big_tbl_name must not exist prior to the join operation. All source tables named on the command line to be merged into *big_tbl_name* must exist. The source tables are read for the join operation but not modified.

- --silent, -s

  Silent mode. Write output only when errors occur.

- --test, -t

  Do not actually pack the table, just test packing it.

- --tmpdir=*dir_name*, -T *dir_name*

  Use the named directory as the location where myisampack creates temporary files.

- --verbose, -v

  Verbose mode. Write information about the progress of the packing operation and its result.

- --version, -V

  Display version information and exit.

- --wait, -w

  Wait and retry if the table is in use. If the mysqld server was invoked with external locking disabled, it is not a good idea to invoke myisampack if the table might be updated by the server during the packing process.

The following sequence of commands illustrates a typical table compression session:

```
shell> ls -l station.*
-rw-rw-r--   1 monty    my         994128 Apr 17 19:00 station.MYD
-rw-rw-r--   1 monty    my          53248 Apr 17 19:00 station.MYI
-rw-rw-r--   1 monty    my           5767 Apr 17 19:00 station.frm

shell> myisamchk -dvv station

MyISAM file:     station
Isam-version:  2
Creation time: 1996-03-13 10:08:58
Recover time:  1997-02-02  3:06:43
Data records:              1192  Deleted blocks:              0
Datafile parts:            1192  Deleted data:                0
Datafile pointer (bytes):     2  Keyfile pointer (bytes):     2
Max datafile length:   54657023  Max keyfile length:   33554431
Recordlength:               834
Record format: Fixed length

table description:
Key Start Len Index   Type                 Root  Blocksize    Rec/key
1   2     4   unique  unsigned long        1024       1024          1
2   32    30  multip. text                10240       1024          1

Field Start Length Type
1     1     1
2     2     4
3     6     4
4     10    1
5     11    20
6     31    1
7     32    30
8     62    35
9     97    35
10    132   35
11    167   4
12    171   16
13    187   35
14    222   4
15    226   16
16    242   20
17    262   20
18    282   20
19    302   30
20    332   4
21    336   4
22    340   1
23    341   8
24    349   8
25    357   8
26    365   2
27    367   2
28    369   4
29    373   4
30    377   1
31    378   2
32    380   8
33    388   4
34    392   4
35    396   4
36    400   4
37    404   1
38    405   4
39    409   4
40    413   4
41    417   4
42    421   4
43    425   4
44    429   20
```

```
45    449   30
46    479   1
47    480   1
48    481   79
49    560   79
50    639   79
51    718   79
52    797   8
53    805   1
54    806   1
55    807   20
56    827   4
57    831   4

shell> myisampack station.MYI
Compressing station.MYI: (1192 records)
- Calculating statistics

normal:     20  empty-space:   16  empty-zero:     12  empty-fill:  11
pre-space:   0  end-space:     12  table-lookups:   5  zero:         7
Original trees:  57  After join: 17
- Compressing file
87.14%
Remember to run myisamchk -rq on compressed tables

shell> myisamchk -rq station
- check record delete-chain
- recovering (with sort) MyISAM-table 'station'
Data records: 1192
- Fixing index 1
- Fixing index 2

shell> mysqladmin -uroot flush-tables


shell> ls -l station.*
-rw-rw-r--   1 monty    my         127874 Apr 17 19:00 station.MYD
-rw-rw-r--   1 monty    my          55296 Apr 17 19:04 station.MYI
-rw-rw-r--   1 monty    my           5767 Apr 17 19:00 station.frm

shell> myisamchk -dvv station

MyISAM file:     station
Isam-version:  2
Creation time: 1996-03-13 10:08:58
Recover time:  1997-04-17 19:04:26
Data records:               1192  Deleted blocks:              0
Datafile parts:             1192  Deleted data:                0
Datafile pointer (bytes):      3  Keyfile pointer (bytes):     1
Max datafile length:    16777215  Max keyfile length:     131071
Recordlength:               834
Record format: Compressed

table description:
Key Start Len Index   Type                 Root  Blocksize    Rec/key
1   2     4   unique  unsigned long       10240       1024          1
2   32    30  multip. text                54272       1024          1

Field Start Length Type                         Huff tree  Bits
1     1     1      constant                             1     0
2     2     4      zerofill(1)                          2     9
3     6     4      no zeros, zerofill(1)                2     9
4     10    1                                           3     9
5     11    20     table-lookup                         4     0
6     31    1                                           3     9
7     32    30     no endspace, not_always              5     9
8     62    35     no endspace, not_always, no empty    6     9
9     97    35     no empty                             7     9
10    132   35     no endspace, not_always, no empty    6     9
11    167   4      zerofill(1)                          2     9
12    171   16     no endspace, not_always, no empty    5     9
13    187   35     no endspace, not_always, no empty    6     9
```

```
14    222   4      zerofill(1)                          2     9
15    226   16     no endspace, not_always, no empty    5     9
16    242   20     no endspace, not_always              8     9
17    262   20     no endspace, no empty                8     9
18    282   20     no endspace, no empty                5     9
19    302   30     no endspace, no empty                6     9
20    332   4      always zero                          2     9
21    336   4      always zero                          2     9
22    340   1                                           3     9
23    341   8      table-lookup                         9     0
24    349   8      table-lookup                        10     0
25    357   8      always zero                          2     9
26    365   2                                           2     9
27    367   2      no zeros, zerofill(1)                2     9
28    369   4      no zeros, zerofill(1)                2     9
29    373   4      table-lookup                        11     0
30    377   1                                           3     9
31    378   2      no zeros, zerofill(1)                2     9
32    380   8      no zeros                             2     9
33    388   4      always zero                          2     9
34    392   4      table-lookup                        12     0
35    396   4      no zeros, zerofill(1)               13     9
36    400   4      no zeros, zerofill(1)                2     9
37    404   1                                           2     9
38    405   4      no zeros                             2     9
39    409   4      always zero                          2     9
40    413   4      no zeros                             2     9
41    417   4      always zero                          2     9
42    421   4      no zeros                             2     9
43    425   4      always zero                          2     9
44    429   20     no empty                             3     9
45    449   30     no empty                             3     9
46    479   1                                          14     4
47    480   1                                          14     4
48    481   79     no endspace, no empty               15     9
49    560   79     no empty                             2     9
50    639   79     no empty                             2     9
51    718   79     no endspace                         16     9
52    797   8      no empty                             2     9
53    805   1                                          17     1
54    806   1                                           3     9
55    807   20     no empty                             3     9
56    827   4      no zeros, zerofill(2)                2     9
57    831   4      no zeros, zerofill(1)                2     9
```

`myisampack` displays the following kinds of information:

- `normal`

  The number of columns for which no extra packing is used.

- `empty-space`

  The number of columns containing values that are only spaces. These occupy one bit.

- `empty-zero`

  The number of columns containing values that are only binary zeros. These occupy one bit.

- `empty-fill`

  The number of integer columns that do not occupy the full byte range of their type. These are changed to a smaller type. For example, a `BIGINT` column (eight bytes) can be stored as a `TINYINT` column (one byte) if all its values are in the range from `-128` to `127`.

- `pre-space`

  The number of decimal columns that are stored with leading spaces. In this case, each value contains a count for the number of leading spaces.

- `end-space`

  The number of columns that have a lot of trailing spaces. In this case, each value contains a count for the number of trailing spaces.

- `table-lookup`

  The column had only a small number of different values, which were converted to an `ENUM` before Huffman compression.

- `zero`

  The number of columns for which all values are zero.

- `Original trees`

  The initial number of Huffman trees.

- `After join`

  The number of distinct Huffman trees left after joining trees to save some header space.

After a table has been compressed, the `Field` lines displayed by `myisamchk -dvv` include additional information about each column:

- `Type`

  The data type. The value may contain any of the following descriptors:

  - `constant`

    All rows have the same value.

  - `no endspace`

    Do not store endspace.

  - `no endspace, not_always`

    Do not store endspace and do not do endspace compression for all values.

  - `no endspace, no empty`

    Do not store endspace. Do not store empty values.

  - `table-lookup`

    The column was converted to an `ENUM`.

  - `zerofill(N)`

    The most significant *`N`* bytes in the value are always 0 and are not stored.

  - `no zeros`

    Do not store zeros.

  - `always zero`

    Zero values are stored using one bit.

- `Huff tree`

  The number of the Huffman tree associated with the column.

- Bits

  The number of bits used in the Huffman tree.

After you run myisampack, use myisamchk to re-create any indexes. At this time, you can also sort the index blocks and create statistics needed for the MySQL optimizer to work more efficiently:

```
shell> myisamchk -rq --sort-index --analyze tbl_name.MYI
```

After you have installed the packed table into the MySQL database directory, you should execute mysqladmin flush-tables to force mysqld to start using the new table.

To unpack a packed table, use the --unpack option to myisamchk.

4.6.6 mysqlaccess — Client for Checking Access Privileges

mysqlaccess is a diagnostic tool that Yves Carlier has provided for the MySQL distribution. It checks the access privileges for a host name, user name, and database combination. mysqlaccess checks access using only the user, db, and host tables. It does not check table, column, or routine privileges specified in the tables_priv, columns_priv, or procs_priv tables.

Invoke mysqlaccess like this:

```
shell> mysqlaccess [host_name [user_name [db_name]]] [options]
```

When mysqlaccess runs, it loads and executes the contents of its configuration file, mysqlaccess.conf. mysqlaccess looks for the configuration file in these locations, in order:

- The directory named by the SYSCONFDIR option to CMake when MySQL was built. By default, this is the etc directory located under the compiled-in installation directory.
- The /etc directory.

mysqlaccess supports the options shown in the following table.

Table 4.16 mysqlaccess Options

Format	Description
--brief	Generate reports in single-line tabular format
--commit	Copy the new access privileges from the temporary tables to the original grant tables
--copy	Reload the temporary grant tables from original ones
--db	Specify the database name
--debug	Specify the debug level
--help	Display help message and exit
--host	Connect to MySQL server on given host
--howto	Display some examples that show how to use mysqlaccess
--old_server	Assume that the server is an old MySQL server (prior to MySQL 3.21)
--password	Password to use when connecting to server
--plan	Display suggestions and ideas for future releases
--preview	Show the privilege differences after making changes to the temporary grant tables
--relnotes	Display release notes
--rhost	Connect to MySQL server on given host

Format	Description
--rollback	Undo the most recent changes to the temporary grant tables.
--spassword	Password to use when connecting to server as the superuser
--superuser	Specify the user name for connecting as the superuser
--table	Generate reports in table format
--user	MySQL user name to use when connecting to server
--version	Display version information and exit

- `--help`, `-?`

  Display a help message and exit.

- `--brief`, `-b`

  Generate reports in single-line tabular format.

- `--commit`

  Copy the new access privileges from the temporary tables to the original grant tables. The grant tables must be flushed for the new privileges to take effect. (For example, execute a `mysqladmin reload` command.)

- `--copy`

  Reload the temporary grant tables from original ones.

- `--db=db_name`, `-d db_name`

  Specify the database name.

- `--debug=N`

  Specify the debug level. *`N`* can be an integer from 0 to 3.

- `--host=host_name`, `-h host_name`

  The host name to use in the access privileges.

- `--howto`

  Display some examples that show how to use `mysqlaccess`.

- `--old_server`

  Assume that the server is an old MySQL server (before MySQL 3.21) that does not yet know how to handle full `WHERE` clauses.

- `--password[=password]`, `-p[password]`

  The password to use when connecting to the server. If you omit the *`password`* value following the `--password` or `-p` option on the command line, `mysqlaccess` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

- `--plan`

  Display suggestions and ideas for future releases.

- `--preview`

Show the privilege differences after making changes to the temporary grant tables.

- `--relnotes`

  Display the release notes.

- `--rhost=host_name`, `-H host_name`

  Connect to the MySQL server on the given host.

- `--rollback`

  Undo the most recent changes to the temporary grant tables.

- `--spassword[=password]`, `-P[password]`

  The password to use when connecting to the server as the superuser. If you omit the *password* value following the `--spassword` or `-p` option on the command line, `mysqlaccess` prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

- `--superuser=user_name`, `-U user_name`

  Specify the user name for connecting as the superuser.

- `--table`, `-t`

  Generate reports in table format.

- `--user=user_name`, `-u user_name`

  The user name to use in the access privileges.

- `--version`, `-v`

  Display version information and exit.

If your MySQL distribution is installed in some nonstandard location, you must change the location where `mysqlaccess` expects to find the `mysql` client. Edit the `mysqlaccess` script at approximately line 18. Search for a line that looks like this:

```
$MYSQL     = '/usr/local/bin/mysql';    # path to mysql executable
```

Change the path to reflect the location where `mysql` actually is stored on your system. If you do not do this, a `Broken pipe` error will occur when you run `mysqlaccess`.

4.6.7 `mysqlbinlog` — Utility for Processing Binary Log Files

The server's binary log consists of files containing “events” that describe modifications to database contents. The server writes these files in binary format. To display their contents in text format, use the `mysqlbinlog` utility. You can also use `mysqlbinlog` to display the contents of relay log files written by a slave server in a replication setup because relay logs have the same format as binary logs. The binary log and relay log are discussed further in Section 5.4.4, “The Binary Log”, and Section 17.2.2, “Replication Relay and Status Logs”.

Invoke `mysqlbinlog` like this:

```
shell> mysqlbinlog [options] log_file ...
```

For example, to display the contents of the binary log file named `binlog.000003`, use this command:

```
shell> mysqlbinlog binlog.0000003
```

The output includes events contained in `binlog.000003`. For statement-based logging, event information includes the SQL statement, the ID of the server on which it was executed, the timestamp when the statement was executed, how much time it took, and so forth. For row-based logging, the event indicates a row change rather than an SQL statement. See Section 17.1.2, “Replication Formats”, for information about logging modes.

Events are preceded by header comments that provide additional information. For example:

```
# at 141
#100309  9:28:36 server id 123  end_log_pos 245
  Query thread_id=3350  exec_time=11  error_code=0
```

In the first line, the number following `at` indicates the file offset, or starting position, of the event in the binary log file.

The second line starts with a date and time indicating when the statement started on the server where the event originated. For replication, this timestamp is propagated to slave servers. `server id` is the `server_id` value of the server where the event originated. `end_log_pos` indicates where the next event starts (that is, it is the end position of the current event + 1). `thread_id` indicates which thread executed the event. `exec_time` is the time spent executing the event, on a master server. On a slave, it is the difference of the end execution time on the slave minus the beginning execution time on the master. The difference serves as an indicator of how much replication lags behind the master. `error_code` indicates the result from executing the event. Zero means that no error occurred.

Note

When using event groups, the file offsets of events may be grouped together and the comments of events may be grouped together. Do not mistake these grouped events for blank file offsets.

The output from `mysqlbinlog` can be re-executed (for example, by using it as input to `mysql`) to redo the statements in the log. This is useful for recovery operations after a server crash. For other usage examples, see the discussion later in this section and in Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”.

Normally, you use `mysqlbinlog` to read binary log files directly and apply them to the local MySQL server. It is also possible to read binary logs from a remote server by using the `--read-from-remote-server` option. To read remote binary logs, the connection parameter options can be given to indicate how to connect to the server. These options are `--host`, `--password`, `--port`, `--protocol`, `--socket`, and `--user`; they are ignored except when you also use the `--read-from-remote-server` option.

When running `mysqlbinlog` against a large binary log, be careful that the filesystem has enough space for the resulting files. To configure the directory that `mysqlbinlog` uses for temporary files, use the `TMPDIR` environment variable.

`mysqlbinlog` supports the following options, which can be specified on the command line or in the `[mysqlbinlog]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.17 `mysqlbinlog` Options

Format	Description	Introduced	Removed
--base64-output	Print binary log entries using base-64 encoding		
--character-sets-dir	Directory where character sets are installed		
--database	List entries for just this database		
--debug	Write debugging log		

Format	Description	Introduced	Removed
--debug-check	Print debugging information when program exits		
--debug-info	Print debugging information, memory, and CPU statistics when program exits		
--default-auth	Authentication plugin to use	5.5.10	
--defaults-extra-file	Read named option file in addition to usual option files		
--defaults-file	Read only named option file		
--defaults-group-suffix	Option group suffix value		
--disable-log-bin	Disable binary logging		
--force-if-open	Read binary log files even if open or not closed properly		
--force-read	If mysqlbinlog reads a binary log event that it does not recognize, it prints a warning		
--help	Display help message and exit		
--hexdump	Display a hex dump of the log in comments		
--host	Connect to MySQL server on given host		
--local-load	Prepare local temporary files for LOAD DATA INFILE in the specified directory		
--no-defaults	Read no option files		
--offset	Skip the first N entries in the log		
--password	Password to use when connecting to server		
--plugin-dir	Directory where plugins are installed	5.5.10	
--port	TCP/IP port number for connection		
--position	Deprecated. Use --start-position		5.5.3
--print-defaults	Print default options		
--protocol	Connection protocol to use		
--read-from-remote-server	Read binary log from MySQL server rather than local log file		
--result-file	Direct output to named file		
--server-id	Extract only those events created by the server having the given server ID		
--server-id-bits	Tell mysqlbinlog how to interpret server IDs in binary log when log was written by a mysqld having its server-id-bits set to less than the maximum; supported only by MySQL Cluster version of mysqlbinlog		
--set-charset	Add a SET NAMES charset_name statement to the output		
--shared-memory-base-name	The name of shared memory to use for shared-memory connections		
--short-form	Display only the statements contained in the log		
--socket	For connections to localhost, the Unix socket file to use		
--ssl-mode	Security state of connection to server	5.5.49	

Format	Description	Introduced	Removed
--start-datetime	Read binary log from first event with timestamp equal to or later than datetime argument		
--start-position	Read binary log from first event with position equal to or greater than argument		
--stop-datetime	Stop reading binary log at first event with timestamp equal to or greater than datetime argument		
--stop-position	Stop reading binary log at first event with position equal to or greater than argument		
--to-last-log	Do not stop at the end of requested binary log from a MySQL server, but rather continue printing to end of last binary log		
--user	MySQL user name to use when connecting to server		
--verbose	Reconstruct row events as SQL statements		
--version	Display version information and exit		

- `--help`, `-?`

  Display a help message and exit.

- `--base64-output[=value]`

  This option determines when events should be displayed encoded as base-64 strings using `BINLOG` statements. The option has these permissible values (not case sensitive):

  - `AUTO` ("automatic") or `UNSPEC` ("unspecified") displays `BINLOG` statements automatically when necessary (that is, for format description events and row events). If no `--base64-output` option is given, the effect is the same as `--base64-output=AUTO`.

    Note

    Automatic `BINLOG` display is the only safe behavior if you intend to use the output of `mysqlbinlog` to re-execute binary log file contents. The other option values are intended only for debugging or testing purposes because they may produce output that does not include all events in executable form.

  - `ALWAYS` displays `BINLOG` statements whenever possible. If the `--base64-output` option is given without a value, the effect is the same as `--base64-output=ALWAYS`.

    Note

    Changes to replication in MySQL 5.6 make output generated by this option unusable, so `ALWAYS` is deprecated as of MySQL 5.5.8 and will be an invalid value in MySQL 5.6

  - `NEVER` causes `BINLOG` statements not to be displayed. `mysqlbinlog` exits with an error if a row event is found that must be displayed using `BINLOG`.

  - `DECODE-ROWS` specifies to `mysqlbinlog` that you intend for row events to be decoded and displayed as commented SQL statements by also specifying the `--verbose` option. Like `NEVER`, `DECODE-ROWS` suppresses display of `BINLOG` statements, but unlike `NEVER`, it does not exit with an error if a row event is found.

For examples that show the effect of `--base64-output` and `--verbose` on row event output, see Section 4.6.7.2, “mysqlbinlog Row Event Display”.

- `--bind-address=ip_address`

  On a computer having multiple network interfaces, use this option to select which interface to use for connecting to the MySQL server.

  This option is supported beginning with MySQL 5.5.8.

- `--character-sets-dir=dir_name`

  The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- `--database=db_name`, `-d db_name`

  This option causes `mysqlbinlog` to output entries from the binary log (local log only) that occur while *`db_name`* is been selected as the default database by `USE`.

  The `--database` option for `mysqlbinlog` is similar to the `--binlog-do-db` option for `mysqld`, but can be used to specify only one database. If `--database` is given multiple times, only the last instance is used.

  The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--binlog-do-db` depend on whether statement-based or row-based logging is in use.

  Statement-based logging. The `--database` option works as follows:

  - While *`db_name`* is the default database, statements are output whether they modify tables in *`db_name`* or a different database.
  - Unless *`db_name`* is selected as the default database, statements are not output, even if they modify tables in *`db_name`*.
  - There is an exception for `CREATE DATABASE`, `ALTER DATABASE`, and `DROP DATABASE`. The database being *created, altered, or dropped* is considered to be the default database when determining whether to output the statement.

  Suppose that the binary log was created by executing these statements using statement-based-logging:

```
INSERT INTO test.t1 (i) VALUES(100);
INSERT INTO db2.t2 (j)  VALUES(200);
USE test;
INSERT INTO test.t1 (i) VALUES(101);
INSERT INTO t1 (i)      VALUES(102);
INSERT INTO db2.t2 (j)  VALUES(201);
USE db2;
INSERT INTO test.t1 (i) VALUES(103);
INSERT INTO db2.t2 (j)  VALUES(202);
INSERT INTO t2 (j)      VALUES(203);
```

  `mysqlbinlog --database=test` does not output the first two `INSERT` statements because there is no default database. It outputs the three `INSERT` statements following `USE test`, but not the three `INSERT` statements following `USE db2`.

  `mysqlbinlog --database=db2` does not output the first two `INSERT` statements because there is no default database. It does not output the three `INSERT` statements following `USE test`, but does output the three `INSERT` statements following `USE db2`.

Row-based logging. mysqlbinlog outputs only entries that change tables belonging to *db_name*. The default database has no effect on this. Suppose that the binary log just described was created using row-based logging rather than statement-based logging. mysqlbinlog --database=test outputs only those entries that modify t1 in the test database, regardless of whether USE was issued or what the default database is.

If a server is running with binlog_format set to MIXED and you want it to be possible to use mysqlbinlog with the --database option, you must ensure that tables that are modified are in the database selected by USE. (In particular, no cross-database updates should be used.)

Note

Prior to MySQL NDB Cluster 7.2.2, this option did not work correctly with NDB Cluster tables unless, unless the binary log was generated using --log-bin-use-v1-row-events=0. (Bug #13067813)

- --debug[=*debug_options*], -# [*debug_options*]

  Write a debugging log. A typical *debug_options* string is d:t:o,*file_name*. The default is d:t:o,/tmp/mysqlbinlog.trace.

- --debug-check

  Print some debugging information when the program exits.

- --debug-info

  Print debugging information and memory and CPU usage statistics when the program exits.

- --default-auth=*plugin*

  A hint about the client-side authentication plugin to use. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- --defaults-extra-file=*file_name*

  Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *file_name* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- --defaults-file=*file_name*

  Use only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. Before MySQL 5.5.8, *file_name* must be the full path name to the file. As of MySQL 5.5.8, the name is interpreted relative to the current directory if given as a relative path name.

- --defaults-group-suffix=*str*

  Read not only the usual option groups, but also groups with the usual names and a suffix of *str*. For example, mysqlbinlog normally reads the [client] and [mysqlbinlog] groups. If the --defaults-group-suffix=_other option is given, mysqlbinlog also reads the [client_other] and [mysqlbinlog_other] groups.

- --disable-log-bin, -D

  Disable binary logging. This is useful for avoiding an endless loop if you use the --to-last-log option and are sending the output to the same MySQL server. This option also is useful when restoring after a crash to avoid duplication of the statements you have logged.

This option requires that you have the SUPER privilege. It causes mysqlbinlog to include a SET sql_log_bin = 0 statement in its output to disable binary logging of the remaining output. The SET statement is ineffective unless you have the SUPER privilege.

- --force-if-open, -F

  Read binary log files even if they are open or were not closed properly.

- --force-read, -f

  With this option, if mysqlbinlog reads a binary log event that it does not recognize, it prints a warning, ignores the event, and continues. Without this option, mysqlbinlog stops if it reads such an event.

- --hexdump, -H

  Display a hex dump of the log in comments, as described in Section 4.6.7.1, “mysqlbinlog Hex Dump Format”. The hex output can be helpful for replication debugging.

- --host=*host_name*, -h *host_name*

  Get the binary log from the MySQL server on the given host.

- --local-load=*dir_name*, -l *dir_name*

  Prepare local temporary files for LOAD DATA INFILE in the specified directory.

  Important

  These temporary files are not automatically removed by mysqlbinlog or any other MySQL program.

- --no-defaults

  Do not read any option files. If program startup fails due to reading unknown options from an option file, --no-defaults can be used to prevent them from being read.

- --offset=*N*, -o *N*

  Skip the first *N* entries in the log.

- --password[=*password*], -p[*password*]

  The password to use when connecting to the server. If you use the short option form (-p), you *cannot* have a space between the option and the password. If you omit the *password* value following the --password or -p option on the command line, mysqlbinlog prompts for one.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line.

- --plugin-dir=*dir_name*

  The directory in which to look for plugins. Specify this option if the --default-auth option is used to specify an authentication plugin but mysqlbinlog does not find it. See Section 6.3.6, “Pluggable Authentication”.

  This option was added in MySQL 5.5.10.

- --port=*port_num*, -P *port_num*

  The TCP/IP port number to use for connecting to a remote server.

- `--position=N`

  Deprecated. Use `--start-position` instead. `--position` was removed in MySQL 5.5.3.

- `--print-defaults`

  Print the program name and all options that it gets from option files.

- `--protocol={TCP|SOCKET|PIPE|MEMORY}`

  The connection protocol to use for connecting to the server. It is useful when the other connection parameters normally would cause a protocol to be used other than the one you want. For details on the permissible values, see Section 4.2.2, “Connecting to the MySQL Server”.

- `--read-from-remote-server`, `-R`

  Read the binary log from a MySQL server rather than reading a local log file. Any connection parameter options are ignored unless this option is given as well. These options are `--host`, `--password`, `--port`, `--protocol`, `--socket`, and `--user`.

  This option requires that the remote server be running. It works only for binary log files on the remote server, not relay log files.

- `--result-file=name`, `-r name`

  Direct output to the given file.

- `--server-id=id`

  Display only those events created by the server having the given server ID.

- `--server-id-bits=N`

  Use only the first `N` bits of the `server_id` to identify the server. If the binary log was written by a `mysqld` with server-id-bits set to less than 32 and user data stored in the most significant bit, running `mysqlbinlog` with `--server-id-bits` set to 32 enables this data to be seen.

  This option is supported only by the versions of `mysqlbinlog` supplied with the NDB Cluster distribution, or built from the NDB Cluster sources.

- `--set-charset=charset_name`

  Add a `SET NAMES charset_name` statement to the output to specify the character set to be used for processing log files.

- `--shared-memory-base-name=name`

  On Windows, the shared-memory name to use, for connections made using shared memory to a local server. The default value is `MYSQL`. The shared-memory name is case sensitive.

  The server must be started with the `--shared-memory` option to enable shared-memory connections.

- `--short-form`, `-s`

  Display only the statements contained in the log, without any extra information or row-based events. This is for testing only, and should not be used in production systems.

- `--socket=path`, `-S path`

  For connections to `localhost`, the Unix socket file to use, or, on Windows, the name of the named pipe to use.

- `--ssl*`

Options that begin with `--ssl` specify whether to connect to the server using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- `--start-datetime=datetime`

  Start reading the binary log at the first event having a timestamp equal to or later than the *`datetime`* argument. The *`datetime`* value is relative to the local time zone on the machine where you run `mysqlbinlog`. The value should be in a format accepted for the `DATETIME` or `TIMESTAMP` data types. For example:

```
shell> mysqlbinlog --start-datetime="2005-12-25 11:25:56" binlog.000003
```

  This option is useful for point-in-time recovery. See Section 7.3, “Example Backup and Recovery Strategy”.

- `--start-position=N`, `-j N`

  Start reading the binary log at the first event having a position equal to or greater than *`N`*. This option applies to the first log file named on the command line.

  This option is useful for point-in-time recovery. See Section 7.3, “Example Backup and Recovery Strategy”.

- `--stop-datetime=datetime`

  Stop reading the binary log at the first event having a timestamp equal to or later than the *`datetime`* argument. This option is useful for point-in-time recovery. See the description of the `--start-datetime` option for information about the *`datetime`* value.

  This option is useful for point-in-time recovery. See Section 7.3, “Example Backup and Recovery Strategy”.

- `--stop-position=N`

  Stop reading the binary log at the first event having a position equal to or greater than *`N`*. This option applies to the last log file named on the command line.

  This option is useful for point-in-time recovery. See Section 7.3, “Example Backup and Recovery Strategy”.

- `--to-last-log`, `-t`

  Do not stop at the end of the requested binary log from a MySQL server, but rather continue printing until the end of the last binary log. If you send the output to the same MySQL server, this may lead to an endless loop. This option requires `--read-from-remote-server`.

- `--user=user_name`, `-u user_name`

  The MySQL user name to use when connecting to a remote server.

- `--verbose`, `-v`

  Reconstruct row events and display them as commented SQL statements. If this option is given twice, the output includes comments to indicate column data types and some metadata.

  For examples that show the effect of `--base64-output` and `--verbose` on row event output, see Section 4.6.7.2, “mysqlbinlog Row Event Display”.

- `--version`, `-V`

Display version information and exit.

In MySQL 5.5, the version number shown for mysqlbinlog is always 3.3.

You can also set the following variable by using --*var_name*=*value* syntax:

- open_files_limit

  Specify the number of open file descriptors to reserve.

You can pipe the output of mysqlbinlog into the mysql client to execute the events contained in the binary log. This technique is used to recover from a crash when you have an old backup (see Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”). For example:

```
shell> mysqlbinlog binlog.000001 | mysql -u root -p
```

Or:

```
shell> mysqlbinlog binlog.[0-9]* | mysql -u root -p
```

You can also redirect the output of mysqlbinlog to a text file instead, if you need to modify the statement log first (for example, to remove statements that you do not want to execute for some reason). After editing the file, execute the statements that it contains by using it as input to the mysql program:

```
shell> mysqlbinlog binlog.000001 > tmpfile
shell> ... edit tmpfile ...
shell> mysql -u root -p < tmpfile
```

When mysqlbinlog is invoked with the --start-position option, it displays only those events with an offset in the binary log greater than or equal to a given position (the given position must match the start of one event). It also has options to stop and start when it sees an event with a given date and time. This enables you to perform point-in-time recovery using the --stop-datetime option (to be able to say, for example, “roll forward my databases to how they were today at 10:30 a.m.”).

If you have more than one binary log to execute on the MySQL server, the safe method is to process them all using a single connection to the server. Here is an example that demonstrates what may be *unsafe*:

```
shell> mysqlbinlog binlog.000001 | mysql -u root -p # DANGER!!
shell> mysqlbinlog binlog.000002 | mysql -u root -p # DANGER!!
```

Processing binary logs this way using multiple connections to the server causes problems if the first log file contains a CREATE TEMPORARY TABLE statement and the second log contains a statement that uses the temporary table. When the first mysql process terminates, the server drops the temporary table. When the second mysql process attempts to use the table, the server reports “unknown table.”

To avoid problems like this, use a *single* mysql process to execute the contents of all binary logs that you want to process. Here is one way to do so:

```
shell> mysqlbinlog binlog.000001 binlog.000002 | mysql -u root -p
```

Another approach is to write all the logs to a single file and then process the file:

```
shell> mysqlbinlog binlog.000001 >  /tmp/statements.sql
shell> mysqlbinlog binlog.000002 >> /tmp/statements.sql
shell> mysql -u root -p -e "source /tmp/statements.sql"
```

mysqlbinlog can produce output that reproduces a LOAD DATA INFILE operation without the original data file. mysqlbinlog copies the data to a temporary file and writes a LOAD DATA LOCAL

INFILE statement that refers to the file. The default location of the directory where these files are written is system-specific. To specify a directory explicitly, use the --local-load option.

Because mysqlbinlog converts LOAD DATA INFILE statements to LOAD DATA LOCAL INFILE statements (that is, it adds LOCAL), both the client and the server that you use to process the statements must be configured with the LOCAL capability enabled. See Section 6.1.6, "Security Issues with LOAD DATA LOCAL".

Warning

The temporary files created for LOAD DATA LOCAL statements are *not* automatically deleted because they are needed until you actually execute those statements. You should delete the temporary files yourself after you no longer need the statement log. The files can be found in the temporary file directory and have names like *original_file_name-#-#*.

4.6.7.1 mysqlbinlog Hex Dump Format

The --hexdump option causes mysqlbinlog to produce a hex dump of the binary log contents:

```
shell> mysqlbinlog --hexdump master-bin.000001
```

The hex output consists of comment lines beginning with #, so the output might look like this for the preceding command:

```
/*!40019 SET @@session.max_insert_delayed_threads=0*/;
/*!50003 SET @OLD_COMPLETION_TYPE=@@COMPLETION_TYPE,COMPLETION_TYPE=0*/;
# at 4
#051024 17:24:13 server id 1  end_log_pos 98
# Position  Timestamp   Type   Master ID        Size      Master Pos    Flags
# 00000004 9d fc 5c 43   0f   01 00 00 00   5e 00 00 00   62 00 00 00   00 00
# 00000017 04 00 35 2e 30 2e 31 35  2d 64 65 62 75 67 2d 6c |..5.0.15.debug.l|
# 00000027 6f 67 00 00 00 00 00 00  00 00 00 00 00 00 00 00 |og..............|
# 00000037 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 |................|
# 00000047 00 00 00 00 9d fc 5c 43  13 38 0d 00 08 00 12 00 |.......C.8......|
# 00000057 04 04 04 04 12 00 00 4b  00 04 1a               |.......K...|
#       Start: binlog v 4, server v 5.0.15-debug-log created 051024 17:24:13
#       at startup
ROLLBACK;
```

Hex dump output currently contains the elements in the following list. This format is subject to change. (For more information about binary log format, see MySQL Internals: The Binary Log.

- Position: The byte position within the log file.
- Timestamp: The event timestamp. In the example shown, '9d fc 5c 43' is the representation of '051024 17:24:13' in hexadecimal.
- Type: The event type code. In the example shown, '0f' indicates a FORMAT_DESCRIPTION_EVENT. The following table lists the possible type codes.

Type	Name	Meaning
00	UNKNOWN_EVENT	This event should never be present in the log.
01	START_EVENT_V3	This indicates the start of a log file written by MySQL 4 or earlier.
02	QUERY_EVENT	The most common type of events. These contain statements executed on the master.
03	STOP_EVENT	Indicates that master has stopped.
04	ROTATE_EVENT	Written when the master switches to a new log file.

Type	Name	Meaning
05	INTVAR_EVENT	Used for AUTO_INCREMENT values or when the LAST_INSERT_ID() function is used in the statement.
06	LOAD_EVENT	Used for LOAD DATA INFILE in MySQL 3.23.
07	SLAVE_EVENT	Reserved for future use.
08	CREATE_FILE_EVENT	Used for LOAD DATA INFILE statements. This indicates the start of execution of such a statement. A temporary file is created on the slave. Used in MySQL 4 only.
09	APPEND_BLOCK_EVENT	Contains data for use in a LOAD DATA INFILE statement. The data is stored in the temporary file on the slave.
0a	EXEC_LOAD_EVENT	Used for LOAD DATA INFILE statements. The contents of the temporary file is stored in the table on the slave. Used in MySQL 4 only.
0b	DELETE_FILE_EVENT	Rollback of a LOAD DATA INFILE statement. The temporary file should be deleted on the slave.
0c	NEW_LOAD_EVENT	Used for LOAD DATA INFILE in MySQL 4 and earlier.
0d	RAND_EVENT	Used to send information about random values if the RAND() function is used in the statement.
0e	USER_VAR_EVENT	Used to replicate user variables.
0f	FORMAT_DESCRIPTION_EVENT	This indicates the start of a log file written by MySQL 5 or later.
10	XID_EVENT	Event indicating commit of an XA transaction.
11	BEGIN_LOAD_QUERY_EVENT	Used for LOAD DATA INFILE statements in MySQL 5 and later.
12	EXECUTE_LOAD_QUERY_EVENT	Used for LOAD DATA INFILE statements in MySQL 5 and later.
13	TABLE_MAP_EVENT	Information about a table definition. Used in MySQL 5.1.5 and later.
14	PRE_GA_WRITE_ROWS_EVENT	Row data for a single table that should be created. Used in MySQL 5.1.5 to 5.1.17.
15	PRE_GA_UPDATE_ROWS_EVENT	Row data for a single table that needs to be updated. Used in MySQL 5.1.5 to 5.1.17.
16	PRE_GA_DELETE_ROWS_EVENT	Row data for a single table that should be deleted. Used in MySQL 5.1.5 to 5.1.17.
17	WRITE_ROWS_EVENT	Row data for a single table that should be created. Used in MySQL 5.1.18 and later.
18	UPDATE_ROWS_EVENT	Row data for a single table that needs to be updated. Used in MySQL 5.1.18 and later.
19	DELETE_ROWS_EVENT	Row data for a single table that should be deleted. Used in MySQL 5.1.18 and later.
1a	INCIDENT_EVENT	Something out of the ordinary happened. Added in MySQL 5.1.18.

- Master ID: The server ID of the master that created the event.
- Size: The size in bytes of the event.
- Master Pos: The position of the next event in the original master log file.
- Flags: 16 flags. The following flags are used. The others are reserved for future use.

Flag	Name	Meaning
01	LOG_EVENT_BINLOG_IN_USE_F	Log file correctly closed. (Used only in FORMAT_DESCRIPTION_EVENT.) If this flag is set (if the flags are, for example, '01 00') in a FORMAT_DESCRIPTION_EVENT, the log file has not been properly closed. Most probably this is because of a master crash (for example, due to power failure).
02		Reserved for future use.
04	LOG_EVENT_THREAD_SPECIFIC_	Set if the event is dependent on the connection it was executed in (for example, '04 00'), for example, if the event uses temporary tables.
08	LOG_EVENT_SUPPRESS_USE_F	Set in some circumstances when the event is not dependent on the default database.

4.6.7.2 mysqlbinlog Row Event Display

The following examples illustrate how mysqlbinlog displays row events that specify data modifications. These correspond to events with the WRITE_ROWS_EVENT, UPDATE_ROWS_EVENT, and DELETE_ROWS_EVENT type codes. The --base64-output=DECODE-ROWS and --verbose options may be used to affect row event output.

Suppose that the server is using row-based binary logging and that you execute the following sequence of statements:

```
CREATE TABLE t
(
  id   INT NOT NULL,
  name VARCHAR(20) NOT NULL,
  date DATE NULL
) ENGINE = InnoDB;

START TRANSACTION;
INSERT INTO t VALUES(1, 'apple', NULL);
UPDATE t SET name = 'pear', date = '2009-01-01' WHERE id = 1;
DELETE FROM t WHERE id = 1;
COMMIT;
```

By default, mysqlbinlog displays row events encoded as base-64 strings using BINLOG statements. Omitting extraneous lines, the output for the row events produced by the preceding statement sequence looks like this:

```
shell> mysqlbinlog log_file
...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAANoAAAAAABEAAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBcBAAAAKAAAAAIBAAAQABEAAAAAAAEAA//8AQAAAAVhcHBsZQ==
'/*!*/;
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAC4BAAAAABEAAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEAAAAAAAEAA////AEAAAAFYXBwbGX4AQAAAARwZWFyIbIP
'/*!*/;
...
# at 400
#080828 15:03:08 server id 1  end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F
```

```
BINLOG '
fAS3SBMBAAAALAAAAJABAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBkBAAAAKgAAALoBAAAQABEAAAAAAAEAA//4AQAAAARwZWFyIbIP
'/*!*/;
```

To see the row events as comments in the form of “pseudo-SQL” statements, run `mysqlbinlog` with the `--verbose` or `-v` option. The output will contain lines beginning with `###`:

```
shell> mysqlbinlog -v log_file
...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAANoAAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBcBAAAAKAAAAAIBAAAQABEAAAAAAAEAA//8AQAAAAVhcHBsZQ==
'/*!*/;
### INSERT INTO test.t
### SET
###   @1=1
###   @2='apple'
###   @3=NULL
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAC4BAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEAAAAAAAEAA////AEAAAAFYXBwbGX4AQAAAARwZWFyIbIP
'/*!*/;
### UPDATE test.t
### WHERE
###   @1=1
###   @2='apple'
###   @3=NULL
### SET
###   @1=1
###   @2='pear'
###   @3='2009:01:01'
...
# at 400
#080828 15:03:08 server id 1  end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAJABAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBkBAAAAKgAAALoBAAAQABEAAAAAAAEAA//4AQAAAARwZWFyIbIP
'/*!*/;
### DELETE FROM test.t
### WHERE
###   @1=1
###   @2='pear'
###   @3='2009:01:01'
```

Specify `--verbose` or `-v` twice to also display data types and some metadata for each column. The output will contain an additional comment following each column change:

```
shell> mysqlbinlog -vv log_file
...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAANoAAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBcBAAAAKAAAAAIBAAAQABEAAAAAAAEAA//8AQAAAAVhcHBsZQ==
'/*!*/;
### INSERT INTO test.t
### SET
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='apple' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3=NULL /* VARSTRING(20) meta=0 nullable=1 is_null=1 */
```

```
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAC4BAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBgBAAAANgAAAGQBAAAQABEAAAAAAAEAA////AEAAAAFYXBwbGX4AQAAAARwZWFyIbIP
'/*!*/;
### UPDATE test.t
### WHERE
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='apple' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3=NULL /* VARSTRING(20) meta=0 nullable=1 is_null=1 */
### SET
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='pear' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3='2009:01:01' /* DATE meta=0 nullable=1 is_null=0 */
...
# at 400
#080828 15:03:08 server id 1  end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F

BINLOG '
fAS3SBMBAAAALAAAAJABAAAAABEAAAAAAAAABHRlc3QAAXQAAwMPCgIUAAQ=
fAS3SBkBAAAAKgAAALoBAAAQABEAAAAAAAEAA//4AQAAAARwZWFyIbIP
'/*!*/;
### DELETE FROM test.t
### WHERE
###   @1=1 /* INT meta=0 nullable=0 is_null=0 */
###   @2='pear' /* VARSTRING(20) meta=20 nullable=0 is_null=0 */
###   @3='2009:01:01' /* DATE meta=0 nullable=1 is_null=0 */
```

You can tell `mysqlbinlog` to suppress the `BINLOG` statements for row events by using the `--base64-output=DECODE-ROWS` option. This is similar to `--base64-output=NEVER` but does not exit with an error if a row event is found. The combination of `--base64-output=DECODE-ROWS` and `--verbose` provides a convenient way to see row events only as SQL statements:

```
shell> mysqlbinlog -v --base64-output=DECODE-ROWS log_file
...
# at 218
#080828 15:03:08 server id 1  end_log_pos 258   Write_rows: table id 17 flags: STMT_END_F
### INSERT INTO test.t
### SET
###   @1=1
###   @2='apple'
###   @3=NULL
...
# at 302
#080828 15:03:08 server id 1  end_log_pos 356   Update_rows: table id 17 flags: STMT_END_F
### UPDATE test.t
### WHERE
###   @1=1
###   @2='apple'
###   @3=NULL
### SET
###   @1=1
###   @2='pear'
###   @3='2009:01:01'
...
# at 400
#080828 15:03:08 server id 1  end_log_pos 442   Delete_rows: table id 17 flags: STMT_END_F
### DELETE FROM test.t
### WHERE
###   @1=1
###   @2='pear'
###   @3='2009:01:01'
```

Note

You should not suppress `BINLOG` statements if you intend to re-execute `mysqlbinlog` output.

The SQL statements produced by `--verbose` for row events are much more readable than the corresponding `BINLOG` statements. However, they do not correspond exactly to the original SQL statements that generated the events. The following limitations apply:

- The original column names are lost and replaced by *`@N`*, where *`N`* is a column number.
- Character set information is not available in the binary log, which affects string column display:
  - There is no distinction made between corresponding binary and nonbinary string types (`BINARY` and `CHAR`, `VARBINARY` and `VARCHAR`, `BLOB` and `TEXT`). The output uses a data type of `STRING` for fixed-length strings and `VARSTRING` for variable-length strings.
  - For multibyte character sets, the maximum number of bytes per character is not present in the binary log, so the length for string types is displayed in bytes rather than in characters. For example, `STRING(4)` will be used as the data type for values from either of these column types:

    ```
    CHAR(4) CHARACTER SET latin1
    CHAR(2) CHARACTER SET ucs2
    ```

  - Due to the storage format for events of type `UPDATE_ROWS_EVENT`, `UPDATE` statements are displayed with the `WHERE` clause preceding the `SET` clause.

Proper interpretation of row events requires the information from the format description event at the beginning of the binary log. Because `mysqlbinlog` does not know in advance whether the rest of the log contains row events, by default it displays the format description event using a `BINLOG` statement in the initial part of the output.

If the binary log is known not to contain any events requiring a `BINLOG` statement (that is, no row events), the `--base64-output=NEVER` option can be used to prevent this header from being written.

4.6.8 mysqldumpslow — Summarize Slow Query Log Files

The MySQL slow query log contains information about queries that take a long time to execute (see Section 5.4.5, “The Slow Query Log”). `mysqldumpslow` parses MySQL slow query log files and prints a summary of their contents.

Normally, `mysqldumpslow` groups queries that are similar except for the particular values of number and string data values. It “abstracts” these values to `N` and `'S'` when displaying summary output. The `-a` and `-n` options can be used to modify value abstracting behavior.

Invoke `mysqldumpslow` like this:

```
shell> mysqldumpslow [options] [log_file ...]
```

`mysqldumpslow` supports the following options.

Table 4.18 `mysqldumpslow` Options

Format	Description
-a	Do not abstract all numbers to N and strings to S
-n	Abstract numbers with at least the specified digits
--debug	Write debugging information
-g	Only consider statements that match the pattern
--help	Display help message and exit
-h	Host name of the server in the log file name
-i	Name of the server instance

Format	Description
-l	Do not subtract lock time from total time
-r	Reverse the sort order
-s	How to sort output
-t	Display only first num queries
--verbose	Verbose mode

- `--help`

  Display a help message and exit.

- `-a`

  Do not abstract all numbers to `N` and strings to `'S'`.

- `--debug`, `-d`

  Run in debug mode.

- `-g pattern`

  Consider only queries that match the (`grep`-style) pattern.

- `-h host_name`

  Host name of MySQL server for `*-slow.log` file name. The value can contain a wildcard. The default is `*` (match all).

- `-i name`

  Name of server instance (if using `mysql.server` startup script).

- `-l`

  Do not subtract lock time from total time.

- `-n N`

  Abstract numbers with at least `N` digits within names.

- `-r`

  Reverse the sort order.

- `-s sort_type`

  How to sort the output. The value of `sort_type` should be chosen from the following list:

  - `t`, `at`: Sort by query time or average query time
  - `l`, `al`: Sort by lock time or average lock time
  - `r`, `ar`: Sort by rows sent or average rows sent
  - `c`: Sort by count

  By default, `mysqldumpslow` sorts by average query time (equivalent to `-s at`).

- `-t N`

  Display only the first `N` queries in the output.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does.

Example of usage:

```
shell> mysqldumpslow

Reading mysql slow query log from /usr/local/mysql/data/mysqld51-apple-slow.log
Count: 1  Time=4.32s (4s)  Lock=0.00s (0s)  Rows=0.0 (0), root[root]@localhost
 insert into t2 select * from t1

Count: 3  Time=2.53s (7s)  Lock=0.00s (0s)  Rows=0.0 (0), root[root]@localhost
 insert into t2 select * from t1 limit N

Count: 3  Time=2.13s (6s)  Lock=0.00s (0s)  Rows=0.0 (0), root[root]@localhost
 insert into t1 select * from t1
```

4.6.9 mysqlhotcopy — A Database Backup Program

`mysqlhotcopy` is a Perl script that was originally written and contributed by Tim Bunce. It uses `FLUSH TABLES`, `LOCK TABLES`, and `cp` or `scp` to make a database backup. It is a fast way to make a backup of the database or single tables, but it can be run only on the same machine where the database directories are located. `mysqlhotcopy` works only for backing up `MyISAM` and `ARCHIVE` tables. It runs on Unix.

To use `mysqlhotcopy`, you must have read access to the files for the tables that you are backing up, the `SELECT` privilege for those tables, the `RELOAD` privilege (to be able to execute `FLUSH TABLES`), and the `LOCK TABLES` privilege (to be able to lock the tables).

```
shell> mysqlhotcopy db_name [/path/to/new_directory]
```

```
shell> mysqlhotcopy db_name_1 ... db_name_n /path/to/new_directory
```

Back up tables in the given database that match a regular expression:

```
shell> mysqlhotcopy db_name./regex/
```

The regular expression for the table name can be negated by prefixing it with a tilde (~):

```
shell> mysqlhotcopy db_name./~regex/
```

`mysqlhotcopy` supports the following options, which can be specified on the command line or in the `[mysqlhotcopy]` and `[client]` groups of an option file. For information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Table 4.19 mysqlhotcopy Options

Format	Description	Introduced
--addtodest	Do not rename target directory (if it exists); merely add files to it	
--allowold	Do not abort if a target exists; rename it by adding an _old suffix	
--checkpoint	Insert checkpoint entries	
--chroot	Base directory of the chroot jail in which mysqld operates	
--debug	Write debugging log	

Format	Description	Introduced
--dryrun	Report actions without performing them	
--flushlog	Flush logs after all tables are locked	
--help	Display help message and exit	
--host	Connect to MySQL server on given host	
--keepold	Do not delete previous (renamed) target when done	
--method	The method for copying files	
--noindices	Do not include full index files in the backup	
--old_server	Connect to server that does not support FLUSH TABLES tbl_list WITH READ LOCK	5.5.3
--password	Password to use when connecting to server	
--port	TCP/IP port number for connection	
--quiet	Be silent except for errors	
--regexp	Copy all databases with names that match the given regular expression	
--resetmaster	Reset the binary log after locking all the tables	
--resetslave	Reset the master.info file after locking all the tables	
--socket	For connections to localhost, the Unix socket file to use	
--tmpdir	The temporary directory	
--user	MySQL user name to use when connecting to server	

- `--help`, `-?`

  Display a help message and exit.

- `--addtodest`

  Do not rename target directory (if it exists); merely add files to it.

- `--allowold`

  Do not abort if a target exists; rename it by adding an `_old` suffix.

- `--checkpoint=`*`db_name.tbl_name`*

  Insert checkpoint entries into the specified database *`db_name`* and table *`tbl_name`*.

- `--chroot=`*`dir_name`*

  Base directory of the `chroot` jail in which `mysqld` operates. The *`dir_name`* value should match that of the `--chroot` option given to `mysqld`.

- `--debug`

  Enable debug output.

- `--dryrun`, `-n`

  Report actions without performing them.

- `--flushlog`

  Flush logs after all tables are locked.

- `--host=`*`host_name`*, `-h` *`host_name`*

The host name of the local host to use for making a TCP/IP connection to the local server. By default, the connection is made to `localhost` using a Unix socket file.

- `--keepold`

  Do not delete previous (renamed) target when done.

- `--method=`*`command`*

  The method for copying files (`cp` or `scp`). The default is `cp`.

- `--noindices`

  Do not include full index files for `MyISAM` tables in the backup. This makes the backup smaller and faster. The indexes for reloaded tables can be reconstructed later with `myisamchk -rq`.

- `--password=`*`password`*, `-p`*`password`*

  The password to use when connecting to the server. The password value is not optional for this option, unlike for other MySQL programs.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line.

- `--port=`*`port_num`*, `-P` *`port_num`*

  The TCP/IP port number to use when connecting to the local server.

- `--old_server`

  As of MySQL 5.5.3, `mysqlhotcopy` uses `FLUSH TABLES` *`tbl_list`* `WITH READ LOCK` to flush and lock tables. Use the `--old_server` option if the server is older than 5.5.3, which is when that statement was introduced. This option was added in MySQL 5.5.3.

- `--quiet`, `-q`

  Be silent except for errors.

- `--record_log_pos=`*`db_name.tbl_name`*

  Record master and slave status in the specified database *`db_name`* and table *`tbl_name`*.

- `--regexp=`*`expr`*

  Copy all databases with names that match the given regular expression.

- `--resetmaster`

  Reset the binary log after locking all the tables.

- `--resetslave`

  Reset the `master.info` file after locking all the tables.

- `--socket=`*`path`*, `-S` *`path`*

  The Unix socket file to use for connections to `localhost`.

- `--suffix=`*`str`*

  The suffix to use for names of copied databases.

- `--tmpdir=dir_name`

  The temporary directory. The default is `/tmp`.

- `--user=user_name`, `-u user_name`

  The MySQL user name to use when connecting to the server.

Use `perldoc` for additional `mysqlhotcopy` documentation, including information about the structure of the tables needed for the `--checkpoint` and `--record_log_pos` options:

```
shell> perldoc mysqlhotcopy
```

4.6.10 mysql_convert_table_format — Convert Tables to Use a Given Storage Engine

`mysql_convert_table_format` converts the tables in a database to use a particular storage engine (`MyISAM` by default). `mysql_convert_table_format` is written in Perl and requires that the `DBI` and `DBD::mysql` Perl modules be installed (see Section 2.12, "Perl Installation Notes").

Invoke `mysql_convert_table_format` like this:

```
shell> mysql_convert_table_format [options]db_name
```

The *db_name* argument indicates the database containing the tables to be converted.

`mysql_convert_table_format` supports the options described in the following list.

- `--help`

  Display a help message and exit.

- `--force`

  Continue even if errors occur.

- `--host=host_name`

  Connect to the MySQL server on the given host.

- `--password=password`

  The password to use when connecting to the server. The password value is not optional for this option, unlike for other MySQL programs.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--port=port_num`

  The TCP/IP port number to use for the connection.

- `--socket=path`

  For connections to `localhost`, the Unix socket file to use.

- `--type=engine_name`

  Specify the storage engine that the tables should be converted to use. The default is `MyISAM` if this option is not given.

- `--user=user_name`

  The MySQL user name to use when connecting to the server.

- `--verbose`

  Verbose mode. Print more information about what the program does.

- `--version`

  Display version information and exit.

4.6.11 mysql_find_rows — Extract SQL Statements from Files

`mysql_find_rows` reads files containing SQL statements and extracts statements that match a given regular expression or that contain `USE db_name` or `SET` statements. The utility expects statements to be terminated with semicolon (`;`) characters.

Invoke `mysql_find_rows` like this:

```
shell> mysql_find_rows [options] [file_name ...]
```

Each *`file_name`* argument should be the name of file containing SQL statements. If no file names are given, `mysql_find_rows` reads the standard input.

Examples:

```
mysql_find_rows --regexp=problem_table --rows=20 < update.log
mysql_find_rows --regexp=problem_table  update-log.1 update-log.2
```

`mysql_find_rows` supports the following options:

- `--help`, `--Information`

  Display a help message and exit.

- `--regexp=pattern`

  Display queries that match the pattern.

- `--rows=N`

  Quit after displaying *`N`* queries.

- `--skip-use-db`

  Do not include `USE db_name` statements in the output.

- `--start_row=N`

  Start output from this row.

4.6.12 mysql_fix_extensions — Normalize Table File Name Extensions

`mysql_fix_extensions` converts the extensions for `MyISAM` (or `ISAM`) table files to their canonical forms. It looks for files with extensions matching any lettercase variant of `.frm`, `.myd`, `.myi`, `.isd`, and `.ism` and renames them to have extensions of `.frm`, `.MYD`, `.MYI`, `.ISD`, and `.ISM`, respectively. This can be useful after transferring the files from a system with case-insensitive file names (such as Windows) to a system with case-sensitive file names.

Invoke `mysql_fix_extensions` like this, where *`data_dir`* is the path name to the MySQL data directory.

```
shell> mysql_fix_extensions data_dir
```

4.6.13 mysql_setpermission — Interactively Set Permissions in Grant Tables

`mysql_setpermission` is a Perl script that was originally written and contributed by Luuk de Boer. It interactively sets permissions in the MySQL grant tables. `mysql_setpermission` is written in Perl and requires that the `DBI` and `DBD::mysql` Perl modules be installed (see Section 2.12, "Perl Installation Notes").

Invoke `mysql_setpermission` like this:

```
shell> mysql_setpermission [options]
```

`options` should be either `--help` to display the help message, or options that indicate how to connect to the MySQL server. The account used when you connect determines which permissions you have when attempting to modify existing permissions in the grant tables.

`mysql_setpermissions` also reads options from the `[client]` and `[perl]` groups in the `.my.cnf` file in your home directory, if the file exists.

`mysql_setpermission` supports the following options:

- `--help`

  Display a help message and exit.

- `--host=`*`host_name`*

  Connect to the MySQL server on the given host.

- `--password=`*`password`*

  The password to use when connecting to the server. The password value is not optional for this option, unlike for other MySQL programs.

  Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, "End-User Guidelines for Password Security". You can use an option file to avoid giving the password on the command line.

- `--port=`*`port_num`*

  The TCP/IP port number to use for the connection.

- `--socket=`*`path`*

  For connections to `localhost`, the Unix socket file to use.

- `--user=`*`user_name`*

  The MySQL user name to use when connecting to the server.

4.6.14 mysql_waitpid — Kill Process and Wait for Its Termination

`mysql_waitpid` signals a process to terminate and waits for the process to exit. It uses the `kill()` system call and Unix signals, so it runs on Unix and Unix-like systems.

Invoke `mysql_waitpid` like this:

```
shell> mysql_waitpid [options] pid wait_time
```

mysql_waitpid sends signal 0 to the process identified by *pid* and waits up to *wait_time* seconds for the process to terminate. *pid* and *wait_time* must be positive integers.

If process termination occurs within the wait time or the process does not exist, mysql_waitpid returns 0. Otherwise, it returns 1.

If the kill() system call cannot handle signal 0, mysql_waitpid() uses signal 1 instead.

mysql_waitpid supports the following options:

- --help, -?, -I

  Display a help message and exit.

- --verbose, -v

  Verbose mode. Display a warning if signal 0 could not be used and signal 1 is used instead.

- --version, -V

  Display version information and exit.

4.6.15 mysql_zap — Kill Processes That Match a Pattern

mysql_zap kills processes that match a pattern. It uses the ps command and Unix signals, so it runs on Unix and Unix-like systems.

Invoke mysql_zap like this:

```
shell> mysql_zap [-signal] [-?Ift] pattern
```

A process matches if its output line from the ps command contains the pattern. By default, mysql_zap asks for confirmation for each process. Respond y to kill the process, or q to exit mysql_zap. For any other response, mysql_zap does not attempt to kill the process.

If the -*signal* option is given, it specifies the name or number of the signal to send to each process. Otherwise, mysql_zap tries first with TERM (signal 15) and then with KILL (signal 9).

mysql_zap supports the following additional options:

- --help, -?, -I

  Display a help message and exit.

- -f

  Force mode. mysql_zap attempts to kill each process without confirmation.

- -t

  Test mode. Display information about each process but do not kill it.

4.7 MySQL Program Development Utilities

This section describes some utilities that you may find useful when developing MySQL programs.

In shell scripts, you can use the my_print_defaults program to parse option files and see what options would be used by a given program. The following example shows the output that my_print_defaults might produce when asked to show the options found in the [client] and [mysql] groups:

```
shell> my_print_defaults client mysql
--port=3306
--socket=/tmp/mysql.sock
--no-auto-rehash
```

Note for developers: Option file handling is implemented in the C client library simply by processing all options in the appropriate group or groups before any command-line arguments. This works well for programs that use the last instance of an option that is specified multiple times. If you have a C or C++ program that handles multiply specified options this way but that doesn't read option files, you need add only two lines to give it that capability. Check the source code of any of the standard MySQL clients to see how to do this.

Several other language interfaces to MySQL are based on the C client library, and some of them provide a way to access option file contents. These include Perl and Python. For details, see the documentation for your preferred interface.

4.7.1 msql2mysql — Convert mSQL Programs for Use with MySQL

Initially, the MySQL C API was developed to be very similar to that for the mSQL database system. Because of this, mSQL programs often can be converted relatively easily for use with MySQL by changing the names of the C API functions.

The `msql2mysql` utility performs the conversion of mSQL C API function calls to their MySQL equivalents. `msql2mysql` converts the input file in place, so make a copy of the original before converting it. For example, use `msql2mysql` like this:

```
shell> cp client-prog.c client-prog.c.orig
shell> msql2mysql client-prog.c
client-prog.c converted
```

Then examine `client-prog.c` and make any post-conversion revisions that may be necessary.

`msql2mysql` uses the `replace` utility to make the function name substitutions. See Section 4.8.2, “replace — A String-Replacement Utility”.

4.7.2 mysql_config — Display Options for Compiling Clients

`mysql_config` provides you with useful information for compiling your MySQL client and connecting it to MySQL. It is a shell script, so it is available only on Unix and Unix-like systems.

`mysql_config` supports the following options.

- `--cflags`

  Compiler flags to find include files and critical compiler flags and defines used when compiling the `libmysqlclient` library. The options returned are tied to the specific compiler that was used when the library was created and might clash with the settings for your own compiler. Use `--include` for more portable options that contain only include paths.

- `--include`

  Compiler options to find MySQL include files.

- `--libmysqld-libs`, `--embedded-libs`, `--embedded`

  Libraries and options required to link with `libmysqld`, the MySQL embedded server.

- `--libs`

  Libraries and options required to link with the MySQL client library.

- `--libs_r`

Libraries and options required to link with the thread-safe MySQL client library. In MySQL 5.5, all client libraries are thread-safe, so this option need not be used. The `--libs` option can be used in all cases.

- `--plugindir`

  The default plugin directory path name, defined when configuring MySQL.

- `--port`

  The default TCP/IP port number, defined when configuring MySQL.

- `--socket`

  The default Unix socket file, defined when configuring MySQL.

- `--variable=`*`var_name`*

  Display the value of the named configuration variable. Permitted *`var_name`* values are `pkgincludedir` (the header file directory), `pkglibdir` (the library directory), and `plugindir` (the plugin directory).

- `--version`

  Version number for the MySQL distribution.

If you invoke `mysql_config` with no options, it displays a list of all options that it supports, and their values:

```
shell> mysql_config
Usage: /usr/local/mysql/bin/mysql_config [options]
Options:
  --cflags         [-I/usr/local/mysql/include/mysql -mcpu=pentiumpro]
  --include        [-I/usr/local/mysql/include/mysql]
  --libs           [-L/usr/local/mysql/lib/mysql -lmysqlclient
                    -lpthread -lm -lrt -lssl -lcrypto -ldl]
  --libs_r         [-L/usr/local/mysql/lib/mysql -lmysqlclient_r
                    -lpthread -lm -lrt -lssl -lcrypto -ldl]
  --plugindir      [/usr/local/mysql/lib/plugin]
  --socket         [/tmp/mysql.sock]
  --port           [3306]
  --version        [5.5.31]
  --libmysqld-libs [-L/usr/local/mysql/lib/mysql -lmysqld
                    -lpthread -lm -lrt -lssl -lcrypto -ldl -lcrypt]
  --variable=VAR   VAR is one of:
          pkgincludedir [/usr/local/mysql/include]
          pkglibdir     [/usr/local/mysql/lib]
          plugindir     [/usr/local/mysql/lib/plugin]
```

You can use `mysql_config` within a command line using backticks to include the output that it produces for particular options. For example, to compile and link a MySQL client program, use `mysql_config` as follows:

```
gcc -c `mysql_config --cflags` progname.c
gcc -o progname progname.o `mysql_config --libs`
```

4.7.3 `my_print_defaults` — Display Options from Option Files

`my_print_defaults` displays the options that are present in option groups of option files. The output indicates what options will be used by programs that read the specified option groups. For example, the `mysqlcheck` program reads the `[mysqlcheck]` and `[client]` option groups. To see what options are present in those groups in the standard option files, invoke `my_print_defaults` like this:

```
shell> my_print_defaults mysqlcheck client
--user=myusername
--password=password
--host=localhost
```

The output consists of options, one per line, in the form that they would be specified on the command line.

`my_print_defaults` supports the following options.

- `--help`, `-?`

  Display a help message and exit.

- `--config-file=file_name`, `--defaults-file=file_name`, `-c file_name`

  Read only the given option file.

- `--debug=debug_options`, `-# debug_options`

  Write a debugging log. A typical `debug_options` string is `d:t:o,file_name`. The default is `d:t:o,/tmp/my_print_defaults.trace`.

- `--defaults-extra-file=file_name`, `--extra-file=file_name`, `-e file_name`

  Read this option file after the global option file but (on Unix) before the user option file.

- `--defaults-group-suffix=suffix`, `-g suffix`

  In addition to the groups named on the command line, read groups that have the given suffix.

- `--no-defaults`, `-n`

  Return an empty string.

- `--verbose`, `-v`

  Verbose mode. Print more information about what the program does.

- `--version`, `-V`

  Display version information and exit.

4.7.4 `resolve_stack_dump` — Resolve Numeric Stack Trace Dump to Symbols

`resolve_stack_dump` resolves a numeric stack dump to symbols.

Invoke `resolve_stack_dump` like this:

```
shell> resolve_stack_dump [options] symbols_file [numeric_dump_file]
```

The symbols file should include the output from the `nm --numeric-sort mysqld` command. The numeric dump file should contain a numeric stack track from `mysqld`. If no numeric dump file is named on the command line, the stack trace is read from the standard input.

`resolve_stack_dump` supports the following options.

- `--help`, `-h`

  Display a help message and exit.

- `--numeric-dump-file=file_name`, `-n file_name`

  Read the stack trace from the given file.

- `--symbols-file=file_name`, `-s file_name`

  Use the given symbols file.

- `--version`, `-V`

  Display version information and exit.

For more information, see Section 24.5.1.5, “Using a Stack Trace”.

4.8 Miscellaneous Programs

4.8.1 `perror` — Explain Error Codes

For most system errors, MySQL displays, in addition to an internal text message, the system error code in one of the following styles:

```
message ... (errno: #)
message ... (Errcode: #)
```

You can find out what the error code means by examining the documentation for your system or by using the `perror` utility.

`perror` prints a description for a system error code or for a storage engine (table handler) error code.

Invoke `perror` like this:

```
shell> perror [options] errorcode ...
```

Example:

```
shell> perror 13 64
OS error code  13:  Permission denied
OS error code  64:  Machine is not on the network
```

To obtain the error message for an NDB Cluster error code, invoke `perror` with the `--ndb` option:

```
shell> perror --ndb errorcode
```

The meaning of system error messages may be dependent on your operating system. A given error code may mean different things on different operating systems.

`perror` supports the following options.

- `--help`, `--info`, `-I`, `-?`

  Display a help message and exit.

- `--ndb`

  Print the error message for an NDB Cluster error code.

- `--silent`, `-s`

  Silent mode. Print only the error message.

- `--verbose`, `-v`

  Verbose mode. Print error code and message. This is the default behavior.

- `--version`, `-V`

  Display version information and exit.

4.8.2 replace — A String-Replacement Utility

The `replace` utility program changes strings in place in files or on the standard input.

Invoke `replace` in one of the following ways:

```
shell> replace from to [from to] ... -- file_name [file_name] ...
shell> replace from to [from to] ... < file_name
```

`from` represents a string to look for and *`to`* represents its replacement. There can be one or more pairs of strings.

Use the `--` option to indicate where the string-replacement list ends and the file names begin. In this case, any file named on the command line is modified in place, so you may want to make a copy of the original before converting it. *`replace`* prints a message indicating which of the input files it actually modifies.

If the `--` option is not given, `replace` reads the standard input and writes to the standard output.

`replace` uses a finite state machine to match longer strings first. It can be used to swap strings. For example, the following command swaps `a` and `b` in the given files, `file1` and `file2`:

```
shell> replace a b b a -- file1 file2 ...
```

The `replace` program is used by `msql2mysql`. See Section 4.7.1, “msql2mysql — Convert mSQL Programs for Use with MySQL”.

`replace` supports the following options.

- `-?`, `-I`

  Display a help message and exit.

- *`-#debug_options`*

  Enable debugging.

- `-s`

  Silent mode. Print less information what the program does.

- `-v`

  Verbose mode. Print more information about what the program does.

- `-V`

  Display version information and exit.

4.8.3 resolveip — Resolve Host name to IP Address or Vice Versa

The `resolveip` utility resolves host names to IP addresses and vice versa.

Invoke `resolveip` like this:

```
shell> resolveip [options] {host_name|ip-addr} ...
```

`resolveip` supports the following options.

- `--help`, `--info`, `-?`, `-I`

  Display a help message and exit.

- `--silent`, `-s`

  Silent mode. Produce less output.

- `--version`, `-V`

  Display version information and exit.

4.9 MySQL Program Environment Variables

This section lists environment variables that are used directly or indirectly by MySQL. Most of these can also be found in other places in this manual.

Options on the command line take precedence over values specified in option files and environment variables, and values in option files take precedence over values in environment variables. In many cases, it is preferable to use an option file instead of environment variables to modify the behavior of MySQL. See Section 4.2.6, “Using Option Files”.

Variable	Description
`CXX`	The name of your C++ compiler (for running `CMake`).
`CC`	The name of your C compiler (for running `CMake`).
`DBI_USER`	The default user name for Perl DBI.
`DBI_TRACE`	Trace options for Perl DBI.
`HOME`	The default path for the `mysql` history file is `$HOME/.mysql_history`.
`LD_RUN_PATH`	Used to specify the location of `libmysqlclient.so`.
`LIBMYSQL_ENABLE_CLEARTEXT_PLUGIN`	Enable `mysql_clear_password` authentication plugin; see Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”.
`MYSQL_DEBUG`	Debug trace options when debugging.
`MYSQL_GROUP_SUFFIX`	Option group suffix value (like specifying `--defaults-group-suffix`).
`MYSQL_HISTFILE`	The path to the `mysql` history file. If this variable is set, its value overrides the default for `$HOME/.mysql_history`.
`MYSQL_HOME`	The path to the directory in which the server-specific `my.cnf` file resides.
`MYSQL_HOST`	The default host name used by the `mysql` command-line client.
`MYSQL_PS1`	The command prompt to use in the `mysql` command-line client.
`MYSQL_PWD`	The default password when connecting to `mysqld`. Using this is insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”.

Variable	Description
MYSQL_TCP_PORT	The default TCP/IP port number.
MYSQL_UNIX_PORT	The default Unix socket file name; used for connections to localhost.
PATH	Used by the shell to find MySQL programs.
TMPDIR	The directory in which temporary files are created.
TZ	This should be set to your local time zone. See Section B.5.3.7, “Time Zone Problems”.
UMASK	The user-file creation mode when creating files. See note following table.
UMASK_DIR	The user-directory creation mode when creating directories. See note following table.
USER	The default user name on Windows when connecting to mysqld.

For information about the mysql history file, see Section 4.5.1.3, “mysql Logging”.

The default UMASK and UMASK_DIR values are 0660 and 0700, respectively. MySQL assumes that the value for UMASK or UMASK_DIR is in octal if it starts with a zero. For example, setting UMASK=0600 is equivalent to UMASK=384 because 0600 octal is 384 decimal.

The UMASK and UMASK_DIR variables, despite their names, are used as modes, not masks:

- If UMASK is set, mysqld uses ($UMASK | 0600) as the mode for file creation, so that newly created files have a mode in the range from 0600 to 0666 (all values octal).
- If UMASK_DIR is set, mysqld uses ($UMASK_DIR | 0700) as the base mode for directory creation, which then is AND-ed with ~(~$UMASK & 0666), so that newly created directories have a mode in the range from 0700 to 0777 (all values octal). The AND operation may remove read and write permissions from the directory mode, but not execute permissions.

Chapter 5 MySQL Server Administration

Table of Contents

5.1 The MySQL Server 425
5.1.1 Configuring the Server 426
5.1.2 Server Configuration Defaults 428
5.1.3 Server Option and Variable Reference 428
5.1.4 Server Command Options 456
5.1.5 Server System Variables 487
5.1.6 Using System Variables 584
5.1.7 Server Status Variables 597
5.1.8 Server SQL Modes 622
5.1.9 IPv6 Support 630
5.1.10 Server-Side Help 634
5.1.11 Server Response to Signals 635
5.1.12 The Server Shutdown Process 635
5.2 The MySQL Data Directory 637
5.3 The mysql System Database 637
5.4 MySQL Server Logs 639
5.4.1 Selecting General Query and Slow Query Log Output Destinations 640
5.4.2 The Error Log 642
5.4.3 The General Query Log 644
5.4.4 The Binary Log 645
5.4.5 The Slow Query Log 657
5.4.6 The DDL Log 659
5.4.7 Server Log Maintenance 659
5.5 MySQL Server Plugins 661
5.5.1 Installing and Uninstalling Plugins 661
5.5.2 Obtaining Server Plugin Information 664
5.5.3 MySQL Enterprise Thread Pool 665
5.6 Running Multiple MySQL Instances on One Machine 671
5.6.1 Setting Up Multiple Data Directories 673
5.6.2 Running Multiple MySQL Instances on Windows 674
5.6.3 Running Multiple MySQL Instances on Unix 677
5.6.4 Using Client Programs in a Multiple-Server Environment 678
5.7 Tracing mysqld Using DTrace 678
5.7.1 mysqld DTrace Probe Reference 679

MySQL Server (`mysqld`) is the main program that does most of the work in a MySQL installation. This chapter provides an overview of MySQL Server and covers general server administration:

- Server configuration
- The data directory, particularly the `mysql` system database
- The server log files
- Management of multiple servers on a single machine

For additional information on administrative topics, see also:

- Chapter 6, *Security*
- Chapter 7, *Backup and Recovery*
- Chapter 17, *Replication*

5.1 The MySQL Server

`mysqld` is the MySQL server. The following discussion covers these MySQL server configuration topics:

- Startup options that the server supports. You can specify these options on the command line, through configuration files, or both.
- Server system variables. These variables reflect the current state and values of the startup options, some of which can be modified while the server is running.
- Server status variables. These variables contain counters and statistics about runtime operation.
- How to set the server SQL mode. This setting modifies certain aspects of SQL syntax and semantics, for example for compatibility with code from other database systems, or to control the error handling for particular situations.
- The server shutdown process. There are performance and reliability considerations depending on the type of table (transactional or nontransactional) and whether you use replication.

Note

Not all storage engines are supported by all MySQL server binaries and configurations. To find out how to determine which storage engines your MySQL server installation supports, see Section 13.7.5.17, “SHOW ENGINES Syntax”.

5.1.1 Configuring the Server

The MySQL server, `mysqld`, has many command options and system variables that can be set at startup to configure its operation. To determine the command option and system variable values used by the server, execute this command:

```
shell> mysqld --verbose --help
```

The command produces a list of all `mysqld` options and configurable system variables. Its output includes the default option and variable values and looks something like this:

```
allow-suspicious-udfs             FALSE
archive                           ON
auto-increment-increment          1
auto-increment-offset             1
autocommit                        TRUE
automatic-sp-privileges           TRUE
back-log                          50
basedir                           /home/jon/bin/mysql-5.5/
...
tmpdir                            /tmp
transaction-alloc-block-size      8192
transaction-isolation             REPEATABLE-READ
transaction-prealloc-size         4096
updatable-views-with-limit        YES
verbose                           TRUE
wait-timeout                      28800
```

To see the current system variable values used by the server as it runs, connect to it and execute this statement:

```
mysql> SHOW VARIABLES;
```

To see some statistical and status indicators for a running server, execute this statement:

```
mysql> SHOW STATUS;
```

System variable and status information also is available using the `mysqladmin` command:

```
shell> mysqladmin variables
shell> mysqladmin extended-status
```

For a full description of all command options, system variables, and status variables, see these sections:

- Section 5.1.4, “Server Command Options”
- Section 5.1.5, “Server System Variables”
- Section 5.1.7, “Server Status Variables”

More detailed monitoring information is available from the Performance Schema; see Chapter 22, *MySQL Performance Schema*.

MySQL uses algorithms that are very scalable, so you can usually run with very little memory. However, normally better performance results from giving MySQL more memory.

When tuning a MySQL server, the two most important variables to configure are `key_buffer_size` and `table_open_cache`. You should first feel confident that you have these set appropriately before trying to change any other variables.

The following examples indicate some typical variable values for different runtime configurations.

- If you have at least 1-2GB of memory and many tables and want maximum performance with a moderate number of clients, use something like this:

  ```
  shell> mysqld_safe --key_buffer_size=384M --table_open_cache=4000 \
             --sort_buffer_size=4M --read_buffer_size=1M &
  ```

- If you have only 256MB of memory and only a few tables, but you still do a lot of sorting, you can use something like this:

  ```
  shell> mysqld_safe --key_buffer_size=64M --sort_buffer_size=1M
  ```

  If there are very many simultaneous connections, swapping problems may occur unless `mysqld` has been configured to use very little memory for each connection. `mysqld` performs better if you have enough memory for all connections.

- With little memory and lots of connections, use something like this:

  ```
  shell> mysqld_safe --key_buffer_size=512K --sort_buffer_size=100K \
             --read_buffer_size=100K &
  ```

  Or even this:

  ```
  shell> mysqld_safe --key_buffer_size=512K --sort_buffer_size=16K \
             --table_open_cache=32 --read_buffer_size=8K \
             --net_buffer_length=1K &
  ```

If you are performing `GROUP BY` or `ORDER BY` operations on tables that are much larger than your available memory, increase the value of `read_rnd_buffer_size` to speed up the reading of rows following sorting operations.

You can make use of the example option files included with your MySQL distribution; see Section 5.1.2, “Server Configuration Defaults”.

If you specify an option on the command line for `mysqld` or `mysqld_safe`, it remains in effect only for that invocation of the server. To use the option every time the server runs, put it in an option file. See Section 4.2.6, “Using Option Files”.

5.1.2 Server Configuration Defaults

The MySQL server has many operating parameters, which you can change at server startup using command-line options or configuration files (option files). It is also possible to change many parameters at runtime. For general instructions on setting parameters at startup or runtime, see Section 5.1.4, “Server Command Options”, and Section 5.1.5, “Server System Variables”.

MySQL provides a number of preconfigured option files that can be used as a basis for tuning the MySQL server. Look for files named `my-small.cnf`, `my-medium.cnf`, `my-large.cnf`, and `my-huge.cnf`, which are sample option files for small, medium, large, and very large systems. On Windows, the extension is `.ini` rather than `.cnf`.

Note

On Windows, the `.ini` or `.cnf` option file extension might not be displayed.

For a binary distribution, look for the sample files in or under your installation directory. If you have a source distribution, look in the `support-files` directory. To use a sample file as a base configuration file, rename a copy of it and place the copy in the appropriate location. Regarding names and appropriate location, see the general information provided in Section 4.2.6, “Using Option Files”. That section also describes option file format and syntax.

5.1.3 Server Option and Variable Reference

The following table provides a list of all the command line options, server and status variables applicable within `mysqld`.

The table lists command-line options (Cmd-line), options valid in configuration files (Option file), server system variables (System Var), and status variables (Status var) in one unified list, with notification of where each option/variable is valid. If a server option set on the command line or in an option file differs from the name of the corresponding server system or status variable, the variable name is noted immediately below the corresponding option. For status variables, the scope of the variable is shown (Scope) as either global, session, or both. Please see the corresponding sections for details on setting and using the options and variables. Where appropriate, a direct link to further information on the item as available.

For a version of this table that is specific to NDB Cluster, see Section 18.3.2.5, “NDB Cluster mysqld Option and Variable Reference”.

Table 5.1 Option and Variable Summary

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
abort-slave-event-count	Yes	Yes				
Aborted_clients				Yes	Global	No
Aborted_connects				Yes	Global	No
allow-suspicious-udfs	Yes	Yes				
ansi	Yes	Yes				
audit-log	Yes	Yes				
audit_log_buffer_size	Yes	Yes	Yes		Global	No
audit_log_file	Yes	Yes	Yes		Global	No
audit_log_flush			Yes		Global	Yes
audit_log_format	Yes	Yes	Yes		Global	No
audit_log_policy	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
audit_log_rotate_on_size	Yes	Yes	Yes		Global	Yes
audit_log_strategy	Yes	Yes	Yes		Global	No
authentication_windows_log_level	Yes	Yes				
authentication_windows_use_principal_name	Yes	Yes				
auto_increment_increment			Yes		Both	Yes
auto_increment_offset			Yes		Both	Yes
autocommit	Yes	Yes	Yes		Varies	Yes
automatic_sp_privileges			Yes		Global	Yes
back_log			Yes		Global	No
basedir	Yes	Yes	Yes		Global	No
big-tables	Yes	Yes			Varies	Yes
- *Variable*: big_tables			Yes		Varies	Yes
bind-address	Yes	Yes				
Binlog_cache_disk_use				Yes	Global	No
binlog_cache_size	Yes	Yes	Yes		Global	Yes
Binlog_cache_use				Yes	Global	No
binlog_direct_non_transactional_updates	Yes	Yes	Yes		Both	Yes
binlog-do-db	Yes	Yes				
binlog-format	Yes	Yes			Both	Yes
- *Variable*: binlog_format			Yes		Both	Yes
binlog-ignore-db	Yes	Yes				
binlog-row-event-max-size	Yes	Yes				
Binlog_stmt_cache_disk_use				Yes	Global	No
binlog_stmt_cache_size	Yes	Yes	Yes		Global	Yes
Binlog_stmt_cache_use				Yes	Global	No
bootstrap	Yes	Yes				
bulk_insert_buffer_size	Yes	Yes	Yes		Both	Yes
Bytes_received				Yes	Both	No
Bytes_sent				Yes	Both	No
character_set_client			Yes		Both	Yes
character-set-client-handshake	Yes	Yes				
character_set_connection			Yes		Both	Yes
character_set_database[a]			Yes		Both	Yes
character-set-filesystem	Yes	Yes			Both	Yes
- *Variable*: character_set_filesystem			Yes		Both	Yes
character_set_results			Yes		Both	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
character-set-server	Yes	Yes			Both	Yes
- *Variable*: character_set_server			Yes		Both	Yes
character_set_system			Yes		Global	No
character-sets-dir	Yes	Yes			Global	No
- *Variable*: character_sets_dir			Yes		Global	No
chroot	Yes	Yes				
collation_connection			Yes		Both	Yes
collation_database[b]			Yes		Both	Yes
collation-server	Yes	Yes			Both	Yes
- *Variable*: collation_server			Yes		Both	Yes
Com_admin_commands				Yes	Both	No
Com_alter_db				Yes	Both	No
Com_alter_db_upgrade				Yes	Both	No
Com_alter_event				Yes	Both	No
Com_alter_function				Yes	Both	No
Com_alter_procedure				Yes	Both	No
Com_alter_server				Yes	Both	No
Com_alter_table				Yes	Both	No
Com_alter_tablespace				Yes	Both	No
Com_analyze				Yes	Both	No
Com_assign_to_keycache				Yes	Both	No
Com_begin				Yes	Both	No
Com_binlog				Yes	Both	No
Com_call_procedure				Yes	Both	No
Com_change_db				Yes	Both	No
Com_change_master				Yes	Both	No
Com_check				Yes	Both	No
Com_checksum				Yes	Both	No
Com_commit				Yes	Both	No
Com_create_db				Yes	Both	No
Com_create_event				Yes	Both	No
Com_create_function				Yes	Both	No
Com_create_index				Yes	Both	No
Com_create_procedure				Yes	Both	No
Com_create_server				Yes	Both	No
Com_create_table				Yes	Both	No
Com_create_trigger				Yes	Both	No
Com_create_udf				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Com_create_user				Yes	Both	No
Com_create_view				Yes	Both	No
Com_dealloc_sql				Yes	Both	No
Com_delete				Yes	Both	No
Com_delete_multi				Yes	Both	No
Com_do				Yes	Both	No
Com_drop_db				Yes	Both	No
Com_drop_event				Yes	Both	No
Com_drop_function				Yes	Both	No
Com_drop_index				Yes	Both	No
Com_drop_procedure				Yes	Both	No
Com_drop_server				Yes	Both	No
Com_drop_table				Yes	Both	No
Com_drop_trigger				Yes	Both	No
Com_drop_user				Yes	Both	No
Com_drop_view				Yes	Both	No
Com_empty_query				Yes	Both	No
Com_execute_sql				Yes	Both	No
Com_flush				Yes	Both	No
Com_grant				Yes	Both	No
Com_ha_close				Yes	Both	No
Com_ha_open				Yes	Both	No
Com_ha_read				Yes	Both	No
Com_help				Yes	Both	No
Com_insert				Yes	Both	No
Com_insert_select				Yes	Both	No
Com_install_plugin				Yes	Both	No
Com_kill				Yes	Both	No
Com_load				Yes	Both	No
Com_lock_tables				Yes	Both	No
Com_optimize				Yes	Both	No
Com_preload_keys				Yes	Both	No
Com_prepare_sql				Yes	Both	No
Com_purge				Yes	Both	No
Com_purge_before_date				Yes	Both	No
Com_release_savepoint				Yes	Both	No
Com_rename_table				Yes	Both	No
Com_rename_user				Yes	Both	No
Com_repair				Yes	Both	No
Com_replace				Yes	Both	No
Com_replace_select				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Com_reset				Yes	Both	No
Com_resignal				Yes	Both	No
Com_revoke				Yes	Both	No
Com_revoke_all				Yes	Both	No
Com_rollback				Yes	Both	No
Com_rollback_to_savepoint				Yes	Both	No
Com_savepoint				Yes	Both	No
Com_select				Yes	Both	No
Com_set_option				Yes	Both	No
Com_show_authors				Yes	Both	No
Com_show_binlog_events				Yes	Both	No
Com_show_binlogs				Yes	Both	No
Com_show_charsets				Yes	Both	No
Com_show_collations				Yes	Both	No
Com_show_contributors				Yes	Both	No
Com_show_create_db				Yes	Both	No
Com_show_create_event				Yes	Both	No
Com_show_create_func				Yes	Both	No
Com_show_create_proc				Yes	Both	No
Com_show_create_table				Yes	Both	No
Com_show_create_trigger				Yes	Both	No
Com_show_databases				Yes	Both	No
Com_show_engine_logs				Yes	Both	No
Com_show_engine_mutex				Yes	Both	No
Com_show_engine_status				Yes	Both	No
Com_show_errors				Yes	Both	No
Com_show_events				Yes	Both	No
Com_show_fields				Yes	Both	No
Com_show_function_code				Yes	Both	No
Com_show_function_status				Yes	Both	No
Com_show_grants				Yes	Both	No
Com_show_keys				Yes	Both	No
Com_show_master_status				Yes	Both	No
Com_show_ndb_status				Yes	Both	No
Com_show_new_master				Yes	Both	No
Com_show_open_tables				Yes	Both	No
Com_show_plugins				Yes	Both	No
Com_show_privileges				Yes	Both	No
Com_show_procedure_code				Yes	Both	No
Com_show_procedure_status				Yes	Both	No
Com_show_processlist				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Com_show_profile				Yes	Both	No
Com_show_profiles				Yes	Both	No
Com_show_relaylog_events				Yes	Both	No
Com_show_slave_hosts				Yes	Both	No
Com_show_slave_status				Yes	Both	No
Com_show_status				Yes	Both	No
Com_show_storage_engines				Yes	Both	No
Com_show_table_status				Yes	Both	No
Com_show_tables				Yes	Both	No
Com_show_triggers				Yes	Both	No
Com_show_variables				Yes	Both	No
Com_show_warnings				Yes	Both	No
Com_signal				Yes	Both	No
Com_slave_start				Yes	Both	No
Com_slave_stop				Yes	Both	No
Com_stmt_close				Yes	Both	No
Com_stmt_execute				Yes	Both	No
Com_stmt_fetch				Yes	Both	No
Com_stmt_prepare				Yes	Both	No
Com_stmt_reprepare				Yes	Both	No
Com_stmt_reset				Yes	Both	No
Com_stmt_send_long_data				Yes	Both	No
Com_truncate				Yes	Both	No
Com_uninstall_plugin				Yes	Both	No
Com_unlock_tables				Yes	Both	No
Com_update				Yes	Both	No
Com_update_multi				Yes	Both	No
Com_xa_commit				Yes	Both	No
Com_xa_end				Yes	Both	No
Com_xa_prepare				Yes	Both	No
Com_xa_recover				Yes	Both	No
Com_xa_rollback				Yes	Both	No
Com_xa_start				Yes	Both	No
completion_type	Yes	Yes	Yes		Both	Yes
Compression				Yes	Session	No
concurrent_insert	Yes	Yes	Yes		Global	Yes
connect_timeout	Yes	Yes	Yes		Global	Yes
Connections				Yes	Global	No
console	Yes	Yes				
core-file	Yes	Yes				
Created_tmp_disk_tables				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Created_tmp_files				Yes	Global	No
Created_tmp_tables				Yes	Both	No
datadir	Yes	Yes	Yes		Global	No
date_format			Yes		Varies	No
datetime_format			Yes		Varies	No
debug	Yes	Yes	Yes		Both	Yes
debug_sync			Yes		Varies	Yes
debug-sync-timeout	Yes	Yes				
default-character-set	Yes	Yes				
default-storage-engine	Yes	Yes			Both	Yes
- *Variable*: default_storage_engine			Yes		Both	Yes
default-time-zone	Yes	Yes				
default_week_format	Yes	Yes	Yes		Both	Yes
defaults-extra-file	Yes					
defaults-file	Yes					
defaults-group-suffix	Yes					
delay-key-write	Yes	Yes			Global	Yes
- *Variable*: delay_key_write			Yes		Global	Yes
Delayed_errors				Yes	Global	No
delayed_insert_limit	Yes	Yes	Yes		Global	Yes
Delayed_insert_threads				Yes	Global	No
delayed_insert_timeout	Yes	Yes	Yes		Global	Yes
delayed_queue_size	Yes	Yes	Yes		Global	Yes
Delayed_writes				Yes	Global	No
des-key-file	Yes	Yes				
disconnect-slave-event-count	Yes	Yes				
div_precision_increment	Yes	Yes	Yes		Both	Yes
enable-locking	Yes	Yes				
enable-named-pipe	Yes	Yes				
- *Variable*: named_pipe						
enable-pstack	Yes	Yes				
engine-condition-pushdown	Yes	Yes			Both	Yes
- *Variable*: engine_condition_pushdown			Yes		Both	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
error_count			Yes		Session	No
event-scheduler	Yes	Yes			Global	Yes
- *Variable*: event_scheduler			Yes		Global	Yes
exit-info	Yes	Yes				
expire_logs_days	Yes	Yes	Yes		Global	Yes
external-locking	Yes	Yes				
- *Variable*: skip_external_locking						
external_user			Yes		Session	No
federated	Yes	Yes				
flush	Yes	Yes	Yes		Global	Yes
Flush_commands				Yes	Global	No
flush_time	Yes	Yes	Yes		Global	Yes
foreign_key_checks			Yes		Varies	Yes
ft_boolean_syntax	Yes	Yes	Yes		Global	Yes
ft_max_word_len	Yes	Yes	Yes		Global	No
ft_min_word_len	Yes	Yes	Yes		Global	No
ft_query_expansion_limit	Yes	Yes	Yes		Global	No
ft_stopword_file	Yes	Yes	Yes		Global	No
gdb	Yes	Yes				
general-log	Yes	Yes			Global	Yes
- *Variable*: general_log			Yes		Global	Yes
general_log_file	Yes	Yes	Yes		Global	Yes
group_concat_max_len	Yes	Yes	Yes		Both	Yes
Handler_commit				Yes	Both	No
Handler_delete				Yes	Both	No
Handler_discover				Yes	Both	No
Handler_prepare				Yes	Both	No
Handler_read_first				Yes	Both	No
Handler_read_key				Yes	Both	No
Handler_read_last				Yes	Both	No
Handler_read_next				Yes	Both	No
Handler_read_prev				Yes	Both	No
Handler_read_rnd				Yes	Both	No
Handler_read_rnd_next				Yes	Both	No
Handler_rollback				Yes	Both	No
Handler_savepoint				Yes	Both	No
Handler_savepoint_rollback				Yes	Both	No
Handler_update				Yes	Both	No
Handler_write				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
have_compress			Yes		Global	No
have_crypt			Yes		Global	No
have_csv			Yes		Global	No
have_dynamic_loading			Yes		Global	No
have_geometry			Yes		Global	No
have_innodb			Yes		Global	No
have_ndbcluster			Yes		Global	No
have_openssl			Yes		Global	No
have_partitioning			Yes		Global	No
have_profiling			Yes		Global	No
have_query_cache			Yes		Global	No
have_rtree_keys			Yes		Global	No
have_ssl			Yes		Global	No
have_symlink			Yes		Global	No
help	Yes	Yes				
hostname			Yes		Global	No
identity			Yes		Session	Yes
ignore-builtin-innodb	Yes	Yes			Global	No
- *Variable*: ignore_builtin_innodb			Yes		Global	No
init_connect	Yes	Yes	Yes		Global	Yes
init-file	Yes	Yes			Global	No
- *Variable*: init_file			Yes		Global	No
init-rpl-role	Yes	Yes				
init_slave	Yes	Yes	Yes		Global	Yes
innodb	Yes	Yes				
innodb_adaptive_flushing	Yes	Yes	Yes		Global	Yes
innodb_adaptive_hash_index	Yes	Yes	Yes		Global	Yes
innodb_additional_mem_pool_size	Yes	Yes	Yes		Global	No
innodb_autoextend_increment	Yes	Yes	Yes		Global	Yes
innodb_autoinc_lock_mode	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_bytes_data				Yes	Global	No
Innodb_buffer_pool_bytes_dirty				Yes	Global	No
innodb_buffer_pool_instances	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_pages_data				Yes	Global	No
Innodb_buffer_pool_pages_dirty				Yes	Global	No
Innodb_buffer_pool_pages_flushed				Yes	Global	No
Innodb_buffer_pool_pages_free				Yes	Global	No
Innodb_buffer_pool_pages_latched				Yes	Global	No
Innodb_buffer_pool_pages_misc				Yes	Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Innodb_buffer_pool_pages_total				Yes	Global	No
Innodb_buffer_pool_read_ahead				Yes	Global	No
Innodb_buffer_pool_read_ahead_evicted				Yes	Global	No
Innodb_buffer_pool_read_ahead_rnd				Yes	Global	No
Innodb_buffer_pool_read_requests				Yes	Global	No
Innodb_buffer_pool_reads				Yes	Global	No
innodb_buffer_pool_size	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_wait_free				Yes	Global	No
Innodb_buffer_pool_write_requests				Yes	Global	No
innodb_change_buffering	Yes	Yes	Yes		Global	Yes
innodb_change_buffering_debug	Yes	Yes	Yes		Global	Yes
innodb_checksums	Yes	Yes	Yes		Global	No
innodb_commit_concurrency	Yes	Yes	Yes		Global	Yes
innodb_concurrency_tickets	Yes	Yes	Yes		Global	Yes
innodb_data_file_path	Yes	Yes	Yes		Global	No
Innodb_data_fsyncs				Yes	Global	No
innodb_data_home_dir	Yes	Yes	Yes		Global	No
Innodb_data_pending_fsyncs				Yes	Global	No
Innodb_data_pending_reads				Yes	Global	No
Innodb_data_pending_writes				Yes	Global	No
Innodb_data_read				Yes	Global	No
Innodb_data_reads				Yes	Global	No
Innodb_data_writes				Yes	Global	No
Innodb_data_written				Yes	Global	No
Innodb_dblwr_pages_written				Yes	Global	No
Innodb_dblwr_writes				Yes	Global	No
innodb_doublewrite	Yes	Yes	Yes		Global	No
innodb_fast_shutdown	Yes	Yes	Yes		Global	Yes
innodb_file_format	Yes	Yes	Yes		Global	Yes
innodb_file_format_check	Yes	Yes	Yes		Global	Varies
innodb_file_format_max	Yes	Yes	Yes		Global	Yes
innodb_file_per_table	Yes	Yes	Yes		Global	Yes
innodb_flush_log_at_trx_commit	Yes	Yes	Yes		Global	Yes
innodb_flush_method	Yes	Yes	Yes		Global	No
innodb_force_load_corrupted	Yes	Yes	Yes		Global	No
innodb_force_recovery	Yes	Yes	Yes		Global	No
Innodb_have_atomic_builtins				Yes	Global	No
innodb_io_capacity	Yes	Yes	Yes		Global	Yes
innodb_large_prefix	Yes	Yes	Yes		Global	Yes
innodb_limit_optimistic_insert_debug	Yes	Yes	Yes		Global	Yes
innodb_lock_wait_timeout	Yes	Yes	Yes		Both	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
innodb_locks_unsafe_for_binlog	Yes	Yes	Yes		Global	No
innodb_log_buffer_size	Yes	Yes	Yes		Global	No
innodb_log_file_size	Yes	Yes	Yes		Global	No
innodb_log_files_in_group	Yes	Yes	Yes		Global	No
innodb_log_group_home_dir	Yes	Yes	Yes		Global	No
Innodb_log_waits				Yes	Global	No
Innodb_log_write_requests				Yes	Global	No
Innodb_log_writes				Yes	Global	No
innodb_max_dirty_pages_pct	Yes	Yes	Yes		Global	Yes
innodb_max_purge_lag	Yes	Yes	Yes		Global	Yes
innodb_mirrored_log_groups	Yes	Yes	Yes		Global	No
innodb_old_blocks_pct	Yes	Yes	Yes		Global	Yes
innodb_old_blocks_time	Yes	Yes	Yes		Global	Yes
innodb_open_files	Yes	Yes	Yes		Global	No
Innodb_os_log_fsyncs				Yes	Global	No
Innodb_os_log_pending_fsyncs				Yes	Global	No
Innodb_os_log_pending_writes				Yes	Global	No
Innodb_os_log_written				Yes	Global	No
Innodb_page_size				Yes	Global	No
Innodb_pages_created				Yes	Global	No
Innodb_pages_read				Yes	Global	No
Innodb_pages_written				Yes	Global	No
innodb_print_all_deadlocks	Yes	Yes	Yes		Global	Yes
innodb_purge_batch_size	Yes	Yes	Yes		Global	Yes
innodb_purge_threads	Yes	Yes	Yes		Global	No
innodb_random_read_ahead	Yes	Yes	Yes		Global	Yes
innodb_read_ahead_threshold	Yes	Yes	Yes		Global	Yes
innodb_read_io_threads	Yes	Yes	Yes		Global	No
innodb_replication_delay	Yes	Yes	Yes		Global	Yes
innodb_rollback_on_timeout	Yes	Yes	Yes		Global	No
innodb_rollback_segments	Yes	Yes	Yes		Global	Yes
Innodb_row_lock_current_waits				Yes	Global	No
Innodb_row_lock_time				Yes	Global	No
Innodb_row_lock_time_avg				Yes	Global	No
Innodb_row_lock_time_max				Yes	Global	No
Innodb_row_lock_waits				Yes	Global	No
Innodb_rows_deleted				Yes	Global	No
Innodb_rows_inserted				Yes	Global	No
Innodb_rows_read				Yes	Global	No
Innodb_rows_updated				Yes	Global	No
innodb_spin_wait_delay	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
innodb_stats_method	Yes	Yes	Yes		Global	Yes
innodb_stats_on_metadata	Yes	Yes	Yes		Global	Yes
innodb_stats_sample_pages	Yes	Yes	Yes		Global	Yes
innodb-status-file	Yes	Yes				
innodb_strict_mode	Yes	Yes	Yes		Both	Yes
innodb_support_xa	Yes	Yes	Yes		Both	Yes
innodb_sync_spin_loops	Yes	Yes	Yes		Global	Yes
innodb_table_locks	Yes	Yes	Yes		Both	Yes
innodb_thread_concurrency	Yes	Yes	Yes		Global	Yes
innodb_thread_sleep_delay	Yes	Yes	Yes		Global	Yes
Innodb_truncated_status_writes				Yes	Global	No
innodb_trx_purge_view_update_only_debug	Yes	Yes	Yes		Global	Yes
innodb_trx_rseg_n_slots_debug	Yes	Yes	Yes		Global	Yes
innodb_use_native_aio	Yes	Yes	Yes		Global	No
innodb_use_sys_malloc	Yes	Yes	Yes		Global	No
innodb_version			Yes		Global	No
innodb_write_io_threads	Yes	Yes	Yes		Global	No
insert_id			Yes		Session	Yes
install	Yes					
install-manual	Yes					
interactive_timeout	Yes	Yes	Yes		Both	Yes
join_buffer_size	Yes	Yes	Yes		Both	Yes
keep_files_on_create	Yes	Yes	Yes		Both	Yes
Key_blocks_not_flushed				Yes	Global	No
Key_blocks_unused				Yes	Global	No
Key_blocks_used				Yes	Global	No
key_buffer_size	Yes	Yes	Yes		Global	Yes
key_cache_age_threshold	Yes	Yes	Yes		Global	Yes
key_cache_block_size	Yes	Yes	Yes		Global	Yes
key_cache_division_limit	Yes	Yes	Yes		Global	Yes
Key_read_requests				Yes	Global	No
Key_reads				Yes	Global	No
Key_write_requests				Yes	Global	No
Key_writes				Yes	Global	No
language	Yes	Yes	Yes		Global	No
large_files_support			Yes		Global	No
large_page_size			Yes		Global	No
large-pages	Yes	Yes			Global	No
- *Variable*: large_pages			Yes		Global	No
last_insert_id			Yes		Session	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Last_query_cost				Yes	Session	No
lc-messages	Yes	Yes			Both	Yes
- *Variable*: lc_messages			Yes		Both	Yes
lc-messages-dir	Yes	Yes			Global	No
- *Variable*: lc_messages_dir			Yes		Global	No
lc_time_names			Yes		Both	Yes
license			Yes		Global	No
local_infile			Yes		Global	Yes
local-service	Yes					
lock_wait_timeout	Yes	Yes	Yes		Both	Yes
locked_in_memory			Yes		Global	No
log	Yes	Yes	Yes		Global	Yes
log-bin	Yes	Yes	Yes		Global	No
log_bin			Yes		Global	No
log-bin-index	Yes	Yes				
log-bin-trust-function-creators	Yes	Yes			Global	Yes
- *Variable*: log_bin_trust_function_creators			Yes		Global	Yes
log-bin-trust-routine-creators	Yes	Yes			Global	Yes
- *Variable*: log_bin_trust_routine_creators			Yes		Global	Yes
log-bin-use-v1-row-events	Yes	Yes			Global	No
- *Variable*: log_bin_use_v1_row_events			Yes		Global	No
log_bin_use_v1_row_events	Yes	Yes	Yes		Global	No
log-error	Yes	Yes			Global	No
- *Variable*: log_error			Yes		Global	No
log-isam	Yes	Yes				
log-output	Yes	Yes			Global	Yes
- *Variable*: log_output			Yes		Global	Yes
log-queries-not-using-indexes	Yes	Yes			Global	Yes
- *Variable*: log_queries_not_using_indexes			Yes		Global	Yes
log-short-format	Yes	Yes				
log-slave-updates	Yes	Yes			Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
- *Variable*: log_slave_updates			Yes		Global	No
log_slave_updates	Yes	Yes	Yes		Global	No
log-slow-admin-statements	Yes	Yes				
log-slow-queries	Yes	Yes			Global	Yes
- *Variable*: log_slow_queries			Yes		Global	Yes
log-slow-slave-statements	Yes	Yes				
log-tc	Yes	Yes				
log-tc-size	Yes	Yes				
log-warnings	Yes	Yes			Both	Yes
- *Variable*: log_warnings			Yes		Both	Yes
long_query_time	Yes	Yes	Yes		Both	Yes
low-priority-updates	Yes	Yes			Both	Yes
- *Variable*: low_priority_updates			Yes		Both	Yes
lower_case_file_system			Yes		Global	No
lower_case_table_names	Yes	Yes	Yes		Global	No
master-connect-retry	Yes	Yes				
master-host	Yes	Yes				
master-info-file	Yes	Yes				
master-password	Yes	Yes				
master-port	Yes	Yes				
master-retry-count	Yes	Yes				
master-ssl	Yes	Yes				
master-ssl-ca	Yes	Yes				
master-ssl-capath	Yes	Yes				
master-ssl-cert	Yes	Yes				
master-ssl-cipher	Yes	Yes				
master-ssl-key	Yes	Yes				
master-user	Yes	Yes				
max_allowed_packet	Yes	Yes	Yes		Both	Yes
max_binlog_cache_size	Yes	Yes	Yes		Global	Yes
max-binlog-dump-events	Yes	Yes				
max_binlog_size	Yes	Yes	Yes		Global	Yes
max_binlog_stmt_cache_size	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
max_connect_errors	Yes	Yes	Yes		Global	Yes
max_connections	Yes	Yes	Yes		Global	Yes
max_delayed_threads	Yes	Yes	Yes		Both	Yes
max_error_count	Yes	Yes	Yes		Both	Yes
max_heap_table_size	Yes	Yes	Yes		Both	Yes
max_insert_delayed_threads			Yes		Both	Yes
max_join_size	Yes	Yes	Yes		Both	Yes
max_length_for_sort_data	Yes	Yes	Yes		Both	Yes
max_long_data_size	Yes	Yes	Yes		Global	No
max_prepared_stmt_count	Yes	Yes	Yes		Global	Yes
max_relay_log_size	Yes	Yes	Yes		Global	Yes
max_seeks_for_key	Yes	Yes	Yes		Both	Yes
max_sort_length	Yes	Yes	Yes		Both	Yes
max_sp_recursion_depth	Yes	Yes	Yes		Both	Yes
max_tmp_tables			Yes		Both	Yes
Max_used_connections				Yes	Global	No
max_user_connections	Yes	Yes	Yes		Both	Yes
max_write_lock_count	Yes	Yes	Yes		Global	Yes
memlock	Yes	Yes				
- *Variable*: locked_in_memory						
metadata_locks_cache_size			Yes		Global	No
min-examined-row-limit	Yes	Yes	Yes		Both	Yes
multi_range_count	Yes	Yes	Yes		Both	Yes
myisam-block-size	Yes	Yes				
myisam_data_pointer_size	Yes	Yes	Yes		Global	Yes
myisam_max_sort_file_size	Yes	Yes	Yes		Global	Yes
myisam_mmap_size	Yes	Yes	Yes		Global	No
myisam-recover	Yes	Yes				
- *Variable*: myisam_recover_options						
myisam-recover-options	Yes	Yes				
- *Variable*: myisam_recover_options						
myisam_recover_options			Yes		Global	No
myisam_repair_threads	Yes	Yes	Yes		Both	Yes
myisam_sort_buffer_size	Yes	Yes	Yes		Both	Yes
myisam_stats_method	Yes	Yes	Yes		Both	Yes
myisam_use_mmap	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
named_pipe			Yes		Global	No
Ndb_api_bytes_received_count				Yes	Global	No
Ndb_api_bytes_received_count_session				Yes	Session	No
Ndb_api_bytes_received_count_slave				Yes	Global	No
Ndb_api_bytes_sent_count				Yes	Global	No
Ndb_api_bytes_sent_count_session				Yes	Session	No
Ndb_api_bytes_sent_count_slave				Yes	Global	No
Ndb_api_event_bytes_count				Yes	Global	No
Ndb_api_event_bytes_count_injector				Yes	Global	No
Ndb_api_event_data_count				Yes	Global	No
Ndb_api_event_data_count_injector				Yes	Global	No
Ndb_api_event_nondata_count				Yes	Global	No
Ndb_api_event_nondata_count_injector				Yes	Global	No
Ndb_api_pk_op_count				Yes	Global	No
Ndb_api_pk_op_count_session				Yes	Session	No
Ndb_api_pk_op_count_slave				Yes	Global	No
Ndb_api_pruned_scan_count				Yes	Global	No
Ndb_api_pruned_scan_count_session				Yes	Session	No
Ndb_api_pruned_scan_count_slave				Yes	Global	No
Ndb_api_range_scan_count				Yes	Global	No
Ndb_api_range_scan_count_session				Yes	Session	No
Ndb_api_range_scan_count_slave				Yes	Global	No
Ndb_api_read_row_count				Yes	Global	No
Ndb_api_read_row_count_session				Yes	Session	No
Ndb_api_read_row_count_slave				Yes	Global	No
Ndb_api_scan_batch_count				Yes	Global	No
Ndb_api_scan_batch_count_session				Yes	Session	No
Ndb_api_scan_batch_count_slave				Yes	Global	No
Ndb_api_table_scan_count				Yes	Global	No
Ndb_api_table_scan_count_session				Yes	Session	No
Ndb_api_table_scan_count_slave				Yes	Global	No
Ndb_api_trans_abort_count				Yes	Global	No
Ndb_api_trans_abort_count_session				Yes	Session	No
Ndb_api_trans_abort_count_slave				Yes	Global	No
Ndb_api_trans_close_count				Yes	Global	No
Ndb_api_trans_close_count_session				Yes	Session	No
Ndb_api_trans_close_count_slave				Yes	Global	No
Ndb_api_trans_commit_count				Yes	Global	No
Ndb_api_trans_commit_count_session				Yes	Session	No
Ndb_api_trans_commit_count_slave				Yes	Global	No
Ndb_api_trans_local_read_row_count				Yes	Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Ndb_api_trans_local_read_row_count_session				Yes	Session	No
Ndb_api_trans_local_read_row_count_slave				Yes	Global	No
Ndb_api_trans_start_count				Yes	Global	No
Ndb_api_trans_start_count_session				Yes	Session	No
Ndb_api_trans_start_count_slave				Yes	Global	No
Ndb_api_uk_op_count				Yes	Global	No
Ndb_api_uk_op_count_session				Yes	Session	No
Ndb_api_uk_op_count_slave				Yes	Global	No
Ndb_api_wait_exec_complete_count				Yes	Global	No
Ndb_api_wait_exec_complete_count_session				Yes	Session	No
Ndb_api_wait_exec_complete_count_slave				Yes	Global	No
Ndb_api_wait_meta_request_count				Yes	Global	No
Ndb_api_wait_meta_request_count_session				Yes	Session	No
Ndb_api_wait_meta_request_count_slave				Yes	Global	No
Ndb_api_wait_nanos_count				Yes	Global	No
Ndb_api_wait_nanos_count_session				Yes	Session	No
Ndb_api_wait_nanos_count_slave				Yes	Global	No
Ndb_api_wait_scan_result_count				Yes	Global	No
Ndb_api_wait_scan_result_count_session				Yes	Session	No
Ndb_api_wait_scan_result_count_slave				Yes	Global	No
ndb_autoincrement_prefetch_sz	Yes	Yes	Yes		Both	Yes
ndb-batch-size	Yes	Yes	Yes		Global	No
ndb-blob-read-batch-bytes	Yes	Yes	Yes		Both	Yes
ndb-blob-write-batch-bytes	Yes	Yes	Yes		Both	Yes
ndb_cache_check_time	Yes	Yes	Yes		Global	Yes
ndb-cluster-connection-pool	Yes	Yes	Yes		Global	No
Ndb_cluster_node_id				Yes	Both	No
Ndb_config_from_host				Yes	Both	No
Ndb_config_from_port				Yes	Both	No
Ndb_conflict_fn_epoch				Yes	Global	No
Ndb_conflict_fn_epoch_trans				Yes	Global	No
Ndb_conflict_fn_max				Yes	Global	No
Ndb_conflict_fn_old				Yes	Global	No
Ndb_conflict_trans_conflict_commit_count				Yes	Global	No
Ndb_conflict_trans_detect_iter_count				Yes	Global	No
Ndb_conflict_trans_reject_count				Yes	Global	No
Ndb_conflict_trans_row_reject_count				Yes	Global	No
ndb-connectstring	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
ndb-deferred-constraints	Yes	Yes			Both	Yes
- *Variable*: ndb_deferred_constraints			Yes		Both	Yes
ndb_deferred_constraints	Yes	Yes	Yes		Both	Yes
ndb-distribution	Yes	Yes			Global	Yes
- *Variable*: ndb_distribution			Yes		Global	Yes
ndb_distribution	Yes	Yes	Yes		Global	Yes
ndb_eventbuffer_max_alloc	Yes	Yes	Yes		Global	Yes
Ndb_execute_count				Yes	Global	No
ndb_extra_logging	Yes	Yes	Yes		Global	Yes
ndb_force_send	Yes	Yes	Yes		Both	Yes
ndb_index_stat_cache_entries	Yes	Yes	Yes		Both	Yes
ndb_index_stat_enable	Yes	Yes	Yes		Both	Yes
ndb_index_stat_option	Yes	Yes	Yes		Both	Yes
ndb_index_stat_update_freq	Yes	Yes	Yes		Both	Yes
ndb_join_pushdown			Yes		Both	Yes
ndb-log-apply-status	Yes	Yes			Global	No
- *Variable*: ndb_log_apply_status			Yes		Global	No
ndb_log_apply_status	Yes	Yes	Yes		Global	No
ndb_log_bin	Yes		Yes		Both	Yes
ndb_log_binlog_index	Yes		Yes		Global	Yes
ndb-log-empty-epochs	Yes	Yes	Yes		Global	Yes
ndb_log_empty_epochs	Yes	Yes	Yes		Global	Yes
ndb-log-empty-update	Yes	Yes	Yes		Global	Yes
ndb_log_empty_update	Yes	Yes	Yes		Global	Yes
ndb-log-orig	Yes	Yes			Global	No
- *Variable*: ndb_log_orig			Yes		Global	No
ndb_log_orig	Yes	Yes	Yes		Global	No
ndb-log-transaction-id	Yes	Yes			Global	No
- *Variable*: ndb_log_transaction_id			Yes		Global	No
ndb_log_transaction_id			Yes		Global	No
ndb-log-update-as-write	Yes	Yes	Yes		Global	Yes
ndb_log_updated_only	Yes	Yes	Yes		Global	Yes
ndb-mgmd-host	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
ndb-nodeid	Yes	Yes		Yes	Global	No
Ndb_number_of_data_nodes				Yes	Global	No
ndb_optimization_delay			Yes		Global	Yes
ndb_optimized_node_selection	Yes	Yes	Yes		Global	No
Ndb_pruned_scan_count				Yes	Global	No
Ndb_pushed_queries_defined				Yes	Global	No
Ndb_pushed_queries_dropped				Yes	Global	No
Ndb_pushed_queries_executed				Yes	Global	No
Ndb_pushed_reads				Yes	Global	No
ndb_report_thresh_binlog_epoch_slip	Yes	Yes	Yes		Global	Yes
ndb_report_thresh_binlog_mem_usage	Yes	Yes	Yes		Global	Yes
Ndb_scan_count				Yes	Global	No
ndb_table_no_logging			Yes		Session	Yes
ndb_table_temporary			Yes		Session	Yes
ndb-transid-mysql-connection-map	Yes					
ndb_use_copying_alter_table			Yes		Both	No
ndb_use_exact_count			Yes		Both	Yes
ndb_use_transactions	Yes	Yes	Yes		Both	Yes
ndb_version			Yes		Global	No
ndb_version_string			Yes		Global	No
ndb-wait-connected	Yes	Yes	Yes		Global	No
ndb-wait-setup	Yes	Yes	Yes		Global	No
ndbcluster	Yes	Yes				
- *Variable*: have_ndbcluster						
ndbinfo_database			Yes		Global	No
ndbinfo_max_bytes	Yes		Yes		Both	Yes
ndbinfo_max_rows	Yes		Yes		Both	Yes
ndbinfo_offline			Yes		Global	Yes
ndbinfo_show_hidden	Yes		Yes		Both	Yes
ndbinfo_table_prefix	Yes		Yes		Both	Yes
ndbinfo_version			Yes		Global	No
net_buffer_length	Yes	Yes	Yes		Both	Yes
net_read_timeout	Yes	Yes	Yes		Both	Yes
net_retry_count	Yes	Yes	Yes		Both	Yes
net_write_timeout	Yes	Yes	Yes		Both	Yes
new	Yes	Yes	Yes		Both	Yes
no-defaults	Yes					
Not_flushed_delayed_rows				Yes	Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
old	Yes	Yes	Yes		Global	No
old-alter-table	Yes	Yes			Both	Yes
- *Variable*: old_alter_table			Yes		Both	Yes
old_passwords			Yes		Both	Yes
old-style-user-limits	Yes	Yes				
one-thread	Yes	Yes				
Open_files				Yes	Global	No
open-files-limit	Yes	Yes			Global	No
- *Variable*: open_files_limit			Yes		Global	No
Open_streams				Yes	Global	No
Open_table_definitions				Yes	Global	No
Open_tables				Yes	Both	No
Opened_files				Yes	Global	No
Opened_table_definitions				Yes	Both	No
Opened_tables				Yes	Both	No
optimizer_prune_level	Yes	Yes	Yes		Both	Yes
optimizer_search_depth	Yes	Yes	Yes		Both	Yes
optimizer_switch	Yes	Yes	Yes		Both	Yes
partition	Yes	Yes				
- *Variable*: have_partitioning						
performance_schema	Yes	Yes	Yes		Global	No
Performance_schema_cond_classes_lost				Yes	Global	No
Performance_schema_cond_instances_lost				Yes	Global	No
performance_schema_events_waits_history_long_size	Yes	Yes	Yes		Global	No
performance_schema_events_waits_history_size	Yes	Yes	Yes		Global	No
Performance_schema_file_classes_lost				Yes	Global	No
Performance_schema_file_handles_lost				Yes	Global	No
Performance_schema_file_instances_lost				Yes	Global	No
Performance_schema_locker_lost				Yes	Global	No
performance_schema_max_cond_classes	Yes	Yes	Yes		Global	No
performance_schema_max_cond_instances	Yes	Yes	Yes		Global	No
performance_schema_max_file_classes	Yes	Yes	Yes		Global	No
performance_schema_max_file_handles	Yes	Yes	Yes		Global	No
performance_schema_max_file_instances	Yes	Yes	Yes		Global	No
performance_schema_max_mutex_classes	Yes	Yes	Yes		Global	No
performance_schema_max_mutex_instances	Yes	Yes	Yes		Global	No
performance_schema_max_rwlock_classes	Yes	Yes	Yes		Global	No
performance_schema_max_rwlock_instances	Yes	Yes	Yes		Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
performance_schema_max_table_handles	Yes	Yes	Yes		Global	No
performance_schema_max_table_instances	Yes	Yes	Yes		Global	No
performance_schema_max_thread_classes	Yes	Yes	Yes		Global	No
performance_schema_max_thread_instances	Yes	Yes	Yes		Global	No
Performance_schema_mutex_classes_lost				Yes	Global	No
Performance_schema_mutex_instances_lost				Yes	Global	No
Performance_schema_rwlock_classes_lost				Yes	Global	No
Performance_schema_rwlock_instances_lost				Yes	Global	No
Performance_schema_table_handles_lost				Yes	Global	No
Performance_schema_table_instances_lost				Yes	Global	No
Performance_schema_thread_classes_lost				Yes	Global	No
Performance_schema_thread_instances_lost				Yes	Global	No
pid-file	Yes	Yes			Global	No
- *Variable*: pid_file			Yes		Global	No
plugin	Yes	Yes				
plugin_dir	Yes	Yes	Yes		Global	No
plugin-load	Yes	Yes				
port	Yes	Yes	Yes		Global	No
port-open-timeout	Yes	Yes				
preload_buffer_size	Yes	Yes	Yes		Both	Yes
Prepared_stmt_count				Yes	Global	No
print-defaults	Yes					
profiling			Yes		Varies	Yes
profiling_history_size	Yes	Yes	Yes		Both	Yes
protocol_version			Yes		Global	No
proxy_user			Yes		Session	No
pseudo_slave_mode			Yes		Session	Yes
pseudo_thread_id			Yes		Session	Yes
Qcache_free_blocks				Yes	Global	No
Qcache_free_memory				Yes	Global	No
Qcache_hits				Yes	Global	No
Qcache_inserts				Yes	Global	No
Qcache_lowmem_prunes				Yes	Global	No
Qcache_not_cached				Yes	Global	No
Qcache_queries_in_cache				Yes	Global	No
Qcache_total_blocks				Yes	Global	No
Queries				Yes	Both	No
query_alloc_block_size	Yes	Yes	Yes		Both	Yes
query_cache_limit	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
query_cache_min_res_unit	Yes	Yes	Yes		Global	Yes
query_cache_size	Yes	Yes	Yes		Global	Yes
query_cache_type	Yes	Yes	Yes		Both	Yes
query_cache_wlock_invalidate	Yes	Yes	Yes		Both	Yes
query_prealloc_size	Yes	Yes	Yes		Both	Yes
Questions				Yes	Both	No
rand_seed1			Yes		Session	Yes
rand_seed2			Yes		Session	Yes
range_alloc_block_size	Yes	Yes	Yes		Both	Yes
read_buffer_size	Yes	Yes	Yes		Both	Yes
read_only	Yes	Yes	Yes		Global	Yes
read_rnd_buffer_size	Yes	Yes	Yes		Both	Yes
relay-log	Yes	Yes			Global	No
- *Variable*: relay_log			Yes		Global	No
relay-log-index	Yes	Yes			Global	No
- *Variable*: relay_log_index			Yes		Global	No
relay_log_index	Yes	Yes	Yes		Global	No
relay-log-info-file	Yes	Yes				
- *Variable*: relay_log_info_file						
relay_log_info_file	Yes	Yes	Yes		Global	No
relay_log_purge	Yes	Yes	Yes		Global	Yes
relay-log-recovery	Yes	Yes				
- *Variable*: relay_log_recovery						
relay_log_recovery	Yes	Yes	Yes		Global	Yes
relay_log_space_limit	Yes	Yes	Yes		Global	No
remove	Yes					
replicate-do-db	Yes	Yes				
replicate-do-table	Yes	Yes				
replicate-ignore-db	Yes	Yes				
replicate-ignore-table	Yes	Yes				
replicate-rewrite-db	Yes	Yes				
replicate-same-server-id	Yes	Yes				
replicate-wild-do-table	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
replicate-wild-ignore-table	Yes	Yes				
report-host	Yes	Yes			Global	No
- *Variable*: report_host			Yes		Global	No
report-password	Yes	Yes			Global	No
- *Variable*: report_password			Yes		Global	No
report-port	Yes	Yes			Global	No
- *Variable*: report_port			Yes		Global	No
report-user	Yes	Yes			Global	No
- *Variable*: report_user			Yes		Global	No
rpl_recovery_rank			Yes		Global	Yes
Rpl_semi_sync_master_clients				Yes	Global	No
rpl_semi_sync_master_enabled			Yes		Global	Yes
Rpl_semi_sync_master_net_avg_wait_time				Yes	Global	No
Rpl_semi_sync_master_net_wait_time				Yes	Global	No
Rpl_semi_sync_master_net_waits				Yes	Global	No
Rpl_semi_sync_master_no_times				Yes	Global	No
Rpl_semi_sync_master_no_tx				Yes	Global	No
Rpl_semi_sync_master_status				Yes	Global	No
Rpl_semi_sync_master_timefunc_failures				Yes	Global	No
rpl_semi_sync_master_timeout			Yes		Global	Yes
rpl_semi_sync_master_trace_level			Yes		Global	Yes
Rpl_semi_sync_master_tx_avg_wait_time				Yes	Global	No
Rpl_semi_sync_master_tx_wait_time				Yes	Global	No
Rpl_semi_sync_master_tx_waits				Yes	Global	No
rpl_semi_sync_master_wait_no_slave			Yes		Global	Yes
Rpl_semi_sync_master_wait_pos_backtraverse				Yes	Global	No
Rpl_semi_sync_master_wait_sessions				Yes	Global	No
Rpl_semi_sync_master_yes_tx				Yes	Global	No
rpl_semi_sync_slave_enabled			Yes		Global	Yes
Rpl_semi_sync_slave_status				Yes	Global	No
rpl_semi_sync_slave_trace_level			Yes		Global	Yes
Rpl_status				Yes	Global	No
safe-mode	Yes	Yes				
safe-show-database	Yes	Yes				
safe-user-create	Yes	Yes				
safemalloc-mem-limit	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
secure-auth	Yes	Yes			Global	Yes
- *Variable*: secure_auth			Yes		Global	Yes
secure-file-priv	Yes	Yes			Global	No
- *Variable*: secure_file_priv			Yes		Global	No
Select_full_join				Yes	Both	No
Select_full_range_join				Yes	Both	No
Select_range				Yes	Both	No
Select_range_check				Yes	Both	No
Select_scan				Yes	Both	No
server-id	Yes	Yes			Global	Yes
- *Variable*: server_id			Yes		Global	Yes
server-id-bits	Yes	Yes			Global	No
- *Variable*: server_id_bits			Yes		Global	No
server_id_bits	Yes	Yes	Yes		Global	No
set-variable	Yes	Yes				
shared_memory	Yes	Yes	Yes		Global	No
shared_memory_base_name	Yes	Yes	Yes		Global	No
show-slave-auth-info	Yes	Yes				
skip-character-set-client-handshake	Yes	Yes				
skip-concurrent-insert	Yes	Yes				
- *Variable*: concurrent_insert						
skip-event-scheduler	Yes	Yes				
skip_external_locking	Yes	Yes	Yes		Global	No
skip-grant-tables	Yes	Yes				
skip-host-cache	Yes	Yes				
skip-locking	Yes	Yes				
skip-name-resolve	Yes	Yes			Global	No
- *Variable*: skip_name_resolve			Yes		Global	No
skip-ndbcluster	Yes	Yes				
skip-networking	Yes	Yes			Global	No
- *Variable*: skip_networking			Yes		Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
skip-new	Yes	Yes				
skip-partition	Yes	Yes				
skip-safemalloc	Yes	Yes				
skip-show-database	Yes	Yes			Global	No
- *Variable*: skip_show_database			Yes		Global	No
skip-slave-start	Yes	Yes				
skip-ssl	Yes	Yes				
skip-stack-trace	Yes	Yes				
skip-symlink	Yes	Yes				
skip-thread-priority	Yes	Yes				
slave_allow_batching	Yes	Yes	Yes		Global	Yes
slave_compressed_protocol	Yes	Yes	Yes		Global	Yes
slave_exec_mode	Yes	Yes	Yes		Global	Yes
Slave_heartbeat_period				Yes	Global	No
slave-load-tmpdir	Yes	Yes			Global	No
- *Variable*: slave_load_tmpdir			Yes		Global	No
slave-max-allowed-packet	Yes	Yes				
- *Variable*: slave_max_allowed_packet						
slave_max_allowed_packet			Yes		Global	Yes
slave-net-timeout	Yes	Yes			Global	Yes
- *Variable*: slave_net_timeout			Yes		Global	Yes
Slave_open_temp_tables				Yes	Global	No
Slave_received_heartbeats				Yes	Global	No
Slave_retried_transactions				Yes	Global	No
Slave_running				Yes	Global	No
slave-skip-errors	Yes	Yes			Global	No
- *Variable*: slave_skip_errors			Yes		Global	No
slave_transaction_retries	Yes	Yes	Yes		Global	Yes
slave_type_conversions	Yes	Yes	Yes		Global	No
Slow_launch_threads				Yes	Both	No
slow_launch_time	Yes	Yes	Yes		Global	Yes
Slow_queries				Yes	Both	No
slow-query-log	Yes	Yes			Global	Yes
- *Variable*: slow_query_log			Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
slow_query_log_file	Yes	Yes	Yes		Global	Yes
slow-start-timeout	Yes	Yes				
socket	Yes	Yes	Yes		Global	No
sort_buffer_size	Yes	Yes	Yes		Both	Yes
Sort_merge_passes				Yes	Both	No
Sort_range				Yes	Both	No
Sort_rows				Yes	Both	No
Sort_scan				Yes	Both	No
sporadic-binlog-dump-fail	Yes	Yes				
sql_auto_is_null			Yes		Varies	Yes
sql_big_selects			Yes		Varies	Yes
sql_big_tables			Yes		Varies	Yes
sql_buffer_result			Yes		Varies	Yes
sql_log_bin			Yes		Varies	Yes
sql_log_off			Yes		Varies	Yes
sql_log_update			Yes		Session	Yes
sql_low_priority_updates			Yes		Both	Yes
sql_max_join_size			Yes		Both	Yes
sql-mode	Yes	Yes			Both	Yes
- *Variable*: sql_mode			Yes		Both	Yes
sql_notes			Yes		Varies	Yes
sql_quote_show_create			Yes		Varies	Yes
sql_safe_updates			Yes		Varies	Yes
sql_select_limit			Yes		Both	Yes
sql_slave_skip_counter			Yes		Global	Yes
sql_warnings			Yes		Varies	Yes
ssl	Yes	Yes				
Ssl_accept_renegotiates				Yes	Global	No
Ssl_accepts				Yes	Global	No
ssl-ca	Yes	Yes			Global	No
- *Variable*: ssl_ca			Yes		Global	No
Ssl_callback_cache_hits				Yes	Global	No
ssl-capath	Yes	Yes			Global	No
- *Variable*: ssl_capath			Yes		Global	No
ssl-cert	Yes	Yes			Global	No
- *Variable*: ssl_cert			Yes		Global	No
Ssl_cipher				Yes	Both	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
ssl-cipher	Yes	Yes			Global	No
- *Variable*: ssl_cipher			Yes		Global	No
Ssl_cipher_list				Yes	Both	No
Ssl_client_connects				Yes	Global	No
Ssl_connect_renegotiates				Yes	Global	No
Ssl_ctx_verify_depth				Yes	Global	No
Ssl_ctx_verify_mode				Yes	Global	No
Ssl_default_timeout				Yes	Both	No
Ssl_finished_accepts				Yes	Global	No
Ssl_finished_connects				Yes	Global	No
ssl-key	Yes	Yes			Global	No
- *Variable*: ssl_key			Yes		Global	No
Ssl_session_cache_hits				Yes	Global	No
Ssl_session_cache_misses				Yes	Global	No
Ssl_session_cache_mode				Yes	Global	No
Ssl_session_cache_overflows				Yes	Global	No
Ssl_session_cache_size				Yes	Global	No
Ssl_session_cache_timeouts				Yes	Global	No
Ssl_sessions_reused				Yes	Both	No
Ssl_used_session_cache_entries				Yes	Global	No
Ssl_verify_depth				Yes	Both	No
Ssl_verify_mode				Yes	Both	No
Ssl_version				Yes	Both	No
standalone	Yes	Yes				
storage_engine			Yes		Both	Yes
stored_program_cache	Yes	Yes	Yes		Global	Yes
super-large-pages	Yes	Yes				
symbolic-links	Yes	Yes				
sync_binlog	Yes	Yes	Yes		Global	Yes
sync_frm	Yes	Yes	Yes		Global	Yes
sync_master_info	Yes	Yes	Yes		Global	Yes
sync_relay_log	Yes	Yes	Yes		Global	Yes
sync_relay_log_info	Yes	Yes	Yes		Global	Yes
sysdate-is-now	Yes	Yes				
system_time_zone			Yes		Global	No
table_definition_cache			Yes		Global	Yes
table_lock_wait_timeout	Yes	Yes	Yes		Global	Yes
Table_locks_immediate				Yes	Global	No
Table_locks_waited				Yes	Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
table_open_cache			Yes		Global	Yes
table_type			Yes		Both	Yes
tc-heuristic-recover	Yes	Yes				
Tc_log_max_pages_used				Yes	Global	No
Tc_log_page_size				Yes	Global	No
Tc_log_page_waits				Yes	Global	No
temp-pool	Yes	Yes				
thread_cache_size	Yes	Yes	Yes		Global	Yes
thread_concurrency	Yes	Yes	Yes		Global	No
thread_handling	Yes	Yes	Yes		Global	No
thread_pool_algorithm	Yes	Yes	Yes		Global	No
thread_pool_high_priority_connection	Yes	Yes	Yes		Both	Yes
thread_pool_max_unused_threads	Yes	Yes	Yes		Global	Yes
thread_pool_prio_kickup_timer	Yes	Yes	Yes		Both	Yes
thread_pool_size	Yes	Yes	Yes		Global	No
thread_pool_stall_limit	Yes	Yes	Yes		Global	Yes
thread_stack	Yes	Yes	Yes		Global	No
Threads_cached				Yes	Global	No
Threads_connected				Yes	Global	No
Threads_created				Yes	Global	No
Threads_running				Yes	Global	No
time_format			Yes		Varies	No
time_zone			Yes		Both	Yes
timed_mutexes	Yes	Yes	Yes		Global	Yes
timestamp			Yes		Session	Yes
tmp_table_size	Yes	Yes	Yes		Both	Yes
tmpdir	Yes	Yes	Yes		Global	No
transaction_alloc_block_size	Yes	Yes	Yes		Both	Yes
transaction_allow_batching			Yes		Session	Yes
transaction-isolation	Yes	Yes				
- *Variable*: tx_isolation						
transaction_prealloc_size	Yes	Yes	Yes		Both	Yes
tx_isolation			Yes		Both	Yes
unique_checks			Yes		Varies	Yes
updatable_views_with_limit	Yes	Yes	Yes		Both	Yes
Uptime				Yes	Global	No
Uptime_since_flush_status				Yes	Global	No
user	Yes	Yes				
verbose	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
version			Yes		Global	No
version_comment			Yes		Global	No
version_compile_machine			Yes		Global	No
version_compile_os			Yes		Global	No
wait_timeout	Yes	Yes	Yes		Both	Yes
warning_count			Yes		Session	No

[a]This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.
[b]This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.

5.1.4 Server Command Options

When you start the `mysqld` server, you can specify program options using any of the methods described in Section 4.2.3, “Specifying Program Options”. The most common methods are to provide options in an option file or on the command line. However, in most cases it is desirable to make sure that the server uses the same options each time it runs. The best way to ensure this is to list them in an option file. See Section 4.2.6, “Using Option Files”. That section also describes option file format and syntax.

`mysqld` reads options from the `[mysqld]` and `[server]` groups. `mysqld_safe` reads options from the `[mysqld]`, `[server]`, `[mysqld_safe]`, and `[safe_mysqld]` groups. `mysql.server` reads options from the `[mysqld]` and `[mysql.server]` groups.

An embedded MySQL server usually reads options from the `[server]`, `[embedded]`, and `[xxxxx_SERVER]` groups, where *xxxxx* is the name of the application into which the server is embedded.

`mysqld` accepts many command options. For a brief summary, execute this command:

```
mysqld --help
```

To see the full list, use this command:

```
mysqld --verbose --help
```

Some of the items in the list are actually system variables that can be set at server startup. These can be displayed at runtime using the `SHOW VARIABLES` statement. Some items displayed by the preceding `mysqld` command do not appear in `SHOW VARIABLES` output; this is because they are options only and not system variables.

The following list shows some of the most common server options. Additional options are described in other sections:

- Options that affect security: See Section 6.1.4, “Security-Related mysqld Options and Variables”.
- SSL-related options: See Section 6.4.2, “Command Options for Encrypted Connections”.
- Binary log control options: See Section 5.4.4, “The Binary Log”.
- Replication-related options: See Section 17.1.3, “Replication and Binary Logging Options and Variables”.
- Options for loading plugins such as pluggable storage engines: See Section 5.5.1, “Installing and Uninstalling Plugins”.
- Options specific to particular storage engines: See Section 14.17, “InnoDB Startup Options and System Variables”, Section 15.3.1, “MyISAM Startup Options”, and MySQL Server Options for NDB Cluster.

Some options control the size of buffers or caches. For a given buffer, the server might need to allocate internal data structures. These structures typically are allocated from the total memory allocated to the buffer, and the amount of space required might be platform dependent. This means that when you assign a value to an option that controls a buffer size, the amount of space actually available might differ from the value assigned. In some cases, the amount might be less than the value assigned. It is also possible that the server will adjust a value upward. For example, if you assign a value of 0 to an option for which the minimal value is 1024, the server will set the value to 1024.

Values for buffer sizes, lengths, and stack sizes are given in bytes unless otherwise specified.

Some options take file name values. Unless otherwise specified, the default file location is the data directory if the value is a relative path name. To specify the location explicitly, use an absolute path name. Suppose that the data directory is `/var/mysql/data`. If a file-valued option is given as a relative path name, it will be located under `/var/mysql/data`. If the value is an absolute path name, its location is as given by the path name.

You can also set the values of server system variables at server startup by using variable names as options. To assign a value to a server system variable, use an option of the form `--var_name=value`. For example, `--key_buffer_size=32M` sets the `key_buffer_size` variable to a value of 32MB.

When you assign a value to a variable, MySQL might automatically correct the value to stay within a given range, or adjust the value to the closest permissible value if only certain values are permitted.

To restrict the maximum value to which a system variable can be set at runtime with the `SET` statement, specify this maximum by using an option of the form `--maximum-var_name=value` at server startup.

You can change the values of most system variables at runtime with the `SET` statement. See Section 13.7.4.1, “SET Syntax for Variable Assignment”.

Section 5.1.5, “Server System Variables”, provides a full description for all variables, and additional information for setting them at server startup and runtime. For information on changing system variables, see Section 5.1.1, “Configuring the Server”.

- `--help`, `-?`

Command-Line Format	`--help`

Display a short help message and exit. Use both the `--verbose` and `--help` options to see the full message.

- `--allow-suspicious-udfs`

Command-Line Format	`--allow-suspicious-udfs`	
Permitted Values	Type	boolean
	Default	`FALSE`

This option controls whether user-defined functions that have only an `xxx` symbol for the main function can be loaded. By default, the option is off and only UDFs that have at least one auxiliary symbol can be loaded; this prevents attempts at loading functions from shared object files other than those containing legitimate UDFs. See Section 24.4.2.6, “UDF Security Precautions”.

- `--ansi`

Command-Line Format	`--ansi`

Use standard (ANSI) SQL syntax instead of MySQL syntax. For more precise control over the server SQL mode, use the `--sql-mode` option instead. See Section 1.7, “MySQL Standards Compliance”, and Section 5.1.8, “Server SQL Modes”.

- `--basedir=dir_name`, `-b dir_name`

Command-Line Format	`--basedir=dir_name`	
System Variable	Name	`basedir`
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The path to the MySQL installation directory. This option sets the `basedir` system variable.

- `--big-tables`

Command-Line Format	`--big-tables`	
System Variable (<= 5.5.2)	Name	`big_tables`
	Scope	Session
	Dynamic	Yes
System Variable (>= 5.5.3)	Name	`big_tables`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	`OFF`

Enable large result sets by saving all temporary sets in files. This option prevents most “table full” errors, but also slows down queries for which in-memory tables would suffice. The server is able to handle large result sets automatically by using memory for small temporary tables and switching to disk tables where necessary.

- `--bind-address=addr`

Command-Line Format	`--bind-address=addr`	
Permitted Values	Type	string
	Default	`0.0.0.0`

The MySQL server listens on a single network socket for TCP/IP connections. This socket is bound to a single address, but it is possible for an address to map onto multiple network interfaces. The default address is `0.0.0.0`. To specify an address explicitly, use the `--bind-address=addr` option at server startup, where *`addr`* is an IPv4 or IPv6 address or a host name. (IPv6 addresses are not supported before MySQL 5.5.3.) If *`addr`* is a host name, the server resolves the name to an IP address and binds to that address.

The server treats different types of addresses as follows:

- If the address is `0.0.0.0`, the server accepts TCP/IP connections on all server host IPv4 interfaces.
- If the address is `::`, the server accepts TCP/IP connections on all server host IPv4 and IPv6 interfaces. Use this address to permit both IPv4 and IPv6 connections on all server interfaces.
- If the address is an IPv4-mapped address, the server accepts TCP/IP connections for that address, in either IPv4 or IPv6 format. For example, if the server is bound to `::ffff:127.0.0.1`, clients can connect using `--host=127.0.0.1` or `--host=::ffff:127.0.0.1`.
- If the address is a “regular” IPv4 or IPv6 address (such as `127.0.0.1` or `::1`), the server accepts TCP/IP connections only for that IPv4 or IPv6 address.

If you intend to bind the server to a specific address, be sure that the `mysql.user` grant table contains an account with administrative privileges that you can use to connect to that address. Otherwise, you will not be able to shut down the server. For example, if you bind the server to `::`, you can connect to it using all existing accounts. But if you bind the server to `::1`, it accepts connections only on that address. In that case, first make sure that the `'root'@'::1'` account is present in the `mysql.user` table so you can still connect to the server to shut it down.

- `--binlog-format={ROW|STATEMENT|MIXED}`

Command-Line Format	`--binlog-format=format`	
System Variable	**Name**	`binlog_format`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.5.15-ndb-7.2.1, <= 5.5.30-ndb-7.2.12)	**Type**	enumeration
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.5.31-ndb-7.2.13)	**Type**	enumeration
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`

Specify whether to use row-based, statement-based, or mixed replication. Statement-based is the default in MySQL 5.5. This is also true for MySQL NDB Cluster 7.2.1 and later. See Section 17.1.2, “Replication Formats”.

Under some conditions, changing this variable at runtime is not possible, or causes replication to fail. See Section 5.4.4.2, “Setting The Binary Log Format”, for more information.

Prior to MySQL 5.5, setting the binary logging format without enabling binary logging prevented the MySQL server from starting. In MySQL 5.5, the server starts in such cases, the `binlog_format` global system variable is set, and a warning is logged instead of an error. (Bug #42928)

- `--bootstrap`

Command-Line Format	`--bootstrap`

This option is used by the `mysql_install_db` program to create the MySQL privilege tables without having to start a full MySQL server.

When the server operates in bootstap mode, some functionality is unavailable that limits the statements permitted in any file named by the `--init-file` option. For more information, see the description of that option.

- `--character-sets-dir=dir_name`

Command-Line Format	--character-sets-dir=dir_name	
System Variable	Name	character_sets_dir
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The directory where character sets are installed. See Section 10.5, “Character Set Configuration”.

- `--character-set-client-handshake`

Command-Line Format	--character-set-client-handshake	
Permitted Values	Type	boolean
	Default	TRUE

Do not ignore character set information sent by the client. To ignore client information and use the default server character set, use `--skip-character-set-client-handshake`; this makes MySQL behave like MySQL 4.0.

- `--character-set-filesystem=charset_name`

Command-Line Format	--character-set-filesystem=name	
System Variable	Name	character_set_filesystem
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string
	Default	binary

The file system character set. This option sets the `character_set_filesystem` system variable.

- `--character-set-server=charset_name`, `-C charset_name`

Command-Line Format	--character-set-server	
System Variable	Name	character_set_server
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string
	Default	latin1

Use *`charset_name`* as the default server character set. See Section 10.5, “Character Set Configuration”. If you use this option to specify a nondefault character set, you should also use `--collation-server` to specify the collation.

- `--chroot=dir_name`, `-r dir_name`

Command-Line Format	--chroot=dir_name	
Permitted Values	Type	directory name

Put the `mysqld` server in a closed environment during startup by using the `chroot()` system call. This is a recommended security measure. Use of this option somewhat limits `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE`.

- `--collation-server=collation_name`

Command-Line Format	--collation-server	
System Variable	Name	collation_server
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string
	Default	latin1_swedish_ci

Use *collation_name* as the default server collation. See Section 10.5, “Character Set Configuration”.

- `--console`

Command-Line Format	--console
Platform Specific	Windows

(Windows only.) Write error log messages to `stderr` and `stdout` (the console). `mysqld` does not close the console window if this option is used.

`--log-error` takes precedence over `--console` if both are given.

- `--core-file`

Command-Line Format	--core-file	
Permitted Values	Type	boolean
	Default	OFF

Write a core file if `mysqld` dies. The name and location of the core file is system dependent. On Linux, a core file named `core.pid` is written to the current working directory of the process, which for `mysqld` is the data directory. *pid* represents the process ID of the server process. On OS X, a core file named `core.pid` is written to the `/cores` directory. On Solaris, use the `coreadm` command to specify where to write the core file and how to name it.

For some systems, to get a core file you must also specify the `--core-file-size` option to `mysqld_safe`. See Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”. On some systems, such as Solaris, you do not get a core file if you are also using the `--user` option. There might be additional restrictions or limitations. For example, it might be necessary to execute `ulimit -c unlimited` before starting the server. Consult your system documentation.

- `--datadir=dir_name`, `-h dir_name`

Command-Line Format	--datadir=dir_name	
System Variable	Name	datadir
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The path to the MySQL server data directory. This option sets the `datadir` system variable. See the description of that variable.

- `--debug[=debug_options]`, `-# [debug_options]`

Command-Line Format	--debug[=debug_options]

System Variable	Name	debug
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (Unix)	Type	string
	Default	d:t:i:o,/tmp/mysqld.trace
Permitted Values (Windows)	Type	string
	Default	d:t:i:O,\mysqld.trace

If MySQL is configured with the -DWITH_DEBUG=1 CMake option, you can use this option to get a trace file of what mysqld is doing. A typical *debug_options* string is d:t:o,*file_name*. The default is d:t:i:o,/tmp/mysqld.trace on Unix and d:t:i:O,\mysqld.trace on Windows.

Using -DWITH_DEBUG=1 to configure MySQL with debugging support enables you to use the --debug="d,parser_debug" option when you start the server. This causes the Bison parser that is used to process SQL statements to dump a parser trace to the server's standard error output. Typically, this output is written to the error log.

This option may be given multiple times. Values that begin with + or - are added to or subtracted from the previous value. For example, --debug=T --debug=+P sets the value to P:T.

For more information, see Section 24.5.3, “The DBUG Package”.

- --debug-sync-timeout[=*N*]

Command-Line Format	--debug-sync-timeout[=#]	
Permitted Values	Type	integer

Controls whether the Debug Sync facility for testing and debugging is enabled. Use of Debug Sync requires that MySQL be configured with the -DENABLE_DEBUG_SYNC=1 CMake option (see Section 2.9.4, “MySQL Source-Configuration Options”). If Debug Sync is not compiled in, this option is not available. The option value is a timeout in seconds. The default value is 0, which disables Debug Sync. To enable it, specify a value greater than 0; this value also becomes the default timeout for individual synchronization points. If the option is given without a value, the timeout is set to 300 seconds.

For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

For additional information about this option, see Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- --default-character-set=*charset_name*

Deprecated	5.0.0	
Removed	5.5.3	
Command-Line Format	--default-character-set=name	
Permitted Values	Type	string

Use *charset_name* as the default character set. This option is deprecated in favor of --character-set-server. See Section 10.5, “Character Set Configuration”. --default-character-set was removed in MySQL 5.5.3.

- --default-collation=*collation_name*

Deprecated	4.1.3

Command-Line Format	--default-collation=name	
Permitted Values	Type	string

Use *collation_name* as the default collation. This option is deprecated in favor of --collation-server. See Section 10.5, "Character Set Configuration". --default-collation was removed in MySQL 5.5.3.

- --default-storage-engine=*type*

Command-Line Format	--default-storage-engine=name	
System Variable (<= 5.5.2)	Name	storage_engine
	Scope	Global, Session
	Dynamic	Yes
System Variable (>= 5.5.3)	Name	default_storage_engine
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (<= 5.5.4)	Type	enumeration
	Default	MyISAM
Permitted Values (>= 5.5.5)	Type	enumeration
	Default	InnoDB

Set the default storage engine (table type) for tables. See Chapter 15, *Alternative Storage Engines*.

If you disable the default storage engine at server startup, you must set the default engine to a different engine or the server will not start.

- --default-time-zone=*timezone*

Command-Line Format	--default-time-zone=name	
Permitted Values	Type	string

Set the default server time zone. This option sets the global time_zone system variable. If this option is not given, the default time zone is the same as the system time zone (given by the value of the system_time_zone system variable.

- --defaults-extra-file=*file_name*

Read this option file after the global option file but (on Unix) before the user option file. If the file does not exist or is otherwise inaccessible, an error occurs. *file_name* is interpreted relative to the current directory if given as a relative path name rather than a full path name. This must be the first option on the command line if it is used.

For additional information about this option, see Section 4.2.7, "Command-Line Options that Affect Option-File Handling".

- --defaults-file=*file_name*

Read only the given option file. If the file does not exist or is otherwise inaccessible, an error occurs. *file_name* is interpreted relative to the current directory if given as a relative path name rather than a full path name.

Note

This must be the first option on the command line if it is used, except that if the server is started with the --defaults-file and --install (or --

> `install-manual`) options, `--install` (or `--install-manual`) must be first.

For additional information about this option, see Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- `--defaults-group-suffix=str`

  Read not only the usual option groups, but also groups with the usual names and a suffix of *`str`*. For example, `mysqld` normally reads the `[mysqld]` group. If the `--defaults-group-suffix=_other` option is given, `mysqld` also reads the `[mysqld_other]` group.

- `--delay-key-write[={OFF|ON|ALL}]`

Command-Line Format	`--delay-key-write[=name]`	
System Variable	**Name**	`delay_key_write`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`ON`
	Valid Values	`ON`
		`OFF`
		`ALL`

  Specify how to use delayed key writes. Delayed key writing causes key buffers not to be flushed between writes for `MyISAM` tables. `OFF` disables delayed key writes. `ON` enables delayed key writes for those tables that were created with the `DELAY_KEY_WRITE` option. `ALL` delays key writes for all `MyISAM` tables. See Section 5.1.1, “Configuring the Server”, and Section 15.3.1, “MyISAM Startup Options”.

> **Note**
>
> If you set this variable to `ALL`, you should not use `MyISAM` tables from within another program (such as another MySQL server or `myisamchk`) when the tables are in use. Doing so leads to index corruption.

  For additional information about this option, see Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- `--des-key-file=file_name`

Command-Line Format	`--des-key-file=file_name`

  Read the default DES keys from this file. These keys are used by the `DES_ENCRYPT()` and `DES_DECRYPT()` functions.

  For additional information about this option, see Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- `--enable-locking`

  This option is deprecated and was removed in MySQL 5.5.3. Use `--external-locking` instead.

- `--enable-named-pipe`

Command-Line Format	`--enable-named-pipe`
Platform Specific	Windows

Enable support for named pipes. This option applies only on Windows.

- `--enable-pstack`

Deprecated	5.1.54	
Removed	5.5.7	
Command-Line Format	`--enable-pstack`	
Permitted Values	**Type**	boolean
	Default	`FALSE`

This option is nonfunctional before MySQL 5.5.7 and removed in 5.5.7.

- `--engine-condition-pushdown={ON|OFF}`

Deprecated	5.5.3, by `optimizer_switch`	
Command-Line Format	`--engine-condition-pushdown`	
System Variable	**Name**	`engine_condition_pushdown`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`ON`

Sets the `engine_condition_pushdown` system variable. For more information, see Section 8.2.1.4, “Engine Condition Pushdown Optimization”.

- `--event-scheduler[=value]`

Command-Line Format	`--event-scheduler[=value]`	
System Variable	**Name**	`event_scheduler`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`OFF`
	Valid Values	`ON`
		`OFF`
		`DISABLED`

Enable or disable, and start or stop, the event scheduler.

For detailed information, see The `--event-scheduler` Option.

- `--exit-info[=flags]`, `-T [flags]`

Command-Line Format	`--exit-info[=flags]`	
Permitted Values	**Type**	integer

This is a bitmask of different flags that you can use for debugging the `mysqld` server. Do not use this option unless you know *exactly* what it does!

- `--external-locking`

Command-Line Format	--external-locking	
Permitted Values	Type	boolean
	Default	FALSE

Enable external locking (system locking), which is disabled by default. If you use this option on a system on which lockd does not fully work (such as Linux), it is easy for mysqld to deadlock.

To disable external locking explicitly, use --skip-external-locking.

External locking affects only MyISAM table access. For more information, including conditions under which it can and cannot be used, see Section 8.11.5, “External Locking”.

- --flush

Command-Line Format	--flush	
System Variable	Name	flush
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	OFF

Flush (synchronize) all changes to disk after each SQL statement. Normally, MySQL does a write of all changes to disk only after each SQL statement and lets the operating system handle the synchronizing to disk. See Section B.5.3.3, “What to Do If MySQL Keeps Crashing”.

Note

If --flush is specified, the value of flush_time does not matter and changes to flush_time have no effect on flush behavior.

- --gdb

Command-Line Format	--gdb	
Permitted Values	Type	boolean
	Default	FALSE

Install an interrupt handler for SIGINT (needed to stop mysqld with ^C to set breakpoints) and disable stack tracing and core file handling. See Section 24.5, “Debugging and Porting MySQL”.

- --general-log[={0|1}]

Command-Line Format	--general-log	
System Variable	Name	general_log
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	OFF

Specify the initial general query log state. With no argument or an argument of 1, the --general-log option enables the log. If omitted or given with an argument of 0, the option disables the log.

- --init-file=*file_name*

Command-Line Format	--init-file=file_name	
System Variable	Name	init_file
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

Read SQL statements from this file at startup. Each statement must be on a single line and should not include comments.

If the server is started with the --bootstrap option, it operates in bootstap mode and some functionality is unavailable that limits the statements permitted in the file. These include statements that relate to account management (such as CREATE USER or GRANT).

- --innodb-*xxx*

  Set an option for the InnoDB storage engine. The InnoDB options are listed in Section 14.17, “InnoDB Startup Options and System Variables”.

- --install [*service_name*]

Command-Line Format	--install [service_name]
Platform Specific	Windows

(Windows only) Install the server as a Windows service that starts automatically during Windows startup. The default service name is MySQL if no *service_name* value is given. For more information, see Section 2.3.7.7, “Starting MySQL as a Windows Service”.

Note

If the server is started with the --defaults-file and --install options, --install must be first.

- --install-manual [*service_name*]

Command-Line Format	--install-manual [service_name]
Platform Specific	Windows

(Windows only) Install the server as a Windows service that must be started manually. It does not start automatically during Windows startup. The default service name is MySQL if no *service_name* value is given. For more information, see Section 2.3.7.7, “Starting MySQL as a Windows Service”.

Note

If the server is started with the --defaults-file and --install-manual options, --install-manual must be first.

- --language=*lang_name*, -L *lang_name*

Deprecated	5.5.0, by lc-messages-dir	
Command-Line Format	--language=name	
System Variable	Name	language
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

	Default	`/usr/local/mysql/share/mysql/english/`

The language to use for error messages. *`lang_name`* can be given as the language name or as the full path name to the directory where the language files are installed. See Section 10.2, “Setting the Error Message Language”.

As of MySQL 5.5, `--lc-messages-dir` and `--lc-messages` should be used rather than `--language`, which is deprecated and handled as an alias for `--lc-messages-dir`.

- `--large-pages`

Command-Line Format	`--large-pages`	
System Variable	**Name**	`large_pages`
	Scope	Global
	Dynamic	No
Platform Specific	Linux	
Permitted Values (Linux)	**Type**	boolean
	Default	`FALSE`

Some hardware/operating system architectures support memory pages greater than the default (usually 4KB). The actual implementation of this support depends on the underlying hardware and operating system. Applications that perform a lot of memory accesses may obtain performance improvements by using large pages due to reduced Translation Lookaside Buffer (TLB) misses.

MySQL supports the Linux implementation of large page support (which is called HugeTLB in Linux). See Section 8.12.4.2, “Enabling Large Page Support”. For Solaris support of large pages, see the description of the `--super-large-pages` option.

`--large-pages` is disabled by default.

- `--lc-messages=`*`locale_name`*

Command-Line Format	`--lc-messages=name`	
System Variable	**Name**	`lc_messages`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	string
	Default	`en_US`

The locale to use for error messages. The default is `en_US`. The server converts the argument to a language name and combines it with the value of `--lc-messages-dir` to produce the location for the error message file. See Section 10.2, “Setting the Error Message Language”.

- `--lc-messages-dir=`*`dir_name`*

Command-Line Format	`--lc-messages-dir=dir_name`	
System Variable	**Name**	`lc_messages_dir`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	directory name

The directory where error messages are located. The server uses the value together with the value of `--lc-messages` to produce the location for the error message file. See Section 10.2, “Setting the Error Message Language”.

- `--local-service`

Command-Line Format	`--local-service`

(Windows only) A `--local-service` option following the service name causes the server to run using the `LocalService` Windows account that has limited system privileges. This account is available only for Windows XP or newer. If both `--defaults-file` and `--local-service` are given following the service name, they can be in any order. See Section 2.3.7.7, “Starting MySQL as a Windows Service”.

- `--log[=file_name]`, `-l [file_name]`

Deprecated	5.1.29, by `general-log`	
Command-Line Format	`--log[=file_name]`	
System Variable	Name	`log`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	file name

This option enables logging to the general query log, which contains entries that record client connections and SQL statements received from clients. The log output destination can be selected with the `--log-output` option. If you omit the file name, MySQL uses *`host_name`*`.log` as the file name. See Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”, and Section 5.4.3, “The General Query Log”.

The `--log` option is deprecated and is removed (along with the `log` system variable) in MySQL 5.6. Instead, use the `--general_log` option to enable the general query log and the `--general_log_file=`*`file_name`* option to set the general query log file name.

- `--log-error[=file_name]`

Command-Line Format	`--log-error[=file_name]`	
System Variable	Name	`log_error`
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

Write the error log and startup messages to this file. See Section 5.4.2, “The Error Log”.

If the option names no file, the error log file name on Unix and Unix-like systems is *`host_name`*`.err` in the data directory. The file name on Windows is the same, unless the `--pid-file` option is specified. In that case, the file name is the PID file base name with a suffix of `.err` in the data directory.

If the option names a file, the error log file has that name (with an `.err` suffix added if the name has no suffix), located under the data directory unless an absolute path name is given to specify a different location.

On Windows, `--log-error` takes precedence over `--console` if both are given.

- `--log-isam[=file_name]`

Command-Line Format	--log-isam[=file_name]	
Permitted Values	Type	file name

Log all MyISAM changes to this file (used only when debugging MyISAM).

- --log-long-format

Deprecated	4.1.0	
Command-Line Format	--log-long-format	

Log extra information to the binary log and slow query log, if they have been activated. For example, the user name and timestamp are logged for all queries. This option is deprecated, as it now represents the default logging behavior. (See the description for --log-short-format.) The --log-queries-not-using-indexes option is available for the purpose of logging queries that do not use indexes to the slow query log. --log-long-format was removed in MySQL 5.5.3.

- --log-output=*value*,...

Command-Line Format	--log-output=name	
System Variable	Name	log_output
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	set
	Default	FILE
	Valid Values	TABLE
		FILE
		NONE

This option determines the destination for general query log and slow query log output. The option value can be given as one or more of the words TABLE, FILE, or NONE. TABLE select logging to the general_log and slow_log tables in the mysql database as a destination. FILE selects logging to log files as a destination. NONE disables logging. If NONE is present in the option value, it takes precedence over any other words that are present. TABLE and FILE can both be given to select to both log output destinations.

This option selects log output destinations, but does not enable log output. To do that, use the --general_log and --slow_query_log options. For FILE logging, the --general_log_file and -slow_query_log_file options determine the log file location. For more information, see Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”.

- --log-queries-not-using-indexes

Command-Line Format	--log-queries-not-using-indexes	
System Variable	Name	log_queries_not_using_indexes
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	OFF

If you are using this option with the slow query log enabled, queries that are expected to retrieve all rows are logged. See Section 5.4.5, “The Slow Query Log”. This option does not necessarily mean

that no index is used. For example, a query that uses a full index scan uses an index but would be logged because the index would not limit the number of rows.

- `--log-short-format`

Command-Line Format	`--log-short-format`	
Permitted Values	Type	boolean
	Default	`FALSE`

Log less information to the slow query log, if it has been activated.

- `--log-slow-admin-statements`

Command-Line Format	`--log-slow-admin-statements`	
Permitted Values	Type	boolean
	Default	`OFF`

Include slow administrative statements in the statements written to the slow query log. Administrative statements include `ALTER TABLE`, `ANALYZE TABLE`, `CHECK TABLE`, `CREATE INDEX`, `DROP INDEX`, `OPTIMIZE TABLE`, and `REPAIR TABLE`.

- `--log-slow-queries[=file_name]`

Deprecated	5.1.29, by `slow-query-log`	
Command-Line Format	`--log-slow-queries[=name]`	
System Variable	Name	`log_slow_queries`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean

This option enables logging to the slow query log, which contains entries for all queries that have taken more than `long_query_time` seconds to execute. See the descriptions of the `--log-long-format` and `--log-short-format` options for details. The log output destination can be selected with the `--log-output` option. If you omit the file name, MySQL uses *`host_name`*`-slow.log` as the file name. See Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”, and Section 5.4.5, “The Slow Query Log”.

The `--log-slow-queries` option is deprecated and is removed (along with the `log_slow_queries` system variable) in MySQL 5.6. Instead, use the `--slow_query_log` option to enable the slow query log and the `--slow_query_log_file=`*`file_name`* option to set the slow query log file name.

- `--log-tc=file_name`

Command-Line Format	`--log-tc=file_name`	
Permitted Values	Type	file name
	Default	`tc.log`

The name of the memory-mapped transaction coordinator log file (for XA transactions that affect multiple storage engines when the binary log is disabled). The default name is `tc.log`. The file is created under the data directory if not given as a full path name. This option is unused.

- `--log-tc-size=size`

Command-Line Format	`--log-tc-size=#`

Permitted Values (32-bit platforms)	**Type**	integer
	Default	24576
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	24576
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	24576
	Maximum	18446744073709551615

The size in bytes of the memory-mapped transaction coordinator log. The default size is 24KB.

- `--log-warnings[=level]`, `-W [level]`

Command-Line Format	`--log-warnings[=#]`	
System Variable	**Name**	`log_warnings`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	1
	Minimum	0
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	1
	Minimum	0
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	1
	Minimum	0
	Maximum	18446744073709551615

Print out warnings such as `Aborted connection...` to the error log. This option is enabled (1) by default. To disable it, use `--log-warnings=0`. Specifying the option without a *`level`* value increments the current value by 1. Enabling this option by setting it greater than 0 is recommended, for example, if you use replication (you get more information about what is happening, such as messages about network failures and reconnections). If the value is greater than 1, aborted connections are written to the error log, and access-denied errors for new connection attempts are written. See Section B.5.2.11, “Communication Errors and Aborted Connections”.

If a slave server was started with `--log-warnings` enabled, the slave prints messages to the error log to provide information about its status, such as the binary log and relay log coordinates where it starts its job, when it is switching to another relay log, when it reconnects after a disconnect, and so forth. The server logs messages about statements that are unsafe for statement-based logging if `--log-warnings` is greater than 0.

- `--low-priority-updates`

Command-Line Format	`--low-priority-updates`	
System Variable	**Name**	`low_priority_updates`

	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`FALSE`

Give table-modifying operations (`INSERT`, `REPLACE`, `DELETE`, `UPDATE`) lower priority than selects. This can also be done using `{INSERT | REPLACE | DELETE | UPDATE} LOW_PRIORITY ...` to lower the priority of only one query, or by `SET LOW_PRIORITY_UPDATES=1` to change the priority in one thread. This affects only storage engines that use only table-level locking (`MyISAM`, `MEMORY`, `MERGE`). See Section 8.11.2, “Table Locking Issues”.

- `--min-examined-row-limit=`*`number`*

Command-Line Format	`--min-examined-row-limit=#`	
System Variable	**Name**	`min_examined_row_limit`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`18446744073709551615`

When this option is set, queries which examine fewer than *`number`* rows are not written to the slow query log. The default is 0.

- `--memlock`

Command-Line Format	`--memlock`	
Permitted Values	**Type**	boolean
	Default	`FALSE`

Lock the `mysqld` process in memory. This option might help if you have a problem where the operating system is causing `mysqld` to swap to disk.

`--memlock` works on systems that support the `mlockall()` system call; this includes Solaris, most Linux distributions that use a 2.4 or higher kernel, and perhaps other Unix systems. On Linux systems, you can tell whether or not `mlockall()` (and thus this option) is supported by checking to see whether or not it is defined in the system `mman.h` file, like this:

```
shell> grep mlockall /usr/include/sys/mman.h
```

If `mlockall()` is supported, you should see in the output of the previous command something like the following:

```
extern int mlockall (int __flags) __THROW;
```

Important

Use of this option may require you to run the server as `root`, which, for reasons of security, is normally not a good idea. See Section 6.1.5, “How to Run MySQL as a Normal User”.

On Linux and perhaps other systems, you can avoid the need to run the server as `root` by changing the `limits.conf` file. See the notes regarding the memlock limit in Section 8.12.4.2, “Enabling Large Page Support”.

You must not try to use this option on a system that does not support the `mlockall()` system call; if you do so, `mysqld` will very likely crash as soon as you try to start it.

- `--myisam-block-size=N`

Command-Line Format	`--myisam-block-size=#`	
Permitted Values	Type	integer
	Default	`1024`
	Minimum	`1024`
	Maximum	`16384`

The block size to be used for `MyISAM` index pages.

- `--myisam-recover[=option[,option]...]]`

This option was renamed in MySQL 5.5.3 to `--myisam-recover-options`. See the description of that option for more information.

- `--myisam-recover-options[=option[,option]...]]`

Introduced	5.5.3	
Command-Line Format	`--myisam-recover-options[=name]`	
Permitted Values	Type	enumeration
	Default	`OFF`
	Valid Values	`OFF`
		`DEFAULT`
		`BACKUP`
		`FORCE`
		`QUICK`

Set the `MyISAM` storage engine recovery mode. The option value is any combination of the values of `OFF`, `DEFAULT`, `BACKUP`, `FORCE`, or `QUICK`. If you specify multiple values, separate them by commas. Specifying the option with no argument is the same as specifying `DEFAULT`, and specifying with an explicit value of `""` disables recovery (same as a value of `OFF`). If recovery is enabled, each time `mysqld` opens a `MyISAM` table, it checks whether the table is marked as crashed or was not closed properly. (The last option works only if you are running with external locking disabled.) If this is the case, `mysqld` runs a check on the table. If the table was corrupted, `mysqld` attempts to repair it.

The following options affect how the repair works.

Option	Description
OFF	No recovery.
DEFAULT	Recovery without backup, forcing, or quick checking.
BACKUP	If the data file was changed during recovery, save a backup of the *tbl_name*.MYD file as *tbl_name-datetime*.BAK.
FORCE	Run recovery even if we would lose more than one row from the .MYD file.
QUICK	Do not check the rows in the table if there are not any delete blocks.

Before the server automatically repairs a table, it writes a note about the repair to the error log. If you want to be able to recover from most problems without user intervention, you should use the options BACKUP,FORCE. This forces a repair of a table even if some rows would be deleted, but it keeps the old data file as a backup so that you can later examine what happened.

This option was named --myisam-recover, before MySQL 5.5.3. The old option name still works because it is recognized as an unambiguous prefix of the new name, --myisam-recover-options. (Option prefix recognition occurs as described in Section 4.2.3, “Specifying Program Options”.)

See Section 15.3.1, “MyISAM Startup Options”.

- --no-defaults

  Do not read any option files. If program startup fails due to reading unknown options from an option file, --no-defaults can be used to prevent them from being read. This must be the first option on the command line if it is used.

  For additional information about this option, see Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- --old-alter-table

Command-Line Format	--old-alter-table	
System Variable	Name	old_alter_table
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	OFF

  When this option is given, the server does not use the optimized method of processing an ALTER TABLE operation. It reverts to using a temporary table, copying over the data, and then renaming the temporary table to the original, as used by MySQL 5.0 and earlier. For more information on the operation of ALTER TABLE, see Section 13.1.7, “ALTER TABLE Syntax”.

- --old-style-user-limits

Command-Line Format	--old-style-user-limits	
Permitted Values	Type	boolean
	Default	FALSE

  Enable old-style user limits. (Before MySQL 5.0.3, account resource limits were counted separately for each host from which a user connected rather than per account row in the user table.) See Section 6.3.4, “Setting Account Resource Limits”.

- `--one-thread`

Command-Line Format	`--one-thread`

Only use one thread (for debugging under Linux). This option is available only if the server is built with debugging enabled. See Section 24.5, “Debugging and Porting MySQL”.

This option is deprecated and is removed in MySQL 5.6. Use `--thread_handling=no-threads` instead.

- `--open-files-limit=count`

Command-Line Format	`--open-files-limit=#`	
System Variable	Name	`open_files_limit`
	Scope	Global
	Dynamic	No
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`platform dependent`

Changes the number of file descriptors available to `mysqld`. You should try increasing the value of this option if `mysqld` gives you the error `Too many open files`. `mysqld` uses the option value to reserve descriptors with `setrlimit()`. Internally, the maximum value for this option is the maximum unsigned integer value, but the actual maximum is platform dependent. If the requested number of file descriptors cannot be allocated, `mysqld` writes a warning to the error log.

`mysqld` may attempt to allocate more than the requested number of descriptors (if they are available), using the values of `max_connections` and `table_open_cache` to estimate whether more descriptors will be needed.

On Unix, the value cannot be set greater than `ulimit -n`.

- `--partition[=value]`

Command-Line Format	`--partition`	
Disabled by	`skip-partition`	
Permitted Values	Type	boolean
	Default	`ON`

Enables or disables user-defined partitioning support in the MySQL Server.

- `--pid-file=file_name`

Command-Line Format	`--pid-file=file_name`	
System Variable	Name	`pid_file`
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The path name of the process ID file. The server creates the file in the data directory unless an absolute path name is given to specify a different directory. This file is used by other programs such as `mysqld_safe` to determine the server's process ID. On Windows, this variable also affects the default error log file name. See Section 5.4.2, “The Error Log”

- `--plugin-xxx`

  Specifies an option that pertains to a server plugin. For example, many storage engines can be built as plugins, and for such engines, options for them can be specified with a `--plugin` prefix. Thus, the `--innodb_file_per_table` option for `InnoDB` can be specified as `--plugin-innodb_file_per_table`.

  For boolean options that can be enabled or disabled, the `--skip` prefix and other alternative formats are supported as well (see Section 4.2.5, “Program Option Modifiers”). For example, `--skip-plugin-innodb_file_per_table` disables `innodb_file_per_table`.

  The rationale for the `--plugin` prefix is that it enables plugin options to be specified unambiguously if there is a name conflict with a built-in server option. For example, were a plugin writer to name a plugin “sql” and implement a “mode” option, the option name might be `--sql-mode`, which would conflict with the built-in option of the same name. In such cases, references to the conflicting name are resolved in favor of the built-in option. To avoid the ambiguity, users can specify the plugin option as `--plugin-sql-mode`. Use of the `--plugin` prefix for plugin options is recommended to avoid any question of ambiguity.

- `--plugin-load=plugin_list`

Command-Line Format	`--plugin-load=plugin_list`	
Permitted Values	**Type**	string

  This option tells the server to load the named plugins at startup. All plugins to load must be named in the same `--plugin-load` option. If multiple `--plugin-load` options are given, only the last one is used.

  The option value is a semicolon-separated list of *`name=plugin_library`* and *`plugin_library`* values. Each *`name`* is the name of a plugin to load, and *`plugin_library`* is the name of the library file that contains the plugin code. If a plugin library is named without any preceding plugin name, the server loads all plugins in the library. The server looks for plugin library files in the directory named by the `plugin_dir` system variable.

  For example, if plugins named `myplug1` and `myplug2` have library files `myplug1.so` and `myplug2.so`, use this option to perform an early plugin load:

```
shell> mysqld --plugin-load="myplug1=myplug1.so;myplug2=myplug2.so"
```

  Quotes are used around the argument value here because otherwise semicolon (`;`) is interpreted as a special character by some command interpreters. (Unix shells treat it as a command terminator, for example.)

  Each named plugin is loaded for a single invocation of `mysqld` only. After a restart, the plugin is not loaded unless `--plugin-load` is used again. This is in contrast to `INSTALL PLUGIN`, which adds an entry to the `mysql.plugins` table to cause the plugin to be loaded for every normal server startup.

  Under normal startup, the server determines which plugins to load by reading the `mysql.plugins` system table. If the server is started with the `--skip-grant-tables` option, it does not consult the `mysql.plugins` table and does not load plugins listed there. `--plugin-load` enables plugins to be loaded even when `--skip-grant-tables` is given. `--plugin-load` also enables plugins to be loaded at startup under configurations when plugins cannot be loaded at runtime.

  For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

- `--port=port_num`, `-P port_num`

Command-Line Format	--port=#	
System Variable	Name	port
	Scope	Global
	Dynamic	No
Permitted Values	Type	integer
	Default	3306
	Minimum	0
	Maximum	65535

The port number to use when listening for TCP/IP connections. On Unix and Unix-like systems, the port number must be 1024 or higher unless the server is started by the root system user.

- --port-open-timeout=*num*

Command-Line Format	--port-open-timeout=#	
Permitted Values	Type	integer
	Default	0

On some systems, when the server is stopped, the TCP/IP port might not become available immediately. If the server is restarted quickly afterward, its attempt to reopen the port can fail. This option indicates how many seconds the server should wait for the TCP/IP port to become free if it cannot be opened. The default is not to wait.

- --print-defaults

Print the program name and all options that it gets from option files. This must be the first option on the command line if it is used, except that it may be used immediately after --defaults-file or --defaults-extra-file.

For additional information about this option, see Section 4.2.7, “Command-Line Options that Affect Option-File Handling”.

- --remove [*service_name*]

Command-Line Format	--remove [service_name]
Platform Specific	Windows

(Windows only) Remove a MySQL Windows service. The default service name is MySQL if no *service_name* value is given. For more information, see Section 2.3.7.7, “Starting MySQL as a Windows Service”.

- --safe-mode

Deprecated	5.5.26
Command-Line Format	--safe-mode

Skip some optimization stages. This option is deprecated and is removed in MySQL 5.6.

- --safe-show-database

Deprecated	4.0.2
Removed	5.5.3
Command-Line Format	--safe-show-database

Permitted Values	Type	boolean

This option was removed in MySQL 5.5.3. There is a `SHOW DATABASES` privilege that can be used to control access to database names on a per-account basis. See Section 6.2.1, “Privileges Provided by MySQL”.

- `--safe-user-create`

Command-Line Format	`--safe-user-create`	
Permitted Values	Type	boolean
	Default	`FALSE`

If this option is enabled, a user cannot create new MySQL users by using the `GRANT` statement unless the user has the `INSERT` privilege for the `mysql.user` table or any column in the table. If you want a user to have the ability to create new users that have those privileges that the user has the right to grant, you should grant the user the following privilege:

```
GRANT INSERT(user) ON mysql.user TO 'user_name'@'host_name';
```

This ensures that the user cannot change any privilege columns directly, but has to use the `GRANT` statement to give privileges to other users.

- `--secure-auth`

Command-Line Format	`--secure-auth`	
System Variable	Name	`secure_auth`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	`OFF`

This option causes the server to block connections by clients that attempt to use accounts that have passwords stored in the old (pre-4.1) format. Use it to prevent all use of passwords employing the old format (and hence insecure communication over the network).

Server startup fails with an error if this option is enabled and the privilege tables are in pre-4.1 format. See Section B.5.2.4, “Client does not support authentication protocol”.

The `mysql` client also has a `--secure-auth` option, which prevents connections to a server if the server requires a password in old format for the client account.

Note

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

- `--secure-file-priv=dir_name`

Command-Line Format	`--secure-file-priv=dir_name`	
System Variable	Name	`secure_file_priv`
	Scope	Global
	Dynamic	No
Permitted Values (<= 5.5.52)	Type	string

	Default	`empty`
	Valid Values	`empty`
		`dirname`
Permitted Values (>= 5.5.53)	**Type**	string
	Default	`platform specific`
	Valid Values	`empty`
		`dirname`
		`NULL`

This option sets the `secure_file_priv` system variable, which is used to limit the effect of data import and export operations, such as those performed by the `LOAD DATA` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. For more information, see the description of `secure_file_priv`.

- `--shared-memory`

Command-Line Format	`--shared-memory[={0,1}]`	
System Variable	**Name**	`shared_memory`
	Scope	Global
	Dynamic	No
Platform Specific	Windows	
Permitted Values	**Type**	boolean
	Default	`FALSE`

Enable shared-memory connections by local clients. This option is available only on Windows.

- `--shared-memory-base-name=`*`name`*

Command-Line Format	`--shared-memory-base-name=name`	
System Variable	**Name**	`shared_memory_base_name`
	Scope	Global
	Dynamic	No
Platform Specific	Windows	
Permitted Values	**Type**	string
	Default	`MYSQL`

The name of shared memory to use for shared-memory connections. This option is available only on Windows. The default name is `MYSQL`. The name is case sensitive.

- `--skip-concurrent-insert`

Turn off the ability to select and insert at the same time on `MyISAM` tables. (This is to be used only if you think you have found a bug in this feature.) See Section 8.11.3, “Concurrent Inserts”.

- `--skip-event-scheduler`

Command-Line Format	`--skip-event-scheduler`
	`--disable-event-scheduler`

Turns the Event Scheduler `OFF`. This is not the same as disabling the Event Scheduler, which requires setting `--event-scheduler=DISABLED`; see The `--event-scheduler` Option, for more information.

- `--skip-grant-tables`

  This option causes the server to start without using the privilege system at all, which gives anyone with access to the server *unrestricted access to all databases*. You can cause a running server to start using the grant tables again by executing `mysqladmin flush-privileges` or `mysqladmin reload` command from a system shell, or by issuing a MySQL `FLUSH PRIVILEGES` statement after connecting to the server.

  This option also causes the server to suppress during its startup sequence the loading of user-defined functions (UDFs), scheduled events, and plugins that were installed with the `INSTALL PLUGIN` statement. To cause plugins to be loaded anyway, use the `--plugin-load` option.

  `FLUSH PRIVILEGES` might be executed implicitly by other actions performed after startup. For example, `mysql_upgrade` flushes the privileges during the upgrade procedure.

- `--skip-host-cache`

  Disable use of the internal host cache for faster name-to-IP resolution. In this case, the server performs a DNS lookup every time a client connects. See Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

- `--skip-innodb`

  Disable the `InnoDB` storage engine. In this case, if the default storage engine is `InnoDB`, the server will not start unless you also use `--default-storage-engine` to set the default to some other engine.

- `--skip-name-resolve`

  Do not resolve host names when checking client connections. Use only IP addresses. If you use this option, all `Host` column values in the grant tables must be IP addresses or `localhost`. See Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

  Depending on the network configuration of your system and the `Host` values for your accounts, clients may need to connect using an explicit `--host` option, such as `--host=localhost`, `--host=127.0.0.1`, or `--host=::1`.

  An attempt to connect to the host `127.0.0.1` normally resolves to the `localhost` account. However, this fails if the server is run with the `--skip-name-resolve` option, so make sure that an account exists that can accept a connection. For example, to be able to connect as `root` using `--host=127.0.0.1` or `--host=::1`, create these accounts:

```
CREATE USER 'root'@'127.0.0.1' IDENTIFIED BY 'root-password';
CREATE USER 'root'@'::1' IDENTIFIED BY 'root-password';
```

- `--skip-networking`

  Do not listen for TCP/IP connections at all. All interaction with `mysqld` must be made using named pipes or shared memory (on Windows) or Unix socket files (on Unix). This option is highly recommended for systems where only local clients are permitted. See Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

- `--skip-partition`

Command-Line Format	`--skip-partition`
	`--disable-partition`

Disables user-defined partitioning. Partitioned tables can be seen using `SHOW TABLES` or by querying the `INFORMATION_SCHEMA.TABLES` table, but cannot be created or modified, nor can data in such tables be accessed. All partition-specific columns in the `INFORMATION_SCHEMA.PARTITIONS` table display `NULL`.

Since `DROP TABLE` removes table definition (`.frm`) files, this statement works on partitioned tables even when partitioning is disabled using the option. The statement, however, does not remove `.par` files associated with partitioned tables in such cases. For this reason, you should avoid dropping partitioned tables with partitioning disabled, or take action to remove the orphaned `.par` files manually.

- `--ssl*`

  Options that begin with `--ssl` specify whether to permit clients to connect using SSL and indicate where to find SSL keys and certificates. See Section 6.4.2, “Command Options for Encrypted Connections”.

- `--standalone`

Command-Line Format	`--standalone`	
Platform Specific	Windows	

  Available on Windows only; instructs the MySQL server not to run as a service.

- `--super-large-pages`

Introduced	5.5.3	
Command-Line Format	`--super-large-pages`	
Platform Specific	Solaris	
Permitted Values (Solaris)	**Type**	boolean
	Default	`FALSE`

  Standard use of large pages in MySQL attempts to use the largest size supported, up to 4MB. Under Solaris, a “super large pages” feature enables uses of pages up to 256MB. This feature is available for recent SPARC platforms. It can be enabled or disabled by using the `--super-large-pages` or `--skip-super-large-pages` option.

- `--symbolic-links`, `--skip-symbolic-links`

Command-Line Format	`--symbolic-links`	
Permitted Values	**Type**	boolean
	Default	`ON`

  Enable or disable symbolic link support. This option has different effects on Windows and Unix:

  - On Windows, enabling symbolic links enables you to establish a symbolic link to a database directory by creating a *`db_name`*`.sym` file that contains the path to the real directory. See Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”.

  - On Unix, enabling symbolic links means that you can link a `MyISAM` index file or data file to another directory with the `INDEX DIRECTORY` or `DATA DIRECTORY` options of the `CREATE TABLE` statement. If you delete or rename the table, the files that its symbolic links point to also are deleted or renamed. See Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”.

- `--skip-safemalloc`

Removed	5.5.6
Command-Line Format	`--skip-safemalloc`

Previously, if MySQL was configured with full debugging support, all MySQL programs check for memory overruns during each memory allocation and memory freeing operation. This checking is very slow, so for the server you can avoid it when you do not need it by using the `--skip-safemalloc` option.

`safemalloc`, along with this option, was removed in MySQL 5.5.6.

- `--skip-show-database`

Command-Line Format	`--skip-show-database`	
System Variable	Name	`skip_show_database`
	Scope	Global
	Dynamic	No

This option sets the `skip_show_database` system variable that controls who is permitted to use the `SHOW DATABASES` statement. See Section 5.1.5, “Server System Variables”.

- `--skip-stack-trace`

Command-Line Format	`--skip-stack-trace`

Do not write stack traces. This option is useful when you are running `mysqld` under a debugger. On some systems, you also must use this option to get a core file. See Section 24.5, “Debugging and Porting MySQL”.

- `--skip-thread-priority`

Deprecated	5.1.29
Command-Line Format	`--skip-thread-priority`

Disable using thread priorities for faster response time. This option is deprecated and is removed in MySQL 5.6.

- `--slow-query-log[={0|1}]`

Command-Line Format	`--slow-query-log`	
System Variable	Name	`slow_query_log`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	`OFF`

Specify the initial slow query log state. With no argument or an argument of 1, the `--slow-query-log` option enables the log. If omitted or given with an argument of 0, the option disables the log.

- `--slow-start-timeout=`*`timeout`*

Introduced	5.5.20	
Command-Line Format	`--slow-start-timeout=#`	
Permitted Values (Windows)	Type	integer

	Default	`15000`

This option controls the Windows service control manager's service start timeout. The value is the maximum number of milliseconds that the service control manager waits before trying to kill the windows service during startup. The default value is 15000 (15 seconds). If the MySQL service takes too long to start, you may need to increase this value. A value of 0 means there is no timeout.

- `--socket=path`

Command-Line Format	`--socket={file_name|pipe_name}`	
System Variable	**Name**	`socket`
	Scope	Global
	Dynamic	No
Permitted Values (Windows)	**Type**	string
	Default	`MySQL`
Permitted Values (Other)	**Type**	string
	Default	`/tmp/mysql.sock`

On Unix, this option specifies the Unix socket file to use when listening for local connections. The default value is `/tmp/mysql.sock`. If this option is given, the server creates the file in the data directory unless an absolute path name is given to specify a different directory. On Windows, the option specifies the pipe name to use when listening for local connections that use a named pipe. The default value is `MySQL` (not case sensitive).

- `--sql-mode=value[,value[,value...]]`

Command-Line Format	`--sql-mode=name`	
System Variable	**Name**	`sql_mode`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	set
	Default	`''`
	Valid Values	`ALLOW_INVALID_DATES`
		`ANSI_QUOTES`
		`ERROR_FOR_DIVISION_BY_ZERO`
		`HIGH_NOT_PRECEDENCE`
		`IGNORE_SPACE`
		`NO_AUTO_CREATE_USER`
		`NO_AUTO_VALUE_ON_ZERO`
		`NO_BACKSLASH_ESCAPES`
		`NO_DIR_IN_CREATE`
		`NO_ENGINE_SUBSTITUTION`
		`NO_FIELD_OPTIONS`
		`NO_KEY_OPTIONS`
		`NO_TABLE_OPTIONS`
		`NO_UNSIGNED_SUBTRACTION`
		`NO_ZERO_DATE`

		NO_ZERO_IN_DATE
		ONLY_FULL_GROUP_BY
		PAD_CHAR_TO_FULL_LENGTH
		PIPES_AS_CONCAT
		REAL_AS_FLOAT
		STRICT_ALL_TABLES
		STRICT_TRANS_TABLES

Set the SQL mode. See Section 5.1.8, “Server SQL Modes”.

Note

MySQL installation programs may configure the SQL mode during the installation process. If the SQL mode differs from the default or from what you expect, check for a setting in an option file that the server reads at startup.

- `--sysdate-is-now`

Command-Line Format	`--sysdate-is-now`	
Permitted Values	**Type**	boolean
	Default	`FALSE`

`SYSDATE()` by default returns the time at which it executes, not the time at which the statement in which it occurs begins executing. This differs from the behavior of `NOW()`. This option causes `SYSDATE()` to be an alias for `NOW()`. For information about the implications for binary logging and replication, see the description for `SYSDATE()` in Section 12.7, “Date and Time Functions” and for `SET TIMESTAMP` in Section 5.1.5, “Server System Variables”.

- `--tc-heuristic-recover={COMMIT|ROLLBACK}`

Command-Line Format	`--tc-heuristic-recover=name`	
Permitted Values	**Type**	enumeration
	Default	`COMMIT`
	Valid Values	`COMMIT`
		`ROLLBACK`

The type of decision to use in the heuristic recovery process. To use this option, two or more storage engines that support XA transactions must be installed.

- `--temp-pool`

Command-Line Format	`--temp-pool`	
Permitted Values (Linux)	**Type**	boolean
	Default	`TRUE`
Permitted Values (Other)	**Type**	boolean
	Default	`FALSE`

This option is ignored except on Linux. On Linux, it causes most temporary files created by the server to use a small set of names, rather than a unique name for each new file. This works around a problem in the Linux kernel dealing with creating many new files with different names. With the old behavior, Linux seems to “leak” memory, because it is being allocated to the directory entry cache rather than to the disk cache.

- `--transaction-isolation=level`

Command-Line Format	--transaction-isolation=name	
Permitted Values	Type	enumeration
	Default	REPEATABLE-READ
	Valid Values	READ-UNCOMMITTED
		READ-COMMITTED
		REPEATABLE-READ
		SERIALIZABLE

Sets the default transaction isolation level. The `level` value can be `READ-UNCOMMITTED`, `READ-COMMITTED`, `REPEATABLE-READ`, or `SERIALIZABLE`. See Section 13.3.6, “SET TRANSACTION Syntax”.

The default transaction isolation level can also be set at runtime using the `SET TRANSACTION` statement or by setting the `tx_isolation` system variable.

- `--tmpdir=dir_name`, `-t dir_name`

Command-Line Format	--tmpdir=dir_name	
System Variable	Name	tmpdir
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The path of the directory to use for creating temporary files. It might be useful if your default `/tmp` directory resides on a partition that is too small to hold temporary tables. This option accepts several paths that are used in round-robin fashion. Paths should be separated by colon characters (`:`) on Unix and semicolon characters (`;`) on Windows. If the MySQL server is acting as a replication slave, you should not set `--tmpdir` to point to a directory on a memory-based file system or to a directory that is cleared when the server host restarts. For more information about the storage location of temporary files, see Section B.5.3.5, “Where MySQL Stores Temporary Files”. A replication slave needs some of its temporary files to survive a machine restart so that it can replicate temporary tables or `LOAD DATA INFILE` operations. If files in the temporary file directory are lost when the server restarts, replication fails.

- `--user={user_name|user_id}`, `-u {user_name|user_id}`

Command-Line Format	--user=name	
Permitted Values	Type	string

Run the `mysqld` server as the user having the name *`user_name`* or the numeric user ID *`user_id`*. (“User” in this context refers to a system login account, not a MySQL user listed in the grant tables.)

This option is *mandatory* when starting `mysqld` as `root`. The server changes its user ID during its startup sequence, causing it to run as that particular user rather than as `root`. See Section 6.1.1, “Security Guidelines”.

To avoid a possible security hole where a user adds a `--user=root` option to a `my.cnf` file (thus causing the server to run as `root`), `mysqld` uses only the first `--user` option specified and produces a warning if there are multiple `--user` options. Options in `/etc/my.cnf` and `$MYSQL_HOME/my.cnf` are processed before command-line options, so it is recommended that you put a `--user` option in `/etc/my.cnf` and specify a value other than `root`. The option in `/etc/my.cnf` is found before any other `--user` options, which ensures that the server runs as a user other than `root`, and that a warning results if any other `--user` option is found.

- `--verbose`, `-v`

  Use this option with the `--help` option for detailed help.

- `--version`, `-V`

  Display version information and exit.

5.1.5 Server System Variables

The MySQL server maintains many system variables that indicate how it is configured. Each system variable has a default value. System variables can be set at server startup using options on the command line or in an option file. Most of them can be changed dynamically at runtime using the `SET` statement, which enables you to modify operation of the server without having to stop and restart it. Setting the global value of a system variable requires the `SUPER` privilege. For some system variables, setting the session value also requires the `SUPER` privilege; if so, it is indicated in the variable description. You can also use system variable values in expressions.

There are several ways to see the names and values of system variables:

- To see the values that a server will use based on its compiled-in defaults and any option files that it reads, use this command:

```
mysqld --verbose --help
```

- To see the values that a server will use based on its compiled-in defaults, ignoring the settings in any option files, use this command:

```
mysqld --no-defaults --verbose --help
```

- To see the current values used by a running server, use the `SHOW VARIABLES` statement.

This section includes a table that lists all system variables and following the table provides a description of each one. Variables with no version indicated are present in all MySQL 5.5 releases. For more information about manipulation of system variables, see Section 5.1.6, “Using System Variables”.

Table 5.2 System Variable Summary

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
audit_log_buffer_size	Yes	Yes	Yes	Global	No
audit_log_file	Yes	Yes	Yes	Global	No
audit_log_flush			Yes	Global	Yes
audit_log_format	Yes	Yes	Yes	Global	No
audit_log_policy	Yes	Yes	Yes	Global	Yes
audit_log_rotate_on_size	Yes	Yes	Yes	Global	Yes
audit_log_strategy	Yes	Yes	Yes	Global	No
auto_increment_increment			Yes	Both	Yes
auto_increment_offset			Yes	Both	Yes
autocommit	Yes	Yes	Yes	Varies	Yes
automatic_sp_privileges			Yes	Global	Yes
back_log			Yes	Global	No
basedir	Yes	Yes	Yes	Global	No
big-tables	Yes	Yes			Yes
- *Variable*: big_tables			Yes	Varies	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
binlog_cache_size	Yes	Yes	Yes	Global	Yes
binlog_direct_non_transactional_updates	Yes	Yes	Yes	Both	Yes
binlog-format	Yes	Yes			Yes
- *Variable*: binlog_format			Yes	Both	Yes
binlog_stmt_cache_size	Yes	Yes	Yes	Global	Yes
bulk_insert_buffer_size	Yes	Yes	Yes	Both	Yes
character_set_client			Yes	Both	Yes
character_set_connection			Yes	Both	Yes
character_set_database[a]			Yes	Both	Yes
character-set-filesystem	Yes	Yes			Yes
- *Variable*: character_set_filesystem			Yes	Both	Yes
character_set_results			Yes	Both	Yes
character-set-server	Yes	Yes			Yes
- *Variable*: character_set_server			Yes	Both	Yes
character_set_system			Yes	Global	No
character-sets-dir	Yes	Yes			No
- *Variable*: character_sets_dir			Yes	Global	No
collation_connection			Yes	Both	Yes
collation_database[b]			Yes	Both	Yes
collation-server	Yes	Yes			Yes
- *Variable*: collation_server			Yes	Both	Yes
completion_type	Yes	Yes	Yes	Both	Yes
concurrent_insert	Yes	Yes	Yes	Global	Yes
connect_timeout	Yes	Yes	Yes	Global	Yes
datadir	Yes	Yes	Yes	Global	No
date_format			Yes	Varies	No
datetime_format			Yes	Varies	No
debug	Yes	Yes	Yes	Both	Yes
debug_sync			Yes	Varies	Yes
default-storage-engine	Yes	Yes			Yes
- *Variable*: default_storage_engine			Yes	Both	Yes
default_week_format	Yes	Yes	Yes	Both	Yes
delay-key-write	Yes	Yes			Yes
- *Variable*: delay_key_write			Yes	Global	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
delayed_insert_limit	Yes	Yes	Yes	Global	Yes
delayed_insert_timeout	Yes	Yes	Yes	Global	Yes
delayed_queue_size	Yes	Yes	Yes	Global	Yes
div_precision_increment	Yes	Yes	Yes	Both	Yes
engine-condition-pushdown	Yes	Yes			Yes
- *Variable*: engine_condition_pushdown			Yes	Both	Yes
error_count			Yes	Session	No
event-scheduler	Yes	Yes			Yes
- *Variable*: event_scheduler			Yes	Global	Yes
expire_logs_days	Yes	Yes	Yes	Global	Yes
external_user			Yes	Session	No
flush	Yes	Yes	Yes	Global	Yes
flush_time	Yes	Yes	Yes	Global	Yes
foreign_key_checks			Yes	Varies	Yes
ft_boolean_syntax	Yes	Yes	Yes	Global	Yes
ft_max_word_len	Yes	Yes	Yes	Global	No
ft_min_word_len	Yes	Yes	Yes	Global	No
ft_query_expansion_limit	Yes	Yes	Yes	Global	No
ft_stopword_file	Yes	Yes	Yes	Global	No
general-log	Yes	Yes			Yes
- *Variable*: general_log			Yes	Global	Yes
general_log_file	Yes	Yes	Yes	Global	Yes
group_concat_max_len	Yes	Yes	Yes	Both	Yes
have_compress			Yes	Global	No
have_crypt			Yes	Global	No
have_csv			Yes	Global	No
have_dynamic_loading			Yes	Global	No
have_geometry			Yes	Global	No
have_innodb			Yes	Global	No
have_ndbcluster			Yes	Global	No
have_openssl			Yes	Global	No
have_partitioning			Yes	Global	No
have_profiling			Yes	Global	No
have_query_cache			Yes	Global	No
have_rtree_keys			Yes	Global	No
have_ssl			Yes	Global	No
have_symlink			Yes	Global	No
hostname			Yes	Global	No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
identity			Yes	Session	Yes
ignore-builtin-innodb	Yes	Yes			No
- *Variable*: ignore_builtin_innodb			Yes	Global	No
init_connect	Yes	Yes	Yes	Global	Yes
init-file	Yes	Yes			No
- *Variable*: init_file			Yes	Global	No
init_slave	Yes	Yes	Yes	Global	Yes
innodb_adaptive_flushing	Yes	Yes	Yes	Global	Yes
innodb_adaptive_hash_index	Yes	Yes	Yes	Global	Yes
innodb_additional_mem_pool_size	Yes	Yes	Yes	Global	No
innodb_autoextend_increment	Yes	Yes	Yes	Global	Yes
innodb_autoinc_lock_mode	Yes	Yes	Yes	Global	No
innodb_buffer_pool_instances	Yes	Yes	Yes	Global	No
innodb_buffer_pool_size	Yes	Yes	Yes	Global	No
innodb_change_buffering	Yes	Yes	Yes	Global	Yes
innodb_change_buffering_debug	Yes	Yes	Yes	Global	Yes
innodb_checksums	Yes	Yes	Yes	Global	No
innodb_commit_concurrency	Yes	Yes	Yes	Global	Yes
innodb_concurrency_tickets	Yes	Yes	Yes	Global	Yes
innodb_data_file_path	Yes	Yes	Yes	Global	No
innodb_data_home_dir	Yes	Yes	Yes	Global	No
innodb_doublewrite	Yes	Yes	Yes	Global	No
innodb_fast_shutdown	Yes	Yes	Yes	Global	Yes
innodb_file_format	Yes	Yes	Yes	Global	Yes
innodb_file_format_check	Yes	Yes	Yes	Global	Varies
innodb_file_format_max	Yes	Yes	Yes	Global	Yes
innodb_file_per_table	Yes	Yes	Yes	Global	Yes
innodb_flush_log_at_trx_commit	Yes	Yes	Yes	Global	Yes
innodb_flush_method	Yes	Yes	Yes	Global	No
innodb_force_load_corrupted	Yes	Yes	Yes	Global	No
innodb_force_recovery	Yes	Yes	Yes	Global	No
innodb_io_capacity	Yes	Yes	Yes	Global	Yes
innodb_large_prefix	Yes	Yes	Yes	Global	Yes
innodb_limit_optimistic_insert_debug	Yes	Yes	Yes	Global	Yes
innodb_lock_wait_timeout	Yes	Yes	Yes	Both	Yes
innodb_locks_unsafe_for_binlog	Yes	Yes	Yes	Global	No
innodb_log_buffer_size	Yes	Yes	Yes	Global	No
innodb_log_file_size	Yes	Yes	Yes	Global	No
innodb_log_files_in_group	Yes	Yes	Yes	Global	No
innodb_log_group_home_dir	Yes	Yes	Yes	Global	No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
innodb_max_dirty_pages_pct	Yes	Yes	Yes	Global	Yes
innodb_max_purge_lag	Yes	Yes	Yes	Global	Yes
innodb_mirrored_log_groups	Yes	Yes	Yes	Global	No
innodb_old_blocks_pct	Yes	Yes	Yes	Global	Yes
innodb_old_blocks_time	Yes	Yes	Yes	Global	Yes
innodb_open_files	Yes	Yes	Yes	Global	No
innodb_print_all_deadlocks	Yes	Yes	Yes	Global	Yes
innodb_purge_batch_size	Yes	Yes	Yes	Global	Yes
innodb_purge_threads	Yes	Yes	Yes	Global	No
innodb_random_read_ahead	Yes	Yes	Yes	Global	Yes
innodb_read_ahead_threshold	Yes	Yes	Yes	Global	Yes
innodb_read_io_threads	Yes	Yes	Yes	Global	No
innodb_replication_delay	Yes	Yes	Yes	Global	Yes
innodb_rollback_on_timeout	Yes	Yes	Yes	Global	No
innodb_rollback_segments	Yes	Yes	Yes	Global	Yes
innodb_spin_wait_delay	Yes	Yes	Yes	Global	Yes
innodb_stats_method	Yes	Yes	Yes	Global	Yes
innodb_stats_on_metadata	Yes	Yes	Yes	Global	Yes
innodb_stats_sample_pages	Yes	Yes	Yes	Global	Yes
innodb_strict_mode	Yes	Yes	Yes	Both	Yes
innodb_support_xa	Yes	Yes	Yes	Both	Yes
innodb_sync_spin_loops	Yes	Yes	Yes	Global	Yes
innodb_table_locks	Yes	Yes	Yes	Both	Yes
innodb_thread_concurrency	Yes	Yes	Yes	Global	Yes
innodb_thread_sleep_delay	Yes	Yes	Yes	Global	Yes
innodb_trx_purge_view_update_only_debug	Yes	Yes	Yes	Global	Yes
innodb_trx_rseg_n_slots_debug	Yes	Yes	Yes	Global	Yes
innodb_use_native_aio	Yes	Yes	Yes	Global	No
innodb_use_sys_malloc	Yes	Yes	Yes	Global	No
innodb_version			Yes	Global	No
innodb_write_io_threads	Yes	Yes	Yes	Global	No
insert_id			Yes	Session	Yes
interactive_timeout	Yes	Yes	Yes	Both	Yes
join_buffer_size	Yes	Yes	Yes	Both	Yes
keep_files_on_create	Yes	Yes	Yes	Both	Yes
key_buffer_size	Yes	Yes	Yes	Global	Yes
key_cache_age_threshold	Yes	Yes	Yes	Global	Yes
key_cache_block_size	Yes	Yes	Yes	Global	Yes
key_cache_division_limit	Yes	Yes	Yes	Global	Yes
language	Yes	Yes	Yes	Global	No
large_files_support			Yes	Global	No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
large_page_size			Yes	Global	No
large-pages	Yes	Yes			No
- *Variable*: large_pages			Yes	Global	No
last_insert_id			Yes	Session	Yes
lc-messages	Yes	Yes			Yes
- *Variable*: lc_messages			Yes	Both	Yes
lc-messages-dir	Yes	Yes			No
- *Variable*: lc_messages_dir			Yes	Global	No
lc_time_names			Yes	Both	Yes
license			Yes	Global	No
local_infile			Yes	Global	Yes
lock_wait_timeout	Yes	Yes	Yes	Both	Yes
locked_in_memory			Yes	Global	No
log	Yes	Yes	Yes	Global	Yes
log-bin	Yes	Yes	Yes	Global	No
log_bin			Yes	Global	No
log-bin-trust-function-creators	Yes	Yes			Yes
- *Variable*: log_bin_trust_function_creators			Yes	Global	Yes
log-bin-trust-routine-creators	Yes	Yes			Yes
- *Variable*: log_bin_trust_routine_creators			Yes	Global	Yes
log-bin-use-v1-row-events	Yes	Yes			No
- *Variable*: log_bin_use_v1_row_events			Yes	Global	No
log_bin_use_v1_row_events	Yes	Yes	Yes	Global	No
log-error	Yes	Yes			No
- *Variable*: log_error			Yes	Global	No
log-output	Yes	Yes			Yes
- *Variable*: log_output			Yes	Global	Yes
log-queries-not-using-indexes	Yes	Yes			Yes
- *Variable*: log_queries_not_using_indexes			Yes	Global	Yes
log-slave-updates	Yes	Yes			No
- *Variable*: log_slave_updates			Yes	Global	No
log_slave_updates	Yes	Yes	Yes	Global	No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
log-slow-queries	Yes	Yes			Yes
- *Variable*: log_slow_queries			Yes	Global	Yes
log-warnings	Yes	Yes			Yes
- *Variable*: log_warnings			Yes	Both	Yes
long_query_time	Yes	Yes	Yes	Both	Yes
low-priority-updates	Yes	Yes			Yes
- *Variable*: low_priority_updates			Yes	Both	Yes
lower_case_file_system			Yes	Global	No
lower_case_table_names	Yes	Yes	Yes	Global	No
max_allowed_packet	Yes	Yes	Yes	Both	Yes
max_binlog_cache_size	Yes	Yes	Yes	Global	Yes
max_binlog_size	Yes	Yes	Yes	Global	Yes
max_binlog_stmt_cache_size	Yes	Yes	Yes	Global	Yes
max_connect_errors	Yes	Yes	Yes	Global	Yes
max_connections	Yes	Yes	Yes	Global	Yes
max_delayed_threads	Yes	Yes	Yes	Both	Yes
max_error_count	Yes	Yes	Yes	Both	Yes
max_heap_table_size	Yes	Yes	Yes	Both	Yes
max_insert_delayed_threads			Yes	Both	Yes
max_join_size	Yes	Yes	Yes	Both	Yes
max_length_for_sort_data	Yes	Yes	Yes	Both	Yes
max_long_data_size	Yes	Yes	Yes	Global	No
max_prepared_stmt_count	Yes	Yes	Yes	Global	Yes
max_relay_log_size	Yes	Yes	Yes	Global	Yes
max_seeks_for_key	Yes	Yes	Yes	Both	Yes
max_sort_length	Yes	Yes	Yes	Both	Yes
max_sp_recursion_depth	Yes	Yes	Yes	Both	Yes
max_tmp_tables			Yes	Both	Yes
max_user_connections	Yes	Yes	Yes	Both	Yes
max_write_lock_count	Yes	Yes	Yes	Global	Yes
metadata_locks_cache_size			Yes	Global	No
min-examined-row-limit	Yes	Yes	Yes	Both	Yes
multi_range_count	Yes	Yes	Yes	Both	Yes
myisam_data_pointer_size	Yes	Yes	Yes	Global	Yes
myisam_max_sort_file_size	Yes	Yes	Yes	Global	Yes
myisam_mmap_size	Yes	Yes	Yes	Global	No
myisam_recover_options			Yes	Global	No
myisam_repair_threads	Yes	Yes	Yes	Both	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
myisam_sort_buffer_size	Yes	Yes	Yes	Both	Yes
myisam_stats_method	Yes	Yes	Yes	Both	Yes
myisam_use_mmap	Yes	Yes	Yes	Global	Yes
named_pipe			Yes	Global	No
ndb_autoincrement_prefetch_sz	Yes	Yes	Yes	Both	Yes
ndb-batch-size	Yes	Yes	Yes	Global	No
ndb-blob-read-batch-bytes	Yes	Yes	Yes	Both	Yes
ndb-blob-write-batch-bytes	Yes	Yes	Yes	Both	Yes
ndb_cache_check_time	Yes	Yes	Yes	Global	Yes
ndb-cluster-connection-pool	Yes	Yes	Yes	Global	No
ndb-deferred-constraints	Yes	Yes			Yes
- *Variable*: ndb_deferred_constraints			Yes	Both	Yes
ndb_deferred_constraints	Yes	Yes	Yes	Both	Yes
ndb-distribution	Yes	Yes			Yes
- *Variable*: ndb_distribution			Yes	Global	Yes
ndb_distribution	Yes	Yes	Yes	Global	Yes
ndb_eventbuffer_max_alloc	Yes	Yes	Yes	Global	Yes
ndb_extra_logging	Yes	Yes	Yes	Global	Yes
ndb_force_send	Yes	Yes	Yes	Both	Yes
ndb_index_stat_cache_entries	Yes	Yes	Yes	Both	Yes
ndb_index_stat_enable	Yes	Yes	Yes	Both	Yes
ndb_index_stat_option	Yes	Yes	Yes	Both	Yes
ndb_index_stat_update_freq	Yes	Yes	Yes	Both	Yes
ndb_join_pushdown			Yes	Both	Yes
ndb-log-apply-status	Yes	Yes			No
- *Variable*: ndb_log_apply_status			Yes	Global	No
ndb_log_apply_status	Yes	Yes	Yes	Global	No
ndb_log_bin	Yes		Yes	Both	Yes
ndb_log_binlog_index	Yes		Yes	Global	Yes
ndb-log-empty-epochs	Yes	Yes	Yes	Global	Yes
ndb_log_empty_epochs	Yes	Yes	Yes	Global	Yes
ndb-log-empty-update	Yes	Yes	Yes	Global	Yes
ndb_log_empty_update	Yes	Yes	Yes	Global	Yes
ndb-log-orig	Yes	Yes			No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
- *Variable*: ndb_log_orig			Yes	Global	No
ndb_log_orig	Yes	Yes	Yes	Global	No
ndb-log-transaction-id	Yes	Yes			No
- *Variable*: ndb_log_transaction_id			Yes	Global	No
ndb_log_transaction_id			Yes	Global	No
ndb-log-update-as-write	Yes	Yes	Yes	Global	Yes
ndb_log_updated_only	Yes	Yes	Yes	Global	Yes
ndb_optimization_delay			Yes	Global	Yes
ndb_optimized_node_selection	Yes	Yes	Yes	Global	No
ndb_report_thresh_binlog_epoch_slip	Yes	Yes	Yes	Global	Yes
ndb_report_thresh_binlog_mem_usage	Yes	Yes	Yes	Global	Yes
ndb_table_no_logging			Yes	Session	Yes
ndb_table_temporary			Yes	Session	Yes
ndb_use_copying_alter_table			Yes	Both	No
ndb_use_exact_count			Yes	Both	Yes
ndb_use_transactions	Yes	Yes	Yes	Both	Yes
ndb_version			Yes	Global	No
ndb_version_string			Yes	Global	No
ndb-wait-connected	Yes	Yes	Yes	Global	No
ndb-wait-setup	Yes	Yes	Yes	Global	No
ndbinfo_database			Yes	Global	No
ndbinfo_max_bytes	Yes		Yes	Both	Yes
ndbinfo_max_rows	Yes		Yes	Both	Yes
ndbinfo_offline			Yes	Global	Yes
ndbinfo_show_hidden	Yes		Yes	Both	Yes
ndbinfo_table_prefix	Yes		Yes	Both	Yes
ndbinfo_version			Yes	Global	No
net_buffer_length	Yes	Yes	Yes	Both	Yes
net_read_timeout	Yes	Yes	Yes	Both	Yes
net_retry_count	Yes	Yes	Yes	Both	Yes
net_write_timeout	Yes	Yes	Yes	Both	Yes
new	Yes	Yes	Yes	Both	Yes
old	Yes	Yes	Yes	Global	No
old-alter-table	Yes	Yes			Yes
- *Variable*: old_alter_table			Yes	Both	Yes
old_passwords			Yes	Both	Yes
open-files-limit	Yes	Yes			No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
- *Variable*: open_files_limit			Yes	Global	No
optimizer_prune_level	Yes	Yes	Yes	Both	Yes
optimizer_search_depth	Yes	Yes	Yes	Both	Yes
optimizer_switch	Yes	Yes	Yes	Both	Yes
performance_schema	Yes	Yes	Yes	Global	No
performance_schema_events_waits_history_long_size	Yes	Yes	Yes	Global	No
performance_schema_events_waits_history_size	Yes	Yes	Yes	Global	No
performance_schema_max_cond_classes	Yes	Yes	Yes	Global	No
performance_schema_max_cond_instances	Yes	Yes	Yes	Global	No
performance_schema_max_file_classes	Yes	Yes	Yes	Global	No
performance_schema_max_file_handles	Yes	Yes	Yes	Global	No
performance_schema_max_file_instances	Yes	Yes	Yes	Global	No
performance_schema_max_mutex_classes	Yes	Yes	Yes	Global	No
performance_schema_max_mutex_instances	Yes	Yes	Yes	Global	No
performance_schema_max_rwlock_classes	Yes	Yes	Yes	Global	No
performance_schema_max_rwlock_instances	Yes	Yes	Yes	Global	No
performance_schema_max_table_handles	Yes	Yes	Yes	Global	No
performance_schema_max_table_instances	Yes	Yes	Yes	Global	No
performance_schema_max_thread_classes	Yes	Yes	Yes	Global	No
performance_schema_max_thread_instances	Yes	Yes	Yes	Global	No
pid-file	Yes	Yes			No
- *Variable*: pid_file			Yes	Global	No
plugin_dir	Yes	Yes	Yes	Global	No
port	Yes	Yes	Yes	Global	No
preload_buffer_size	Yes	Yes	Yes	Both	Yes
profiling			Yes	Varies	Yes
profiling_history_size	Yes	Yes	Yes	Both	Yes
protocol_version			Yes	Global	No
proxy_user			Yes	Session	No
pseudo_slave_mode			Yes	Session	Yes
pseudo_thread_id			Yes	Session	Yes
query_alloc_block_size	Yes	Yes	Yes	Both	Yes
query_cache_limit	Yes	Yes	Yes	Global	Yes
query_cache_min_res_unit	Yes	Yes	Yes	Global	Yes
query_cache_size	Yes	Yes	Yes	Global	Yes
query_cache_type	Yes	Yes	Yes	Both	Yes
query_cache_wlock_invalidate	Yes	Yes	Yes	Both	Yes
query_prealloc_size	Yes	Yes	Yes	Both	Yes
rand_seed1			Yes	Session	Yes
rand_seed2			Yes	Session	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
range_alloc_block_size	Yes	Yes	Yes	Both	Yes
read_buffer_size	Yes	Yes	Yes	Both	Yes
read_only	Yes	Yes	Yes	Global	Yes
read_rnd_buffer_size	Yes	Yes	Yes	Both	Yes
relay-log	Yes	Yes			No
- *Variable*: relay_log			Yes	Global	No
relay-log-index	Yes	Yes			No
- *Variable*: relay_log_index			Yes	Global	No
relay_log_index	Yes	Yes	Yes	Global	No
relay_log_info_file	Yes	Yes	Yes	Global	No
relay_log_purge	Yes	Yes	Yes	Global	Yes
relay_log_recovery	Yes	Yes	Yes	Global	Yes
relay_log_space_limit	Yes	Yes	Yes	Global	No
report-host	Yes	Yes			No
- *Variable*: report_host			Yes	Global	No
report-password	Yes	Yes			No
- *Variable*: report_password			Yes	Global	No
report-port	Yes	Yes			No
- *Variable*: report_port			Yes	Global	No
report-user	Yes	Yes			No
- *Variable*: report_user			Yes	Global	No
rpl_recovery_rank			Yes	Global	Yes
rpl_semi_sync_master_enabled			Yes	Global	Yes
rpl_semi_sync_master_timeout			Yes	Global	Yes
rpl_semi_sync_master_trace_level			Yes	Global	Yes
rpl_semi_sync_master_wait_no_slave			Yes	Global	Yes
rpl_semi_sync_slave_enabled			Yes	Global	Yes
rpl_semi_sync_slave_trace_level			Yes	Global	Yes
secure-auth	Yes	Yes			Yes
- *Variable*: secure_auth			Yes	Global	Yes
secure-file-priv	Yes	Yes			No
- *Variable*: secure_file_priv			Yes	Global	No
server-id	Yes	Yes			Yes
- *Variable*: server_id			Yes	Global	Yes
server-id-bits	Yes	Yes			No

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
- *Variable*: server_id_bits			Yes	Global	No
server_id_bits	Yes	Yes	Yes	Global	No
shared_memory	Yes	Yes	Yes	Global	No
shared_memory_base_name	Yes	Yes	Yes	Global	No
skip_external_locking	Yes	Yes	Yes	Global	No
skip-name-resolve	Yes	Yes			No
- *Variable*: skip_name_resolve			Yes	Global	No
skip-networking	Yes	Yes			No
- *Variable*: skip_networking			Yes	Global	No
skip-show-database	Yes	Yes			No
- *Variable*: skip_show_database			Yes	Global	No
slave_allow_batching	Yes	Yes	Yes	Global	Yes
slave_compressed_protocol	Yes	Yes	Yes	Global	Yes
slave_exec_mode	Yes	Yes	Yes	Global	Yes
slave-load-tmpdir	Yes	Yes			No
- *Variable*: slave_load_tmpdir			Yes	Global	No
slave_max_allowed_packet			Yes	Global	Yes
slave-net-timeout	Yes	Yes			Yes
- *Variable*: slave_net_timeout			Yes	Global	Yes
slave-skip-errors	Yes	Yes			No
- *Variable*: slave_skip_errors			Yes	Global	No
slave_transaction_retries	Yes	Yes	Yes	Global	Yes
slave_type_conversions	Yes	Yes	Yes	Global	No
slow_launch_time	Yes	Yes	Yes	Global	Yes
slow-query-log	Yes	Yes			Yes
- *Variable*: slow_query_log			Yes	Global	Yes
slow_query_log_file	Yes	Yes	Yes	Global	Yes
socket	Yes	Yes	Yes	Global	No
sort_buffer_size	Yes	Yes	Yes	Both	Yes
sql_auto_is_null			Yes	Varies	Yes
sql_big_selects			Yes	Varies	Yes
sql_big_tables			Yes	Varies	Yes
sql_buffer_result			Yes	Varies	Yes
sql_log_bin			Yes	Varies	Yes
sql_log_off			Yes	Varies	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
sql_log_update			Yes	Session	Yes
sql_low_priority_updates			Yes	Both	Yes
sql_max_join_size			Yes	Both	Yes
sql-mode	Yes	Yes			Yes
- *Variable*: sql_mode			Yes	Both	Yes
sql_notes			Yes	Varies	Yes
sql_quote_show_create			Yes	Varies	Yes
sql_safe_updates			Yes	Varies	Yes
sql_select_limit			Yes	Both	Yes
sql_slave_skip_counter			Yes	Global	Yes
sql_warnings			Yes	Varies	Yes
ssl-ca	Yes	Yes			No
- *Variable*: ssl_ca			Yes	Global	No
ssl-capath	Yes	Yes			No
- *Variable*: ssl_capath			Yes	Global	No
ssl-cert	Yes	Yes			No
- *Variable*: ssl_cert			Yes	Global	No
ssl-cipher	Yes	Yes			No
- *Variable*: ssl_cipher			Yes	Global	No
ssl-key	Yes	Yes			No
- *Variable*: ssl_key			Yes	Global	No
storage_engine			Yes	Both	Yes
stored_program_cache	Yes	Yes	Yes	Global	Yes
sync_binlog	Yes	Yes	Yes	Global	Yes
sync_frm	Yes	Yes	Yes	Global	Yes
sync_master_info	Yes	Yes	Yes	Global	Yes
sync_relay_log	Yes	Yes	Yes	Global	Yes
sync_relay_log_info	Yes	Yes	Yes	Global	Yes
system_time_zone			Yes	Global	No
table_definition_cache			Yes	Global	Yes
table_lock_wait_timeout	Yes	Yes	Yes	Global	Yes
table_open_cache			Yes	Global	Yes
table_type			Yes	Both	Yes
thread_cache_size	Yes	Yes	Yes	Global	Yes
thread_concurrency	Yes	Yes	Yes	Global	No
thread_handling	Yes	Yes	Yes	Global	No
thread_pool_algorithm	Yes	Yes	Yes	Global	No
thread_pool_high_priority_connection	Yes	Yes	Yes	Both	Yes
thread_pool_max_unused_threads	Yes	Yes	Yes	Global	Yes

Name	Cmd-Line	Option File	System Var	Var Scope	Dynamic
thread_pool_prio_kickup_timer	Yes	Yes	Yes	Both	Yes
thread_pool_size	Yes	Yes	Yes	Global	No
thread_pool_stall_limit	Yes	Yes	Yes	Global	Yes
thread_stack	Yes	Yes	Yes	Global	No
time_format			Yes	Varies	No
time_zone			Yes	Both	Yes
timed_mutexes	Yes	Yes	Yes	Global	Yes
timestamp			Yes	Session	Yes
tmp_table_size	Yes	Yes	Yes	Both	Yes
tmpdir	Yes	Yes	Yes	Global	No
transaction_alloc_block_size	Yes	Yes	Yes	Both	Yes
transaction_allow_batching			Yes	Session	Yes
transaction_prealloc_size	Yes	Yes	Yes	Both	Yes
tx_isolation			Yes	Both	Yes
unique_checks			Yes	Varies	Yes
updatable_views_with_limit	Yes	Yes	Yes	Both	Yes
version			Yes	Global	No
version_comment			Yes	Global	No
version_compile_machine			Yes	Global	No
version_compile_os			Yes	Global	No
wait_timeout	Yes	Yes	Yes	Both	Yes
warning_count			Yes	Session	No

[a] This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.
[b] This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.

For additional system variable information, see these sections:

- Section 5.1.6, “Using System Variables”, discusses the syntax for setting and displaying system variable values.
- Section 5.1.6.2, “Dynamic System Variables”, lists the variables that can be set at runtime.
- Information on tuning system variables can be found in Section 5.1.1, “Configuring the Server”.
- Section 14.17, “InnoDB Startup Options and System Variables”, lists `InnoDB` system variables.
- NDB Cluster System Variables, lists system variables which are specific to NDB Cluster.
- For information on server system variables specific to replication, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

Note

Some of the following variable descriptions refer to “enabling” or “disabling” a variable. These variables can be enabled with the `SET` statement by setting them to `ON` or `1`, or disabled by setting them to `OFF` or `0`. However, before MySQL 5.5.10, to set such a variable on the command line or in an option file, you must set it to `1` or `0`; setting it to `ON` or `OFF` will not work. For example, on the command line, `--delay_key_write=1` works but `--delay_key_write=ON` does not. As of MySQL 5.5.10, boolean variables can

be set at startup to the values `ON`, `TRUE`, `OFF`, and `FALSE` (not case sensitive). See Section 4.2.5, “Program Option Modifiers”.

Some system variables control the size of buffers or caches. For a given buffer, the server might need to allocate internal data structures. These structures typically are allocated from the total memory allocated to the buffer, and the amount of space required might be platform dependent. This means that when you assign a value to a system variable that controls a buffer size, the amount of space actually available might differ from the value assigned. In some cases, the amount might be less than the value assigned. It is also possible that the server will adjust a value upward. For example, if you assign a value of 0 to a variable for which the minimal value is 1024, the server will set the value to 1024.

Values for buffer sizes, lengths, and stack sizes are given in bytes unless otherwise specified.

Some system variables take file name values. Unless otherwise specified, the default file location is the data directory if the value is a relative path name. To specify the location explicitly, use an absolute path name. Suppose that the data directory is `/var/mysql/data`. If a file-valued variable is given as a relative path name, it will be located under `/var/mysql/data`. If the value is an absolute path name, its location is as given by the path name.

- `authentication_windows_log_level`

Introduced	5.5.16	
Command-Line Format	`--authentication-windows-log-level`	
Permitted Values	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4`

This variable is available only if the `authentication_windows` Windows authentication plugin is enabled and debugging code is enabled. See Section 6.5.1.5, “Windows Pluggable Authentication”.

This variable sets the logging level for the Windows authentication plugin. The following table shows the permitted values.

Value	Description
0	No logging
1	Log only error messages
2	Log level 1 messages and warning messages
3	Log level 2 messages and information notes
4	Log level 3 messages and debug messages

This variable was added in MySQL 5.5.16.

- `authentication_windows_use_principal_name`

Introduced	5.5.16	
Command-Line Format	`--authentication-windows-use-principal-name`	
Permitted Values	**Type**	boolean
	Default	`ON`

This variable is available only if the `authentication_windows` Windows authentication plugin is enabled. See Section 6.5.1.5, “Windows Pluggable Authentication”.

A client that authenticates using the `InitSecurityContext()` function should provide a string identifying the service to which it connects (*`targetName`*). MySQL uses the principal name (UPN) of the account under which the server is running. The UPN has the form *`user_id@computer_name`* and need not be registered anywhere to be used. This UPN is sent by the server at the beginning of authentication handshake.

This variable controls whether the server sends the UPN in the initial challenge. By default, the variable is enabled. For security reasons, it can be disabled to avoid sending the server's account name to a client in clear text. If the variable is disabled, the server always sends a `0x00` byte in the first challenge, the client does not specify *`targetName`*, and as a result, NTLM authentication is used.

If the server fails to obtain its UPN (which will happen primarily in environments that do not support Kerberos authentication), the UPN is not sent by the server and NTLM authentication is used.

This variable was added in MySQL 5.5.16.

- `autocommit`

Command-Line Format	`--autocommit[=#]` (>= 5.5.8)	
System Variable (<= 5.5.2)	**Name**	`autocommit`
	Scope	Session
	Dynamic	Yes
System Variable (>= 5.5.3)	**Name**	`autocommit`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`ON`

The autocommit mode. If set to 1, all changes to a table take effect immediately. If set to 0, you must use `COMMIT` to accept a transaction or `ROLLBACK` to cancel it. If `autocommit` is 0 and you change it to 1, MySQL performs an automatic `COMMIT` of any open transaction. Another way to begin a transaction is to use a `START TRANSACTION` or `BEGIN` statement. See Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”.

By default, client connections begin with `autocommit` set to 1. To cause clients to begin with a default of 0, set the global `autocommit` value by starting the server with the `--autocommit=0` option. To set the variable using an option file, include these lines:

```
[mysqld]
autocommit=0
```

Before MySQL 5.5.8, the global `autocommit` value cannot be set at startup. As a workaround, set the `init_connect` system variable:

```
SET GLOBAL init_connect='SET autocommit=0';
```

The `init_connect` variable can also be set on the command line or in an option file. To set the variable as just shown using an option file, include these lines:

```
[mysqld]
init_connect='SET autocommit=0'
```

For users that have the SUPER privilege, the content of init_connect is not executed (unlike the effect of setting the global autocommit value at startup).

- automatic_sp_privileges

System Variable	Name	automatic_sp_privileges
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	TRUE

When this variable has a value of 1 (the default), the server automatically grants the EXECUTE and ALTER ROUTINE privileges to the creator of a stored routine, if the user cannot already execute and alter or drop the routine. (The ALTER ROUTINE privilege is required to drop the routine.) The server also automatically drops those privileges from the creator when the routine is dropped. If automatic_sp_privileges is 0, the server does not automatically add or drop these privileges.

The creator of a routine is the account used to execute the CREATE statement for it. This might not be the same as the account named as the DEFINER in the routine definition.

See also Section 20.2.2, “Stored Routines and MySQL Privileges”.

- back_log

System Variable	Name	back_log
	Scope	Global
	Dynamic	No
Permitted Values	Type	integer
	Default	50
	Minimum	1
	Maximum	65535

The number of outstanding connection requests MySQL can have. This comes into play when the main MySQL thread gets very many connection requests in a very short time. It then takes some time (although very little) for the main thread to check the connection and start a new thread. The back_log value indicates how many requests can be stacked during this short time before MySQL momentarily stops answering new requests. You need to increase this only if you expect a large number of connections in a short period of time.

In other words, this value is the size of the listen queue for incoming TCP/IP connections. Your operating system has its own limit on the size of this queue. The manual page for the Unix listen() system call should have more details. Check your OS documentation for the maximum value for this variable. back_log cannot be set higher than your operating system limit.

- basedir

Command-Line Format	--basedir=dir_name	
System Variable	Name	basedir
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The path to the MySQL installation base directory.

- `big_tables`

Command-Line Format	`--big-tables`	
System Variable (<= 5.5.2)	**Name**	`big_tables`
	Scope	Session
	Dynamic	Yes
System Variable (>= 5.5.3)	**Name**	`big_tables`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

If set to 1, all temporary tables are stored on disk rather than in memory. This is a little slower, but the error `The table tbl_name is full` does not occur for `SELECT` operations that require a large temporary table. The default value for a new connection is 0 (use in-memory temporary tables). Normally, you should never need to set this variable, because in-memory tables are automatically converted to disk-based tables as required.

Note

This variable was formerly named `sql_big_tables`.

- `bulk_insert_buffer_size`

Command-Line Format	`--bulk-insert-buffer-size=#`	
System Variable	**Name**	`bulk_insert_buffer_size`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`8388608`
	Minimum	`0`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`8388608`
	Minimum	`0`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`8388608`
	Minimum	`0`
	Maximum	`18446744073709551615`

`MyISAM` uses a special tree-like cache to make bulk inserts faster for `INSERT ... SELECT`, `INSERT ... VALUES (...), (...), ...`, and `LOAD DATA INFILE` when adding data to nonempty tables. This variable limits the size of the cache tree in bytes per thread. Setting it to 0 disables this optimization. The default value is 8MB.

- `character_set_client`

System Variable	Name	character_set_client
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string

The character set for statements that arrive from the client. The session value of this variable is set using the character set requested by the client when the client connects to the server. (Many clients support a `--default-character-set` option to enable this character set to be specified explicitly. See also Section 10.1.4, “Connection Character Sets and Collations”.) The global value of the variable is used to set the session value in cases when the client-requested value is unknown or not available, or the server is configured to ignore client requests:

- The client is from a version of MySQL older than MySQL 4.1, and thus does not request a character set.
- The client requests a character set not known to the server. For example, a Japanese-enabled client requests `sjis` when connecting to a server not configured with `sjis` support.
- `mysqld` was started with the `--skip-character-set-client-handshake` option, which causes it to ignore client character set configuration. This reproduces MySQL 4.0 behavior and is useful should you wish to upgrade the server without upgrading all the clients.

`ucs2`, `utf16`, and `utf32` cannot be used as a client character set, which means that they also do not work for `SET NAMES` or `SET CHARACTER SET`.

- `character_set_connection`

System Variable	Name	character_set_connection
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string

The character set used for literals that do not have a character set introducer and for number-to-string conversion. For information about introducers, see Section 10.1.3.8, “Character Set Introducers”.

- `character_set_database`

System Variable	Name	character_set_database
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string
	Default	latin1
Footnote	This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.	

The character set used by the default database. The server sets this variable whenever the default database changes. If there is no default database, the variable has the same value as `character_set_server`.

- `character_set_filesystem`

Command-Line Format	--character-set-filesystem=name

System Variable	Name	character_set_filesystem
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string
	Default	binary

The file system character set. This variable is used to interpret string literals that refer to file names, such as in the `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. Such file names are converted from `character_set_client` to `character_set_filesystem` before the file opening attempt occurs. The default value is `binary`, which means that no conversion occurs. For systems on which multibyte file names are permitted, a different value may be more appropriate. For example, if the system represents file names using UTF-8, set `character_set_filesystem` to `'utf8'`.

- `character_set_results`

System Variable	Name	character_set_results
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string

The character set used for returning query results such as result sets or error messages to the client.

- `character_set_server`

Command-Line Format	--character-set-server	
System Variable	Name	character_set_server
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string
	Default	latin1

The server's default character set.

- `character_set_system`

System Variable	Name	character_set_system
	Scope	Global
	Dynamic	No
Permitted Values	Type	string
	Default	utf8

The character set used by the server for storing identifiers. The value is always `utf8`.

- `character_sets_dir`

Command-Line Format	--character-sets-dir=dir_name	
System Variable	Name	character_sets_dir
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The directory where character sets are installed.

- `collation_connection`

System Variable	Name	collation_connection
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string

The collation of the connection character set.

- `collation_database`

System Variable	Name	collation_database
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string
	Default	latin1_swedish_ci
Footnote	This option is dynamic, but only the server should set this information. You should not set the value of this variable manually.	

The collation used by the default database. The server sets this variable whenever the default database changes. If there is no default database, the variable has the same value as `collation_server`.

- `collation_server`

Command-Line Format	--collation-server	
System Variable	Name	collation_server
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string
	Default	latin1_swedish_ci

The server's default collation.

- `completion_type`

Command-Line Format	--completion-type=#	
System Variable	Name	completion_type
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (<= 5.5.2)	Type	integer
	Default	0
	Valid Values	0
		1
		2
Permitted Values (>= 5.5.3)	Type	enumeration
	Default	NO_CHAIN

	Valid Values	NO_CHAIN
		CHAIN
		RELEASE
		0
		1
		2

The transaction completion type. This variable can take the values shown in the following table. As of MySQL 5.5.3, the variable can be assigned using either the name values or corresponding integer values. Before 5.5.3, only the integer values can be used.

Value	Description
NO_CHAIN (or 0)	COMMIT and ROLLBACK are unaffected. This is the default value.
CHAIN (or 1)	COMMIT and ROLLBACK are equivalent to COMMIT AND CHAIN and ROLLBACK AND CHAIN, respectively. (A new transaction starts immediately with the same isolation level as the just-terminated transaction.)
RELEASE (or 2)	COMMIT and ROLLBACK are equivalent to COMMIT RELEASE and ROLLBACK RELEASE, respectively. (The server disconnects after terminating the transaction.)

completion_type affects transactions that begin with START TRANSACTION or BEGIN and end with COMMIT or ROLLBACK. It does not apply to implicit commits resulting from execution of the statements listed in Section 13.3.3, “Statements That Cause an Implicit Commit”. It also does not apply for XA COMMIT, XA ROLLBACK, or when autocommit=1.

- concurrent_insert

Command-Line Format	--concurrent-insert[=#]	
System Variable	**Name**	concurrent_insert
	Scope	Global
	Dynamic	Yes
Permitted Values (<= 5.5.2)	**Type**	integer
	Default	1
	Valid Values	0
		1
		2
Permitted Values (>= 5.5.3)	**Type**	enumeration
	Default	AUTO
	Valid Values	NEVER
		AUTO
		ALWAYS
		0
		1
		2

If AUTO (the default), MySQL permits INSERT and SELECT statements to run concurrently for MyISAM tables that have no free blocks in the middle of the data file. If you start mysqld with --skip-new, this variable is set to NEVER.

This variable can take the values shown in the following table. As of MySQL 5.5.3, the variable can be assigned using either the name values or corresponding integer values. Before 5.5.3, only the integer values can be used.

Value	Description
`NEVER` (or 0)	Disables concurrent inserts
`AUTO` (or 1)	(Default) Enables concurrent insert for `MyISAM` tables that do not have holes
`ALWAYS` (or 2)	Enables concurrent inserts for all `MyISAM` tables, even those that have holes. For a table with a hole, new rows are inserted at the end of the table if it is in use by another thread. Otherwise, MySQL acquires a normal write lock and inserts the row into the hole.

See also Section 8.11.3, “Concurrent Inserts”.

- `connect_timeout`

Command-Line Format	`--connect-timeout=#`	
System Variable	Name	`connect_timeout`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`10`
	Minimum	`2`
	Maximum	`31536000`

The number of seconds that the `mysqld` server waits for a connect packet before responding with `Bad handshake`. The default value is 10 seconds.

Increasing the `connect_timeout` value might help if clients frequently encounter errors of the form `Lost connection to MySQL server at 'XXX', system error: errno`.

- `datadir`

Command-Line Format	`--datadir=dir_name`	
System Variable	Name	`datadir`
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The path to the MySQL server data directory. Relative paths are resolved with respect to the current directory. If the server will be started automatically (that is, in contexts for which you cannot assume what the current directory will be), it is best to specify the `datadir` value as an absolute path.

- `date_format`

This variable is unused.

- `datetime_format`

This variable is unused.

- `debug`

Command-Line Format	--debug[=debug_options]	
System Variable	Name	debug
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (Unix)	Type	string
	Default	d:t:i:o,/tmp/mysqld.trace
Permitted Values (Windows)	Type	string
	Default	d:t:i:O,\mysqld.trace

This variable indicates the current debugging settings. It is available only for servers built with debugging support. The initial value comes from the value of instances of the `--debug` option given at server startup. The global and session values may be set at runtime; the `SUPER` privilege is required, even for the session value.

Assigning a value that begins with `+` or `-` cause the value to added to or subtracted from the current value:

```
mysql> SET debug = 'T';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| T       |
+---------+

mysql> SET debug = '+P';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| P:T     |
+---------+

mysql> SET debug = '-P';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| T       |
+---------+
```

For more information, see Section 24.5.3, “The DBUG Package”.

- `debug_sync`

System Variable (<= 5.5.2)	Name	debug_sync
	Scope	Global, Session
	Dynamic	Yes
System Variable (>= 5.5.3)	Name	debug_sync
	Scope	Session
	Dynamic	Yes
Permitted Values	Type	string

This variable is the user interface to the Debug Sync facility. Use of Debug Sync requires that MySQL be configured with the `-DENABLE_DEBUG_SYNC=1 CMake` option (see Section 2.9.4,

"MySQL Source-Configuration Options"). If Debug Sync is not compiled in, this system variable is not available.

The global variable value is read only and indicates whether the facility is enabled. By default, Debug Sync is disabled and the value of `debug_sync` is `OFF`. If the server is started with `--debug-sync-timeout=N`, where `N` is a timeout value greater than 0, Debug Sync is enabled and the value of `debug_sync` is `ON - current signal` followed by the signal name. Also, `N` becomes the default timeout for individual synchronization points.

The session value can be read by any user and will have the same value as the global variable. The session value can be set by users that have the `SUPER` privilege to control synchronization points.

For a description of the Debug Sync facility and how to use synchronization points, see MySQL Internals: Test Synchronization.

- `default_storage_engine`

Command-Line Format	`--default-storage-engine=name`	
System Variable (<= 5.5.2)	**Name**	`storage_engine`
	Scope	Global, Session
	Dynamic	Yes
System Variable (>= 5.5.3)	**Name**	`default_storage_engine`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (<= 5.5.4)	**Type**	enumeration
	Default	`MyISAM`
Permitted Values (>= 5.5.5)	**Type**	enumeration
	Default	`InnoDB`

The default storage engine. To set the storage engine at server startup, use the `--default-storage-engine` option. See Section 5.1.4, "Server Command Options".

To see which storage engines are available and enabled, use the `SHOW ENGINES` statement or query the `INFORMATION_SCHEMA ENGINES` table.

If you disable the default storage engine at server startup, you must set the default engine to a different engine or the server will not start.

This variable is to be used in preference to `storage_engine`, which is now deprecated.

- `default_week_format`

Command-Line Format	`--default-week-format=#`	
System Variable	**Name**	`default_week_format`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`7`

The default mode value to use for the `WEEK()` function. See Section 12.7, "Date and Time Functions".

- `delay_key_write`

Command-Line Format	`--delay-key-write[=name]`	
System Variable	Name	`delay_key_write`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	enumeration
	Default	`ON`
	Valid Values	`ON`
		`OFF`
		`ALL`

This option applies only to `MyISAM` tables. It can have one of the following values to affect handling of the `DELAY_KEY_WRITE` table option that can be used in `CREATE TABLE` statements.

Option	Description
`OFF`	`DELAY_KEY_WRITE` is ignored.
`ON`	MySQL honors any `DELAY_KEY_WRITE` option specified in `CREATE TABLE` statements. This is the default value.
`ALL`	All new opened tables are treated as if they were created with the `DELAY_KEY_WRITE` option enabled.

If `DELAY_KEY_WRITE` is enabled for a table, the key buffer is not flushed for the table on every index update, but only when the table is closed. This speeds up writes on keys a lot, but if you use this feature, you should add automatic checking of all `MyISAM` tables by starting the server with the `--myisam-recover-options` option (for example, `--myisam-recover-options=BACKUP,FORCE`). See Section 5.1.4, “Server Command Options”, and Section 15.3.1, “MyISAM Startup Options”.

Warning

If you enable external locking with `--external-locking`, there is no protection against index corruption for tables that use delayed key writes.

- `delayed_insert_limit`

Command-Line Format	`--delayed-insert-limit=#`	
System Variable	Name	`delayed_insert_limit`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	`100`
	Minimum	`1`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	Type	integer
	Default	`100`
	Minimum	`1`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	Type	integer

	Default	100
	Minimum	1
	Maximum	18446744073709551615

After inserting `delayed_insert_limit` delayed rows, the `INSERT DELAYED` handler thread checks whether there are any `SELECT` statements pending. If so, it permits them to execute before continuing to insert delayed rows.

- `delayed_insert_timeout`

Command-Line Format	`--delayed-insert-timeout=#`	
System Variable	**Name**	`delayed_insert_timeout`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	300

How many seconds an `INSERT DELAYED` handler thread should wait for `INSERT` statements before terminating.

- `delayed_queue_size`

Command-Line Format	`--delayed-queue-size=#`	
System Variable	**Name**	`delayed_queue_size`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	1000
	Minimum	1
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	1000
	Minimum	1
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	1000
	Minimum	1
	Maximum	18446744073709551615

This is a per-table limit on the number of rows to queue when handling `INSERT DELAYED` statements. If the queue becomes full, any client that issues an `INSERT DELAYED` statement waits until there is room in the queue again.

- `div_precision_increment`

Command-Line Format	`--div-precision-increment=#`	
System Variable	**Name**	`div_precision_increment`
	Scope	Global, Session
	Dynamic	Yes

Permitted Values	**Type**	integer
	Default	4
	Minimum	0
	Maximum	30

This variable indicates the number of digits by which to increase the scale of the result of division operations performed with the / operator. The default value is 4. The minimum and maximum values are 0 and 30, respectively. The following example illustrates the effect of increasing the default value.

```
mysql> SELECT 1/7;
+--------+
| 1/7    |
+--------+
| 0.1429 |
+--------+
mysql> SET div_precision_increment = 12;
mysql> SELECT 1/7;
+----------------+
| 1/7            |
+----------------+
| 0.142857142857 |
+----------------+
```

- `engine_condition_pushdown`

Deprecated	5.5.3, by `optimizer_switch`	
Command-Line Format	`--engine-condition-pushdown`	
System Variable	**Name**	`engine_condition_pushdown`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`ON`

The engine condition pushdown optimization enables processing for certain comparisons to be "pushed down" to the storage engine level for more efficient execution. For more information, see Section 8.2.1.4, "Engine Condition Pushdown Optimization".

Engine condition pushdown is used only by the `NDBCLUSTER` storage engine. Enabling this optimization on a MySQL Server acting as an NDB Cluster SQL node causes `WHERE` conditions on unindexed columns to be evaluated on the cluster's data nodes and only the rows that match to be sent back to the SQL node that issued the query. This greatly reduces the amount of cluster data that must be sent over the network, increasing the efficiency with which results are returned.

The `engine_condition_pushdown` variable controls whether engine condition pushdown is enabled. By default, this variable is `ON` (1). Setting it to `OFF` (0) disables pushdown.

This variable is deprecated as of MySQL 5.5.3 and is removed in MySQL 5.6. Use the `engine_condition_pushdown` flag of the `optimizer_switch` variable instead. See Section 8.9.2, "Switchable Optimizations".

- `error_count`

The number of errors that resulted from the last statement that generated messages. This variable is read only. See Section 13.7.5.18, "SHOW ERRORS Syntax".

- `event_scheduler`

Command-Line Format	--event-scheduler[=value]	
System Variable	Name	event_scheduler
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	enumeration
	Default	OFF
	Valid Values	ON
		OFF
		DISABLED

This variable indicates the status of the Event Scheduler; possible values are ON, OFF, and DISABLED, with the default being OFF. This variable and its effects on the Event Scheduler's operation are discussed in greater detail in the Overview section of the Events chapter.

- expire_logs_days

Command-Line Format	--expire-logs-days=#	
System Variable	Name	expire_logs_days
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	0
	Minimum	0
	Maximum	99

The number of days for automatic binary log file removal. The default is 0, which means "no automatic removal." Possible removals happen at startup and when the binary log is flushed. Log flushing occurs as indicated in Section 5.4, "MySQL Server Logs".

To remove binary log files manually, use the PURGE BINARY LOGS statement. See Section 13.4.1.1, "PURGE BINARY LOGS Syntax".

- external_user

Introduced	5.5.7	
System Variable	Name	external_user
	Scope	Session
	Dynamic	No
Permitted Values	Type	string

The external user name used during the authentication process, as set by the plugin used to authenticate the client. With native (built-in) MySQL authentication, or if the plugin does not set the value, this variable is NULL. See Section 6.3.7, "Proxy Users".

- flush

Command-Line Format	--flush	
System Variable	Name	flush
	Scope	Global

	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

If `ON`, the server flushes (synchronizes) all changes to disk after each SQL statement. Normally, MySQL does a write of all changes to disk only after each SQL statement and lets the operating system handle the synchronizing to disk. See Section B.5.3.3, "What to Do If MySQL Keeps Crashing". This variable is set to `ON` if you start `mysqld` with the `--flush` option.

Note

If `flush` is enabled, the value of `flush_time` does not matter and changes to `flush_time` have no effect on flush behavior.

- `flush_time`

Command-Line Format	`--flush-time=#`	
System Variable	**Name**	`flush_time`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`0`
	Minimum	`0`
Permitted Values (Windows)	**Type**	integer
	Default	`1800`
	Minimum	`0`

If this is set to a nonzero value, all tables are closed every `flush_time` seconds to free up resources and synchronize unflushed data to disk. This option is best used only on systems with minimal resources.

Note

If `flush` is enabled, the value of `flush_time` does not matter and changes to `flush_time` have no effect on flush behavior.

- `foreign_key_checks`

System Variable (<= 5.5.2)	**Name**	`foreign_key_checks`
	Scope	Session
	Dynamic	Yes
System Variable (>= 5.5.3)	**Name**	`foreign_key_checks`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`1`

If set to 1 (the default), foreign key constraints for `InnoDB` tables are checked. If set to 0, foreign key constraints are ignored, with a couple of exceptions. When re-creating a table that was dropped, an error is returned if the table definition does not conform to the foreign key constraints referencing the table. Likewise, an `ALTER TABLE` operation returns an error if a foreign key definition is incorrectly formed. For more information, see Section 13.1.17.6, "Using FOREIGN KEY Constraints".

Disabling foreign key checking can be useful for reloading `InnoDB` tables in an order different from that required by their parent/child relationships. See Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”.

Setting `foreign_key_checks` to 0 also affects data definition statements: `DROP SCHEMA` drops a schema even if it contains tables that have foreign keys that are referred to by tables outside the schema, and `DROP TABLE` drops tables that have foreign keys that are referred to by other tables.

Note

Setting `foreign_key_checks` to 1 does not trigger a scan of the existing table data. Therefore, rows added to the table while `foreign_key_checks=0` will not be verified for consistency.

Warning

With `foreign_key_checks=0`, dropping an index required by a foreign key constraint places the table in an inconsistent state and causes the foreign key check that occurs at table load to fail. To avoid this problem, remove the foreign key constraint before dropping the index (Bug #70260).

- `ft_boolean_syntax`

Command-Line Format	`--ft-boolean-syntax=name`	
System Variable	**Name**	`ft_boolean_syntax`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	string
	Default	`+ -><()~*:""&|`

The list of operators supported by boolean full-text searches performed using `IN BOOLEAN MODE`. See Section 12.9.2, “Boolean Full-Text Searches”.

The default variable value is `'+ -><()~*:""&|'`. The rules for changing the value are as follows:

- Operator function is determined by position within the string.
- The replacement value must be 14 characters.
- Each character must be an ASCII nonalphanumeric character.
- Either the first or second character must be a space.
- No duplicates are permitted except the phrase quoting operators in positions 11 and 12. These two characters are not required to be the same, but they are the only two that may be.
- Positions 10, 13, and 14 (which by default are set to `:`, `&`, and `|`) are reserved for future extensions.

- `ft_max_word_len`

Command-Line Format	`--ft-max-word-len=#`	
System Variable	**Name**	`ft_max_word_len`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer

	Minimum	10

The maximum length of the word to be included in a FULLTEXT index.

Note

FULLTEXT indexes must be rebuilt after changing this variable. Use REPAIR TABLE *tbl_name* QUICK.

- ft_min_word_len

Command-Line Format	--ft-min-word-len=#	
System Variable	**Name**	ft_min_word_len
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	4
	Minimum	1

The minimum length of the word to be included in a FULLTEXT index.

Note

FULLTEXT indexes must be rebuilt after changing this variable. Use REPAIR TABLE *tbl_name* QUICK.

- ft_query_expansion_limit

Command-Line Format	--ft-query-expansion-limit=#	
System Variable	**Name**	ft_query_expansion_limit
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	20
	Minimum	0
	Maximum	1000

The number of top matches to use for full-text searches performed using WITH QUERY EXPANSION.

- ft_stopword_file

Command-Line Format	--ft-stopword-file=file_name	
System Variable	**Name**	ft_stopword_file
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	file name

The file from which to read the list of stopwords for full-text searches. The server looks for the file in the data directory unless an absolute path name is given to specify a different directory. All the words from the file are used; comments are *not* honored. By default, a built-in list of stopwords is used (as defined in the storage/myisam/ft_static.c file). Setting this variable to the empty string ('') disables stopword filtering. See also Section 12.9.4, “Full-Text Stopwords”.

Note

`FULLTEXT` indexes must be rebuilt after changing this variable or the contents of the stopword file. Use `REPAIR TABLE tbl_name QUICK`.

- `general_log`

Command-Line Format	`--general-log`	
System Variable	**Name**	`general_log`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Whether the general query log is enabled. The value can be 0 (or `OFF`) to disable the log or 1 (or `ON`) to enable the log. The default value depends on whether the `--general_log` option is given. The destination for log output is controlled by the `log_output` system variable; if that value is `NONE`, no log entries are written even if the log is enabled.

- `general_log_file`

Command-Line Format	`--general-log-file=file_name`	
System Variable	**Name**	`general_log_file`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	file name
	Default	`host_name.log`

The name of the general query log file. The default value is *`host_name`*`.log`, but the initial value can be changed with the `--general_log_file` option.

- `group_concat_max_len`

Command-Line Format	`--group-concat-max-len=#`	
System Variable	**Name**	`group_concat_max_len`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`1024`
	Minimum	`4`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`1024`
	Minimum	`4`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`1024`
	Minimum	`4`

Maximum	18446744073709551615

The maximum permitted result length in bytes for the `GROUP_CONCAT()` function. The default is 1024.

- `have_compress`

  `YES` if the `zlib` compression library is available to the server, `NO` if not. If not, the `COMPRESS()` and `UNCOMPRESS()` functions cannot be used.

- `have_crypt`

  `YES` if the `crypt()` system call is available to the server, `NO` if not. If not, the `ENCRYPT()` function cannot be used.

- `have_csv`

  `YES` if `mysqld` supports `CSV` tables, `NO` if not.

  This variable is deprecated and is removed in MySQL 5.6. Use `SHOW ENGINES` instead.

- `have_dynamic_loading`

  `YES` if `mysqld` supports dynamic loading of plugins, `NO` if not. If the value is `NO`, you cannot use options such as `--plugin-load` to load plugins at server startup, or the `INSTALL PLUGIN` statement to load plugins at runtime.

- `have_geometry`

  `YES` if the server supports spatial data types, `NO` if not.

- `have_innodb`

  `YES` if `mysqld` supports `InnoDB` tables. `DISABLED` if `--skip-innodb` is used.

  This variable is deprecated and is removed in MySQL 5.6. Use `SHOW ENGINES` instead.

- `have_openssl`

  This variable is an alias for `have_ssl`.

- `have_partitioning`

  `YES` if `mysqld` supports partitioning.

  This variable is deprecated and is removed in MySQL 5.6. Use `SHOW PLUGINS` instead. For more information, see Chapter 19, *Partitioning*.

- `have_profiling`

  `YES` if statement profiling capability is present, `NO` if not. If present, the `profiling` system variable controls whether this capability is enabled or disabled. See Section 13.7.5.32, “SHOW PROFILES Syntax”.

- `have_query_cache`

  `YES` if `mysqld` supports the query cache, `NO` if not.

- `have_rtree_keys`

  `YES` if `RTREE` indexes are available, `NO` if not. (These are used for spatial indexes in `MyISAM` tables.)

- `have_ssl`

YES if mysqld supports SSL connections, NO if not. DISABLED indicates that the server was compiled with SSL support, but was not started with the appropriate --ssl-*xxx* options. For more information, see Section 6.4.5, “Building MySQL with Support for Encrypted Connections”.

- have_symlink

  YES if symbolic link support is enabled, NO if not. This is required on Unix for support of the DATA DIRECTORY and INDEX DIRECTORY table options, and on Windows for support of data directory symlinks. If the server is started with the --skip-symbolic-links option, the value is DISABLED.

- hostname

System Variable	Name	hostname
	Scope	Global
	Dynamic	No
Permitted Values	Type	string

  The server sets this variable to the server host name at startup.

- identity

  This variable is a synonym for the last_insert_id variable. It exists for compatibility with other database systems. You can read its value with SELECT @@identity, and set it using SET identity.

- init_connect

Command-Line Format	--init-connect=name	
System Variable	Name	init_connect
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	string

  A string to be executed by the server for each client that connects. The string consists of one or more SQL statements, separated by semicolon characters. For example, each client session begins by default with autocommit mode enabled. For older servers (before MySQL 5.5.8), there is no global autocommit system variable to specify that autocommit should be disabled by default, but as a workaround init_connect can be used to achieve the same effect:

```
SET GLOBAL init_connect='SET autocommit=0';
```

  The init_connect variable can also be set on the command line or in an option file. To set the variable as just shown using an option file, include these lines:

```
[mysqld]
init_connect='SET autocommit=0'
```

  For users that have the SUPER privilege, the content of init_connect is not executed. This is done so that an erroneous value for init_connect does not prevent all clients from connecting. For example, the value might contain a statement that has a syntax error, thus causing client connections to fail. Not executing init_connect for users that have the SUPER privilege enables them to open a connection and fix the init_connect value.

  The server discards any result sets produced by statements in the value of of init_connect.

- init_file

Command-Line Format	--init-file=file_name	
System Variable	Name	init_file
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The name of the file specified with the --init-file option when you start the server. This should be a file containing SQL statements that you want the server to execute when it starts. Each statement must be on a single line and should not include comments. For more information, see the description of --init-file.

- innodb_*xxx*

  InnoDB system variables are listed in Section 14.17, "InnoDB Startup Options and System Variables". These variables control many aspects of storage, memory use, and I/O patterns for InnoDB tables, and are especially important now that InnoDB is the default storage engine.

- insert_id

  The value to be used by the following INSERT or ALTER TABLE statement when inserting an AUTO_INCREMENT value. This is mainly used with the binary log.

- interactive_timeout

Command-Line Format	--interactive-timeout=#	
System Variable	Name	interactive_timeout
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	28800
	Minimum	1

The number of seconds the server waits for activity on an interactive connection before closing it. An interactive client is defined as a client that uses the CLIENT_INTERACTIVE option to mysql_real_connect(). See also wait_timeout.

- join_buffer_size

Command-Line Format	--join-buffer-size=#	
System Variable	Name	join_buffer_size
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (Windows, >= 5.5.3)	Type	integer
	Default	131072
	Minimum	128
	Maximum	4294967295
Permitted Values (Windows, 32-bit platforms, <= 5.5.2)	Type	integer
	Default	131072
	Minimum	8200
	Maximum	4294967295

Permitted Values (Windows, 64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	131072
	Minimum	8228
	Maximum	4294967295
Permitted Values (Other, 32-bit platforms, <= 5.5.2)	**Type**	integer
	Default	131072
	Minimum	8200
	Maximum	4294967295
Permitted Values (Other, 32-bit platforms, >= 5.5.3)	**Type**	integer
	Default	131072
	Minimum	128
	Maximum	4294967295
Permitted Values (Other, 64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	131072
	Minimum	8228
	Maximum	18446744073709547520
Permitted Values (Other, 64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	131072
	Minimum	128
	Maximum	18446744073709547520

The minimum size of the buffer that is used for plain index scans, range index scans, and joins that do not use indexes and thus perform full table scans. Normally, the best way to get fast joins is to add indexes. Increase the value of `join_buffer_size` to get a faster full join when adding indexes is not possible. One join buffer is allocated for each full join between two tables. For a complex join between several tables for which indexes are not used, multiple join buffers might be necessary.

There is no gain from setting the buffer larger than required to hold each matching row, and all joins allocate at least the minimum size, so use caution in setting this variable to a large value globally. It is better to keep the global setting small and change to a larger setting only in sessions that are doing large joins. Memory allocation time can cause substantial performance drops if the global size is larger than needed by most queries that use it.

The maximum permissible setting for `join_buffer_size` is 4GB−1. Larger values are permitted for 64-bit platforms (except 64-bit Windows, for which large values are truncated to 4GB−1 with a warning).

Prior to MySQL 5.5.3, the minimum allowed value for this variable was 8200 for 32-bit platforms and 8228 for 64-bit platforms. In MySQL 5.5.3 and later, the minimum is 128 for all platforms.

For additional information about join buffering, see Section 8.2.1.5, “Nested-Loop Join Algorithms”.

- `keep_files_on_create`

Command-Line Format	`--keep-files-on-create=#`	
System Variable	**Name**	`keep_files_on_create`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean

	Default	`OFF`

If a `MyISAM` table is created with no `DATA DIRECTORY` option, the `.MYD` file is created in the database directory. By default, if `MyISAM` finds an existing `.MYD` file in this case, it overwrites it. The same applies to `.MYI` files for tables created with no `INDEX DIRECTORY` option. To suppress this behavior, set the `keep_files_on_create` variable to `ON` (1), in which case `MyISAM` will not overwrite existing files and returns an error instead. The default value is `OFF` (0).

If a `MyISAM` table is created with a `DATA DIRECTORY` or `INDEX DIRECTORY` option and an existing `.MYD` or `.MYI` file is found, MyISAM always returns an error. It will not overwrite a file in the specified directory.

- `key_buffer_size`

Command-Line Format	`--key-buffer-size=#`	
System Variable	**Name**	`key_buffer_size`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`8388608`
	Minimum	`8`
	Maximum	`4294967295`
Permitted Values (64-bit platforms)	**Type**	integer
	Default	`8388608`
	Minimum	`8`
	Maximum	`OS_PER_PROCESS_LIMIT`

Index blocks for `MyISAM` tables are buffered and are shared by all threads. `key_buffer_size` is the size of the buffer used for index blocks. The key buffer is also known as the key cache.

The maximum permissible setting for `key_buffer_size` is 4GB−1 on 32-bit platforms. Larger values are permitted for 64-bit platforms. The effective maximum size might be less, depending on your available physical RAM and per-process RAM limits imposed by your operating system or hardware platform. The value of this variable indicates the amount of memory requested. Internally, the server allocates as much memory as possible up to this amount, but the actual allocation might be less.

You can increase the value to get better index handling for all reads and multiple writes; on a system whose primary function is to run MySQL using the `MyISAM` storage engine, 25% of the machine's total memory is an acceptable value for this variable. However, you should be aware that, if you make the value too large (for example, more than 50% of the machine's total memory), your system might start to page and become extremely slow. This is because MySQL relies on the operating system to perform file system caching for data reads, so you must leave some room for the file system cache. You should also consider the memory requirements of any other storage engines that you may be using in addition to `MyISAM`.

For even more speed when writing many rows at the same time, use `LOCK TABLES`. See Section 8.2.4.1, “Optimizing INSERT Statements”.

You can check the performance of the key buffer by issuing a `SHOW STATUS` statement and examining the `Key_read_requests`, `Key_reads`, `Key_write_requests`, and `Key_writes` status variables. (See Section 13.7.5, “SHOW Syntax”.) The `Key_reads/Key_read_requests` ratio should normally be less than 0.01. The `Key_writes/Key_write_requests` ratio is usually near 1 if you are using mostly updates and deletes, but might be much smaller if you tend to do

updates that affect many rows at the same time or if you are using the `DELAY_KEY_WRITE` table option.

The fraction of the key buffer in use can be determined using `key_buffer_size` in conjunction with the `Key_blocks_unused` status variable and the buffer block size, which is available from the `key_cache_block_size` system variable:

```
1 - ((Key_blocks_unused * key_cache_block_size) / key_buffer_size)
```

This value is an approximation because some space in the key buffer is allocated internally for administrative structures. Factors that influence the amount of overhead for these structures include block size and pointer size. As block size increases, the percentage of the key buffer lost to overhead tends to decrease. Larger blocks results in a smaller number of read operations (because more keys are obtained per read), but conversely an increase in reads of keys that are not examined (if not all keys in a block are relevant to a query).

It is possible to create multiple `MyISAM` key caches. The size limit of 4GB applies to each cache individually, not as a group. See Section 8.10.2, “The MyISAM Key Cache”.

- `key_cache_age_threshold`

Command-Line Format	`--key-cache-age-threshold=#`	
System Variable	**Name**	`key_cache_age_threshold`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`300`
	Minimum	`100`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`300`
	Minimum	`100`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`300`
	Minimum	`100`
	Maximum	`18446744073709551615`

This value controls the demotion of buffers from the hot sublist of a key cache to the warm sublist. Lower values cause demotion to happen more quickly. The minimum value is 100. The default value is 300. See Section 8.10.2, “The MyISAM Key Cache”.

- `key_cache_block_size`

Command-Line Format	`--key-cache-block-size=#`	
System Variable	**Name**	`key_cache_block_size`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`1024`

	Minimum	512
	Maximum	16384

The size in bytes of blocks in the key cache. The default value is 1024. See Section 8.10.2, “The MyISAM Key Cache”.

- `key_cache_division_limit`

Command-Line Format	`--key-cache-division-limit=#`	
System Variable	**Name**	`key_cache_division_limit`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`100`
	Minimum	1
	Maximum	100

The division point between the hot and warm sublists of the key cache buffer list. The value is the percentage of the buffer list to use for the warm sublist. Permissible values range from 1 to 100. The default value is 100. See Section 8.10.2, “The MyISAM Key Cache”.

- `language`

Deprecated	5.5.0, by `lc-messages-dir`	
Command-Line Format	`--language=name`	
System Variable	**Name**	`language`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	directory name
	Default	`/usr/local/mysql/share/mysql/english/`

The directory where error messages are located. See Section 10.2, “Setting the Error Message Language”.

The `language` system variable is removed as of MySQL 5.5.0 (although the `--language` command-line option can still be used). Similar information is available from the `lc_messages_dir` and `lc_messages` variables.

- `large_files_support`

System Variable	**Name**	`large_files_support`
	Scope	Global
	Dynamic	No

Whether `mysqld` was compiled with options for large file support.

- `large_pages`

Command-Line Format	`--large-pages`	
System Variable	**Name**	`large_pages`
	Scope	Global

	Dynamic	No
Platform Specific	Linux	
Permitted Values (Linux)	**Type**	boolean
	Default	`FALSE`

Whether large page support is enabled (via the `--large-pages` option). See Section 8.12.4.2, “Enabling Large Page Support”.

- `large_page_size`

System Variable	**Name**	`large_page_size`
	Scope	Global
	Dynamic	No
Permitted Values (Linux)	**Type**	integer
	Default	`0`

If large page support is enabled, this shows the size of memory pages. Large memory pages are supported only on Linux; on other platforms, the value of this variable is always 0. See Section 8.12.4.2, “Enabling Large Page Support”.

- `last_insert_id`

The value to be returned from `LAST_INSERT_ID()`. This is stored in the binary log when you use `LAST_INSERT_ID()` in a statement that updates a table. Setting this variable does not update the value returned by the `mysql_insert_id()` C API function.

- `lc_messages`

Command-Line Format	`--lc-messages=name`	
System Variable	**Name**	`lc_messages`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	string
	Default	`en_US`

The locale to use for error messages. The default is `en_US`. The server converts the argument to a language name and combines it with the value of `lc_messages_dir` to produce the location for the error message file. See Section 10.2, “Setting the Error Message Language”.

- `lc_messages_dir`

Command-Line Format	`--lc-messages-dir=dir_name`	
System Variable	**Name**	`lc_messages_dir`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	directory name

The directory where error messages are located. The server uses the value together with the value of `lc_messages` to produce the location for the error message file. See Section 10.2, “Setting the Error Message Language”.

- `lc_time_names`

System Variable	Name	lc_time_names
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	string

This variable specifies the locale that controls the language used to display day and month names and abbreviations. This variable affects the output from the `DATE_FORMAT()`, `DAYNAME()` and `MONTHNAME()` functions. Locale names are POSIX-style values such as `'ja_JP'` or `'pt_BR'`. The default value is `'en_US'` regardless of your system's locale setting. For further information, see Section 10.7, “MySQL Server Locale Support”.

- `license`

System Variable	Name	license
	Scope	Global
	Dynamic	No
Permitted Values	Type	string
	Default	GPL

The type of license the server has.

- `local_infile`

System Variable	Name	local_infile
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	ON

This variable controls server-side `LOCAL` capability for `LOAD DATA` statements. Depending on the `local_infile` setting, the server refuses or permits local data loading by clients that have `LOCAL` enabled on the client side.

To explicitly cause the server to refuse or permit `LOAD DATA LOCAL` statements (regardless of how client programs and libraries are configured at build time or runtime), start `mysqld` with `local_infile` disabled or enabled, respectively. `local_infile` can also be set at runtime. For more information, see Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

- `lock_wait_timeout`

Introduced	5.5.3	
Command-Line Format	`--lock-wait-timeout=#`	
System Variable	Name	lock_wait_timeout
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	31536000
	Minimum	1
	Maximum	31536000

This variable specifies the timeout in seconds for attempts to acquire metadata locks. The permissible values range from 1 to 31536000 (1 year). The default is 31536000.

This timeout applies to all statements that use metadata locks. These include DML and DDL operations on tables, views, stored procedures, and stored functions, as well as `LOCK TABLES`, `FLUSH TABLES WITH READ LOCK`, and `HANDLER` statements.

This timeout does not apply to implicit accesses to system tables in the `mysql` database, such as grant tables modified by `GRANT` or `REVOKE` statements or table logging statements. The timeout does apply to system tables accessed directly, such as with `SELECT` or `UPDATE`.

The timeout value applies separately for each metadata lock attempt. A given statement can require more than one lock, so it is possible for the statement to block for longer than the `lock_wait_timeout` value before reporting a timeout error. When lock timeout occurs, `ER_LOCK_WAIT_TIMEOUT` is reported.

`lock_wait_timeout` does not apply to delayed inserts, which always execute with a timeout of 1 year. This is done to avoid unnecessary timeouts because a session that issues a delayed insert receives no notification of delayed insert timeouts.

- `locked_in_memory`

System Variable	Name	locked_in_memory
	Scope	Global
	Dynamic	No

Whether `mysqld` was locked in memory with `--memlock`.

- `log`

Deprecated	5.1.29, by general-log	
Command-Line Format	--log[=file_name]	
System Variable	Name	log
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	file name

Whether logging of all statements to the general query log is enabled. See Section 5.4.3, “The General Query Log”.

This variable is deprecated and is removed in MySQL 5.6. Use `general_log` instead.

- `log_bin_trust_function_creators`

Command-Line Format	--log-bin-trust-function-creators	
System Variable	Name	log_bin_trust_function_creators
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	FALSE

This variable applies when binary logging is enabled. It controls whether stored function creators can be trusted not to create stored functions that will cause unsafe events to be written to the binary log. If set to 0 (the default), users are not permitted to create or alter stored functions unless they

have the SUPER privilege in addition to the CREATE ROUTINE or ALTER ROUTINE privilege. A setting of 0 also enforces the restriction that a function must be declared with the DETERMINISTIC characteristic, or with the READS SQL DATA or NO SQL characteristic. If the variable is set to 1, MySQL does not enforce these restrictions on stored function creation. This variable also applies to trigger creation. See Section 20.7, “Binary Logging of Stored Programs”.

- log_bin_trust_routine_creators

  This is the old name for log_bin_trust_function_creators. This variable is deprecated and was removed in MySQL 5.5.3.

- log_error

Command-Line Format	--log-error[=file_name]	
System Variable	Name	log_error
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The name of the error log file, or empty if the server is writing error messages to the console rather than to a named file. See Section 5.4.2, “The Error Log”.

- log_output

Command-Line Format	--log-output=name	
System Variable	Name	log_output
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	set
	Default	FILE
	Valid Values	TABLE
		FILE
		NONE

The destination for general query log and slow query log output. The value can be a comma-separated list of one or more of the words TABLE (log to tables), FILE (log to files), or NONE (do not log to tables or files). The default value is FILE. NONE, if present, takes precedence over any other specifiers. If the value is NONE log entries are not written even if the logs are enabled. If the logs are not enabled, no logging occurs even if the value of log_output is not NONE. For more information, see Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”.

- log_queries_not_using_indexes

Command-Line Format	--log-queries-not-using-indexes	
System Variable	Name	log_queries_not_using_indexes
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	OFF

Whether queries that do not use indexes are logged to the slow query log. See Section 5.4.5, “The Slow Query Log”.

- `log_slow_queries`

Deprecated	5.1.29, by `slow-query-log`	
Command-Line Format	`--log-slow-queries[=name]`	
System Variable	**Name**	`log_slow_queries`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean

Whether slow queries should be logged. "Slow" is determined by the value of the `long_query_time` variable. See Section 5.4.5, "The Slow Query Log".

This variable is deprecated and is removed in MySQL 5.6. Use `slow_query_log` instead.

- `log_warnings`

Command-Line Format	`--log-warnings[=#]`	
System Variable	**Name**	`log_warnings`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`1`
	Minimum	`0`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`1`
	Minimum	`0`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`1`
	Minimum	`0`
	Maximum	`18446744073709551615`

Whether to produce additional warning messages to the error log. This variable is enabled by default with a value of 1. To disable it, set it to 0. If the value is greater than 0, the server logs messages about statements that are unsafe for statement-based logging. If the value is greater than 1, the server logs aborted connections and access-denied errors for new connection attempts. See Section B.5.2.11, "Communication Errors and Aborted Connections".

- `long_query_time`

Command-Line Format	`--long-query-time=#`	
System Variable	**Name**	`long_query_time`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	numeric
	Default	`10`
	Minimum	`0`

If a query takes longer than this many seconds, the server increments the `Slow_queries` status variable. If the slow query log is enabled, the query is logged to the slow query log file. This value is measured in real time, not CPU time, so a query that is under the threshold on a lightly loaded system might be above the threshold on a heavily loaded one. The minimum and default values of `long_query_time` are 0 and 10, respectively. The value can be specified to a resolution of microseconds. For logging to a file, times are written including the microseconds part. For logging to tables, only integer times are written; the microseconds part is ignored. See Section 5.4.5, "The Slow Query Log".

- `low_priority_updates`

Command-Line Format	`--low-priority-updates`	
System Variable	Name	`low_priority_updates`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	`FALSE`

If set to `1`, all `INSERT`, `UPDATE`, `DELETE`, and `LOCK TABLE WRITE` statements wait until there is no pending `SELECT` or `LOCK TABLE READ` on the affected table. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`). This variable previously was named `sql_low_priority_updates`.

- `lower_case_file_system`

System Variable	Name	`lower_case_file_system`
	Scope	Global
	Dynamic	No
Permitted Values	Type	boolean

This variable describes the case sensitivity of file names on the file system where the data directory is located. `OFF` means file names are case sensitive, `ON` means they are not case sensitive. This variable is read only because it reflects a file system attribute and setting it would have no effect on the file system.

- `lower_case_table_names`

Command-Line Format	`--lower-case-table-names[=#]`	
System Variable	Name	`lower_case_table_names`
	Scope	Global
	Dynamic	No
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`2`

If set to 0, table names are stored as specified and comparisons are case sensitive. If set to 1, table names are stored in lowercase on disk and comparisons are not case sensitive. If set to 2, table names are stored as given but compared in lowercase. This option also applies to database names and table aliases. For additional information, see Section 9.2.2, "Identifier Case Sensitivity".

On Windows the default value is 1. On OS X, the default value is 2.

You should *not* set `lower_case_table_names` to 0 if you are running MySQL on a system where the data directory resides on a case-insensitive file system (such as on Windows or OS X). It is an unsupported combination that could result in a hang condition when running an `INSERT INTO ... SELECT ... FROM tbl_name` operation with the wrong `tbl_name` letter case. With `MyISAM`, accessing table names using different letter cases could cause index corruption.

As of MySQL 5.5.46, an error message is printed and the server exits if you attempt to start the server with `--lower_case_table_names=0` on a case-insensitive file system.

If you are using `InnoDB` tables, you should set this variable to 1 on all platforms to force names to be converted to lowercase.

The setting of this variable has no effect on replication filtering options. This is a known issue which is fixed in MySQL 5.6. See Section 17.2.3, "How Servers Evaluate Replication Filtering Rules", for more information.

You should not use different settings for `lower_case_table_names` on replication masters and slaves. In particular, you should not do this when the slave uses a case-sensitive file system, as this can cause replication to fail. This is a known issue which is fixed in MySQL 5.6. For more information, see Section 17.4.1.38, "Replication and Variables".

- `max_allowed_packet`

Command-Line Format	`--max-allowed-packet=#`	
System Variable	**Name**	`max_allowed_packet`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`1048576`
	Minimum	`1024`
	Maximum	`1073741824`

The maximum size of one packet or any generated/intermediate string.

The packet message buffer is initialized to `net_buffer_length` bytes, but can grow up to `max_allowed_packet` bytes when needed. This value by default is small, to catch large (possibly incorrect) packets.

You must increase this value if you are using large `BLOB` columns or long strings. It should be as big as the largest `BLOB` you want to use. The protocol limit for `max_allowed_packet` is 1GB. The value should be a multiple of 1024; nonmultiples are rounded down to the nearest multiple.

When you change the message buffer size by changing the value of the `max_allowed_packet` variable, you should also change the buffer size on the client side if your client program permits it. The default `max_allowed_packet` value built in to the client library is 1GB, but individual client programs might override this. For example, `mysql` and `mysqldump` have defaults of 16MB and 24MB, respectively. They also enable you to change the client-side value by setting `max_allowed_packet` on the command line or in an option file.

The session value of this variable is read only. The client can receive up to as many bytes as the session value. However, the server will not send to the client more bytes than the current global `max_allowed_packet` value. (The global value could be less than the session value if the global value is changed after the client connects.)

- `max_connect_errors`

Command-Line Format	--max-connect-errors=#	
System Variable	Name	max_connect_errors
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	10
	Minimum	1
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	Type	integer
	Default	10
	Minimum	1
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	Type	integer
	Default	10
	Minimum	1
	Maximum	18446744073709551615

If more than this many successive connection requests from a host are interrupted without a successful connection, the server blocks that host from further connections. You can unblock blocked hosts by flushing the host cache. To do so, issue a `FLUSH HOSTS` statement or execute a `mysqladmin flush-hosts` command. If a connection is established successfully within fewer than `max_connect_errors` attempts after a previous connection was interrupted, the error count for the host is cleared to zero. However, once a host is blocked, flushing the host cache is the only way to unblock it.

- `max_connections`

Command-Line Format	--max-connections=#	
System Variable	Name	max_connections
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	151
	Minimum	1
	Maximum	100000

The maximum permitted number of simultaneous client connections. By default, this is 151. See Section B.5.2.7, “Too many connections”, for more information.

Increasing this value increases the number of file descriptors that `mysqld` requires. See Section 8.4.3.1, “How MySQL Opens and Closes Tables”, for comments on file descriptor limits.

`mysqld` actually permits `max_connections+1` clients to connect. The extra connection is reserved for use by accounts that have the `SUPER` privilege. By granting the `SUPER` privilege to administrators and not to normal users (who should not need it), an administrator can connect to the server and use `SHOW PROCESSLIST` to diagnose problems even if the maximum number of unprivileged clients are connected. See Section 13.7.5.30, “SHOW PROCESSLIST Syntax”.

- `max_delayed_threads`

Command-Line Format	--max-delayed-threads=#	
System Variable	Name	max_delayed_threads
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	20
	Minimum	0
	Maximum	16384

Do not start more than this number of threads to handle INSERT DELAYED statements. If you try to insert data into a new table after all INSERT DELAYED threads are in use, the row is inserted as if the DELAYED attribute was not specified. If you set this to 0, MySQL never creates a thread to handle DELAYED rows; in effect, this disables DELAYED entirely.

For the SESSION value of this variable, the only valid values are 0 or the GLOBAL value.

- max_error_count

Command-Line Format	--max-error-count=#	
System Variable	Name	max_error_count
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	64
	Minimum	0
	Maximum	65535

The maximum number of error, warning, and note messages to be stored for display by the SHOW ERRORS and SHOW WARNINGS statements.

- max_heap_table_size

Command-Line Format	--max-heap-table-size=#	
System Variable	Name	max_heap_table_size
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	16777216
	Minimum	16384
	Maximum	4294967295
Permitted Values (64-bit platforms)	Type	integer
	Default	16777216
	Minimum	16384
	Maximum	18446744073709551615

This variable sets the maximum size to which user-created MEMORY tables are permitted to grow. The value of the variable is used to calculate MEMORY table MAX_ROWS values. Setting this variable has no effect on any existing MEMORY table, unless the table is re-created with a statement such as

`CREATE TABLE` or altered with `ALTER TABLE` or `TRUNCATE TABLE`. A server restart also sets the maximum size of existing `MEMORY` tables to the global `max_heap_table_size` value.

This variable is also used in conjunction with `tmp_table_size` to limit the size of internal in-memory tables. See Section 8.4.4, “Internal Temporary Table Use in MySQL”.

`max_heap_table_size` is not replicated. See Section 17.4.1.20, “Replication and MEMORY Tables”, and Section 17.4.1.38, “Replication and Variables”, for more information.

- `max_insert_delayed_threads`

System Variable	Name	max_insert_delayed_threads
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer

This variable is a synonym for `max_delayed_threads`.

- `max_join_size`

Command-Line Format	--max-join-size=#	
System Variable	Name	max_join_size
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	18446744073709551615
	Minimum	1
	Maximum	18446744073709551615

Do not permit statements that probably need to examine more than `max_join_size` rows (for single-table statements) or row combinations (for multiple-table statements) or that are likely to do more than `max_join_size` disk seeks. By setting this value, you can catch statements where keys are not used properly and that would probably take a long time. Set it if your users tend to perform joins that lack a `WHERE` clause, that take a long time, or that return millions of rows.

Setting this variable to a value other than `DEFAULT` resets the value of `sql_big_selects` to `0`. If you set the `sql_big_selects` value again, the `max_join_size` variable is ignored.

If a query result is in the query cache, no result size check is performed, because the result has previously been computed and it does not burden the server to send it to the client.

This variable previously was named `sql_max_join_size`.

- `max_length_for_sort_data`

Command-Line Format	--max-length-for-sort-data=#	
System Variable	Name	max_length_for_sort_data
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	1024
	Minimum	4
	Maximum	8388608

The cutoff on the size of index values that determines which `filesort` algorithm to use. See Section 8.2.1.10, “ORDER BY Optimization”.

- `max_long_data_size`

Introduced	5.5.11	
Deprecated	5.5.11	
Command-Line Format	`--max-long-data-size=#`	
System Variable	**Name**	`max_long_data_size`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`1048576`
	Minimum	`1024`
	Maximum	`4294967295`

The maximum size of parameter values that can be sent with the `mysql_stmt_send_long_data()` C API function. If not set at server startup, the default is the value of the `max_allowed_packet` system variable. This variable is deprecated. In MySQL 5.6, it is removed and the maximum parameter size is controlled by `max_allowed_packet`.

- `max_prepared_stmt_count`

Command-Line Format	`--max-prepared-stmt-count=#`	
System Variable	**Name**	`max_prepared_stmt_count`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`16382`
	Minimum	`0`
	Maximum	`1048576`

This variable limits the total number of prepared statements in the server. (The sum of the number of prepared statements across all sessions.) It can be used in environments where there is the potential for denial-of-service attacks based on running the server out of memory by preparing huge numbers of statements. If the value is set lower than the current number of prepared statements, existing statements are not affected and can be used, but no new statements can be prepared until the current number drops below the limit. The default value is 16,382. The permissible range of values is from 0 to 1 million. Setting the value to 0 disables prepared statements.

- `max_relay_log_size`

Command-Line Format	`--max-relay-log-size=#`	
System Variable	**Name**	`max_relay_log_size`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`0`
	Minimum	`0`

	Maximum	1073741824

If a write by a replication slave to its relay log causes the current log file size to exceed the value of this variable, the slave rotates the relay logs (closes the current file and opens the next one). If `max_relay_log_size` is 0, the server uses `max_binlog_size` for both the binary log and the relay log. If `max_relay_log_size` is greater than 0, it constrains the size of the relay log, which enables you to have different sizes for the two logs. You must set `max_relay_log_size` to between 4096 bytes and 1GB (inclusive), or to 0. The default value is 0. See Section 17.2.1, "Replication Implementation Details".

- `max_seeks_for_key`

Command-Line Format	`--max-seeks-for-key=#`	
System Variable	**Name**	`max_seeks_for_key`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	4294967295
	Minimum	1
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	18446744073709547520
	Minimum	1
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	18446744073709551615
	Minimum	1
	Maximum	18446744073709551615

Limit the assumed maximum number of seeks when looking up rows based on a key. The MySQL optimizer assumes that no more than this number of key seeks are required when searching for matching rows in a table by scanning an index, regardless of the actual cardinality of the index (see Section 13.7.5.23, "SHOW INDEX Syntax"). By setting this to a low value (say, 100), you can force MySQL to prefer indexes instead of table scans.

- `max_sort_length`

Command-Line Format	`--max-sort-length=#`	
System Variable	**Name**	`max_sort_length`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	1024
	Minimum	4
	Maximum	8388608

The number of bytes to use when sorting data values. The server uses only the first `max_sort_length` bytes of each value and ignores the rest. Consequently, values that differ only after the first `max_sort_length` bytes compare as equal for `GROUP BY`, `ORDER BY`, and `DISTINCT` operations.

Increasing the value of `max_sort_length` may require increasing the value of `sort_buffer_size` as well. For details, see Section 8.2.1.10, “ORDER BY Optimization”

- `max_sp_recursion_depth`

Command-Line Format	`--max-sp-recursion-depth[=#]`	
System Variable	Name	`max_sp_recursion_depth`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`0`
	Maximum	`255`

The number of times that any given stored procedure may be called recursively. The default value for this option is 0, which completely disables recursion in stored procedures. The maximum value is 255.

Stored procedure recursion increases the demand on thread stack space. If you increase the value of `max_sp_recursion_depth`, it may be necessary to increase thread stack size by increasing the value of `thread_stack` at server startup.

- `max_tmp_tables`

This variable is unused.

- `max_user_connections`

Command-Line Format	`--max-user-connections=#`	
System Variable	Name	`max_user_connections`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4294967295`

The maximum number of simultaneous connections permitted to any given MySQL user account. A value of 0 (the default) means “no limit.”

This variable has a global value that can be set at server startup or runtime. It also has a read-only session value that indicates the effective simultaneous-connection limit that applies to the account associated with the current session. The session value is initialized as follows:

- If the user account has a nonzero `MAX_USER_CONNECTIONS` resource limit, the session `max_user_connections` value is set to that limit.
- Otherwise, the session `max_user_connections` value is set to the global value.

Account resource limits are specified using the `GRANT` statement. See Section 6.3.4, “Setting Account Resource Limits”, and Section 13.7.1.3, “GRANT Syntax”.

- `max_write_lock_count`

Command-Line Format	`--max-write-lock-count=#`

System Variable	**Name**	`max_write_lock_count`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`4294967295`
	Minimum	`1`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`18446744073709547520`
	Minimum	`1`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`18446744073709551615`
	Minimum	`1`
	Maximum	`18446744073709551615`

After this many write locks, permit some pending read lock requests to be processed in between.

- `metadata_locks_cache_size`

Introduced	5.5.19	
System Variable	**Name**	`metadata_locks_cache_size`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`1024`
	Minimum	`1`
	Maximum	`1048576`

The size of the metadata locks cache. The server uses this cache to avoid creation and destruction of synchronization objects. This is particularly helpful on systems where such operations are expensive, such as Windows XP. This variable was added in MySQL 5.5.19.

- `min_examined_row_limit`

Command-Line Format	`--min-examined-row-limit=#`	
System Variable	**Name**	`min_examined_row_limit`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`0`
	Minimum	`0`

	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	18446744073709551615

Queries that examine fewer than this number of rows are not logged to the slow query log.

- `multi_range_count`

Command-Line Format	`--multi-range-count=#`	
System Variable	**Name**	`multi_range_count`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	256
	Minimum	1
	Maximum	4294967295

The maximum number of ranges to send to a table handler at once during range selects. The default value is 256. Sending multiple ranges to a handler at once can improve the performance of certain selects dramatically. This is especially true for the `NDBCLUSTER` table handler, which needs to send the range requests to all nodes. Sending a batch of those requests at once reduces communication costs significantly.

This variable is deprecated in MySQL 5.1, and is no longer supported in MySQL 5.5, in which arbitrarily long lists of ranges can be processed.

- `myisam_data_pointer_size`

Command-Line Format	`--myisam-data-pointer-size=#`	
System Variable	**Name**	`myisam_data_pointer_size`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	6
	Minimum	2
	Maximum	7

The default pointer size in bytes, to be used by `CREATE TABLE` for `MyISAM` tables when no `MAX_ROWS` option is specified. This variable cannot be less than 2 or larger than 7. The default value is 6. See Section B.5.2.12, “The table is full”.

- `myisam_max_sort_file_size`

Command-Line Format	`--myisam-max-sort-file-size=#`	
System Variable	**Name**	`myisam_max_sort_file_size`
	Scope	Global
	Dynamic	Yes

Permitted Values (32-bit platforms)	**Type**	integer
	Default	2147483648
Permitted Values (64-bit platforms)	**Type**	integer
	Default	9223372036854775807

The maximum size of the temporary file that MySQL is permitted to use while re-creating a MyISAM index (during REPAIR TABLE, ALTER TABLE, or LOAD DATA INFILE). If the file size would be larger than this value, the index is created using the key cache instead, which is slower. The value is given in bytes.

If MyISAM index files exceed this size and disk space is available, increasing the value may help performance. The space must be available in the file system containing the directory where the original index file is located.

- myisam_mmap_size

Introduced	5.5.1	
Command-Line Format	--myisam-mmap-size=#	
System Variable	**Name**	myisam_mmap_size
	Scope	Global
	Dynamic	No
Permitted Values (32-bit platforms)	**Type**	integer
	Default	4294967295
	Minimum	7
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	18446744073709547520
	Minimum	7
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	18446744073709551615
	Minimum	7
	Maximum	18446744073709551615

The maximum amount of memory to use for memory mapping compressed MyISAM files. If many compressed MyISAM tables are used, the value can be decreased to reduce the likelihood of memory-swapping problems.

- myisam_recover_options

System Variable	**Name**	myisam_recover_options
	Scope	Global
	Dynamic	No

The value of the --myisam-recover-options option. See Section 5.1.4, “Server Command Options”.

- myisam_repair_threads

Command-Line Format	--myisam-repair-threads=#

System Variable	Name	myisam_repair_threads
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	1
	Minimum	1
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	Type	integer
	Default	1
	Minimum	1
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	Type	integer
	Default	1
	Minimum	1
	Maximum	18446744073709551615

If this value is greater than 1, MyISAM table indexes are created in parallel (each index in its own thread) during the Repair by sorting process. The default value is 1.

Note

Multi-threaded repair is still *beta-quality* code.

- myisam_sort_buffer_size

Command-Line Format	--myisam-sort-buffer-size=#	
System Variable	Name	myisam_sort_buffer_size
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (Windows, 32-bit platforms)	Type	integer
	Default	8388608
	Minimum	4096
	Maximum	4294967295
Permitted Values (Windows, 64-bit platforms, <= 5.5.21)	Type	integer
	Default	8388608
	Minimum	4096
	Maximum	4294967295
Permitted Values (Windows, 64-bit platforms, >= 5.5.22)	Type	integer
	Default	8388608
	Minimum	4096
	Maximum	18446744073709551615
Permitted Values (Other, 32-bit platforms)	Type	integer
	Default	8388608
	Minimum	4096
	Maximum	4294967295

Permitted Values (Other, 64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	8388608
	Minimum	4096
	Maximum	18446744073709547520
Permitted Values (Other, 64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	8388608
	Minimum	4096
	Maximum	18446744073709551615

The size of the buffer that is allocated when sorting MyISAM indexes during a REPAIR TABLE or when creating indexes with CREATE INDEX or ALTER TABLE.

The maximum permissible setting for myisam_sort_buffer_size is 4GB−1. Larger values are permitted for 64-bit platforms (except 64-bit Windows prior to MySQL 5.5.222, for which large values are truncated to 4GB−1 with a warning).

- myisam_stats_method

Command-Line Format	--myisam-stats-method=name	
System Variable	**Name**	myisam_stats_method
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	nulls_unequal
	Valid Values	nulls_equal
		nulls_unequal
		nulls_ignored

How the server treats NULL values when collecting statistics about the distribution of index values for MyISAM tables. This variable has three possible values, nulls_equal, nulls_unequal, and nulls_ignored. For nulls_equal, all NULL index values are considered equal and form a single value group that has a size equal to the number of NULL values. For nulls_unequal, NULL values are considered unequal, and each NULL forms a distinct value group of size 1. For nulls_ignored, NULL values are ignored.

The method that is used for generating table statistics influences how the optimizer chooses indexes for query execution, as described in Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”.

- myisam_use_mmap

Command-Line Format	--myisam-use-mmap	
System Variable	**Name**	myisam_use_mmap
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	OFF

Use memory mapping for reading and writing MyISAM tables.

- named_pipe

System Variable	Name	named_pipe
	Scope	Global
	Dynamic	No
Platform Specific	Windows	
Permitted Values (Windows)	Type	boolean
	Default	OFF

(Windows only.) Indicates whether the server supports connections over named pipes.

- net_buffer_length

Command-Line Format	--net-buffer-length=#	
System Variable	Name	net_buffer_length
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	16384
	Minimum	1024
	Maximum	1048576

Each client thread is associated with a connection buffer and result buffer. Both begin with a size given by net_buffer_length but are dynamically enlarged up to max_allowed_packet bytes as needed. The result buffer shrinks to net_buffer_length after each SQL statement.

This variable should not normally be changed, but if you have very little memory, you can set it to the expected length of statements sent by clients. If statements exceed this length, the connection buffer is automatically enlarged. The maximum value to which net_buffer_length can be set is 1MB.

The session value of this variable is read only.

- net_read_timeout

Command-Line Format	--net-read-timeout=#	
System Variable	Name	net_read_timeout
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	30
	Minimum	1

The number of seconds to wait for more data from a connection before aborting the read. When the server is reading from the client, net_read_timeout is the timeout value controlling when to abort. When the server is writing to the client, net_write_timeout is the timeout value controlling when to abort. See also slave_net_timeout.

- net_retry_count

Command-Line Format	--net-retry-count=#	
System Variable	Name	net_retry_count
	Scope	Global, Session

	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`10`
	Minimum	`1`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`10`
	Minimum	`1`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`10`
	Minimum	`1`
	Maximum	`18446744073709551615`

If a read or write on a communication port is interrupted, retry this many times before giving up. This value should be set quite high on FreeBSD because internal interrupts are sent to all threads.

- `net_write_timeout`

Command-Line Format	`--net-write-timeout=#`	
System Variable	**Name**	`net_write_timeout`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`60`
	Minimum	`1`

The number of seconds to wait for a block to be written to a connection before aborting the write. See also `net_read_timeout`.

- `new`

Command-Line Format	`--new`	
System Variable	**Name**	`new`
	Scope	Global, Session
	Dynamic	Yes
Disabled by	`skip-new`	
Permitted Values	**Type**	boolean
	Default	`FALSE`

This variable was used in MySQL 4.0 to turn on some 4.1 behaviors, and is retained for backward compatibility. Its value is always `OFF`.

In NDB Cluster, setting this variable to `ON` makes it possible to employ partitioning types other than `KEY` or `LINEAR KEY` with `NDB` tables. *This feature is experimental only, and not supported in production*. For additional information, see User-defined partitioning and the NDB storage engine (NDB Cluster).

- `old`

Command-Line Format	--old	
System Variable	Name	old
	Scope	Global
	Dynamic	No

old is a compatibility variable. It is disabled by default, but can be enabled at startup to revert the server to behaviors present in older versions.

When old is enabled, it changes the default scope of index hints to that used prior to MySQL 5.1.17. That is, index hints with no FOR clause apply only to how indexes are used for row retrieval and not to resolution of ORDER BY or GROUP BY clauses. (See Section 8.9.3, “Index Hints”.) Take care about enabling this in a replication setup. With statement-based binary logging, having different modes for the master and slaves might lead to replication errors.

- old_alter_table

Command-Line Format	--old-alter-table	
System Variable	Name	old_alter_table
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	OFF

When this variable is enabled, the server does not use the optimized method of processing an ALTER TABLE operation. It reverts to using a temporary table, copying over the data, and then renaming the temporary table to the original, as used by MySQL 5.0 and earlier. For more information on the operation of ALTER TABLE, see Section 13.1.7, “ALTER TABLE Syntax”.

- old_passwords

System Variable	Name	old_passwords
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	0

This variable controls the password hashing method used by the PASSWORD() function. It also influences password hashing performed by CREATE USER and GRANT statements that specify a password using an IDENTIFIED BY clause.

The following table shows, for each password hashing method, the permitted value of old_passwords and which authentication plugins use the hashing method.

Password Hashing Method	old_passwords Value	Associated Authentication Plugin
MySQL 4.1 native hashing	0 or OFF	mysql_native_password
Pre-4.1 (“old”) hashing	1 or ON	mysql_old_password

If old_passwords=1, PASSWORD(*str*) returns the same value as OLD_PASSWORD(*str*). The latter function is not affected by the value of old_passwords.

For additional information about authentication plugins and hashing formats, see Section 6.3.6, “Pluggable Authentication”, and Section 6.1.2.4, “Password Hashing in MySQL”.

Note

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

- `one_shot`

  This is not a variable, but it can be used when setting some variables. It is described in Section 13.7.4.1, “SET Syntax for Variable Assignment”.

- `open_files_limit`

Command-Line Format	`--open-files-limit=#`	
System Variable	**Name**	`open_files_limit`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`platform dependent`

  The number of files that the operating system permits `mysqld` to open. This is the real value permitted by the system and might be different from the value you gave using the `--open-files-limit` option to `mysqld` or `mysqld_safe`. The value is 0 on systems where MySQL cannot change the number of open files.

- `optimizer_prune_level`

Command-Line Format	`--optimizer-prune-level[=#]`	
System Variable	**Name**	`optimizer_prune_level`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`1`

  Controls the heuristics applied during query optimization to prune less-promising partial plans from the optimizer search space. A value of 0 disables heuristics so that the optimizer performs an exhaustive search. A value of 1 causes the optimizer to prune plans based on the number of rows retrieved by intermediate plans.

- `optimizer_search_depth`

Command-Line Format	`--optimizer-search-depth[=#]`	
System Variable	**Name**	`optimizer_search_depth`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`62`

	Minimum	0
	Maximum	63

The maximum depth of search performed by the query optimizer. Values larger than the number of relations in a query result in better query plans, but take longer to generate an execution plan for a query. Values smaller than the number of relations in a query return an execution plan quicker, but the resulting plan may be far from being optimal. If set to 0, the system automatically picks a reasonable value. If set to 63, the optimizer switches to the algorithm used in MySQL 5.0.0 (and previous versions) for performing searches. The value of 63 is deprecated and will be treated as invalid in a future MySQL release.

- `optimizer_switch`

Command-Line Format	`--optimizer-switch=value`	
System Variable	**Name**	`optimizer_switch`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (<= 5.5.2)	**Type**	set
	Valid Values	`index_merge={on|off}`
		`index_merge_intersection={on|off}`
		`index_merge_sort_union={on|off}`
		`index_merge_union={on|off}`
Permitted Values (>= 5.5.3)	**Type**	set
	Valid Values	`engine_condition_pushdown={on|off}`
		`index_merge={on|off}`
		`index_merge_intersection={on|off}`
		`index_merge_sort_union={on|off}`
		`index_merge_union={on|off}`

The `optimizer_switch` system variable enables control over optimizer behavior. The value of this variable is a set of flags, each of which has a value of `on` or `off` to indicate whether the corresponding optimizer behavior is enabled or disabled. This variable has global and session values and can be changed at runtime. The global default can be set at server startup.

To see the current set of optimizer flags, select the variable value:

```
mysql> SELECT @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=on,
                    index_merge_sort_union=on,
                    index_merge_intersection=on,
                    engine_condition_pushdown=on
```

For more information about the syntax of this variable and the optimizer behaviors that it controls, see Section 8.9.2, “Switchable Optimizations”.

- `performance_schema_xxx`

Performance Schema system variables are listed in Section 22.11, “Performance Schema System Variables”. These variables may be used to configure Performance Schema operation.

- `pid_file`

Command-Line Format	`--pid-file=file_name`

System Variable	Name	pid_file
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The path name of the process ID (PID) file. On Windows, this variable also affects the default error log file name. See Section 5.4.2, “The Error Log”. This variable can be set with the `--pid-file` option.

- `plugin_dir`

Command-Line Format	--plugin-dir=dir_name	
System Variable	Name	plugin_dir
	Scope	Global
	Dynamic	No
Permitted Values (>= 5.5.5)	Type	directory name
	Default	BASEDIR/lib/plugin
Permitted Values (Windows, <= 5.5.4)	Type	directory name
	Default	BASEDIR/lib/plugin
Permitted Values (Other, <= 5.5.4)	Type	directory name
	Default	BASEDIR/lib/mysql/plugin

The path name of the plugin directory.

If the plugin directory is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making `plugin_dir` read only to the server or by setting `--secure-file-priv` to a directory where `SELECT` writes can be made safely.

- `port`

Command-Line Format	--port=#	
System Variable	Name	port
	Scope	Global
	Dynamic	No
Permitted Values	Type	integer
	Default	3306
	Minimum	0
	Maximum	65535

The number of the port on which the server listens for TCP/IP connections. This variable can be set with the `--port` option.

- `preload_buffer_size`

Command-Line Format	--preload-buffer-size=#	
System Variable	Name	preload_buffer_size
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer

	Default	32768
	Minimum	1024
	Maximum	1073741824

The size of the buffer that is allocated when preloading indexes.

- `profiling`

  If set to 0 or `OFF` (the default), statement profiling is disabled. If set to 1 or `ON`, statement profiling is enabled and the `SHOW PROFILE` and `SHOW PROFILES` statements provide access to profiling information. See Section 13.7.5.32, “SHOW PROFILES Syntax”.

- `profiling_history_size`

  The number of statements for which to maintain profiling information if `profiling` is enabled. The default value is 15. The maximum value is 100. Setting the value to 0 effectively disables profiling. See Section 13.7.5.32, “SHOW PROFILES Syntax”.

- `protocol_version`

System Variable	**Name**	`protocol_version`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer

The version of the client/server protocol used by the MySQL server.

- `proxy_user`

Introduced	5.5.7	
System Variable	**Name**	`proxy_user`
	Scope	Session
	Dynamic	No
Permitted Values	**Type**	string

If the current client is a proxy for another user, this variable is the proxy user account name. Otherwise, this variable is `NULL`. See Section 6.3.7, “Proxy Users”.

- `pseudo_slave_mode`

Introduced	5.5.30	
System Variable	**Name**	`pseudo_slave_mode`
	Scope	Session
	Dynamic	Yes
Permitted Values	**Type**	integer

This variable is for internal server use. It was added in MySQL 5.5.30.

- `pseudo_thread_id`

System Variable	**Name**	`pseudo_thread_id`
	Scope	Session
	Dynamic	Yes

Permitted Values	**Type**	integer

This variable is for internal server use.

- `query_alloc_block_size`

Command-Line Format	`--query-alloc-block-size=#`	
System Variable	**Name**	`query_alloc_block_size`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`8192`
	Minimum	`1024`
	Maximum	`4294967295`
	Block Size	`1024`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`8192`
	Minimum	`1024`
	Maximum	`18446744073709547520`
	Block Size	`1024`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`8192`
	Minimum	`1024`
	Maximum	`18446744073709551615`
	Block Size	`1024`

The allocation size of memory blocks that are allocated for objects created during statement parsing and execution. If you have problems with memory fragmentation, it might help to increase this parameter.

- `query_cache_limit`

Command-Line Format	`--query-cache-limit=#`	
System Variable	**Name**	`query_cache_limit`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`1048576`
	Minimum	`0`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`1048576`
	Minimum	`0`
	Maximum	`18446744073709547520`

Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	1048576
	Minimum	0
	Maximum	18446744073709551615

Do not cache results that are larger than this number of bytes. The default value is 1MB.

- `query_cache_min_res_unit`

Command-Line Format	`--query-cache-min-res-unit=#`	
System Variable	**Name**	`query_cache_min_res_unit`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	4096
	Minimum	512
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	4096
	Minimum	512
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	4096
	Minimum	512
	Maximum	18446744073709551615

The minimum size (in bytes) for blocks allocated by the query cache. The default value is 4096 (4KB). Tuning information for this variable is given in Section 8.10.3.3, “Query Cache Configuration”.

- `query_cache_size`

Command-Line Format	`--query-cache-size=#`	
System Variable	**Name**	`query_cache_size`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	0
	Minimum	0

	Maximum	18446744073709551615

The amount of memory allocated for caching query results. The default value is 0, which disables the query cache. To reduce overhead significantly, you should also start the server with `query_cache_type=0` if you will not be using the query cache.

The permissible values are multiples of 1024; other values are rounded down to the nearest multiple. For nonzero values of `query_cache_size`, that many bytes of memory are allocated even if `query_cache_type=0`. See Section 8.10.3.3, “Query Cache Configuration”, for more information.

The query cache needs a minimum size of about 40KB to allocate its structures. (The exact size depends on system architecture.) If you set the value of `query_cache_size` too small, a warning will occur, as described in Section 8.10.3.3, “Query Cache Configuration”.

- `query_cache_type`

Command-Line Format	`--query-cache-type=#`	
System Variable	**Name**	`query_cache_type`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`1`
	Valid Values	`0`
		`1`
		`2`

Set the query cache type. Setting the `GLOBAL` value sets the type for all clients that connect thereafter. Individual clients can set the `SESSION` value to affect their own use of the query cache. Possible values are shown in the following table.

Option	Description
`0` or `OFF`	Do not cache results in or retrieve results from the query cache. Note that this does not deallocate the query cache buffer. To do that, you should set `query_cache_size` to 0.
`1` or `ON`	Cache all cacheable query results except for those that begin with `SELECT SQL_NO_CACHE`.
`2` or `DEMAND`	Cache results only for cacheable queries that begin with `SELECT SQL_CACHE`.

This variable defaults to `ON`.

If the server is started with `query_cache_type` set to 0, it does not acquire the query cache mutex at all, which means that the query cache cannot be enabled at runtime and there is reduced overhead in query execution.

- `query_cache_wlock_invalidate`

Command-Line Format	`--query-cache-wlock-invalidate`	
System Variable	**Name**	`query_cache_wlock_invalidate`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`FALSE`

Normally, when one client acquires a `WRITE` lock on a `MyISAM` table, other clients are not blocked from issuing statements that read from the table if the query results are present in the query cache. Setting this variable to 1 causes acquisition of a `WRITE` lock for a table to invalidate any queries in the query cache that refer to the table. This forces other clients that attempt to access the table to wait while the lock is in effect.

- `query_prealloc_size`

Command-Line Format	`--query-prealloc-size=#`	
System Variable	**Name**	`query_prealloc_size`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`8192`
	Minimum	`8192`
	Maximum	`4294967295`
	Block Size	`1024`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`8192`
	Minimum	`8192`
	Maximum	`18446744073709547520`
	Block Size	`1024`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`8192`
	Minimum	`8192`
	Maximum	`18446744073709551615`
	Block Size	`1024`

The size of the persistent buffer used for statement parsing and execution. This buffer is not freed between statements. If you are running complex queries, a larger `query_prealloc_size` value might be helpful in improving performance, because it can reduce the need for the server to perform memory allocation during query execution operations.

- `rand_seed1`

The `rand_seed1` and `rand_seed2` variables exist as session variables only, and can be set but not read. The variables—but not their values—are shown in the output of `SHOW VARIABLES`.

The purpose of these variables is to support replication of the `RAND()` function. For statements that invoke `RAND()`, the master passes two values to the slave, where they are used to seed the random number generator. The slave uses these values to set the session variables `rand_seed1` and `rand_seed2` so that `RAND()` on the slave generates the same value as on the master.

- `rand_seed2`

See the description for `rand_seed1`.

- `range_alloc_block_size`

Command-Line Format	--range-alloc-block-size=#	
System Variable	Name	range_alloc_block_size
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	4096
	Minimum	4096
	Maximum	4294967295
	Block Size	1024
Permitted Values (64-bit platforms, >= 5.5.3)	Type	integer
	Default	4096
	Minimum	4096
	Maximum	18446744073709551615
	Block Size	1024

The size of blocks that are allocated when doing range optimization.

- read_buffer_size

Command-Line Format	--read-buffer-size=#	
System Variable	Name	read_buffer_size
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	131072
	Minimum	8200
	Maximum	2147479552

Each thread that does a sequential scan for a MyISAM table allocates a buffer of this size (in bytes) for each table it scans. If you do many sequential scans, you might want to increase this value, which defaults to 131072. The value of this variable should be a multiple of 4KB. If it is set to a value that is not a multiple of 4KB, its value will be rounded down to the nearest multiple of 4KB.

This option is also used in the following context for all storage engines:

- For caching the indexes in a temporary file (not a temporary table), when sorting rows for ORDER BY.
- For bulk insert into partitions.
- For caching results of nested queries.

and in one other storage engine-specific way: to determine the memory block size for MEMORY tables.

The maximum permissible setting for read_buffer_size is 2GB.

For more information about memory use during different operations, see Section 8.12.4.1, “How MySQL Uses Memory”.

- `read_only`

Command-Line Format	`--read-only`	
System Variable	Name	`read_only`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	`OFF`

When the `read_only` system variable is enabled, the server permits no client updates except from users who have the `SUPER` privilege. This variable is disabled by default.

Even with `read_only` enabled, the server permits these operations:

- Updates performed by slave threads, if the server is a replication slave. In replication setups, it can be useful to enable `read_only` on slave servers to ensure that slaves accept updates only from the master server and not from clients.
- Use of `ANALYZE TABLE` or `OPTIMIZE TABLE` statements. The purpose of read-only mode is to prevent changes to table structure or contents. Analysis and optimization do not qualify as such changes. This means, for example, that consistency checks on read-only replication slaves can be performed with `mysqlcheck --all-databases --analyze`.
- Operations on `TEMPORARY` tables.
- Inserts into the log tables (`mysql.general_log` and `mysql.slow_log`; see Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”).

`read_only` exists only as a `GLOBAL` variable, so changes to its value require the `SUPER` privilege. Changes to `read_only` on a master server are not replicated to slave servers. The value can be set on a slave server independent of the setting on the master.

The following conditions apply to attempts to enable `read_only`:

- The attempt fails and an error occurs if you have any explicit locks (acquired with `LOCK TABLES`) or have a pending transaction.
- The attempt blocks while other clients hold explicit table locks or have pending transactions, until the locks are released and the transactions end. While the attempt to enable `read_only` is pending, requests by other clients for table locks or to begin transactions also block until `read_only` has been set.
- As of MySQL 5.5.3, the attempt blocks if there are active transactions that hold metadata locks, until those transactions end.
- `read_only` can be enabled while you hold a global read lock (acquired with `FLUSH TABLES WITH READ LOCK`) because that does not involve table locks.

- `read_rnd_buffer_size`

Command-Line Format	`--read-rnd-buffer-size=#`	
System Variable	Name	`read_rnd_buffer_size`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (<= 5.5.2)	Type	integer
	Default	`262144`

	Minimum	8200
	Maximum	2147483647
Permitted Values (>= 5.5.3)	**Type**	integer
	Default	262144
	Minimum	1
	Maximum	2147483647

When reading rows from a `MyISAM` table in sorted order following a key-sorting operation, the rows are read through this buffer to avoid disk seeks. See Section 8.2.1.10, “ORDER BY Optimization”. Setting the variable to a large value can improve `ORDER BY` performance by a lot. However, this is a buffer allocated for each client, so you should not set the global variable to a large value. Instead, change the session variable only from within those clients that need to run large queries.

The maximum permissible setting for `read_rnd_buffer_size` is 2GB.

For more information about memory use during different operations, see Section 8.12.4.1, “How MySQL Uses Memory”.

- `relay_log_purge`

Command-Line Format	`--relay-log-purge`	
System Variable	**Name**	`relay_log_purge`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`TRUE`

Disables or enables automatic purging of relay log files as soon as they are not needed any more. The default value is 1 (`ON`).

- `relay_log_space_limit`

Command-Line Format	`--relay-log-space-limit=#`	
System Variable	**Name**	`relay_log_space_limit`
	Scope	Global
	Dynamic	No
Permitted Values (32-bit platforms)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	18446744073709551615

The maximum amount of space to use for all relay logs.

- `report_host`

Command-Line Format	`--report-host=host_name`	
System Variable	Name	`report_host`
	Scope	Global
	Dynamic	No
Permitted Values	Type	string

The value of the `--report-host` option.

- `report_password`

Command-Line Format	`--report-password=name`	
System Variable	Name	`report_password`
	Scope	Global
	Dynamic	No
Permitted Values	Type	string

The value of the `--report-password` option. Not the same as the password used for the MySQL replication user account.

- `report_port`

Command-Line Format	`--report-port=#`	
System Variable	Name	`report_port`
	Scope	Global
	Dynamic	No
Permitted Values (<= 5.5.22)	Type	integer
	Default	`3306`
	Minimum	`0`
	Maximum	`65535`
Permitted Values (>= 5.5.23)	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`65535`

The value of the `--report-port` option.

- `report_user`

Command-Line Format	`--report-user=name`	
System Variable	Name	`report_user`
	Scope	Global
	Dynamic	No
Permitted Values	Type	string

The value of the `--report-user` option. Not the same as the name for the MySQL replication user account.

- `rpl_semi_sync_master_enabled`

System Variable	Name	rpl_semi_sync_master_enabled
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	OFF

Controls whether semisynchronous replication is enabled on the master. To enable or disable the plugin, set this variable to `ON` or `OFF` (or 1 or 0), respectively. The default is `OFF`.

This variable is available only if the master-side semisynchronous replication plugin is installed.

- `rpl_semi_sync_master_timeout`

System Variable	Name	rpl_semi_sync_master_timeout
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	10000

A value in milliseconds that controls how long the master waits on a commit for acknowledgment from a slave before timing out and reverting to asynchronous replication. The default value is 10000 (10 seconds).

This variable is available only if the master-side semisynchronous replication plugin is installed.

- `rpl_semi_sync_master_trace_level`

System Variable	Name	rpl_semi_sync_master_trace_level
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	32

The semisynchronous replication debug trace level on the master. Four levels are defined:

- 1 = general level (for example, time function failures)
- 16 = detail level (more verbose information)
- 32 = net wait level (more information about network waits)
- 64 = function level (information about function entry and exit)

This variable is available only if the master-side semisynchronous replication plugin is installed.

- `rpl_semi_sync_master_wait_no_slave`

System Variable	Name	rpl_semi_sync_master_wait_no_slave
	Scope	Global

	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`ON`

With semisynchronous replication, for each transaction, the master waits until timeout for acknowledgment of receipt from some semisynchronous slave. If no response occurs during this period, the master reverts to normal replication. This variable controls whether the master waits for the timeout to expire before reverting to normal replication even if the slave count drops to zero during the timeout period.

If the value is `ON` (the default), it is permissible for the slave count to drop to zero during the timeout period (for example, if slaves disconnect). The master still waits for the timeout, so as long as some slave reconnects and acknowledges the transaction within the timeout interval, semisynchronous replication continues.

If the value is `OFF`, the master reverts to normal replication if the slave count drops to zero during the timeout period.

This variable is available only if the master-side semisynchronous replication plugin is installed.

- `rpl_semi_sync_slave_enabled`

System Variable	**Name**	`rpl_semi_sync_slave_enabled`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Controls whether semisynchronous replication is enabled on the slave. To enable or disable the plugin, set this variable to `ON` or `OFF` (or 1 or 0), respectively. The default is `OFF`.

This variable is available only if the slave-side semisynchronous replication plugin is installed.

- `rpl_semi_sync_slave_trace_level`

System Variable	**Name**	`rpl_semi_sync_slave_trace_level`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`32`

The semisynchronous replication debug trace level on the slave. See `rpl_semi_sync_master_trace_level` for the permissible values.

This variable is available only if the slave-side semisynchronous replication plugin is installed.

- `secure_auth`

Command-Line Format	`--secure-auth`	
System Variable	**Name**	`secure_auth`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean

	Default	`OFF`

If this variable is enabled, the server blocks connections by clients that attempt to use accounts that have passwords stored in the old (pre-4.1) format.

Enable this variable to prevent all use of passwords employing the old format (and hence insecure communication over the network).

Server startup fails with an error if this variable is enabled and the privilege tables are in pre-4.1 format. See Section B.5.2.4, “Client does not support authentication protocol”.

Note

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

- `secure_file_priv`

Command-Line Format	`--secure-file-priv=dir_name`	
System Variable	**Name**	`secure_file_priv`
	Scope	Global
	Dynamic	No
Permitted Values (<= 5.5.52)	**Type**	string
	Default	`empty`
	Valid Values	`empty`
		`dirname`
Permitted Values (>= 5.5.53)	**Type**	string
	Default	`platform specific`
	Valid Values	`empty`
		`dirname`
		`NULL`

This variable is used to limit the effect of data import and export operations, such as those performed by the `LOAD DATA` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. These operations are permitted only to users who have the `FILE` privilege.

`secure_file_priv` may be set as follows:

- If empty, the variable has no effect. This is not a secure setting.
- If set to the name of a directory, the server limits import and export operations to work only with files in that directory. The directory must exist; the server will not create it.
- If set to `NULL`, the server disables import and export operations. This value is permitted as of MySQL 5.5.53.

Before MySQL 5.5.53, this variable is empty by default. As of 5.5.53, the default value is platform specific and depends on the value of the `INSTALL_LAYOUT` `CMake` option, as shown in the following table. To specify the default `secure_file_priv` value explicitly if you are building from source, use the `INSTALL_SECURE_FILE_PRIVDIR` `CMake` option.

`INSTALL_LAYOUT` Value	**Default `secure_file_priv` Value**
`STANDALONE`, `WIN`	`NULL`

INSTALL_LAYOUT Value	Default secure_file_priv Value
DEB, RPM, SLES, SVR4	/var/lib/mysql-files
Otherwise	mysql-files under the CMAKE_INSTALL_PREFIX value

To set the default secure_file_priv value for the libmysqld embedded server, use the INSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR CMake option. The default value for this option is NULL.

As of MySQL 5.5.53, the server checks the value of secure_file_priv at startup and writes a warning to the error log if the value is insecure. A non-NULL value is considered insecure if it is empty, or the value is the data directory or a subdirectory of it, or a directory that is accessible by all users. If secure_file_priv is set to a nonexistent path, the server writes an error message to the error log and exits.

- server_id

Command-Line Format	--server-id=#	
System Variable	Name	server_id
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	0
	Minimum	0
	Maximum	4294967295

The server ID, used in replication to give each master and slave a unique identity. This variable is set by the --server-id option. For each server participating in replication, you should pick a positive integer in the range from 1 to 2^{32} − 1 to act as that server's ID.

- shared_memory

Command-Line Format	--shared-memory[={0,1}]	
System Variable	Name	shared_memory
	Scope	Global
	Dynamic	No
Platform Specific	Windows	
Permitted Values	Type	boolean
	Default	FALSE

(Windows only.) Whether the server permits shared-memory connections.

- shared_memory_base_name

Command-Line Format	--shared-memory-base-name=name	
System Variable	Name	shared_memory_base_name
	Scope	Global
	Dynamic	No
Platform Specific	Windows	
Permitted Values	Type	string
	Default	MYSQL

(Windows only.) The name of shared memory to use for shared-memory connections. This is useful when running multiple MySQL instances on a single physical machine. The default name is `MYSQL`. The name is case sensitive.

- `skip_external_locking`

Command-Line Format	`--skip-external-locking`	
System Variable	Name	`skip_external_locking`
	Scope	Global
	Dynamic	No
Permitted Values	Type	boolean
	Default	`ON`

This is `OFF` if `mysqld` uses external locking (system locking), `ON` if external locking is disabled. This affects only `MyISAM` table access.

This variable is set by the `--external-locking` or `--skip-external-locking` option. External locking is disabled by default.

External locking affects only `MyISAM` table access. For more information, including conditions under which it can and cannot be used, see Section 8.11.5, “External Locking”.

- `skip_name_resolve`

Command-Line Format	`--skip-name-resolve`	
System Variable	Name	`skip_name_resolve`
	Scope	Global
	Dynamic	No
Permitted Values	Type	boolean
	Default	`OFF`

This variable is set from the value of the `--skip-name-resolve` option. If it is `OFF`, `mysqld` resolves host names when checking client connections. If it is `ON`, `mysqld` uses only IP numbers; in this case, all `Host` column values in the grant tables must be IP addresses or `localhost`. See Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

- `skip_networking`

Command-Line Format	`--skip-networking`	
System Variable	Name	`skip_networking`
	Scope	Global
	Dynamic	No

This is `ON` if the server permits only local (non-TCP/IP) connections. On Unix, local connections use a Unix socket file. On Windows, local connections use a named pipe or shared memory. This variable can be set to `ON` with the `--skip-networking` option.

- `skip_show_database`

Command-Line Format	`--skip-show-database`	
System Variable	Name	`skip_show_database`
	Scope	Global

	Dynamic	No

This prevents people from using the `SHOW DATABASES` statement if they do not have the `SHOW DATABASES` privilege. This can improve security if you have concerns about users being able to see databases belonging to other users. Its effect depends on the `SHOW DATABASES` privilege: If the variable value is `ON`, the `SHOW DATABASES` statement is permitted only to users who have the `SHOW DATABASES` privilege, and the statement displays all database names. If the value is `OFF`, `SHOW DATABASES` is permitted to all users, but displays the names of only those databases for which the user has the `SHOW DATABASES` or other privilege. (Note that *any* global privilege is considered a privilege for the database.)

- `slow_launch_time`

Command-Line Format	`--slow-launch-time=#`	
System Variable	**Name**	`slow_launch_time`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	2

If creating a thread takes longer than this many seconds, the server increments the `Slow_launch_threads` status variable.

- `slow_query_log`

Command-Line Format	`--slow-query-log`	
System Variable	**Name**	`slow_query_log`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Whether the slow query log is enabled. The value can be 0 (or `OFF`) to disable the log or 1 (or `ON`) to enable the log. The default value depends on whether the `--slow_query_log` option is given. The destination for log output is controlled by the `log_output` system variable; if that value is `NONE`, no log entries are written even if the log is enabled.

"Slow" is determined by the value of the `long_query_time` variable. See Section 5.4.5, "The Slow Query Log".

- `slow_query_log_file`

Command-Line Format	`--slow-query-log-file=file_name`	
System Variable	**Name**	`slow_query_log_file`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	file name
	Default	`host_name-slow.log`

The name of the slow query log file. The default value is *`host_name`*`-slow.log`, but the initial value can be changed with the `--slow_query_log_file` option.

- `socket`

Command-Line Format	--socket={file_name|pipe_name}	
System Variable	Name	socket
	Scope	Global
	Dynamic	No
Permitted Values (Windows)	Type	string
	Default	MySQL
Permitted Values (Other)	Type	string
	Default	/tmp/mysql.sock

On Unix platforms, this variable is the name of the socket file that is used for local client connections. The default is /tmp/mysql.sock. (For some distribution formats, the directory might be different, such as /var/lib/mysql for RPMs.)

On Windows, this variable is the name of the named pipe that is used for local client connections. The default value is MySQL (not case sensitive).

- sort_buffer_size

Command-Line Format	--sort-buffer-size=#	
System Variable	Name	sort_buffer_size
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (Windows)	Type	integer
	Default	2097144
	Minimum	32768
	Maximum	4294967295
Permitted Values (Other, 32-bit platforms)	Type	integer
	Default	2097144
	Minimum	32768
	Maximum	4294967295
Permitted Values (Other, 64-bit platforms)	Type	integer
	Default	2097144
	Minimum	32768
	Maximum	18446744073709551615

Each session that must perform a sort allocates a buffer of this size. sort_buffer_size is not specific to any storage engine and applies in a general manner for optimization. At minimum the sort_buffer_size value must be large enough to accommodate fifteen tuples in the sort buffer. Also, increasing the value of max_sort_length may require increasing the value of sort_buffer_size. For more information, see Section 8.2.1.10, “ORDER BY Optimization”

If you see many Sort_merge_passes per second in SHOW GLOBAL STATUS output, you can consider increasing the sort_buffer_size value to speed up ORDER BY or GROUP BY operations that cannot be improved with query optimization or improved indexing. The entire buffer is allocated even if it is not all needed, so setting it larger than required globally will slow down most queries that sort. It is best to increase it as a session setting, and only for the sessions that need a larger size. On Linux, there are thresholds of 256KB and 2MB where larger values may significantly slow down memory allocation, so you should consider staying below one of those values. Experiment to find the best value for your workload. See Section B.5.3.5, “Where MySQL Stores Temporary Files”.

The maximum permissible setting for `sort_buffer_size` is 4GB−1. Larger values are permitted for 64-bit platforms (except 64-bit Windows, for which large values are truncated to 4GB−1 with a warning).

- `sql_auto_is_null`

System Variable (<= 5.5.2)	**Name**	`sql_auto_is_null`
	Scope	Session
	Dynamic	Yes
System Variable (>= 5.5.3)	**Name**	`sql_auto_is_null`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (<= 5.5.2)	**Type**	boolean
	Default	`1`
Permitted Values (>= 5.5.3)	**Type**	boolean
	Default	`0`

If this variable is set to 1, then after a statement that successfully inserts an automatically generated `AUTO_INCREMENT` value, you can find that value by issuing a statement of the following form:

```
SELECT * FROM tbl_name WHERE auto_col IS NULL
```

If the statement returns a row, the value returned is the same as if you invoked the `LAST_INSERT_ID()` function. For details, including the return value after a multiple-row insert, see Section 12.14, “Information Functions”. If no `AUTO_INCREMENT` value was successfully inserted, the `SELECT` statement returns no row.

The behavior of retrieving an `AUTO_INCREMENT` value by using an `IS NULL` comparison is used by some ODBC programs, such as Access. See Obtaining Auto-Increment Values. This behavior can be disabled by setting `sql_auto_is_null` to 0.

The default value of `sql_auto_is_null` is 0 as of MySQL 5.5.3, and 1 for earlier versions.

- `sql_big_selects`

System Variable (<= 5.5.2)	**Name**	`sql_big_selects`
	Scope	Session
	Dynamic	Yes
System Variable (>= 5.5.3)	**Name**	`sql_big_selects`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`1`

If set to 0, MySQL aborts `SELECT` statements that are likely to take a very long time to execute (that is, statements for which the optimizer estimates that the number of examined rows exceeds the value of `max_join_size`). This is useful when an inadvisable `WHERE` statement has been issued. The default value for a new connection is 1, which permits all `SELECT` statements.

If you set the `max_join_size` system variable to a value other than `DEFAULT`, `sql_big_selects` is set to 0.

- `sql_buffer_result`

System Variable (<= 5.5.2)	**Name**	`sql_buffer_result`
	Scope	Session
	Dynamic	Yes
System Variable (>= 5.5.3)	**Name**	`sql_buffer_result`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`0`

If set to 1, `sql_buffer_result` forces results from `SELECT` statements to be put into temporary tables. This helps MySQL free the table locks early and can be beneficial in cases where it takes a long time to send results to the client. The default value is 0.

- `sql_log_bin`

System Variable (<= 5.5.2)	**Name**	`sql_log_bin`
	Scope	Session
	Dynamic	Yes
System Variable (>= 5.5.3, <= 5.5.40)	**Name**	`sql_log_bin`
	Scope	Global, Session
	Dynamic	Yes
System Variable (>= 5.5.41)	**Name**	`sql_log_bin`
	Scope	Session
	Dynamic	Yes
Permitted Values	**Type**	boolean

This variable controls whether logging to the binary log is done. The default value is 1 (do logging). To change logging for the current session, change the session value of this variable. The session user must have the `SUPER` privilege to set this variable.

It is not possible to set `@@session.sql_log_bin` within a transaction or subquery.

As of MySQL 5.5.41, the global `sql_log_bin` variable is read only and cannot be modified. The global scope is deprecated and will be removed in a future MySQL release. Prior to 5.5.41, `sql_log_bin` can be set as a global or session variable. Setting `sql_log_bin` globally is only detected when a new session is started. Any sessions previously running are not impacted when setting `sql_log_bin` globally.

Warning

Incorrect use of `sql_log_bin` with a global scope means any changes made in an already running session are *still* being recorded to the binary log and therefore replicated. Exercise extreme caution using `sql_log_bin` with a global scope as the above situation could cause unexpected results including replication failure.

- `sql_log_off`

System Variable (<= 5.5.2)	**Name**	`sql_log_off`
	Scope	Session

	Dynamic	Yes
System Variable (>= 5.5.3)	**Name**	`sql_log_off`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`0`

This variable controls whether logging to the general query log is done. The default value is 0 (do logging). To change logging for the current session, change the session value of this variable. The session user must have the `SUPER` privilege to set this option. The default value is 0.

- `sql_log_update`

Deprecated	5.0.0, by `sql_log_bin`	
Removed	5.5.3	
System Variable	**Name**	`sql_log_update`
	Scope	Session
	Dynamic	Yes
Permitted Values	**Type**	boolean

This variable is deprecated, and is mapped to `sql_log_bin`. It was removed in MySQL 5.5.3.

- `sql_mode`

Command-Line Format	`--sql-mode=name`	
System Variable	**Name**	`sql_mode`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	set
	Default	`''`
	Valid Values	`ALLOW_INVALID_DATES`
		`ANSI_QUOTES`
		`ERROR_FOR_DIVISION_BY_ZERO`
		`HIGH_NOT_PRECEDENCE`
		`IGNORE_SPACE`
		`NO_AUTO_CREATE_USER`
		`NO_AUTO_VALUE_ON_ZERO`
		`NO_BACKSLASH_ESCAPES`
		`NO_DIR_IN_CREATE`
		`NO_ENGINE_SUBSTITUTION`
		`NO_FIELD_OPTIONS`
		`NO_KEY_OPTIONS`
		`NO_TABLE_OPTIONS`
		`NO_UNSIGNED_SUBTRACTION`
		`NO_ZERO_DATE`
		`NO_ZERO_IN_DATE`

		ONLY_FULL_GROUP_BY
		PAD_CHAR_TO_FULL_LENGTH
		PIPES_AS_CONCAT
		REAL_AS_FLOAT
		STRICT_ALL_TABLES
		STRICT_TRANS_TABLES

The current server SQL mode, which can be set dynamically. For details, see Section 5.1.8, “Server SQL Modes”.

Note

MySQL installation programs may configure the SQL mode during the installation process. If the SQL mode differs from the default or from what you expect, check for a setting in an option file that the server reads at startup.

- `sql_notes`

  If set to 1 (the default), warnings of `Note` level increment `warning_count` and the server records them. If set to 0, `Note` warnings do not increment `warning_count` and the server does not record them. `mysqldump` includes output to set this variable to 0 so that reloading the dump file does not produce warnings for events that do not affect the integrity of the reload operation.

- `sql_quote_show_create`

  If set to 1 (the default), the server quotes identifiers for `SHOW CREATE TABLE` and `SHOW CREATE DATABASE` statements. If set to 0, quoting is disabled. This option is enabled by default so that replication works for identifiers that require quoting. See Section 13.7.5.12, “SHOW CREATE TABLE Syntax”, and Section 13.7.5.8, “SHOW CREATE DATABASE Syntax”.

- `sql_safe_updates`

  If set to 1, MySQL aborts `UPDATE` or `DELETE` statements that do not use a key in the `WHERE` clause or a `LIMIT` clause. (Specifically, `UPDATE` statements must have a `WHERE` clause that uses a key or a `LIMIT` clause, or both. `DELETE` statements must have both.) This makes it possible to catch `UPDATE` or `DELETE` statements where keys are not used properly and that would probably change or delete a large number of rows. The default value is 0.

- `sql_select_limit`

System Variable	**Name**	`sql_select_limit`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	integer

  The maximum number of rows to return from `SELECT` statements. The default value for a new connection is the maximum number of rows that the server permits per table. Typical default values are $(2^{32})-1$ or $(2^{64})-1$. If you have changed the limit, the default value can be restored by assigning a value of `DEFAULT`.

  If a `SELECT` has a `LIMIT` clause, the `LIMIT` takes precedence over the value of `sql_select_limit`.

- `sql_warnings`

  This variable controls whether single-row `INSERT` statements produce an information string if warnings occur. The default is 0. Set the value to 1 to produce an information string.

- `ssl_ca`

Command-Line Format	`--ssl-ca=file_name`	
System Variable	Name	`ssl_ca`
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The path to a file with a list of trusted SSL Certificate Authorities.

- `ssl_capath`

Command-Line Format	`--ssl-capath=dir_name`	
System Variable	Name	`ssl_capath`
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The path to a directory that contains trusted SSL CA certificates in PEM format.

- `ssl_cert`

Command-Line Format	`--ssl-cert=file_name`	
System Variable	Name	`ssl_cert`
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The name of the SSL certificate file to use for establishing a secure connection.

- `ssl_cipher`

Command-Line Format	`--ssl-cipher=name`	
System Variable	Name	`ssl_cipher`
	Scope	Global
	Dynamic	No
Permitted Values	Type	string

The list of permitted ciphers for SSL encryption.

- `ssl_key`

Command-Line Format	`--ssl-key=file_name`	
System Variable	Name	`ssl_key`
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The name of the SSL key file to use for establishing a secure connection.

- `storage_engine`

System Variable	Name	storage_engine
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (<= 5.5.4)	Type	enumeration
	Default	MyISAM
Permitted Values (>= 5.5.5)	Type	enumeration
	Default	InnoDB

The default storage engine (table type). To set the storage engine at server startup, use the `--default-storage-engine` option. See Section 5.1.4, “Server Command Options”.

This variable is deprecated as of MySQL 5.5.3. Use `default_storage_engine` instead.

- `stored_program_cache`

Introduced	5.5.21	
Command-Line Format	`--stored-program-cache=#`	
System Variable	Name	stored_program_cache
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	256
	Minimum	256
	Maximum	524288

Sets a soft upper limit for the number of cached stored routines per connection. The value of this variable is specified in terms of the number of stored routines held in each of the two caches maintained by the MySQL Server for, respectively, stored procedures and stored functions.

Whenever a stored routine is executed this cache size is checked before the first or top-level statement in the routine is parsed; if the number of routines of the same type (stored procedures or stored functions according to which is being executed) exceeds the limit specified by this variable, the corresponding cache is flushed and memory previously allocated for cached objects is freed. This allows the cache to be flushed safely, even when there are dependencies between stored routines.

- `sync_frm`

Command-Line Format	`--sync-frm`	
System Variable	Name	sync_frm
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	TRUE

If this variable is set to 1, when any nontemporary table is created its `.frm` file is synchronized to disk (using `fdatasync()`). This is slower but safer in case of a crash. The default is 1.

- `system_time_zone`

System Variable	Name	system_time_zone

	Scope	Global
	Dynamic	No
Permitted Values	**Type**	string

The server system time zone. When the server begins executing, it inherits a time zone setting from the machine defaults, possibly modified by the environment of the account used for running the server or the startup script. The value is used to set `system_time_zone`. Typically the time zone is specified by the `TZ` environment variable. It also can be specified using the `--timezone` option of the `mysqld_safe` script.

The `system_time_zone` variable differs from `time_zone`. Although they might have the same value, the latter variable is used to initialize the time zone for each client that connects. See Section 10.6, “MySQL Server Time Zone Support”.

- `table_definition_cache`

System Variable	**Name**	`table_definition_cache`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`400`
	Minimum	`400`
	Maximum	`524288`

The number of table definitions (from `.frm` files) that can be stored in the definition cache. If you use a large number of tables, you can create a large table definition cache to speed up opening of tables. The table definition cache takes less space and does not use file descriptors, unlike the normal table cache. The minimum and default values are both 400.

- `table_lock_wait_timeout`

Removed	5.5.3	
Command-Line Format	`--table-lock-wait-timeout=#`	
System Variable	**Name**	`table_lock_wait_timeout`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`50`
	Minimum	`1`
	Maximum	`1073741824`

This variable is unused. It was removed in 5.5.3.

- `table_open_cache`

System Variable	**Name**	`table_open_cache`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`400`

	Minimum	1
	Maximum	524288

The number of open tables for all threads. Increasing this value increases the number of file descriptors that `mysqld` requires. You can check whether you need to increase the table cache by checking the `Opened_tables` status variable. See Section 5.1.7, “Server Status Variables”. If the value of `Opened_tables` is large and you do not use `FLUSH TABLES` often (which just forces all tables to be closed and reopened), then you should increase the value of the `table_open_cache` variable. For more information about the table cache, see Section 8.4.3.1, “How MySQL Opens and Closes Tables”.

- `table_type`

  This variable was removed in MySQL 5.5.3. Use `storage_engine` instead.

- `thread_cache_size`

Command-Line Format	`--thread-cache-size=#`	
System Variable	**Name**	`thread_cache_size`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`16384`

How many threads the server should cache for reuse. When a client disconnects, the client's threads are put in the cache if there are fewer than `thread_cache_size` threads there. Requests for threads are satisfied by reusing threads taken from the cache if possible, and only when the cache is empty is a new thread created. This variable can be increased to improve performance if you have a lot of new connections. Normally, this does not provide a notable performance improvement if you have a good thread implementation. However, if your server sees hundreds of connections per second you should normally set `thread_cache_size` high enough so that most new connections use cached threads. By examining the difference between the `Connections` and `Threads_created` status variables, you can see how efficient the thread cache is. For details, see Section 5.1.7, “Server Status Variables”.

- `thread_concurrency`

Command-Line Format	`--thread-concurrency=#`	
System Variable	**Name**	`thread_concurrency`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`10`
	Minimum	`1`
	Maximum	`512`

This variable is specific to Solaris 8 and earlier systems, for which `mysqld` invokes the `thr_setconcurrency()` function with the variable value. This function enables applications to give the threads system a hint about the desired number of threads that should be run at the same time. Current Solaris versions document this as having no effect.

- `thread_handling`

Command-Line Format	`--thread-handling=name`	
System Variable	Name	`thread_handling`
	Scope	Global
	Dynamic	No
Permitted Values (<= 5.5.13)	Type	enumeration
	Default	`one-thread-per-connection`
	Valid Values	`no-threads`
		`one-thread-per-connection`
Permitted Values (>= 5.5.16)	Type	enumeration
	Default	`one-thread-per-connection`
	Valid Values	`no-threads`
		`one-thread-per-connection`
		`dynamically-loaded`

The thread-handling model used by the server for connection threads. The permissible user-settable values are `no-threads` (the server uses a single thread to handle one connection) and `one-thread-per-connection` (the server uses one thread to handle each client connection; this is the default). `no-threads` is useful for debugging under Linux; see Section 24.5, “Debugging and Porting MySQL”.

If the thread pool plugin is enabled, the server sets the `thread_handling` value to `dynamically-loaded`. See Section 5.5.3.2, “Thread Pool Installation”.

- `thread_pool_algorithm`

Introduced	5.5.16	
Command-Line Format	`--thread-pool-algorithm=#`	
System Variable	Name	`thread_pool_algorithm`
	Scope	Global
	Dynamic	No
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`1`

This variable controls which algorithm the thread pool plugin uses:

- A value of 0 (the default) uses a conservative low-concurrency algorithm which is most well tested and is known to produce very good results.
- A value of 1 increases the concurrency and uses a more aggressive algorithm which at times has been known to perform 5–10% better on optimal thread counts, but has degrading performance as the number of connections increases. Its use should be considered as experimental and not supported.

  This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

- `thread_pool_high_priority_connection`

Introduced	5.5.16	
Command-Line Format	`--thread-pool-high-priority-connection=#`	
System Variable	Name	`thread_pool_high_priority_connection`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`1`

This variable affects queuing of new statements prior to execution. If the value is 0 (false, the default), statement queuing uses both the low-priority and high-priority queues. If the value is 1 (true), queued statements always go to the high-priority queue.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

- `thread_pool_max_unused_threads`

Introduced	5.5.16	
Command-Line Format	`--thread-pool-max-unused-threads=#`	
System Variable	Name	`thread_pool_max_unused_threads`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4096`

The maximum permitted number of unused threads in the thread pool. This variable makes it possible to limit the amount of memory used by sleeping threads.

A value of 0 (the default) means no limit on the number of sleeping threads. A value of *N* where *N* is greater than 0 means 1 consumer thread and *N*−1 reserve threads. In this case, if a thread is ready to sleep but the number of sleeping threads is already at the maximum, the thread exits rather than going to sleep.

A sleeping thread is either sleeping as a consumer thread or a reserve thread. The thread pool permits one thread to be the consumer thread when sleeping. If a thread goes to sleep and there is no existing consumer thread, it will sleep as a consumer thread. When a thread must be woken up, a consumer thread is selected if there is one. A reserve thread is selected only when there is no consumer thread to wake up.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

- `thread_pool_prio_kickup_timer`

Introduced	5.5.16	
Command-Line Format	`--thread-pool-prio-kickup-timer=#`	
System Variable	Name	`thread_pool_prio_kickup_timer`

	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	1000
	Minimum	0
	Maximum	4294967294

This variable affects statements waiting for execution in the low-priority queue. The value is the number of milliseconds before a waiting statement is moved to the high-priority queue. The default is 1000 (1 second). The range of values is 0 to $2^{32} - 2$.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

- `thread_pool_size`

Introduced	5.5.16	
Command-Line Format	`--thread-pool-size=#`	
System Variable	**Name**	`thread_pool_size`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	16
	Minimum	1
	Maximum	64

The number of thread groups in the thread pool. This is the most important parameter controlling thread pool performance. It affects how many statements can execute simultaneously. The default value is 16, with a range from 1 to 64 of permissible values. If a value outside this range is specified, the thread pool plugin does not load and the server writes a message to the error log.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

- `thread_pool_stall_limit`

Introduced	5.5.16	
Command-Line Format	`--thread-pool-stall-limit=#`	
System Variable	**Name**	`thread_pool_stall_limit`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	6
	Minimum	4
	Maximum	600

This variable affects executing statements. The value is the amount of time a statement has to finish after starting to execute before it becomes defined as stalled, at which point the thread pool permits the thread group to begin executing another statement. The value is measured in 10 millisecond units, so a value of 6 (the default) means 60ms. The range of values is 4 to 600 (40ms to 6s). Short

wait values permit threads to start more quickly. Short values are also better for avoiding deadlock situations. Long wait values are useful for workloads that include long-running statements, to avoid starting too many new statements while the current ones execute.

This variable was added in MySQL 5.5.16. It is available only if the thread pool plugin is enabled. See Section 5.5.3, “MySQL Enterprise Thread Pool”

- `thread_stack`

Command-Line Format	`--thread-stack=#`	
System Variable	**Name**	`thread_stack`
	Scope	Global
	Dynamic	No
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`196608`
	Minimum	`131072`
	Maximum	`4294967295`
	Block Size	`1024`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`262144`
	Minimum	`131072`
	Maximum	`18446744073709547520`
	Block Size	`1024`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`262144`
	Minimum	`131072`
	Maximum	`18446744073709551615`
	Block Size	`1024`

The stack size for each thread. Many of the limits detected by the `crash-me` test are dependent on this value. See Section 8.13.2, “The MySQL Benchmark Suite”. The default of 192KB (256KB for 64-bit systems) is large enough for normal operation. If the thread stack size is too small, it limits the complexity of the SQL statements that the server can handle, the recursion depth of stored procedures, and other memory-consuming actions.

- `time_format`

This variable is unused.

- `time_zone`

System Variable	**Name**	`time_zone`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	string

The current time zone. This variable is used to initialize the time zone for each client that connects. By default, the initial value of this is `'SYSTEM'` (which means, “use the value of

system_time_zone"). The value can be specified explicitly at server startup with the --default-time-zone option. See Section 10.6, "MySQL Server Time Zone Support".

Note

If set to SYSTEM, every MySQL function call that requires a timezone calculation makes a system library call to determine the current system timezone. This call may be protected by a global mutex, resulting in contention.

- timed_mutexes

Deprecated	5.5.39	
Command-Line Format	--timed-mutexes	
System Variable	**Name**	timed_mutexes
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	OFF

This variable is deprecated; it has no use. It will be removed in a future MySQL release.

- timestamp

System Variable	**Name**	timestamp
	Scope	Session
	Dynamic	Yes
Permitted Values	**Type**	numeric

Set the time for this client. This is used to get the original timestamp if you use the binary log to restore rows. *timestamp_value* should be a Unix epoch timestamp (a value like that returned by UNIX_TIMESTAMP(), not a value in 'YYYY-MM-DD hh:mm:ss' format) or DEFAULT.

Setting timestamp to a constant value causes it to retain that value until it is changed again. Setting timestamp to DEFAULT causes its value to be the current date and time as of the time it is accessed.

SET timestamp affects the value returned by NOW() but not by SYSDATE(). This means that timestamp settings in the binary log have no effect on invocations of SYSDATE(). The server can be started with the --sysdate-is-now option to cause SYSDATE() to be an alias for NOW(), in which case SET timestamp affects both functions.

- tmp_table_size

Command-Line Format	--tmp-table-size=#	
System Variable	**Name**	tmp_table_size
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	16777216
	Minimum	1024
	Maximum	18446744073709551615

The maximum size of internal in-memory temporary tables. This variable does not apply to user-created `MEMORY` tables.

The actual limit is determined from whichever of the values of `tmp_table_size` and `max_heap_table_size` is smaller. If an in-memory temporary table exceeds the limit, MySQL automatically converts it to an on-disk `MyISAM` table. Increase the value of `tmp_table_size` (and `max_heap_table_size` if necessary) if you do many advanced `GROUP BY` queries and you have lots of memory.

You can compare the number of internal on-disk temporary tables created to the total number of internal temporary tables created by comparing the values of the `Created_tmp_disk_tables` and `Created_tmp_tables` variables.

See also Section 8.4.4, “Internal Temporary Table Use in MySQL”.

- `tmpdir`

Command-Line Format	`--tmpdir=dir_name`	
System Variable	**Name**	`tmpdir`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	directory name

The directory used for temporary files and temporary tables. This variable can be set to a list of several paths that are used in round-robin fashion. Paths should be separated by colon characters (`:`) on Unix and semicolon characters (`;`) on Windows.

The multiple-directory feature can be used to spread the load between several physical disks. If the MySQL server is acting as a replication slave, you should not set `tmpdir` to point to a directory on a memory-based file system or to a directory that is cleared when the server host restarts. A replication slave needs some of its temporary files to survive a machine restart so that it can replicate temporary tables or `LOAD DATA INFILE` operations. If files in the temporary file directory are lost when the server restarts, replication fails. You can set the slave's temporary directory using the `slave_load_tmpdir` variable. In that case, the slave will not use the general `tmpdir` value and you can set `tmpdir` to a nonpermanent location.

- `transaction_alloc_block_size`

Command-Line Format	`--transaction-alloc-block-size=#`	
System Variable	**Name**	`transaction_alloc_block_size`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (>= 5.5.43)	**Type**	integer
	Default	`8192`
	Minimum	`1024`
	Maximum	`131072`
	Block Size	`1024`
Permitted Values (32-bit platforms, <= 5.5.42)	**Type**	integer
	Default	`8192`
	Minimum	`1024`
	Maximum	`4294967295`

	Block Size	1024
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	8192
	Minimum	1024
	Maximum	18446744073709547520
	Block Size	1024
Permitted Values (64-bit platforms, >= 5.5.3, <= 5.5.42)	**Type**	integer
	Default	8192
	Minimum	1024
	Maximum	18446744073709551615
	Block Size	1024

The amount in bytes by which to increase a per-transaction memory pool which needs memory. See the description of `transaction_prealloc_size`.

- `transaction_prealloc_size`

Command-Line Format	`--transaction-prealloc-size=#`	
System Variable	**Name**	`transaction_prealloc_size`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (>= 5.5.43)	**Type**	integer
	Default	4096
	Minimum	1024
	Maximum	131072
	Block Size	1024
Permitted Values (32-bit platforms, <= 5.5.42)	**Type**	integer
	Default	4096
	Minimum	1024
	Maximum	4294967295
	Block Size	1024
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	4096
	Minimum	1024
	Maximum	18446744073709547520
	Block Size	1024
Permitted Values (64-bit platforms, >= 5.5.3, <= 5.5.42)	**Type**	integer
	Default	4096
	Minimum	1024
	Maximum	18446744073709551615

	Block Size	1024

There is a per-transaction memory pool from which various transaction-related allocations take memory. The initial size of the pool in bytes is `transaction_prealloc_size`. For every allocation that cannot be satisfied from the pool because it has insufficient memory available, the pool is increased by `transaction_alloc_block_size` bytes. When the transaction ends, the pool is truncated to `transaction_prealloc_size` bytes.

By making `transaction_prealloc_size` sufficiently large to contain all statements within a single transaction, you can avoid many `malloc()` calls.

- `tx_isolation`

System Variable	**Name**	`tx_isolation`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`REPEATABLE-READ`
	Valid Values	`READ-UNCOMMITTED`
		`READ-COMMITTED`
		`REPEATABLE-READ`
		`SERIALIZABLE`

The default transaction isolation level. Defaults to `REPEATABLE-READ`.

This variable can be set directly, or indirectly using the `SET TRANSACTION` statement. See Section 13.3.6, “SET TRANSACTION Syntax”. If you set `tx_isolation` directly to an isolation level name that contains a space, the name should be enclosed within quotation marks, with the space replaced by a dash. For example:

```
SET tx_isolation = 'READ-COMMITTED';
```

Any unique prefix of a valid value may be used to set the value of this variable.

The default transaction isolation level can also be set at startup using the `--transaction-isolation` server option.

- `unique_checks`

System Variable (<= 5.5.2)	**Name**	`unique_checks`
	Scope	Session
	Dynamic	Yes
System Variable (>= 5.5.3)	**Name**	`unique_checks`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`1`

If set to 1 (the default), uniqueness checks for secondary indexes in `InnoDB` tables are performed. If set to 0, storage engines are permitted to assume that duplicate keys are not present in input data. If you know for certain that your data does not contain uniqueness violations, you can set this to 0 to speed up large table imports to `InnoDB`.

Setting this variable to 0 does not *require* storage engines to ignore duplicate keys. An engine is still permitted to check for them and issue duplicate-key errors if it detects them.

- `updatable_views_with_limit`

Command-Line Format	`--updatable-views-with-limit=#`	
System Variable	Name	`updatable_views_with_limit`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	`1`

This variable controls whether updates to a view can be made when the view does not contain all columns of the primary key defined in the underlying table, if the update statement contains a `LIMIT` clause. (Such updates often are generated by GUI tools.) An update is an `UPDATE` or `DELETE` statement. Primary key here means a `PRIMARY KEY`, or a `UNIQUE` index in which no column can contain `NULL`.

The variable can have two values:

- `1` or `YES`: Issue a warning only (not an error message). This is the default value.
- `0` or `NO`: Prohibit the update.

- `version`

The version number for the server. The value might also include a suffix indicating server build or configuration information. `-log` indicates that one or more of the general log, slow query log, or binary log are enabled. `-debug` indicates that the server was built with debugging support enabled.

- `version_comment`

System Variable	Name	`version_comment`
	Scope	Global
	Dynamic	No
Permitted Values	Type	string

The `CMake` configuration program has a `COMPILATION_COMMENT` option that permits a comment to be specified when building MySQL. This variable contains the value of that comment. See Section 2.9.4, “MySQL Source-Configuration Options”.

- `version_compile_machine`

System Variable	Name	`version_compile_machine`
	Scope	Global
	Dynamic	No
Permitted Values	Type	string

The type of machine or architecture on which MySQL was built.

- `version_compile_os`

System Variable	Name	`version_compile_os`
	Scope	Global

	Dynamic	No
Permitted Values	**Type**	string

The type of operating system on which MySQL was built.

- `wait_timeout`

Command-Line Format	`--wait-timeout=#`	
System Variable	**Name**	`wait_timeout`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (Windows)	**Type**	integer
	Default	`28800`
	Minimum	`1`
	Maximum	`2147483`
Permitted Values (Other)	**Type**	integer
	Default	`28800`
	Minimum	`1`
	Maximum	`31536000`

The number of seconds the server waits for activity on a noninteractive connection before closing it.

On thread startup, the session `wait_timeout` value is initialized from the global `wait_timeout` value or from the global `interactive_timeout` value, depending on the type of client (as defined by the `CLIENT_INTERACTIVE` connect option to `mysql_real_connect()`). See also `interactive_timeout`.

- `warning_count`

The number of errors, warnings, and notes that resulted from the last statement that generated messages. This variable is read only. See Section 13.7.5.41, “SHOW WARNINGS Syntax”.

5.1.6 Using System Variables

The MySQL server maintains many system variables that indicate how it is configured. Section 5.1.5, “Server System Variables”, describes the meaning of these variables. Each system variable has a default value. System variables can be set at server startup using options on the command line or in an option file. Most of them can be changed dynamically while the server is running by means of the `SET` statement, which enables you to modify operation of the server without having to stop and restart it. You can also use system variable values in expressions.

There are two scopes in which system variables exist. Global variables affect the overall operation of the server. Session variables affect its operation for individual client connections. A given system variable can have both a global and a session value. Global and session system variables are related as follows:

- When the server starts, it initializes each global variable to its default value. These defaults can be changed by options specified on the command line or in an option file. (See Section 4.2.3, “Specifying Program Options”.)
- The server also maintains a set of session variables for each client that connects. The client's session variables are initialized at connect time using the current values of the corresponding global variables. For example, a client's SQL mode is controlled by the session `sql_mode` value, which is initialized when the client connects to the value of the global `sql_mode` value.

For some system variables, the session value is not initialized from the corresponding global value; if so, that is indicated in the variable description.

System variable values can be set globally at server startup by using options on the command line or in an option file. When you use a startup option to set a variable that takes a numeric value, the value can be given with a suffix of `K`, `M`, or `G` (either uppercase or lowercase) to indicate a multiplier of 1024, 1024^2 or 1024^3; that is, units of kilobytes, megabytes, or gigabytes, respectively. Thus, the following command starts the server with an `InnoDB` log file size of 16 megabytes and a maximum packet size of one gigabyte:

```
mysqld --innodb_log_file_size=16M --max_allowed_packet=1G
```

Within an option file, those variables are set like this:

```
[mysqld]
innodb_log_file_size=16M
max_allowed_packet=1G
```

The lettercase of suffix letters does not matter; `16M` and `16m` are equivalent, as are `1G` and `1g`.

To restrict the maximum value to which a system variable can be set at runtime with the `SET` statement, specify this maximum by using an option of the form `--maximum-`*`var_name=value`* at server startup. For example, to prevent the value of `innodb_log_file_size` from being increased to more than 32MB at runtime, use the option `--maximum-innodb_log_file_size=32M`.

Many system variables are dynamic and can be changed at runtime by using the `SET` statement. For a list, see Section 5.1.6.2, “Dynamic System Variables”. To change a system variable with `SET`, refer to it by name, optionally preceded by a modifier:

- To indicate that a variable is a global variable, precede its name by the `GLOBAL` keyword or the `@@global.` qualifier:

  ```
  SET GLOBAL max_connections = 1000;
  SET @@global.max_connections = 1000;
  ```

  The `SUPER` privilege is required to set global variables.

- To indicate that a variable is a session variable, precede its name by the `SESSION` keyword or either the `@@session.` or `@@` qualifier:

  ```
  SET SESSION sql_mode = 'TRADITIONAL';
  SET @@session.sql_mode = 'TRADITIONAL';
  SET @@sql_mode = 'TRADITIONAL';
  ```

  Setting a session variable normally requires no special privilege, although there are exceptions that require the `SUPER` privilege (such as `sql_log_bin`). A client can change its own session variables, but not those of any other client.

- `LOCAL` and `@@local.` are synonyms for `SESSION` and `@@session.`.

- If no modifier is present, `SET` changes the session variable.

- An error occurs under these circumstances:

  - Use of `SET GLOBAL` (or `@@global.`) when setting a variable that has only a session value:

    ```
    mysql> SET GLOBAL sql_log_bin = ON;
    ERROR 1231 (42000): Variable 'sql_log_bin' can't be
    set to the value of 'ON'
    ```

- Omission of `GLOBAL` (or `@@global.`) when setting a variable that has only a global value:

```
mysql> SET max_connections = 1000;
ERROR 1229 (HY000): Variable 'max_connections' is a
GLOBAL variable and should be set with SET GLOBAL
```

- Use of `SET SESSION` (or `@@SESSION.`) when setting a variable that has only a global value:

```
mysql> SET SESSION max_connections = 1000;
ERROR 1229 (HY000): Variable 'max_connections' is a
GLOBAL variable and should be set with SET GLOBAL
```

The preceding modifiers apply only to system variables. An error occurs for attempts to apply them to user-defined variables, stored procedure or function parameters, or stored program local variables.

A `SET` statement can contain multiple variable assignments, separated by commas. This statement assigns values to a user-defined variable and a system variable:

```
SET @x = 1, SESSION sql_mode = '';
```

If you set multiple system variables, the most recent `GLOBAL` or `SESSION` modifier in the statement is used for following assignments that have no modifier specified.

Examples of multiple-variable assignment:

```
SET GLOBAL sort_buffer_size = 1000000, SESSION sort_buffer_size = 1000000;
SET @@global.sort_buffer_size = 1000000, @@local.sort_buffer_size = 1000000;
SET GLOBAL max_connections = 1000, sort_buffer_size = 1000000;
```

If any variable assignment in a `SET` statement fails, the entire statement fails and no variables are changed.

If you change a session system variable, the value remains in effect within your session until you change the variable to a different value or the session ends. The change has no effect on other sessions.

If you change a global system variable, the value is remembered and used for new sessions until you change the variable to a different value or the server exits. The change is visible to any client that accesses the global variable. However, the change affects the corresponding session variable only for clients that connect after the change. The global variable change does not affect the session variable for any current client sessions (not even the session within which the `SET GLOBAL` statement occurred).

To make a global system variable setting permanent so that it applies across server restarts, you should also set it in an option file.

To set a `GLOBAL` value to the compiled-in MySQL default value or a `SESSION` variable to the current corresponding `GLOBAL` value, set the variable to the value `DEFAULT`. For example, the following two statements are identical in setting the session value of `max_join_size` to the current global value:

```
SET @@session.max_join_size=DEFAULT;
SET @@session.max_join_size=@@global.max_join_size;
```

Not all system variables can be set to `DEFAULT`. In such cases, assigning `DEFAULT` results in an error.

It is not permitted to assign `DEFAULT` to user-defined variables, and not supported for stored procedure or function parameters or stored program local variables. This results in an error for user-defined variables, and the results are undefined for parameters or local variables.

To refer to the value of a system variable in expressions, use one of the `@@`-modifiers. For example, you can retrieve values in a `SELECT` statement like this:

```
SELECT @@global.sql_mode, @@session.sql_mode, @@sql_mode;
```

For a reference to a system variable in an expression as *`@@var_name`* (rather than with `@@global.` or `@@session.`), MySQL returns the session value if it exists and the global value otherwise. This differs from `SET @@var_name = expr`, which always refers to the session value.

Suffixes for specifying a value multiplier can be used when setting a variable at server startup, but not to set the value with `SET` at runtime. On the other hand, with `SET` you can assign a variable's value using an expression, which is not true when you set a variable at server startup. For example, the first of the following lines is legal at server startup, but the second is not:

```
shell> mysql --max_allowed_packet=16M
shell> mysql --max_allowed_packet=16*1024*1024
```

Conversely, the second of the following lines is legal at runtime, but the first is not:

```
mysql> SET GLOBAL max_allowed_packet=16M;
mysql> SET GLOBAL max_allowed_packet=16*1024*1024;
```

Note

Some system variables can be enabled with the `SET` statement by setting them to `ON` or `1`, or disabled by setting them to `OFF` or `0`. However, to set such a variable on the command line or in an option file, you must set it to `1` or `0`; setting it to `ON` or `OFF` will not work. For example, on the command line, `--delay_key_write=1` works but `--delay_key_write=ON` does not.

To display system variable names and values, use the `SHOW VARIABLES` statement:

```
mysql> SHOW VARIABLES;
+---------------------------------+-----------------------------------+
| Variable_name                   | Value                             |
+---------------------------------+-----------------------------------+
| auto_increment_increment        | 1                                 |
| auto_increment_offset           | 1                                 |
| automatic_sp_privileges         | ON                                |
| back_log                        | 50                                |
| basedir                         | /home/mysql/                      |
| binlog_cache_size               | 32768                             |
| bulk_insert_buffer_size         | 8388608                           |
| character_set_client            | utf8                              |
| character_set_connection        | utf8                              |
| character_set_database          | latin1                            |
| character_set_filesystem        | binary                            |
| character_set_results           | utf8                              |
| character_set_server            | latin1                            |
| character_set_system            | utf8                              |
| character_sets_dir              | /home/mysql/share/mysql/charsets/ |
| collation_connection            | utf8_general_ci                   |
| collation_database              | latin1_swedish_ci                 |
| collation_server                | latin1_swedish_ci                 |
...
| innodb_additional_mem_pool_size | 1048576                           |
| innodb_autoextend_increment     | 8                                 |
| innodb_buffer_pool_size         | 8388608                           |
| innodb_checksums                | ON                                |
| innodb_commit_concurrency       | 0                                 |
| innodb_concurrency_tickets      | 500                               |
| innodb_data_file_path           | ibdata1:10M:autoextend            |
| innodb_data_home_dir            |                                   |
...
| version                         | 5.5.56-log                        |
| version_comment                 | Source distribution               |
| version_compile_machine         | i686                              |
| version_compile_os              | suse-linux                        |
```

```
| wait_timeout                    | 28800                           |
+---------------------------------+---------------------------------+
```

With a `LIKE` clause, the statement displays only those variables that match the pattern. To obtain a specific variable name, use a `LIKE` clause as shown:

```
SHOW VARIABLES LIKE 'max_join_size';
SHOW SESSION VARIABLES LIKE 'max_join_size';
```

To get a list of variables whose name match a pattern, use the `%` wildcard character in a `LIKE` clause:

```
SHOW VARIABLES LIKE '%size%';
SHOW GLOBAL VARIABLES LIKE '%size%';
```

Wildcard characters can be used in any position within the pattern to be matched. Strictly speaking, because `_` is a wildcard that matches any single character, you should escape it as `\_` to match it literally. In practice, this is rarely necessary.

For `SHOW VARIABLES`, if you specify neither `GLOBAL` nor `SESSION`, MySQL returns `SESSION` values.

The reason for requiring the `GLOBAL` keyword when setting `GLOBAL`-only variables but not when retrieving them is to prevent problems in the future:

- Were we to remove a `SESSION` variable that has the same name as a `GLOBAL` variable, a client with the `SUPER` privilege might accidentally change the `GLOBAL` variable rather than just the `SESSION` variable for its own connection.
- Were we to add a `SESSION` variable with the same name as a `GLOBAL` variable, a client that intends to change the `GLOBAL` variable might find only its own `SESSION` variable changed.

5.1.6.1 Structured System Variables

A structured variable differs from a regular system variable in two respects:

- Its value is a structure with components that specify server parameters considered to be closely related.
- There might be several instances of a given type of structured variable. Each one has a different name and refers to a different resource maintained by the server.

MySQL supports one structured variable type, which specifies parameters governing the operation of key caches. A key cache structured variable has these components:

- `key_buffer_size`
- `key_cache_block_size`
- `key_cache_division_limit`
- `key_cache_age_threshold`

This section describes the syntax for referring to structured variables. Key cache variables are used for syntax examples, but specific details about how key caches operate are found elsewhere, in Section 8.10.2, “The MyISAM Key Cache”.

To refer to a component of a structured variable instance, you can use a compound name in *`instance_name.component_name`* format. Examples:

```
hot_cache.key_buffer_size
hot_cache.key_cache_block_size
cold_cache.key_cache_block_size
```

For each structured system variable, an instance with the name of `default` is always predefined. If you refer to a component of a structured variable without any instance name, the `default` instance

is used. Thus, `default.key_buffer_size` and `key_buffer_size` both refer to the same system variable.

Structured variable instances and components follow these naming rules:

- For a given type of structured variable, each instance must have a name that is unique *within* variables of that type. However, instance names need not be unique *across* structured variable types. For example, each structured variable has an instance named `default`, so `default` is not unique across variable types.
- The names of the components of each structured variable type must be unique across all system variable names. If this were not true (that is, if two different types of structured variables could share component member names), it would not be clear which default structured variable to use for references to member names that are not qualified by an instance name.
- If a structured variable instance name is not legal as an unquoted identifier, refer to it as a quoted identifier using backticks. For example, `hot-cache` is not legal, but `` `hot-cache` `` is.
- `global`, `session`, and `local` are not legal instance names. This avoids a conflict with notation such as `@@global.`*`var_name`* for referring to nonstructured system variables.

Currently, the first two rules have no possibility of being violated because the only structured variable type is the one for key caches. These rules will assume greater significance if some other type of structured variable is created in the future.

With one exception, you can refer to structured variable components using compound names in any context where simple variable names can occur. For example, you can assign a value to a structured variable using a command-line option:

```
shell> mysqld --hot_cache.key_buffer_size=64K
```

In an option file, use this syntax:

```
[mysqld]
hot_cache.key_buffer_size=64K
```

If you start the server with this option, it creates a key cache named `hot_cache` with a size of 64KB in addition to the default key cache that has a default size of 8MB.

Suppose that you start the server as follows:

```
shell> mysqld --key_buffer_size=256K \
         --extra_cache.key_buffer_size=128K \
         --extra_cache.key_cache_block_size=2048
```

In this case, the server sets the size of the default key cache to 256KB. (You could also have written `--default.key_buffer_size=256K`.) In addition, the server creates a second key cache named `extra_cache` that has a size of 128KB, with the size of block buffers for caching table index blocks set to 2048 bytes.

The following example starts the server with three different key caches having sizes in a 3:1:1 ratio:

```
shell> mysqld --key_buffer_size=6M \
         --hot_cache.key_buffer_size=2M \
         --cold_cache.key_buffer_size=2M
```

Structured variable values may be set and retrieved at runtime as well. For example, to set a key cache named `hot_cache` to a size of 10MB, use either of these statements:

```
mysql> SET GLOBAL hot_cache.key_buffer_size = 10*1024*1024;
mysql> SET @@global.hot_cache.key_buffer_size = 10*1024*1024;
```

To retrieve the cache size, do this:

```
mysql> SELECT @@global.hot_cache.key_buffer_size;
```

However, the following statement does not work. The variable is not interpreted as a compound name, but as a simple string for a `LIKE` pattern-matching operation:

```
mysql> SHOW GLOBAL VARIABLES LIKE 'hot_cache.key_buffer_size';
```

This is the exception to being able to use structured variable names anywhere a simple variable name may occur.

5.1.6.2 Dynamic System Variables

Many server system variables are dynamic and can be set at runtime using `SET GLOBAL` or `SET SESSION`. You can also obtain their values using `SELECT`. See Section 5.1.6, “Using System Variables”.

The following table shows the full list of all dynamic system variables. The last column indicates for each variable whether `GLOBAL` or `SESSION` (or both) apply. The table also lists session options that can be set with the `SET` statement. Section 5.1.5, “Server System Variables”, discusses these options.

Variables that have a type of “string” take a string value. Variables that have a type of “numeric” take a numeric value. Variables that have a type of “boolean” can be set to 0, 1, `ON` or `OFF`. (If you set them on the command line or in an option file, use the numeric values.) Variables that are marked as “enumeration” normally should be set to one of the available values for the variable, but can also be set to the number that corresponds to the desired enumeration value. For enumerated system variables, the first enumeration value corresponds to 0. This differs from `ENUM` columns, for which the first enumeration value corresponds to 1.

Table 5.3 Dynamic Variable Summary

Variable Name	Variable Type	Variable Scope
`audit_log_flush`	boolean	`GLOBAL`
`audit_log_policy`	enumeration	`GLOBAL`
`audit_log_rotate_on_size`	integer	`GLOBAL`
`auto_increment_increment`	integer	`GLOBAL` | `SESSION`
`auto_increment_offset`	integer	`GLOBAL` | `SESSION`
`autocommit`	boolean	`GLOBAL` | `SESSION`
`automatic_sp_privileges`	boolean	`GLOBAL`
`big_tables`	boolean	`GLOBAL` | `SESSION`
`binlog_cache_size`	integer	`GLOBAL`
`binlog_direct_non_transactional_updates`	boolean	`GLOBAL` | `SESSION`
`binlog_format`	enumeration	`GLOBAL` | `SESSION`
`binlog_stmt_cache_size`	integer	`GLOBAL`
`bulk_insert_buffer_size`	integer	`GLOBAL` | `SESSION`
`character_set_client`	string	`GLOBAL` | `SESSION`
`character_set_connection`	string	`GLOBAL` | `SESSION`
`character_set_database`	string	`GLOBAL` | `SESSION`
`character_set_filesystem`	string	`GLOBAL` | `SESSION`
`character_set_results`	string	`GLOBAL` | `SESSION`
`character_set_server`	string	`GLOBAL` | `SESSION`

Variable Name	Variable Type	Variable Scope
collation_connection	string	GLOBAL | SESSION
collation_database	string	GLOBAL | SESSION
collation_server	string	GLOBAL | SESSION
completion_type	enumeration	GLOBAL | SESSION
concurrent_insert	enumeration	GLOBAL
connect_timeout	integer	GLOBAL
debug	string	GLOBAL | SESSION
debug_sync	string	SESSION
default_storage_engine	enumeration	GLOBAL | SESSION
default_week_format	integer	GLOBAL | SESSION
delay_key_write	enumeration	GLOBAL
delayed_insert_limit	integer	GLOBAL
delayed_insert_timeout	integer	GLOBAL
delayed_queue_size	integer	GLOBAL
div_precision_increment	integer	GLOBAL | SESSION
engine_condition_pushdown	boolean	GLOBAL | SESSION
event_scheduler	enumeration	GLOBAL
expire_logs_days	integer	GLOBAL
flush	boolean	GLOBAL
flush_time	integer	GLOBAL
foreign_key_checks	boolean	GLOBAL | SESSION
ft_boolean_syntax	string	GLOBAL
general_log	boolean	GLOBAL
general_log_file	filename	GLOBAL
group_concat_max_len	integer	GLOBAL | SESSION
identity	integer	SESSION
init_connect	string	GLOBAL
init_slave	string	GLOBAL
innodb_adaptive_flushing	boolean	GLOBAL
innodb_adaptive_hash_index	boolean	GLOBAL
innodb_autoextend_increment	integer	GLOBAL
innodb_change_buffering	enumeration	GLOBAL
innodb_change_buffering_debug	integer	GLOBAL
innodb_commit_concurrency	integer	GLOBAL
innodb_concurrency_tickets	integer	GLOBAL
innodb_fast_shutdown	integer	GLOBAL
innodb_file_format	string	GLOBAL
innodb_file_format_check	boolean	GLOBAL
innodb_file_format_max	string	GLOBAL
innodb_file_per_table	boolean	GLOBAL
innodb_flush_log_at_trx_commit	enumeration	GLOBAL

Variable Name	Variable Type	Variable Scope
innodb_io_capacity	integer	GLOBAL
innodb_large_prefix	boolean	GLOBAL
innodb_limit_optimistic_insert_debug	integer	GLOBAL
innodb_lock_wait_timeout	integer	GLOBAL | SESSION
innodb_max_dirty_pages_pct	numeric	GLOBAL
innodb_max_purge_lag	integer	GLOBAL
innodb_old_blocks_pct	integer	GLOBAL
innodb_old_blocks_time	integer	GLOBAL
innodb_print_all_deadlocks	boolean	GLOBAL
innodb_purge_batch_size	integer	GLOBAL
innodb_random_read_ahead	boolean	GLOBAL
innodb_read_ahead_threshold	integer	GLOBAL
innodb_replication_delay	integer	GLOBAL
innodb_rollback_segments	integer	GLOBAL
innodb_spin_wait_delay	integer	GLOBAL
innodb_stats_method	enumeration	GLOBAL
innodb_stats_on_metadata	boolean	GLOBAL
innodb_stats_sample_pages	integer	GLOBAL
innodb_strict_mode	boolean	GLOBAL | SESSION
innodb_support_xa	boolean	GLOBAL | SESSION
innodb_sync_spin_loops	integer	GLOBAL
innodb_table_locks	boolean	GLOBAL | SESSION
innodb_thread_concurrency	integer	GLOBAL
innodb_thread_sleep_delay	integer	GLOBAL
innodb_trx_purge_view_update_only_debug	boolean	GLOBAL
innodb_trx_rseg_n_slots_debug	integer	GLOBAL
insert_id	integer	SESSION
interactive_timeout	integer	GLOBAL | SESSION
join_buffer_size	integer	GLOBAL | SESSION
keep_files_on_create	boolean	GLOBAL | SESSION
key_buffer_size	integer	GLOBAL
key_cache_age_threshold	integer	GLOBAL
key_cache_block_size	integer	GLOBAL
key_cache_division_limit	integer	GLOBAL
last_insert_id	integer	SESSION
lc_messages	string	GLOBAL | SESSION
lc_time_names	string	GLOBAL | SESSION
local_infile	boolean	GLOBAL
lock_wait_timeout	integer	GLOBAL | SESSION
log	filename	GLOBAL
log_bin_trust_function_creators	boolean	GLOBAL

Variable Name	Variable Type	Variable Scope
log_bin_trust_routine_creators	boolean	GLOBAL
log_output	set	GLOBAL
log_queries_not_using_indexes	boolean	GLOBAL
log_slow_queries	boolean	GLOBAL
log_warnings	integer	GLOBAL | SESSION
long_query_time	numeric	GLOBAL | SESSION
low_priority_updates	boolean	GLOBAL | SESSION
max_allowed_packet	integer	GLOBAL | SESSION
max_binlog_cache_size	integer	GLOBAL
max_binlog_size	integer	GLOBAL
max_binlog_stmt_cache_size	integer	GLOBAL
max_connect_errors	integer	GLOBAL
max_connections	integer	GLOBAL
max_delayed_threads	integer	GLOBAL | SESSION
max_error_count	integer	GLOBAL | SESSION
max_heap_table_size	integer	GLOBAL | SESSION
max_insert_delayed_threads	integer	GLOBAL | SESSION
max_join_size	integer	GLOBAL | SESSION
max_length_for_sort_data	integer	GLOBAL | SESSION
max_prepared_stmt_count	integer	GLOBAL
max_relay_log_size	integer	GLOBAL
max_seeks_for_key	integer	GLOBAL | SESSION
max_sort_length	integer	GLOBAL | SESSION
max_sp_recursion_depth	integer	GLOBAL | SESSION
max_tmp_tables	integer	GLOBAL | SESSION
max_user_connections	integer	GLOBAL | SESSION
max_write_lock_count	integer	GLOBAL
min_examined_row_limit	integer	GLOBAL | SESSION
multi_range_count	integer	GLOBAL | SESSION
myisam_data_pointer_size	integer	GLOBAL
myisam_max_sort_file_size	integer	GLOBAL
myisam_repair_threads	integer	GLOBAL | SESSION
myisam_sort_buffer_size	integer	GLOBAL | SESSION
myisam_stats_method	enumeration	GLOBAL | SESSION
myisam_use_mmap	boolean	GLOBAL
ndb_autoincrement_prefetch_sz	integer	GLOBAL | SESSION
ndb_blob_read_batch_bytes	integer	GLOBAL | SESSION
ndb_blob_write_batch_bytes	integer	GLOBAL | SESSION
ndb_cache_check_time	integer	GLOBAL
ndb_deferred_constraints	integer	GLOBAL | SESSION
ndb_deferred_constraints	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
ndb_distribution	enumeration	GLOBAL
ndb_distribution={KEYHASH|LINHASH}	enumeration	GLOBAL
ndb_eventbuffer_max_alloc	integer	GLOBAL
ndb_extra_logging	integer	GLOBAL
ndb_force_send	boolean	GLOBAL | SESSION
ndb_index_stat_cache_entries	integer	GLOBAL | SESSION
ndb_index_stat_enable	boolean	GLOBAL | SESSION
ndb_index_stat_option	string	GLOBAL | SESSION
ndb_index_stat_update_freq	integer	GLOBAL | SESSION
ndb_join_pushdown	boolean	GLOBAL | SESSION
ndb_log_bin	boolean	GLOBAL | SESSION
ndb_log_binlog_index	boolean	GLOBAL
ndb_log_empty_epochs	boolean	GLOBAL
ndb_log_empty_epochs	boolean	GLOBAL
ndb_log_empty_update	boolean	GLOBAL
ndb_log_empty_update	boolean	GLOBAL
ndb_log_update_as_write	boolean	GLOBAL
ndb_log_updated_only	boolean	GLOBAL
ndb_optimization_delay	integer	GLOBAL
ndb_report_thresh_binlog_epoch_slip	integer	GLOBAL
ndb_report_thresh_binlog_mem_usage	integer	GLOBAL
ndb_table_no_logging	boolean	SESSION
ndb_table_temporary	boolean	SESSION
ndb_use_exact_count	boolean	GLOBAL | SESSION
ndb_use_transactions	boolean	GLOBAL | SESSION
ndbinfo_max_bytes	integer	GLOBAL | SESSION
ndbinfo_max_rows	integer	GLOBAL | SESSION
ndbinfo_offline	boolean	GLOBAL
ndbinfo_show_hidden	boolean	GLOBAL | SESSION
ndbinfo_table_prefix	string	GLOBAL | SESSION
net_buffer_length	integer	GLOBAL | SESSION
net_read_timeout	integer	GLOBAL | SESSION
net_retry_count	integer	GLOBAL | SESSION
net_write_timeout	integer	GLOBAL | SESSION
new	boolean	GLOBAL | SESSION
old_alter_table	boolean	GLOBAL | SESSION
old_passwords	boolean	GLOBAL | SESSION
optimizer_prune_level	boolean	GLOBAL | SESSION
optimizer_search_depth	integer	GLOBAL | SESSION
optimizer_switch	set	GLOBAL | SESSION
preload_buffer_size	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
profiling	boolean	GLOBAL | SESSION
profiling_history_size	integer	GLOBAL | SESSION
pseudo_slave_mode	integer	SESSION
pseudo_thread_id	integer	SESSION
query_alloc_block_size	integer	GLOBAL | SESSION
query_cache_limit	integer	GLOBAL
query_cache_min_res_unit	integer	GLOBAL
query_cache_size	integer	GLOBAL
query_cache_type	enumeration	GLOBAL | SESSION
query_cache_wlock_invalidate	boolean	GLOBAL | SESSION
query_prealloc_size	integer	GLOBAL | SESSION
rand_seed1	integer	SESSION
rand_seed2	integer	SESSION
range_alloc_block_size	integer	GLOBAL | SESSION
read_buffer_size	integer	GLOBAL | SESSION
read_only	boolean	GLOBAL
read_rnd_buffer_size	integer	GLOBAL | SESSION
relay_log_purge	boolean	GLOBAL
relay_log_recovery	boolean	GLOBAL
rpl_recovery_rank	integer	GLOBAL
rpl_semi_sync_master_enabled	boolean	GLOBAL
rpl_semi_sync_master_timeout	integer	GLOBAL
rpl_semi_sync_master_trace_level	integer	GLOBAL
rpl_semi_sync_master_wait_no_slave	boolean	GLOBAL
rpl_semi_sync_slave_enabled	boolean	GLOBAL
rpl_semi_sync_slave_trace_level	integer	GLOBAL
secure_auth	boolean	GLOBAL
server_id	integer	GLOBAL
slave_allow_batching	boolean	GLOBAL
slave_compressed_protocol	boolean	GLOBAL
slave_exec_mode	enumeration	GLOBAL
slave_max_allowed_packet	integer	GLOBAL
slave_net_timeout	integer	GLOBAL
slave_transaction_retries	integer	GLOBAL
slow_launch_time	integer	GLOBAL
slow_query_log	boolean	GLOBAL
slow_query_log_file	filename	GLOBAL
sort_buffer_size	integer	GLOBAL | SESSION
sql_auto_is_null	boolean	GLOBAL | SESSION
sql_big_selects	boolean	GLOBAL | SESSION
sql_big_tables	boolean	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
sql_buffer_result	boolean	GLOBAL | SESSION
sql_log_bin	boolean	SESSION
sql_log_off	boolean	GLOBAL | SESSION
sql_log_update	boolean	SESSION
sql_low_priority_updates	boolean	GLOBAL | SESSION
sql_max_join_size	integer	GLOBAL | SESSION
sql_mode	set	GLOBAL | SESSION
sql_notes	boolean	GLOBAL | SESSION
sql_quote_show_create	boolean	GLOBAL | SESSION
sql_safe_updates	boolean	GLOBAL | SESSION
sql_select_limit	integer	GLOBAL | SESSION
sql_slave_skip_counter	integer	GLOBAL
sql_warnings	boolean	GLOBAL | SESSION
storage_engine	enumeration	GLOBAL | SESSION
stored_program_cache	integer	GLOBAL
sync_binlog	integer	GLOBAL
sync_frm	boolean	GLOBAL
sync_master_info	integer	GLOBAL
sync_relay_log	integer	GLOBAL
sync_relay_log_info	integer	GLOBAL
table_definition_cache	integer	GLOBAL
table_lock_wait_timeout	integer	GLOBAL
table_open_cache	integer	GLOBAL
table_type	enumeration	GLOBAL | SESSION
thread_cache_size	integer	GLOBAL
thread_pool_high_priority_connection	integer	GLOBAL | SESSION
thread_pool_max_unused_threads	integer	GLOBAL
thread_pool_prio_kickup_timer	integer	GLOBAL | SESSION
thread_pool_stall_limit	integer	GLOBAL
time_zone	string	GLOBAL | SESSION
timed_mutexes	boolean	GLOBAL
timestamp	numeric	SESSION
tmp_table_size	integer	GLOBAL | SESSION
transaction_alloc_block_size	integer	GLOBAL | SESSION
transaction_allow_batching	boolean	SESSION
transaction_prealloc_size	integer	GLOBAL | SESSION
tx_isolation	enumeration	GLOBAL | SESSION
unique_checks	boolean	GLOBAL | SESSION
updatable_views_with_limit	boolean	GLOBAL | SESSION
wait_timeout	integer	GLOBAL | SESSION

5.1.7 Server Status Variables

The MySQL server maintains many status variables that provide information about its operation. You can view these variables and their values by using the `SHOW [GLOBAL | SESSION] STATUS` statement (see Section 13.7.5.36, “SHOW STATUS Syntax”). The optional `GLOBAL` keyword aggregates the values over all connections, and `SESSION` shows the values for the current connection.

```
mysql> SHOW GLOBAL STATUS;
+-----------------------------------+------------+
| Variable_name                     | Value      |
+-----------------------------------+------------+
| Aborted_clients                   | 0          |
| Aborted_connects                  | 0          |
| Bytes_received                    | 155372598  |
| Bytes_sent                        | 1176560426 |
...
| Connections                       | 30023      |
| Created_tmp_disk_tables           | 0          |
| Created_tmp_files                 | 3          |
| Created_tmp_tables                | 2          |
...
| Threads_created                   | 217        |
| Threads_running                   | 88         |
| Uptime                            | 1389872    |
+-----------------------------------+------------+
```

Several status variables provide statement counts. To determine the number of statements executed, use these relationships:

```
  SUM(Com_xxx) + Qcache_hits
= Questions + statements executed within stored programs
= Queries
```

Many status variables are reset to 0 by the `FLUSH STATUS` statement.

The following table lists all available server status variables:

Table 5.4 Status Variable Summary

Variable Name	Variable Type	Variable Scope
`Aborted_clients`	integer	`GLOBAL`
`Aborted_connects`	integer	`GLOBAL`
`Binlog_cache_disk_use`	integer	`GLOBAL`
`Binlog_cache_use`	integer	`GLOBAL`
`Binlog_stmt_cache_disk_use`	integer	`GLOBAL`
`Binlog_stmt_cache_use`	integer	`GLOBAL`
`Bytes_received`	integer	`GLOBAL` | `SESSION`
`Bytes_sent`	integer	`GLOBAL` | `SESSION`
`Com_admin_commands`	integer	`GLOBAL` | `SESSION`
`Com_alter_db`	integer	`GLOBAL` | `SESSION`
`Com_alter_db_upgrade`	integer	`GLOBAL` | `SESSION`
`Com_alter_event`	integer	`GLOBAL` | `SESSION`
`Com_alter_function`	integer	`GLOBAL` | `SESSION`
`Com_alter_procedure`	integer	`GLOBAL` | `SESSION`
`Com_alter_server`	integer	`GLOBAL` | `SESSION`
`Com_alter_table`	integer	`GLOBAL` | `SESSION`

Variable Name	Variable Type	Variable Scope
Com_alter_tablespace	integer	GLOBAL | SESSION
Com_analyze	integer	GLOBAL | SESSION
Com_assign_to_keycache	integer	GLOBAL | SESSION
Com_begin	integer	GLOBAL | SESSION
Com_binlog	integer	GLOBAL | SESSION
Com_call_procedure	integer	GLOBAL | SESSION
Com_change_db	integer	GLOBAL | SESSION
Com_change_master	integer	GLOBAL | SESSION
Com_check	integer	GLOBAL | SESSION
Com_checksum	integer	GLOBAL | SESSION
Com_commit	integer	GLOBAL | SESSION
Com_create_db	integer	GLOBAL | SESSION
Com_create_event	integer	GLOBAL | SESSION
Com_create_function	integer	GLOBAL | SESSION
Com_create_index	integer	GLOBAL | SESSION
Com_create_procedure	integer	GLOBAL | SESSION
Com_create_server	integer	GLOBAL | SESSION
Com_create_table	integer	GLOBAL | SESSION
Com_create_trigger	integer	GLOBAL | SESSION
Com_create_udf	integer	GLOBAL | SESSION
Com_create_user	integer	GLOBAL | SESSION
Com_create_view	integer	GLOBAL | SESSION
Com_dealloc_sql	integer	GLOBAL | SESSION
Com_delete	integer	GLOBAL | SESSION
Com_delete_multi	integer	GLOBAL | SESSION
Com_do	integer	GLOBAL | SESSION
Com_drop_db	integer	GLOBAL | SESSION
Com_drop_event	integer	GLOBAL | SESSION
Com_drop_function	integer	GLOBAL | SESSION
Com_drop_index	integer	GLOBAL | SESSION
Com_drop_procedure	integer	GLOBAL | SESSION
Com_drop_server	integer	GLOBAL | SESSION
Com_drop_table	integer	GLOBAL | SESSION
Com_drop_trigger	integer	GLOBAL | SESSION
Com_drop_user	integer	GLOBAL | SESSION
Com_drop_view	integer	GLOBAL | SESSION
Com_empty_query	integer	GLOBAL | SESSION
Com_execute_sql	integer	GLOBAL | SESSION
Com_flush	integer	GLOBAL | SESSION
Com_grant	integer	GLOBAL | SESSION
Com_ha_close	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
Com_ha_open	integer	GLOBAL | SESSION
Com_ha_read	integer	GLOBAL | SESSION
Com_help	integer	GLOBAL | SESSION
Com_insert	integer	GLOBAL | SESSION
Com_insert_select	integer	GLOBAL | SESSION
Com_install_plugin	integer	GLOBAL | SESSION
Com_kill	integer	GLOBAL | SESSION
Com_load	integer	GLOBAL | SESSION
Com_lock_tables	integer	GLOBAL | SESSION
Com_optimize	integer	GLOBAL | SESSION
Com_preload_keys	integer	GLOBAL | SESSION
Com_prepare_sql	integer	GLOBAL | SESSION
Com_purge	integer	GLOBAL | SESSION
Com_purge_before_date	integer	GLOBAL | SESSION
Com_release_savepoint	integer	GLOBAL | SESSION
Com_rename_table	integer	GLOBAL | SESSION
Com_rename_user	integer	GLOBAL | SESSION
Com_repair	integer	GLOBAL | SESSION
Com_replace	integer	GLOBAL | SESSION
Com_replace_select	integer	GLOBAL | SESSION
Com_reset	integer	GLOBAL | SESSION
Com_resignal	integer	GLOBAL | SESSION
Com_revoke	integer	GLOBAL | SESSION
Com_revoke_all	integer	GLOBAL | SESSION
Com_rollback	integer	GLOBAL | SESSION
Com_rollback_to_savepoint	integer	GLOBAL | SESSION
Com_savepoint	integer	GLOBAL | SESSION
Com_select	integer	GLOBAL | SESSION
Com_set_option	integer	GLOBAL | SESSION
Com_show_authors	integer	GLOBAL | SESSION
Com_show_binlog_events	integer	GLOBAL | SESSION
Com_show_binlogs	integer	GLOBAL | SESSION
Com_show_charsets	integer	GLOBAL | SESSION
Com_show_collations	integer	GLOBAL | SESSION
Com_show_contributors	integer	GLOBAL | SESSION
Com_show_create_db	integer	GLOBAL | SESSION
Com_show_create_event	integer	GLOBAL | SESSION
Com_show_create_func	integer	GLOBAL | SESSION
Com_show_create_proc	integer	GLOBAL | SESSION
Com_show_create_table	integer	GLOBAL | SESSION
Com_show_create_trigger	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
Com_show_databases	integer	GLOBAL | SESSION
Com_show_engine_logs	integer	GLOBAL | SESSION
Com_show_engine_mutex	integer	GLOBAL | SESSION
Com_show_engine_status	integer	GLOBAL | SESSION
Com_show_errors	integer	GLOBAL | SESSION
Com_show_events	integer	GLOBAL | SESSION
Com_show_fields	integer	GLOBAL | SESSION
Com_show_function_code	integer	GLOBAL | SESSION
Com_show_function_status	integer	GLOBAL | SESSION
Com_show_grants	integer	GLOBAL | SESSION
Com_show_keys	integer	GLOBAL | SESSION
Com_show_master_status	integer	GLOBAL | SESSION
Com_show_ndb_status	integer	GLOBAL | SESSION
Com_show_new_master	integer	GLOBAL | SESSION
Com_show_open_tables	integer	GLOBAL | SESSION
Com_show_plugins	integer	GLOBAL | SESSION
Com_show_privileges	integer	GLOBAL | SESSION
Com_show_procedure_code	integer	GLOBAL | SESSION
Com_show_procedure_status	integer	GLOBAL | SESSION
Com_show_processlist	integer	GLOBAL | SESSION
Com_show_profile	integer	GLOBAL | SESSION
Com_show_profiles	integer	GLOBAL | SESSION
Com_show_relaylog_events	integer	GLOBAL | SESSION
Com_show_slave_hosts	integer	GLOBAL | SESSION
Com_show_slave_status	integer	GLOBAL | SESSION
Com_show_status	integer	GLOBAL | SESSION
Com_show_storage_engines	integer	GLOBAL | SESSION
Com_show_table_status	integer	GLOBAL | SESSION
Com_show_tables	integer	GLOBAL | SESSION
Com_show_triggers	integer	GLOBAL | SESSION
Com_show_variables	integer	GLOBAL | SESSION
Com_show_warnings	integer	GLOBAL | SESSION
Com_signal	integer	GLOBAL | SESSION
Com_slave_start	integer	GLOBAL | SESSION
Com_slave_stop	integer	GLOBAL | SESSION
Com_stmt_close	integer	GLOBAL | SESSION
Com_stmt_execute	integer	GLOBAL | SESSION
Com_stmt_fetch	integer	GLOBAL | SESSION
Com_stmt_prepare	integer	GLOBAL | SESSION
Com_stmt_reprepare	integer	GLOBAL | SESSION
Com_stmt_reset	integer	GLOBAL | SESSION

Variable Name	Variable Type	Variable Scope
Com_stmt_send_long_data	integer	GLOBAL | SESSION
Com_truncate	integer	GLOBAL | SESSION
Com_uninstall_plugin	integer	GLOBAL | SESSION
Com_unlock_tables	integer	GLOBAL | SESSION
Com_update	integer	GLOBAL | SESSION
Com_update_multi	integer	GLOBAL | SESSION
Com_xa_commit	integer	GLOBAL | SESSION
Com_xa_end	integer	GLOBAL | SESSION
Com_xa_prepare	integer	GLOBAL | SESSION
Com_xa_recover	integer	GLOBAL | SESSION
Com_xa_rollback	integer	GLOBAL | SESSION
Com_xa_start	integer	GLOBAL | SESSION
Compression	integer	SESSION
Connections	integer	GLOBAL
Created_tmp_disk_tables	integer	GLOBAL | SESSION
Created_tmp_files	integer	GLOBAL
Created_tmp_tables	integer	GLOBAL | SESSION
Delayed_errors	integer	GLOBAL
Delayed_insert_threads	integer	GLOBAL
Delayed_writes	integer	GLOBAL
Flush_commands	integer	GLOBAL
Handler_commit	integer	GLOBAL | SESSION
Handler_delete	integer	GLOBAL | SESSION
Handler_discover	integer	GLOBAL | SESSION
Handler_prepare	integer	GLOBAL | SESSION
Handler_read_first	integer	GLOBAL | SESSION
Handler_read_key	integer	GLOBAL | SESSION
Handler_read_last	integer	GLOBAL | SESSION
Handler_read_next	integer	GLOBAL | SESSION
Handler_read_prev	integer	GLOBAL | SESSION
Handler_read_rnd	integer	GLOBAL | SESSION
Handler_read_rnd_next	integer	GLOBAL | SESSION
Handler_rollback	integer	GLOBAL | SESSION
Handler_savepoint	integer	GLOBAL | SESSION
Handler_savepoint_rollback	integer	GLOBAL | SESSION
Handler_update	integer	GLOBAL | SESSION
Handler_write	integer	GLOBAL | SESSION
Innodb_buffer_pool_bytes_data	integer	GLOBAL
Innodb_buffer_pool_bytes_dirty	integer	GLOBAL
Innodb_buffer_pool_pages_data	integer	GLOBAL
Innodb_buffer_pool_pages_dirty	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
Innodb_buffer_pool_pages_flushed	integer	GLOBAL
Innodb_buffer_pool_pages_free	integer	GLOBAL
Innodb_buffer_pool_pages_latched	integer	GLOBAL
Innodb_buffer_pool_pages_misc	integer	GLOBAL
Innodb_buffer_pool_pages_total	integer	GLOBAL
Innodb_buffer_pool_read_ahead	integer	GLOBAL
Innodb_buffer_pool_read_ahead_evicted	integer	GLOBAL
Innodb_buffer_pool_read_ahead_rnd	integer	GLOBAL
Innodb_buffer_pool_read_requests	integer	GLOBAL
Innodb_buffer_pool_reads	integer	GLOBAL
Innodb_buffer_pool_wait_free	integer	GLOBAL
Innodb_buffer_pool_write_requests	integer	GLOBAL
Innodb_data_fsyncs	integer	GLOBAL
Innodb_data_pending_fsyncs	integer	GLOBAL
Innodb_data_pending_reads	integer	GLOBAL
Innodb_data_pending_writes	integer	GLOBAL
Innodb_data_read	integer	GLOBAL
Innodb_data_reads	integer	GLOBAL
Innodb_data_writes	integer	GLOBAL
Innodb_data_written	integer	GLOBAL
Innodb_dblwr_pages_written	integer	GLOBAL
Innodb_dblwr_writes	integer	GLOBAL
Innodb_have_atomic_builtins	integer	GLOBAL
Innodb_log_waits	integer	GLOBAL
Innodb_log_write_requests	integer	GLOBAL
Innodb_log_writes	integer	GLOBAL
Innodb_os_log_fsyncs	integer	GLOBAL
Innodb_os_log_pending_fsyncs	integer	GLOBAL
Innodb_os_log_pending_writes	integer	GLOBAL
Innodb_os_log_written	integer	GLOBAL
Innodb_page_size	integer	GLOBAL
Innodb_pages_created	integer	GLOBAL
Innodb_pages_read	integer	GLOBAL
Innodb_pages_written	integer	GLOBAL
Innodb_row_lock_current_waits	integer	GLOBAL
Innodb_row_lock_time	integer	GLOBAL
Innodb_row_lock_time_avg	integer	GLOBAL
Innodb_row_lock_time_max	integer	GLOBAL
Innodb_row_lock_waits	integer	GLOBAL
Innodb_rows_deleted	integer	GLOBAL
Innodb_rows_inserted	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
Innodb_rows_read	integer	GLOBAL
Innodb_rows_updated	integer	GLOBAL
Innodb_truncated_status_writes	integer	GLOBAL
Key_blocks_not_flushed	integer	GLOBAL
Key_blocks_unused	integer	GLOBAL
Key_blocks_used	integer	GLOBAL
Key_read_requests	integer	GLOBAL
Key_reads	integer	GLOBAL
Key_write_requests	integer	GLOBAL
Key_writes	integer	GLOBAL
Last_query_cost	numeric	SESSION
Max_used_connections	integer	GLOBAL
Ndb_api_bytes_received_count	integer	GLOBAL
Ndb_api_bytes_received_count_session	integer	SESSION
Ndb_api_bytes_received_count_slave	integer	GLOBAL
Ndb_api_bytes_sent_count	integer	GLOBAL
Ndb_api_bytes_sent_count_session	integer	SESSION
Ndb_api_bytes_sent_count_slave	integer	GLOBAL
Ndb_api_event_bytes_count	integer	GLOBAL
Ndb_api_event_bytes_count_injector	integer	GLOBAL
Ndb_api_event_data_count	integer	GLOBAL
Ndb_api_event_data_count_injector	integer	GLOBAL
Ndb_api_event_nondata_count	integer	GLOBAL
Ndb_api_event_nondata_count_injector	integer	GLOBAL
Ndb_api_pk_op_count	integer	GLOBAL
Ndb_api_pk_op_count_session	integer	SESSION
Ndb_api_pk_op_count_slave	integer	GLOBAL
Ndb_api_pruned_scan_count	integer	GLOBAL
Ndb_api_pruned_scan_count_session	integer	SESSION
Ndb_api_pruned_scan_count_slave	integer	GLOBAL
Ndb_api_range_scan_count	integer	GLOBAL
Ndb_api_range_scan_count_session	integer	SESSION
Ndb_api_range_scan_count_slave	integer	GLOBAL
Ndb_api_read_row_count	integer	GLOBAL
Ndb_api_read_row_count_session	integer	SESSION
Ndb_api_read_row_count_slave	integer	GLOBAL
Ndb_api_scan_batch_count	integer	GLOBAL
Ndb_api_scan_batch_count_session	integer	SESSION
Ndb_api_scan_batch_count_slave	integer	GLOBAL
Ndb_api_table_scan_count	integer	GLOBAL
Ndb_api_table_scan_count_session	integer	SESSION

Variable Name	Variable Type	Variable Scope
Ndb_api_table_scan_count_slave	integer	GLOBAL
Ndb_api_trans_abort_count	integer	GLOBAL
Ndb_api_trans_abort_count_session	integer	SESSION
Ndb_api_trans_abort_count_slave	integer	GLOBAL
Ndb_api_trans_close_count	integer	GLOBAL
Ndb_api_trans_close_count_session	integer	SESSION
Ndb_api_trans_close_count_slave	integer	GLOBAL
Ndb_api_trans_commit_count	integer	GLOBAL
Ndb_api_trans_commit_count_session	integer	SESSION
Ndb_api_trans_commit_count_slave	integer	GLOBAL
Ndb_api_trans_local_read_row_count	integer	GLOBAL
Ndb_api_trans_local_read_row_count_session	integer	SESSION
Ndb_api_trans_local_read_row_count_slave	integer	GLOBAL
Ndb_api_trans_start_count	integer	GLOBAL
Ndb_api_trans_start_count_session	integer	SESSION
Ndb_api_trans_start_count_slave	integer	GLOBAL
Ndb_api_uk_op_count	integer	GLOBAL
Ndb_api_uk_op_count_session	integer	SESSION
Ndb_api_uk_op_count_slave	integer	GLOBAL
Ndb_api_wait_exec_complete_count	integer	GLOBAL
Ndb_api_wait_exec_complete_count_session	integer	SESSION
Ndb_api_wait_exec_complete_count_slave	integer	GLOBAL
Ndb_api_wait_meta_request_count	integer	GLOBAL
Ndb_api_wait_meta_request_count_session	integer	SESSION
Ndb_api_wait_meta_request_count_slave	integer	GLOBAL
Ndb_api_wait_nanos_count	integer	GLOBAL
Ndb_api_wait_nanos_count_session	integer	SESSION
Ndb_api_wait_nanos_count_slave	integer	GLOBAL
Ndb_api_wait_scan_result_count	integer	GLOBAL
Ndb_api_wait_scan_result_count_session	integer	SESSION
Ndb_api_wait_scan_result_count_slave	integer	GLOBAL
Ndb_cluster_node_id	integer	GLOBAL | SESSION
Ndb_config_from_host	integer	GLOBAL | SESSION
Ndb_config_from_port	integer	GLOBAL | SESSION
Ndb_conflict_fn_epoch	integer	GLOBAL
Ndb_conflict_fn_epoch_trans	integer	GLOBAL
Ndb_conflict_fn_max	integer	GLOBAL
Ndb_conflict_fn_old	integer	GLOBAL
Ndb_conflict_trans_conflict_commit_count	integer	GLOBAL
Ndb_conflict_trans_detect_iter_count	integer	GLOBAL
Ndb_conflict_trans_reject_count	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
Ndb_conflict_trans_row_reject_count	integer	GLOBAL
Ndb_execute_count	integer	GLOBAL
Ndb_cluster_node_id	integer	GLOBAL
Ndb_number_of_data_nodes	integer	GLOBAL
Ndb_pruned_scan_count	integer	GLOBAL
Ndb_pushed_queries_defined	integer	GLOBAL
Ndb_pushed_queries_dropped	integer	GLOBAL
Ndb_pushed_queries_executed	integer	GLOBAL
Ndb_pushed_reads	integer	GLOBAL
Ndb_scan_count	integer	GLOBAL
Not_flushed_delayed_rows	integer	GLOBAL
Open_files	integer	GLOBAL
Open_streams	integer	GLOBAL
Open_table_definitions	integer	GLOBAL
Open_tables	integer	GLOBAL | SESSION
Opened_files	integer	GLOBAL
Opened_table_definitions	integer	GLOBAL | SESSION
Opened_tables	integer	GLOBAL | SESSION
Performance_schema_cond_classes_lost	integer	GLOBAL
Performance_schema_cond_instances_lost	integer	GLOBAL
Performance_schema_file_classes_lost	integer	GLOBAL
Performance_schema_file_handles_lost	integer	GLOBAL
Performance_schema_file_instances_lost	integer	GLOBAL
Performance_schema_locker_lost	integer	GLOBAL
Performance_schema_mutex_classes_lost	integer	GLOBAL
Performance_schema_mutex_instances_lost	integer	GLOBAL
Performance_schema_rwlock_classes_lost	integer	GLOBAL
Performance_schema_rwlock_instances_lost	integer	GLOBAL
Performance_schema_table_handles_lost	integer	GLOBAL
Performance_schema_table_instances_lost	integer	GLOBAL
Performance_schema_thread_classes_lost	integer	GLOBAL
Performance_schema_thread_instances_lost	integer	GLOBAL
Prepared_stmt_count	integer	GLOBAL
Qcache_free_blocks	integer	GLOBAL
Qcache_free_memory	integer	GLOBAL
Qcache_hits	integer	GLOBAL
Qcache_inserts	integer	GLOBAL
Qcache_lowmem_prunes	integer	GLOBAL
Qcache_not_cached	integer	GLOBAL
Qcache_queries_in_cache	integer	GLOBAL
Qcache_total_blocks	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
Queries	integer	GLOBAL | SESSION
Questions	integer	GLOBAL | SESSION
Rpl_semi_sync_master_clients	integer	GLOBAL
Rpl_semi_sync_master_net_avg_wait_time	integer	GLOBAL
Rpl_semi_sync_master_net_wait_time	integer	GLOBAL
Rpl_semi_sync_master_net_waits	integer	GLOBAL
Rpl_semi_sync_master_no_times	integer	GLOBAL
Rpl_semi_sync_master_no_tx	integer	GLOBAL
Rpl_semi_sync_master_status	boolean	GLOBAL
Rpl_semi_sync_master_timefunc_failures	integer	GLOBAL
Rpl_semi_sync_master_tx_avg_wait_time	integer	GLOBAL
Rpl_semi_sync_master_tx_wait_time	integer	GLOBAL
Rpl_semi_sync_master_tx_waits	integer	GLOBAL
Rpl_semi_sync_master_wait_pos_backtraverse	integer	GLOBAL
Rpl_semi_sync_master_wait_sessions	integer	GLOBAL
Rpl_semi_sync_master_yes_tx	integer	GLOBAL
Rpl_semi_sync_slave_status	boolean	GLOBAL
Rpl_status	string	GLOBAL
Select_full_join	integer	GLOBAL | SESSION
Select_full_range_join	integer	GLOBAL | SESSION
Select_range	integer	GLOBAL | SESSION
Select_range_check	integer	GLOBAL | SESSION
Select_scan	integer	GLOBAL | SESSION
Slave_heartbeat_period	numeric	GLOBAL
Slave_open_temp_tables	integer	GLOBAL
Slave_received_heartbeats		GLOBAL
Slave_retried_transactions	integer	GLOBAL
Slave_running	boolean	GLOBAL
Slow_launch_threads	integer	GLOBAL | SESSION
Slow_queries	integer	GLOBAL | SESSION
Sort_merge_passes	integer	GLOBAL | SESSION
Sort_range	integer	GLOBAL | SESSION
Sort_rows	integer	GLOBAL | SESSION
Sort_scan	integer	GLOBAL | SESSION
Ssl_accept_renegotiates	integer	GLOBAL
Ssl_accepts	integer	GLOBAL
Ssl_callback_cache_hits	integer	GLOBAL
Ssl_cipher	string	GLOBAL | SESSION
Ssl_cipher_list	string	GLOBAL | SESSION
Ssl_client_connects	integer	GLOBAL
Ssl_connect_renegotiates	integer	GLOBAL

Variable Name	Variable Type	Variable Scope
Ssl_ctx_verify_depth	integer	GLOBAL
Ssl_ctx_verify_mode	integer	GLOBAL
Ssl_default_timeout	integer	GLOBAL | SESSION
Ssl_finished_accepts	integer	GLOBAL
Ssl_finished_connects	integer	GLOBAL
Ssl_session_cache_hits	integer	GLOBAL
Ssl_session_cache_misses	integer	GLOBAL
Ssl_session_cache_mode	string	GLOBAL
Ssl_session_cache_overflows	integer	GLOBAL
Ssl_session_cache_size	integer	GLOBAL
Ssl_session_cache_timeouts	integer	GLOBAL
Ssl_sessions_reused	integer	GLOBAL | SESSION
Ssl_used_session_cache_entries	integer	GLOBAL
Ssl_verify_depth	integer	GLOBAL | SESSION
Ssl_verify_mode	integer	GLOBAL | SESSION
Ssl_version	string	GLOBAL | SESSION
Table_locks_immediate	integer	GLOBAL
Table_locks_waited	integer	GLOBAL
Tc_log_max_pages_used	integer	GLOBAL
Tc_log_page_size	integer	GLOBAL
Tc_log_page_waits	integer	GLOBAL
Threads_cached	integer	GLOBAL
Threads_connected	integer	GLOBAL
Threads_created	integer	GLOBAL
Threads_running	integer	GLOBAL
Uptime	integer	GLOBAL
Uptime_since_flush_status	integer	GLOBAL

The status variables have the following meanings. For meanings of status variables specific to NDB Cluster, see NDB Cluster Status Variables.

- Aborted_clients

  The number of connections that were aborted because the client died without closing the connection properly. See Section B.5.2.11, “Communication Errors and Aborted Connections”.

- Aborted_connects

  The number of failed attempts to connect to the MySQL server. See Section B.5.2.11, “Communication Errors and Aborted Connections”.

- Binlog_cache_disk_use

  The number of transactions that used the binary log cache but that exceeded the value of binlog_cache_size and used a temporary file to store changes from the transaction.

  In MySQL versions 5.5.3 through 5.5.8, this variable also included the number of nontransactional statements that caused the binary log transaction cache to be written to disk. Beginning with

MySQL 5.5.9, the number of such nontransactional statements is tracked separately in the `Binlog_stmt_cache_disk_use` status variable.

- `Binlog_cache_use`

  The number of transactions that used the binary log cache.

- `Binlog_stmt_cache_disk_use`

  The number of nontransaction statements that used the binary log statement cache but that exceeded the value of `binlog_stmt_cache_size` and used a temporary file to store those statements.

- `Binlog_stmt_cache_use`

  The number of nontransactional statements that used the binary log statement cache.

- `Bytes_received`

  The number of bytes received from all clients.

- `Bytes_sent`

  The number of bytes sent to all clients.

- `Com_xxx`

  The `Com_xxx` statement counter variables indicate the number of times each *`xxx`* statement has been executed. There is one status variable for each type of statement. For example, `Com_delete` and `Com_update` count `DELETE` and `UPDATE` statements, respectively. `Com_delete_multi` and `Com_update_multi` are similar but apply to `DELETE` and `UPDATE` statements that use multiple-table syntax.

  If a query result is returned from query cache, the server increments the `Qcache_hits` status variable, not `Com_select`. See Section 8.10.3.4, “Query Cache Status and Maintenance”.

  The discussion at the beginning of this section indicates how to relate these statement-counting status variables to other such variables.

  All of the `Com_stmt_xxx` variables are increased even if a prepared statement argument is unknown or an error occurred during execution. In other words, their values correspond to the number of requests issued, not to the number of requests successfully completed.

  The `Com_stmt_xxx` status variables are as follows:

  - `Com_stmt_prepare`
  - `Com_stmt_execute`
  - `Com_stmt_fetch`
  - `Com_stmt_send_long_data`
  - `Com_stmt_reset`
  - `Com_stmt_close`

  Those variables stand for prepared statement commands. Their names refer to the `COM_xxx` command set used in the network layer. In other words, their values increase whenever prepared statement API calls such as `mysql_stmt_prepare()`, `mysql_stmt_execute()`, and so forth are executed. However, `Com_stmt_prepare`, `Com_stmt_execute` and `Com_stmt_close` also increase for `PREPARE`, `EXECUTE`, or `DEALLOCATE PREPARE`, respectively. Additionally, the

values of the older statement counter variables `Com_prepare_sql`, `Com_execute_sql`, and `Com_dealloc_sql` increase for the `PREPARE`, `EXECUTE`, and `DEALLOCATE PREPARE` statements. `Com_stmt_fetch` stands for the total number of network round-trips issued when fetching from cursors.

`Com_stmt_reprepare` indicates the number of times statements were automatically reprepared by the server after metadata changes to tables or views referred to by the statement. A reprepare operation increments `Com_stmt_reprepare`, and also `Com_stmt_prepare`.

- `Compression`

  Whether the client connection uses compression in the client/server protocol.

- `Connections`

  The number of connection attempts (successful or not) to the MySQL server.

- `Created_tmp_disk_tables`

  The number of internal on-disk temporary tables created by the server while executing statements.

  If an internal temporary table is created initially as an in-memory table but becomes too large, MySQL automatically converts it to an on-disk table. The maximum size for in-memory temporary tables is the minimum of the `tmp_table_size` and `max_heap_table_size` values. If `Created_tmp_disk_tables` is large, you may want to increase the `tmp_table_size` or `max_heap_table_size` value to lessen the likelihood that internal temporary tables in memory will be converted to on-disk tables.

  You can compare the number of internal on-disk temporary tables created to the total number of internal temporary tables created by comparing the values of the `Created_tmp_disk_tables` and `Created_tmp_tables` variables.

  See also Section 8.4.4, “Internal Temporary Table Use in MySQL”.

- `Created_tmp_files`

  How many temporary files `mysqld` has created.

- `Created_tmp_tables`

  The number of internal temporary tables created by the server while executing statements.

  You can compare the number of internal on-disk temporary tables created to the total number of internal temporary tables created by comparing the values of the `Created_tmp_disk_tables` and `Created_tmp_tables` variables.

  See also Section 8.4.4, “Internal Temporary Table Use in MySQL”.

  Each invocation of the `SHOW STATUS` statement uses an internal temporary table and increments the global `Created_tmp_tables` value.

- `Delayed_errors`

  The number of rows written with `INSERT DELAYED` for which some error occurred (probably `duplicate key`).

- `Delayed_insert_threads`

  The number of `INSERT DELAYED` handler threads in use.

- `Delayed_writes`

  The number of `INSERT DELAYED` rows written.

- `Flush_commands`

  The number of times the server flushes tables, whether because a user executed a `FLUSH TABLES` statement or due to internal server operation. It is also incremented by receipt of a `COM_REFRESH` packet. This is in contrast to `Com_flush`, which indicates how many `FLUSH` statements have been executed, whether `FLUSH TABLES`, `FLUSH LOGS`, and so forth.

- `Handler_commit`

  The number of internal `COMMIT` statements.

- `Handler_delete`

  The number of times that rows have been deleted from tables.

- `Handler_prepare`

  A counter for the prepare phase of two-phase commit operations.

- `Handler_read_first`

  The number of times the first entry in an index was read. If this value is high, it suggests that the server is doing a lot of full index scans; for example, `SELECT col1 FROM foo`, assuming that `col1` is indexed.

- `Handler_read_key`

  The number of requests to read a row based on a key. If this value is high, it is a good indication that your tables are properly indexed for your queries.

- `Handler_read_last`

  The number of requests to read the last key in an index. With `ORDER BY`, the server will issue a first-key request followed by several next-key requests, whereas with `ORDER BY DESC`, the server will issue a last-key request followed by several previous-key requests.

- `Handler_read_next`

  The number of requests to read the next row in key order. This value is incremented if you are querying an index column with a range constraint or if you are doing an index scan.

- `Handler_read_prev`

  The number of requests to read the previous row in key order. This read method is mainly used to optimize `ORDER BY ... DESC`.

- `Handler_read_rnd`

  The number of requests to read a row based on a fixed position. This value is high if you are doing a lot of queries that require sorting of the result. You probably have a lot of queries that require MySQL to scan entire tables or you have joins that do not use keys properly.

- `Handler_read_rnd_next`

  The number of requests to read the next row in the data file. This value is high if you are doing a lot of table scans. Generally this suggests that your tables are not properly indexed or that your queries are not written to take advantage of the indexes you have.

- `Handler_rollback`

  The number of requests for a storage engine to perform a rollback operation.

- `Handler_savepoint`

The number of requests for a storage engine to place a savepoint.

- `Handler_savepoint_rollback`

  The number of requests for a storage engine to roll back to a savepoint.

- `Handler_update`

  The number of requests to update a row in a table.

- `Handler_write`

  The number of requests to insert a row in a table.

- `Innodb_buffer_pool_bytes_data`

  The total number of bytes in the `InnoDB` buffer pool containing data. The number includes both dirty and clean pages. For more accurate memory usage calculations than with `Innodb_buffer_pool_pages_data`, when compressed tables cause the buffer pool to hold pages of different sizes.

- `Innodb_buffer_pool_pages_data`

  The number of pages in the `InnoDB` buffer pool containing data. The number includes both dirty and clean pages. When using compressed tables, the reported `Innodb_buffer_pool_pages_data` value may be larger than `Innodb_buffer_pool_pages_total` (Bug #59550).

- `Innodb_buffer_pool_bytes_dirty`

  The total current number of bytes held in dirty pages in the `InnoDB` buffer pool. For more accurate memory usage calculations than with `Innodb_buffer_pool_pages_dirty`, when compressed tables cause the buffer pool to hold pages of different sizes.

- `Innodb_buffer_pool_pages_dirty`

  The number of pages currently dirty.

- `Innodb_buffer_pool_pages_flushed`

  The number of buffer pool page-flush requests.

- `Innodb_buffer_pool_pages_free`

  The number of free pages.

- `Innodb_buffer_pool_pages_latched`

  The number of latched pages in `InnoDB` buffer pool. These are pages currently being read or written or that cannot be flushed or removed for some other reason. Calculation of this variable is expensive, so it is available only when the `UNIV_DEBUG` system is defined at server build time.

- `Innodb_buffer_pool_pages_misc`

  The number of pages that are busy because they have been allocated for administrative overhead such as row locks or the adaptive hash index. This value can also be calculated as `Innodb_buffer_pool_pages_total` − `Innodb_buffer_pool_pages_free` − `Innodb_buffer_pool_pages_data`. When using compressed tables, `Innodb_buffer_pool_pages_misc` may report an out-of-bounds value (Bug #59550).

- `Innodb_buffer_pool_pages_total`

The total size of the InnoDB buffer pool, in pages. When using compressed tables, the reported Innodb_buffer_pool_pages_data value may be larger than Innodb_buffer_pool_pages_total (Bug #59550)

- Innodb_buffer_pool_read_ahead

  The number of pages read into the InnoDB buffer pool by the read-ahead background thread.

- Innodb_buffer_pool_read_ahead_evicted

  The number of pages read into the InnoDB buffer pool by the read-ahead background thread that were subsequently evicted without having been accessed by queries.

- Innodb_buffer_pool_read_ahead_rnd

  The number of “random” read-aheads initiated by InnoDB. This happens when a query scans a large portion of a table but in random order.

- Innodb_buffer_pool_read_requests

  The number of logical read requests.

- Innodb_buffer_pool_reads

  The number of logical reads that InnoDB could not satisfy from the buffer pool, and had to read directly from the disk.

- Innodb_buffer_pool_wait_free

  Normally, writes to the InnoDB buffer pool happen in the background. However, if it is necessary to read or create a page and no clean pages are available, it is also necessary to wait for pages to be flushed first. This counter counts instances of these waits. If the buffer pool size has been set properly, this value should be small.

- Innodb_buffer_pool_write_requests

  The number writes done to the InnoDB buffer pool.

- Innodb_data_fsyncs

  The number of fsync() operations so far.

- Innodb_data_pending_fsyncs

  The current number of pending fsync() operations.

- Innodb_data_pending_reads

  The current number of pending reads.

- Innodb_data_pending_writes

  The current number of pending writes.

- Innodb_data_read

  The amount of data read since the server was started (in bytes).

- Innodb_data_reads

  The total number of data reads (OS file reads).

- Innodb_data_writes

The total number of data writes.

- `Innodb_data_written`

  The amount of data written so far, in bytes.

- `Innodb_dblwr_pages_written`

  The number of pages that have been written for doublewrite operations. See Section 14.15.1, “InnoDB Disk I/O”.

- `Innodb_dblwr_writes`

  The number of doublewrite operations that have been performed. See Section 14.15.1, “InnoDB Disk I/O”.

- `Innodb_have_atomic_builtins`

  Indicates whether the server was built with atomic instructions.

- `Innodb_log_waits`

  The number of times that the log buffer was too small and a wait was required for it to be flushed before continuing.

- `Innodb_log_write_requests`

  The number of log write requests.

- `Innodb_log_writes`

  The number of physical writes to the log file.

- `Innodb_os_log_fsyncs`

  The number of `fsync()` writes done to the log file.

- `Innodb_os_log_pending_fsyncs`

  The number of pending log file `fsync()` operations.

- `Innodb_os_log_pending_writes`

  The number of pending log file writes.

- `Innodb_os_log_written`

  The number of bytes written to the log file.

- `Innodb_page_size`

  The compiled-in `InnoDB` page size (default 16KB). Many values are counted in pages; the page size enables them to be easily converted to bytes.

- `Innodb_pages_created`

  The number of pages created.

- `Innodb_pages_read`

  The number of pages read from the `InnoDB` buffer pool by operations on `InnoDB` tables.

- `Innodb_pages_written`

The number of pages written.

- `Innodb_row_lock_current_waits`

  The number of row locks currently being waited for.

- `Innodb_row_lock_time`

  The total time spent in acquiring row locks, in milliseconds.

- `Innodb_row_lock_time_avg`

  The average time to acquire a row lock, in milliseconds.

- `Innodb_row_lock_time_max`

  The maximum time to acquire a row lock, in milliseconds.

- `Innodb_row_lock_waits`

  The number of times a row lock had to be waited for.

- `Innodb_rows_deleted`

  The number of rows deleted from `InnoDB` tables.

- `Innodb_rows_inserted`

  The number of rows inserted into `InnoDB` tables.

- `Innodb_rows_read`

  The number of rows read from `InnoDB` tables.

- `Innodb_rows_updated`

  The number of rows updated in `InnoDB` tables.

- `Innodb_truncated_status_writes`

  The number of times output from the `SHOW ENGINE INNODB STATUS` is truncated. Monitoring applications that parse the output from this command can test this value before and after issuing the `SHOW ENGINE` command, to confirm if the output is complete or not.

- `Key_blocks_not_flushed`

  The number of key blocks in the key cache that have changed but have not yet been flushed to disk.

- `Key_blocks_unused`

  The number of unused blocks in the key cache. You can use this value to determine how much of the key cache is in use; see the discussion of `key_buffer_size` in Section 5.1.5, “Server System Variables”.

- `Key_blocks_used`

  The number of used blocks in the key cache. This value is a high-water mark that indicates the maximum number of blocks that have ever been in use at one time.

- `Key_read_requests`

  The number of requests to read a key block from the cache.

- `Key_reads`

  The number of physical reads of a key block from disk. If `Key_reads` is large, then your `key_buffer_size` value is probably too small. The cache miss rate can be calculated as `Key_reads`/`Key_read_requests`.

- `Key_write_requests`

  The number of requests to write a key block to the cache.

- `Key_writes`

  The number of physical writes of a key block to disk.

- `Last_query_cost`

  The total cost of the last compiled query as computed by the query optimizer. This is useful for comparing the cost of different query plans for the same query. The default value of 0 means that no query has been compiled yet. The default value is 0. `Last_query_cost` has session scope.

  The `Last_query_cost` value can be computed accurately only for simple “flat” queries, not complex queries such as those with subqueries or `UNION`. For the latter, the value is set to 0.

- `Max_used_connections`

  The maximum number of connections that have been in use simultaneously since the server started.

- `Not_flushed_delayed_rows`

  The number of rows waiting to be written in `INSERT DELAYED` queues.

- `Open_files`

  The number of files that are open. This count includes regular files opened by the server. It does not include other types of files such as sockets or pipes. Also, the count does not include files that storage engines open using their own internal functions rather than asking the server level to do so.

- `Open_streams`

  The number of streams that are open (used mainly for logging).

- `Open_table_definitions`

  The number of cached `.frm` files.

- `Open_tables`

  The number of tables that are open.

- `Opened_files`

  The number of files that have been opened with `my_open()` (a `mysys` library function). Parts of the server that open files without using this function do not increment the count.

- `Opened_table_definitions`

  The number of `.frm` files that have been cached.

- `Opened_tables`

  The number of tables that have been opened. If `Opened_tables` is big, your `table_open_cache` value is probably too small.

- `Performance_schema_`*`xxx`*

Performance Schema status variables are listed in Section 22.12, “Performance Schema Status Variables”. These variables provide information about instrumentation that could not be loaded or created due to memory constraints.

- `Prepared_stmt_count`

  The current number of prepared statements. (The maximum number of statements is given by the `max_prepared_stmt_count` system variable.)

- `Qcache_free_blocks`

  The number of free memory blocks in the query cache.

- `Qcache_free_memory`

  The amount of free memory for the query cache.

- `Qcache_hits`

  The number of query cache hits.

  The discussion at the beginning of this section indicates how to relate this statement-counting status variable to other such variables.

- `Qcache_inserts`

  The number of queries added to the query cache.

- `Qcache_lowmem_prunes`

  The number of queries that were deleted from the query cache because of low memory.

- `Qcache_not_cached`

  The number of noncached queries (not cacheable, or not cached due to the `query_cache_type` setting).

- `Qcache_queries_in_cache`

  The number of queries registered in the query cache.

- `Qcache_total_blocks`

  The total number of blocks in the query cache.

- `Queries`

  The number of statements executed by the server. This variable includes statements executed within stored programs, unlike the `Questions` variable. It does not count `COM_PING` or `COM_STATISTICS` commands.

  The discussion at the beginning of this section indicates how to relate this statement-counting status variable to other such variables.

- `Questions`

  The number of statements executed by the server. This includes only statements sent to the server by clients and not statements executed within stored programs, unlike the `Queries` variable. This variable does not count `COM_PING`, `COM_STATISTICS`, `COM_STMT_PREPARE`, `COM_STMT_CLOSE`, or `COM_STMT_RESET` commands.

  The discussion at the beginning of this section indicates how to relate this statement-counting status variable to other such variables.

- `Rpl_semi_sync_master_clients`

  The number of semisynchronous slaves.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_net_avg_wait_time`

  The average time in microseconds the master waited for a slave reply.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_net_wait_time`

  The total time in microseconds the master waited for slave replies.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_net_waits`

  The total number of times the master waited for slave replies.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_no_times`

  The number of times the master turned off semisynchronous replication.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_no_tx`

  The number of commits that were not acknowledged successfully by a slave.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_status`

  Whether semisynchronous replication currently is operational on the master. The value is `ON` if the plugin has been enabled and a commit acknowledgment has occurred. It is `OFF` if the plugin is not enabled or the master has fallen back to asynchronous replication due to commit acknowledgment timeout.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_timefunc_failures`

  The number of times the master failed when calling time functions such as `gettimeofday()`.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_tx_avg_wait_time`

  The average time in microseconds the master waited for each transaction.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_tx_wait_time`

  The total time in microseconds the master waited for transactions.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_tx_waits`

The total number of times the master waited for transactions.

This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_wait_pos_backtraverse`

  The total number of times the master waited for an event with binary coordinates lower than events waited for previously. This can occur when the order in which transactions start waiting for a reply is different from the order in which their binary log events are written.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_wait_sessions`

  The number of sessions currently waiting for slave replies.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_master_yes_tx`

  The number of commits that were acknowledged successfully by a slave.

  This variable is available only if the master-side semisynchronous replication plugin is installed.

- `Rpl_semi_sync_slave_status`

  Whether semisynchronous replication currently is operational on the slave. This is `ON` if the plugin has been enabled and the slave I/O thread is running, `OFF` otherwise.

  This variable is available only if the slave-side semisynchronous replication plugin is installed.

- `Rpl_status`

  The status of fail-safe replication (not implemented). This variable is unused and is removed in MySQL 5.6.

- `Select_full_join`

  The number of joins that perform table scans because they do not use indexes. If this value is not 0, you should carefully check the indexes of your tables.

- `Select_full_range_join`

  The number of joins that used a range search on a reference table.

- `Select_range`

  The number of joins that used ranges on the first table. This is normally not a critical issue even if the value is quite large.

- `Select_range_check`

  The number of joins without keys that check for key usage after each row. If this is not 0, you should carefully check the indexes of your tables.

- `Select_scan`

  The number of joins that did a full scan of the first table.

- `Slave_heartbeat_period`

  Shows the replication heartbeat interval (in seconds) on a replication slave.

- `Slave_open_temp_tables`

  The number of temporary tables that the slave SQL thread currently has open. If the value is greater than zero, it is not safe to shut down the slave; see Section 17.4.1.31, “Replication and Temporary Tables”.

- `Slave_received_heartbeats`

  This counter increments with each replication heartbeat received by a replication slave since the last time that the slave was restarted or reset, or a `CHANGE MASTER TO` statement was issued.

- `Slave_retried_transactions`

  The total number of times since startup that the replication slave SQL thread has retried transactions.

- `Slave_running`

  This is `ON` if this server is a replication slave that is connected to a replication master, and both the I/O and SQL threads are running; otherwise, it is `OFF`.

- `Slow_launch_threads`

  The number of threads that have taken more than `slow_launch_time` seconds to create.

- `Slow_queries`

  The number of queries that have taken more than `long_query_time` seconds. This counter increments regardless of whether the slow query log is enabled. For information about that log, see Section 5.4.5, “The Slow Query Log”.

- `Sort_merge_passes`

  The number of merge passes that the sort algorithm has had to do. If this value is large, you should consider increasing the value of the `sort_buffer_size` system variable.

- `Sort_range`

  The number of sorts that were done using ranges.

- `Sort_rows`

  The number of sorted rows.

- `Sort_scan`

  The number of sorts that were done by scanning the table.

- `Ssl_accept_renegotiates`

  The number of negotiates needed to establish the connection.

- `Ssl_accepts`

  The number of accepted SSL connections.

- `Ssl_callback_cache_hits`

  The number of callback cache hits.

- `Ssl_cipher`

  The current encryption cipher (empty for unencrypted connections).

- `Ssl_cipher_list`

The list of possible SSL ciphers (empty for non-SSL connections).

- `Ssl_client_connects`

  The number of SSL connection attempts to an SSL-enabled master.

- `Ssl_connect_renegotiates`

  The number of negotiates needed to establish the connection to an SSL-enabled master.

- `Ssl_ctx_verify_depth`

  The SSL context verification depth (how many certificates in the chain are tested).

- `Ssl_ctx_verify_mode`

  The SSL context verification mode.

- `Ssl_default_timeout`

  The default SSL timeout.

- `Ssl_finished_accepts`

  The number of successful SSL connections to the server.

- `Ssl_finished_connects`

  The number of successful slave connections to an SSL-enabled master.

- `Ssl_session_cache_hits`

  The number of SSL session cache hits.

- `Ssl_session_cache_misses`

  The number of SSL session cache misses.

- `Ssl_session_cache_mode`

  The SSL session cache mode.

- `Ssl_session_cache_overflows`

  The number of SSL session cache overflows.

- `Ssl_session_cache_size`

  The SSL session cache size.

- `Ssl_session_cache_timeouts`

  The number of SSL session cache timeouts.

- `Ssl_sessions_reused`

  How many SSL connections were reused from the cache.

- `Ssl_used_session_cache_entries`

  How many SSL session cache entries were used.

- `Ssl_verify_depth`

  The verification depth for replication SSL connections.

- `Ssl_verify_mode`

  The verification mode used by the server for a connection that uses SSL. The value is a bitmask; bits are defined in the `openssl/ssl.h` header file:

  ```
  # define SSL_VERIFY_NONE                 0x00
  # define SSL_VERIFY_PEER                 0x01
  # define SSL_VERIFY_FAIL_IF_NO_PEER_CERT 0x02
  # define SSL_VERIFY_CLIENT_ONCE          0x04
  ```

  `SSL_VERIFY_PEER` indicates that the server asks for a client certificate. If the client supplies one, the server performs verification and proceeds only if verification is successful. `SSL_VERIFY_CLIENT_ONCE` indicates that a request for the client certificate will be done only in the initial handshake.

- `Ssl_version`

  The SSL protocol version of the connection; for example, TLSv1. If the connection is not encrypted, the value is empty.

- `Table_locks_immediate`

  The number of times that a request for a table lock could be granted immediately.

- `Table_locks_waited`

  The number of times that a request for a table lock could not be granted immediately and a wait was needed. If this is high and you have performance problems, you should first optimize your queries, and then either split your table or tables or use replication.

- `Tc_log_max_pages_used`

  For the memory-mapped implementation of the log that is used by `mysqld` when it acts as the transaction coordinator for recovery of internal XA transactions, this variable indicates the largest number of pages used for the log since the server started. If the product of `Tc_log_max_pages_used` and `Tc_log_page_size` is always significantly less than the log size, the size is larger than necessary and can be reduced. (The size is set by the `--log-tc-size` option. This variable is unused: It is unneeded for binary log-based recovery, and the memory-mapped recovery log method is not used unless the number of storage engines that are capable of two-phase commit and that support XA transactions is greater than one. (`InnoDB` is the only applicable engine.)

- `Tc_log_page_size`

  The page size used for the memory-mapped implementation of the XA recovery log. The default value is determined using `getpagesize()`. This variable is unused for the same reasons as described for `Tc_log_max_pages_used`.

- `Tc_log_page_waits`

  For the memory-mapped implementation of the recovery log, this variable increments each time the server was not able to commit a transaction and had to wait for a free page in the log. If this value is large, you might want to increase the log size (with the `--log-tc-size` option). For binary log-based recovery, this variable increments each time the binary log cannot be closed because there are two-phase commits in progress. (The close operation waits until all such transactions are finished.)

- `Threads_cached`

  The number of threads in the thread cache.

- `Threads_connected`

The number of currently open connections.

- `Threads_created`

  The number of threads created to handle connections. If `Threads_created` is big, you may want to increase the `thread_cache_size` value. The cache miss rate can be calculated as `Threads_created`/`Connections`.

- `Threads_running`

  The number of threads that are not sleeping.

- `Uptime`

  The number of seconds that the server has been up.

- `Uptime_since_flush_status`

  The number of seconds since the most recent `FLUSH STATUS` statement.

5.1.8 Server SQL Modes

The MySQL server can operate in different SQL modes, and can apply these modes differently for different clients, depending on the value of the `sql_mode` system variable. DBAs can set the global SQL mode to match site server operating requirements, and each application can set its session SQL mode to its own requirements.

Modes affect the SQL syntax MySQL supports and the data validation checks it performs. This makes it easier to use MySQL in different environments and to use MySQL together with other database servers.

- Setting the SQL Mode
- The Most Important SQL Modes
- Full List of SQL Modes
- Combination SQL Modes
- Strict SQL Mode

For answers to questions often asked about server SQL modes in MySQL, see Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”.

When working with `InnoDB` tables, consider also the `innodb_strict_mode` system variable. It enables additional error checks for `InnoDB` tables.

Setting the SQL Mode

The default SQL mode is empty (no modes set).

To set the SQL mode at server startup, use the `--sql-mode="modes"` option on the command line, or `sql-mode="modes"` in an option file such as `my.cnf` (Unix operating systems) or `my.ini` (Windows). *`modes`* is a list of different modes separated by commas. To clear the SQL mode explicitly, set it to an empty string using `--sql-mode=""` on the command line, or `sql-mode=""` in an option file.

Note

MySQL installation programs may configure the SQL mode during the installation process. If the SQL mode differs from the default or from what you expect, check for a setting in an option file that the server reads at startup.

To change the SQL mode at runtime, set the global or session `sql_mode` system variable using a `SET` statement:

```
SET GLOBAL sql_mode = 'modes';
SET SESSION sql_mode = 'modes';
```

Setting the `GLOBAL` variable requires the `SUPER` privilege and affects the operation of all clients that connect from that time on. Setting the `SESSION` variable affects only the current client. Each client can change its session `sql_mode` value at any time.

To determine the current global or session `sql_mode` value, use the following statements:

```
SELECT @@GLOBAL.sql_mode;
SELECT @@SESSION.sql_mode;
```

Important

SQL mode and user-defined partitioning. Changing the server SQL mode after creating and inserting data into partitioned tables can cause major changes in the behavior of such tables, and could lead to loss or corruption of data. It is strongly recommended that you never change the SQL mode once you have created tables employing user-defined partitioning.

When replicating partitioned tables, differing SQL modes on master and slave can also lead to problems. For best results, you should always use the same server SQL mode on the master and on the slave.

See Section 19.5, “Restrictions and Limitations on Partitioning”, for more information.

The Most Important SQL Modes

The most important `sql_mode` values are probably these:

- `ANSI`

  This mode changes syntax and behavior to conform more closely to standard SQL. It is one of the special combination modes listed at the end of this section.

- `STRICT_TRANS_TABLES`

  If a value could not be inserted as given into a transactional table, abort the statement. For a nontransactional table, abort the statement if the value occurs in a single-row statement or the first row of a multiple-row statement. More details are given later in this section.

- `TRADITIONAL`

  Make MySQL behave like a “traditional” SQL database system. A simple description of this mode is “give an error instead of a warning” when inserting an incorrect value into a column. It is one of the special combination modes listed at the end of this section.

  Note

  The `INSERT` or `UPDATE` aborts as soon as the error is noticed. This may not be what you want if you are using a nontransactional storage engine, because data changes made prior to the error may not be rolled back, resulting in a “partially done” update.

When this manual refers to “strict mode,” it means a mode with either or both `STRICT_TRANS_TABLES` or `STRICT_ALL_TABLES` enabled.

Full List of SQL Modes

The following list describes all supported SQL modes:

- `ALLOW_INVALID_DATES`

  Do not perform full checking of dates. Check only that the month is in the range from 1 to 12 and the day is in the range from 1 to 31. This is very convenient for Web applications where you obtain year, month, and day in three different fields and you want to store exactly what the user inserted (without date validation). This mode applies to `DATE` and `DATETIME` columns. It does not apply `TIMESTAMP` columns, which always require a valid date.

  The server requires that month and day values be legal, and not merely in the range 1 to 12 and 1 to 31, respectively. With strict mode disabled, invalid dates such as `'2004-04-31'` are converted to `'0000-00-00'` and a warning is generated. With strict mode enabled, invalid dates generate an error. To permit such dates, enable `ALLOW_INVALID_DATES`.

- `ANSI_QUOTES`

  Treat `"` as an identifier quote character (like the `` ` `` quote character) and not as a string quote character. You can still use `` ` `` to quote identifiers with this mode enabled. With `ANSI_QUOTES` enabled, you cannot use double quotation marks to quote literal strings, because it is interpreted as an identifier.

- `ERROR_FOR_DIVISION_BY_ZERO`

  The `ERROR_FOR_DIVISION_BY_ZERO` mode affects handling of division by zero, which includes `MOD(N,0)`. For data-change operations (`INSERT`, `UPDATE`), its effect also depends on whether strict SQL mode is enabled.

  - If this mode is not enabled, division by zero inserts `NULL` and produces no warning.
  - If this mode is enabled, division by zero inserts `NULL` and produces a warning.
  - If this mode and strict mode are enabled, division by zero produces an error, unless `IGNORE` is given as well. For `INSERT IGNORE` and `UPDATE IGNORE`, division by zero inserts `NULL` and produces a warning.

  For `SELECT`, division by zero returns `NULL`. Enabling `ERROR_FOR_DIVISION_BY_ZERO` causes a warning to be produced as well, regardless of whether strict mode is enabled.

- `HIGH_NOT_PRECEDENCE`

  The precedence of the `NOT` operator is such that expressions such as `NOT a BETWEEN b AND c` are parsed as `NOT (a BETWEEN b AND c)`. In some older versions of MySQL, the expression was parsed as `(NOT a) BETWEEN b AND c`. The old higher-precedence behavior can be obtained by enabling the `HIGH_NOT_PRECEDENCE` SQL mode.

  ```
  mysql> SET sql_mode = '';
  mysql> SELECT NOT 1 BETWEEN -5 AND 5;
          -> 0
  mysql> SET sql_mode = 'HIGH_NOT_PRECEDENCE';
  mysql> SELECT NOT 1 BETWEEN -5 AND 5;
          -> 1
  ```

- `IGNORE_SPACE`

  Permit spaces between a function name and the `(` character. This causes built-in function names to be treated as reserved words. As a result, identifiers that are the same as function names must be quoted as described in Section 9.2, “Schema Object Names”. For example, because there is a `COUNT()` function, the use of `count` as a table name in the following statement causes an error:

```
mysql> CREATE TABLE count (i INT);
ERROR 1064 (42000): You have an error in your SQL syntax
```

The table name should be quoted:

```
mysql> CREATE TABLE `count` (i INT);
Query OK, 0 rows affected (0.00 sec)
```

The IGNORE_SPACE SQL mode applies to built-in functions, not to user-defined functions or stored functions. It is always permissible to have spaces after a UDF or stored function name, regardless of whether IGNORE_SPACE is enabled.

For further discussion of IGNORE_SPACE, see Section 9.2.4, “Function Name Parsing and Resolution”.

- NO_AUTO_CREATE_USER

  Prevent the GRANT statement from automatically creating new users if it would otherwise do so, unless authentication information is specified. The statement must specify a nonempty password using IDENTIFIED BY or an authentication plugin using IDENTIFIED WITH.

- NO_AUTO_VALUE_ON_ZERO

  NO_AUTO_VALUE_ON_ZERO affects handling of AUTO_INCREMENT columns. Normally, you generate the next sequence number for the column by inserting either NULL or 0 into it. NO_AUTO_VALUE_ON_ZERO suppresses this behavior for 0 so that only NULL generates the next sequence number.

  This mode can be useful if 0 has been stored in a table's AUTO_INCREMENT column. (Storing 0 is not a recommended practice, by the way.) For example, if you dump the table with mysqldump and then reload it, MySQL normally generates new sequence numbers when it encounters the 0 values, resulting in a table with contents different from the one that was dumped. Enabling NO_AUTO_VALUE_ON_ZERO before reloading the dump file solves this problem. mysqldump now automatically includes in its output a statement that enables NO_AUTO_VALUE_ON_ZERO, to avoid this problem.

- NO_BACKSLASH_ESCAPES

  Disable the use of the backslash character (\) as an escape character within strings. With this mode enabled, backslash becomes an ordinary character like any other.

- NO_DIR_IN_CREATE

  When creating a table, ignore all INDEX DIRECTORY and DATA DIRECTORY directives. This option is useful on slave replication servers.

- NO_ENGINE_SUBSTITUTION

  Control automatic substitution of the default storage engine when a statement such as CREATE TABLE or ALTER TABLE specifies a storage engine that is disabled or not compiled in.

  Because storage engines can be pluggable at runtime, unavailable engines are treated the same way:

  With NO_ENGINE_SUBSTITUTION disabled, for CREATE TABLE the default engine is used and a warning occurs if the desired engine is unavailable. For ALTER TABLE, a warning occurs and the table is not altered.

  With NO_ENGINE_SUBSTITUTION enabled, an error occurs and the table is not created or altered if the desired engine is unavailable.

- NO_FIELD_OPTIONS

  Do not print MySQL-specific column options in the output of SHOW CREATE TABLE. This mode is used by mysqldump in portability mode.

- NO_KEY_OPTIONS

  Do not print MySQL-specific index options in the output of SHOW CREATE TABLE. This mode is used by mysqldump in portability mode.

- NO_TABLE_OPTIONS

  Do not print MySQL-specific table options (such as ENGINE) in the output of SHOW CREATE TABLE. This mode is used by mysqldump in portability mode.

- NO_UNSIGNED_SUBTRACTION

  Subtraction between integer values, where one is of type UNSIGNED, produces an unsigned result by default. Prior to MySQL 5.5.5, if the result would otherwise have been negative, it becomes the maximum integer value:

```
mysql> SET sql_mode = '';
mysql> SELECT CAST(0 AS UNSIGNED) - 1;
+-------------------------+
| CAST(0 AS UNSIGNED) - 1 |
+-------------------------+
|    18446744073709551615 |
+-------------------------+
```

  As of MySQL 5.5.5, if the result would otherwise have been negative, an error results:

```
mysql> SET sql_mode = '';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT CAST(0 AS UNSIGNED) - 1;
ERROR 1690 (22003): BIGINT UNSIGNED value is out of range in '(cast(0 as unsigned) - 1)'
```

  If the NO_UNSIGNED_SUBTRACTION SQL mode is enabled, the result is negative:

```
mysql> SET sql_mode = 'NO_UNSIGNED_SUBTRACTION';
mysql> SELECT CAST(0 AS UNSIGNED) - 1;
+-------------------------+
| CAST(0 AS UNSIGNED) - 1 |
+-------------------------+
|                      -1 |
+-------------------------+
```

  If the result of such an operation is used to update an UNSIGNED integer column, the result is clipped to the maximum value for the column type, or clipped to 0 if NO_UNSIGNED_SUBTRACTION is enabled. If strict SQL mode is enabled, an error occurs and the column remains unchanged.

  When NO_UNSIGNED_SUBTRACTION is enabled, the subtraction result is signed, *even if any operand is unsigned*. For example, compare the type of column c2 in table t1 with that of column c2 in table t2:

```
mysql> SET sql_mode='';
mysql> CREATE TABLE test (c1 BIGINT UNSIGNED NOT NULL);
mysql> CREATE TABLE t1 SELECT c1 - 1 AS c2 FROM test;
mysql> DESCRIBE t1;
+-------+---------------------+------+-----+---------+-------+
| Field | Type                | Null | Key | Default | Extra |
+-------+---------------------+------+-----+---------+-------+
```

```
| c2    | bigint(21) unsigned | NO   |     | 0       |       |
+-------+---------------------+------+-----+---------+-------+

mysql> SET sql_mode='NO_UNSIGNED_SUBTRACTION';
mysql> CREATE TABLE t2 SELECT c1 - 1 AS c2 FROM test;
mysql> DESCRIBE t2;
+-------+------------+------+-----+---------+-------+
| Field | Type       | Null | Key | Default | Extra |
+-------+------------+------+-----+---------+-------+
| c2    | bigint(21) | NO   |     | 0       |       |
+-------+------------+------+-----+---------+-------+
```

This means that `BIGINT UNSIGNED` is not 100% usable in all contexts. See Section 12.10, “Cast Functions and Operators”.

- `NO_ZERO_DATE`

  The `NO_ZERO_DATE` mode affects whether the server permits `'0000-00-00'` as a valid date. Its effect also depends on whether strict SQL mode is enabled.

  - If this mode is not enabled, `'0000-00-00'` is permitted and inserts produce no warning.
  - If this mode is enabled, `'0000-00-00'` is permitted and inserts produce a warning.
  - If this mode and strict mode are enabled, `'0000-00-00'` is not permitted and inserts produce an error, unless `IGNORE` is given as well. For `INSERT IGNORE` and `UPDATE IGNORE`, `'0000-00-00'` is permitted and inserts produce a warning.

- `NO_ZERO_IN_DATE`

  The `NO_ZERO_IN_DATE` mode affects whether the server permits dates in which the year part is nonzero but the month or day part is 0. (This mode affects dates such as `'2010-00-01'` or `'2010-01-00'`, but not `'0000-00-00'`. To control whether the server permits `'0000-00-00'`, use the `NO_ZERO_DATE` mode.) The effect of `NO_ZERO_IN_DATE` also depends on whether strict SQL mode is enabled.

  - If this mode is not enabled, dates with zero parts are permitted and inserts produce no warning.
  - If this mode is enabled, dates with zero parts are inserted as `'0000-00-00'` and produce a warning.
  - If this mode and strict mode are enabled, dates with zero parts are not permitted and inserts produce an error, unless `IGNORE` is given as well. For `INSERT IGNORE` and `UPDATE IGNORE`, dates with zero parts are inserted as `'0000-00-00'` and produce a warning.

- `ONLY_FULL_GROUP_BY`

  Reject queries for which the select list or `HAVING` condition refer to nonaggregated columns that are not named in the `GROUP BY` clause.

  A MySQL extension to standard SQL permits references in the `HAVING` clause to aliased expressions in the select list. Enabling `ONLY_FULL_GROUP_BY` disables this extension, thus requiring the `HAVING` clause to be written using unaliased expressions.

  For additional discussion and examples, see Section 12.16.3, “MySQL Handling of GROUP BY”.

- `PAD_CHAR_TO_FULL_LENGTH`

  By default, trailing spaces are trimmed from `CHAR` column values on retrieval. If `PAD_CHAR_TO_FULL_LENGTH` is enabled, trimming does not occur and retrieved `CHAR` values are padded to their full length. This mode does not apply to `VARCHAR` columns, for which trailing spaces are retained on retrieval.

```
mysql> CREATE TABLE t1 (c1 CHAR(10));
Query OK, 0 rows affected (0.37 sec)

mysql> INSERT INTO t1 (c1) VALUES('xy');
Query OK, 1 row affected (0.01 sec)

mysql> SET sql_mode = '';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT c1, CHAR_LENGTH(c1) FROM t1;
+------+----------------+
| c1   | CHAR_LENGTH(c1) |
+------+----------------+
| xy   |              2 |
+------+----------------+
1 row in set (0.00 sec)

mysql> SET sql_mode = 'PAD_CHAR_TO_FULL_LENGTH';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT c1, CHAR_LENGTH(c1) FROM t1;
+------------+----------------+
| c1         | CHAR_LENGTH(c1) |
+------------+----------------+
| xy         |             10 |
+------------+----------------+
1 row in set (0.00 sec)
```

- `PIPES_AS_CONCAT`

  Treat `||` as a string concatenation operator (same as `CONCAT()`) rather than as a synonym for `OR`.

- `REAL_AS_FLOAT`

  Treat `REAL` as a synonym for `FLOAT`. By default, MySQL treats `REAL` as a synonym for `DOUBLE`.

- `STRICT_ALL_TABLES`

  Enable strict SQL mode for all storage engines. Invalid data values are rejected. For details, see Strict SQL Mode.

- `STRICT_TRANS_TABLES`

  Enable strict SQL mode for transactional storage engines, and when possible for nontransactional storage engines. For details, see Strict SQL Mode.

Combination SQL Modes

The following special modes are provided as shorthand for combinations of mode values from the preceding list.

- `ANSI`

  Equivalent to `REAL_AS_FLOAT`, `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`.

  `ANSI` mode also causes the server to return an error for queries where a set function *`S`* with an outer reference *`S(outer_ref)`* cannot be aggregated in the outer query against which the outer reference has been resolved. This is such a query:

```
SELECT * FROM t1 WHERE t1.a IN (SELECT MAX(t1.b) FROM t2 WHERE ...);
```

  Here, `MAX(t1.b)` cannot aggregated in the outer query because it appears in the `WHERE` clause of that query. Standard SQL requires an error in this situation. If `ANSI` mode is not enabled, the server treats *`S(outer_ref)`* in such queries the same way that it would interpret *`S(const)`*.

See Section 1.7, “MySQL Standards Compliance”.

- `DB2`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`.

- `MAXDB`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`, `NO_AUTO_CREATE_USER`.

- `MSSQL`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`.

- `MYSQL323`

  Equivalent to `MYSQL323`, `HIGH_NOT_PRECEDENCE`. This means `HIGH_NOT_PRECEDENCE` plus some `SHOW CREATE TABLE` behaviors specific to `MYSQL323`:

  - `TIMESTAMP` column display does not include `DEFAULT` or `ON UPDATE` attributes that were introduced in MySQL 4.1.
  - String column display does not include character set and collation attributes that were introduced in MySQL 4.1. For `CHAR` and `VARCHAR` columns, if the collation is binary, `BINARY` is appended to the column type.
  - The `ENGINE=`*`engine_name`* table option displays as `TYPE=`*`engine+name`*.
  - For `MEMORY` tables, the storage engine is displayed as `HEAP`.

- `MYSQL40`

  Equivalent to `MYSQL40`, `HIGH_NOT_PRECEDENCE`. This means `HIGH_NOT_PRECEDENCE` plus some behaviors specific to `MYSQL40`. These are the same as for `MYSQL323`, except that `SHOW CREATE TABLE` does not display `HEAP` as the storage engine for `MEMORY` tables.

- `ORACLE`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`, `NO_AUTO_CREATE_USER`.

- `POSTGRESQL`

  Equivalent to `PIPES_AS_CONCAT`, `ANSI_QUOTES`, `IGNORE_SPACE`, `NO_KEY_OPTIONS`, `NO_TABLE_OPTIONS`, `NO_FIELD_OPTIONS`.

- `TRADITIONAL`

  Equivalent to `STRICT_TRANS_TABLES`, `STRICT_ALL_TABLES`, `NO_ZERO_IN_DATE`, `NO_ZERO_DATE`, `ERROR_FOR_DIVISION_BY_ZERO`, `NO_AUTO_CREATE_USER`, and `NO_ENGINE_SUBSTITUTION`.

Strict SQL Mode

Strict mode controls how MySQL handles invalid or missing values in data-change statements such as `INSERT` or `UPDATE`. A value can be invalid for several reasons. For example, it might have the wrong data type for the column, or it might be out of range. A value is missing when a new row to be inserted does not contain a value for a non-`NULL` column that has no explicit `DEFAULT` clause in its definition. (For a `NULL` column, `NULL` is inserted if the value is missing.)

If strict mode is not in effect, MySQL inserts adjusted values for invalid or missing values and produces warnings (see Section 13.7.5.41, “SHOW WARNINGS Syntax”). In strict mode, you can produce this behavior by using `INSERT IGNORE` or `UPDATE IGNORE`.

For statements such as `SELECT` that do not change data, invalid values generate a warning in strict mode, not an error.

Strict mode does not affect whether foreign key constraints are checked. `foreign_key_checks` can be used for that. (See Section 5.1.5, “Server System Variables”.)

Strict SQL mode is in effect if either `STRICT_ALL_TABLES` or `STRICT_TRANS_TABLES` is enabled, although the effects of these modes differ somewhat:

- For transactional tables, an error occurs for invalid or missing values in a data-change statement when either `STRICT_ALL_TABLES` or `STRICT_TRANS_TABLES` is enabled. The statement is aborted and rolled back.
- For nontransactional tables, the behavior is the same for either mode if the bad value occurs in the first row to be inserted or updated: The statement is aborted and the table remains unchanged. If the statement inserts or modifies multiple rows and the bad value occurs in the second or later row, the result depends on which strict mode is enabled:
  - For `STRICT_ALL_TABLES`, MySQL returns an error and ignores the rest of the rows. However, because the earlier rows have been inserted or updated, the result is a partial update. To avoid this, use single-row statements, which can be aborted without changing the table.
  - For `STRICT_TRANS_TABLES`, MySQL converts an invalid value to the closest valid value for the column and inserts the adjusted value. If a value is missing, MySQL inserts the implicit default value for the column data type. In either case, MySQL generates a warning rather than an error and continues processing the statement. Implicit defaults are described in Section 11.6, “Data Type Default Values”.

Strict mode also affects handling of division by zero, zero dates, and zeros in dates, in conjunction with the `ERROR_FOR_DIVISION_BY_ZERO`, `NO_ZERO_DATE`, and `NO_ZERO_IN_DATE` modes. For details, see the descriptions of those modes.

5.1.9 IPv6 Support

As of MySQL 5.5.3, support for IPv6 includes these capabilities:

- MySQL Server can accept TCP/IP connections from clients connecting over IPv6. For example, this command connects over IPv6 to the MySQL server on the local host:

```
shell> mysql -h ::1
```

  To use this capability, two things must be true:

  - Your system must be configured to support IPv6. See Section 5.1.9.1, “Verifying System Support for IPv6”.
  - The default MySQL server configuration permits only IPv4 connections, so the server must be configured for IPv6 connections. To permit IPv6 connections in addition to or instead of IPv4 connections, start the server with an appropriate `--bind-address` option. See Section 5.1.5, “Server System Variables”.

- MySQL account names permit IPv6 addresses to enable DBAs to specify privileges for clients that connect to the server over IPv6. See Section 6.2.3, “Specifying Account Names”. IPv6 addresses can be specified in account names in statements such as `CREATE USER`, `GRANT`, and `REVOKE`. For example:

```
mysql> CREATE USER 'bill'@'::1' IDENTIFIED BY 'secret';
mysql> GRANT SELECT ON mydb.* TO 'bill'@'::1';
```

The following sections describe how to set up MySQL so that clients can connect to the server over IPv6.

5.1.9.1 Verifying System Support for IPv6

Before MySQL Server can accept IPv6 connections, the operating system on your server host must support IPv6. As a simple test to determine whether that is true, try this command:

```
shell> ping6 ::1
16 bytes from ::1, icmp_seq=0 hlim=64 time=0.171 ms
16 bytes from ::1, icmp_seq=1 hlim=64 time=0.077 ms
...
```

To produce a description of your system's network interfaces, invoke `ifconfig -a` and look for IPv6 addresses in the output.

If your host does not support IPv6, consult your system documentation for instructions on enabling it. It might be that you need only reconfigure an existing network interface to add an IPv6 address. Or a more extensive change might be needed, such as rebuilding the kernel with IPv6 options enabled.

These links may be helpful in setting up IPv6 on various platforms:

- Windows XP
- Gentoo Linux
- Ubuntu Linux
- Linux (Generic)
- OS X

5.1.9.2 Configuring the MySQL Server to Permit IPv6 Connections

The MySQL server listens on a single network socket for TCP/IP connections. This socket is bound to a single address, but it is possible for an address to map onto multiple network interfaces. The default address is `0.0.0.0`. To specify an address explicitly, use the `--bind-address=addr` option at server startup, where *`addr`* is an IPv4 or IPv6 address or a host name. (IPv6 addresses are not supported before MySQL 5.5.3.) If *`addr`* is a host name, the server resolves the name to an IP address and binds to that address.

The server treats different types of addresses as follows:

- If the address is `0.0.0.0`, the server accepts TCP/IP connections on all server host IPv4 interfaces.
- If the address is `::`, the server accepts TCP/IP connections on all server host IPv4 and IPv6 interfaces. Use this address to permit both IPv4 and IPv6 connections on all server interfaces.
- If the address is an IPv4-mapped address, the server accepts TCP/IP connections for that address, in either IPv4 or IPv6 format. For example, if the server is bound to `::ffff:127.0.0.1`, clients can connect using `--host=127.0.0.1` or `--host=::ffff:127.0.0.1`.
- If the address is a “regular” IPv4 or IPv6 address (such as `127.0.0.1` or `::1`), the server accepts TCP/IP connections only for that IPv4 or IPv6 address.

If you intend to bind the server to a specific address, be sure that the `mysql.user` grant table contains an account with administrative privileges that you can use to connect to that address. Otherwise, you will not be able to shut down the server. For example, if you bind the server to `::`, you can connect

to it using all existing accounts. But if you bind the server to `::1`, it accepts connections only on that address. In that case, first make sure that the `'root'@'::1'` account is present in the `mysql.user` table so you can still connect to the server to shut it down.

5.1.9.3 Connecting Using the IPv6 Local Host Address

The following procedure shows how to configure MySQL to permit IPv6 connections by clients that connect to the local server using the `::1` local host address. The instructions given here assume that your system supports IPv6.

1. Start the MySQL server with an appropriate `--bind-address` option to permit it to accept IPv6 connections. For example, put the following lines in your server option file and restart the server:

   ```
   [mysqld]
   bind-address = ::
   ```

   Alternatively, you can bind the server to `::1`, but that makes the server more restrictive for TCP/IP connections. It accepts only IPv6 connections for that single address and rejects IPv4 connections. For more information, see Section 5.1.9.2, “Configuring the MySQL Server to Permit IPv6 Connections”.

2. As an administrator, connect to the server and create an account for a local user who will connect from the `::1` local IPv6 host address:

   ```
   mysql> CREATE USER 'ipv6user'@'::1' IDENTIFIED BY 'ipv6pass';
   ```

   For the permitted syntax of IPv6 addresses in account names, see Section 6.2.3, “Specifying Account Names”. In addition to the `CREATE USER` statement, you can issue `GRANT` statements that give specific privileges to the account, although that is not necessary for the remaining steps in this procedure.

3. Invoke the `mysql` client to connect to the server using the new account:

   ```
   shell> mysql -h ::1 -u ipv6user -pipv6pass
   ```

4. Try some simple statements that show connection information:

   ```
   mysql> STATUS
   ...
   Connection:   ::1 via TCP/IP
   ...

   mysql> SELECT CURRENT_USER();
   +----------------+
   | CURRENT_USER() |
   +----------------+
   | ipv6user@::1   |
   +----------------+
   ```

5.1.9.4 Connecting Using IPv6 Nonlocal Host Addresses

The following procedure shows how to configure MySQL to permit IPv6 connections by remote clients. It is similar to the preceding procedure for local clients, but the server and client hosts are distinct and each has its own nonlocal IPv6 address. The example uses these addresses:

```
Server host: 2001:db8:0:f101::1
Client host: 2001:db8:0:f101::2
```

These addresses are chosen from the nonroutable address range recommended by IANA for documentation purposes and suffice for testing on your local network. To accept IPv6 connections from

clients outside the local network, the server host must have a public address. If your network provider assigns you an IPv6 address, you can use that. Otherwise, another way to obtain an address is to use an IPv6 broker; see Section 5.1.9.5, “Obtaining an IPv6 Address from a Broker”.

1. Start the MySQL server with an appropriate `--bind-address` option to permit it to accept IPv6 connections. For example, put the following lines in your server option file and restart the server:

   ```
   [mysqld]
   bind-address = ::
   ```

   Alternatively, you can bind the server to `2001:db8:0:f101::1`, but that makes the server more restrictive for TCP/IP connections. It accepts only IPv6 connections for that single address and rejects IPv4 connections. For more information, see Section 5.1.9.2, “Configuring the MySQL Server to Permit IPv6 Connections”.

2. On the server host (`2001:db8:0:f101::1`), create an account for a user who will connect from the client host (`2001:db8:0:f101::2`):

   ```
   mysql> CREATE USER 'remoteipv6user'@'2001:db8:0:f101::2' IDENTIFIED BY 'remoteipv6pass';
   ```

3. On the client host (`2001:db8:0:f101::2`), invoke the `mysql` client to connect to the server using the new account:

   ```
   shell> mysql -h 2001:db8:0:f101::1 -u remoteipv6user -premoteipv6pass
   ```

4. Try some simple statements that show connection information:

   ```
   mysql> STATUS
   ...
   Connection:   2001:db8:0:f101::1 via TCP/IP
   ...

   mysql> SELECT CURRENT_USER();
   +----------------------------------+
   | CURRENT_USER()                   |
   +----------------------------------+
   | remoteipv6user@2001:db8:0:f101::2 |
   +----------------------------------+
   ```

5.1.9.5 Obtaining an IPv6 Address from a Broker

If you do not have a public IPv6 address that enables your system to communicate over IPv6 outside your local network, you can obtain one from an IPv6 broker. The Wikipedia IPv6 Tunnel Broker page lists several brokers and their features, such as whether they provide static addresses and the supported routing protocols.

After configuring your server host to use a broker-supplied IPv6 address, start the MySQL server with an appropriate `--bind-address` option to permit the server to accept IPv6 connections. For example, put the following lines in the server option file and restart the server:

```
[mysqld]
bind-address = ::
```

Alternatively, you can bind the server to the specific IPv6 address provided by the broker, but that makes the server more restrictive for TCP/IP connections. It accepts only IPv6 connections for that single address and rejects IPv4 connections. For more information, see Section 5.1.9.2, “Configuring the MySQL Server to Permit IPv6 Connections”. In addition, if the broker allocates dynamic addresses, the address provided for your system might change the next time you connect to the broker. If so, any accounts you create that name the original address become invalid. To bind to a specific address but

avoid this change-of-address problem, you may be able to arrange with the broker for a static IPv6 address.

The following example shows how to use Freenet6 as the broker and the `gogoc` IPv6 client package on Gentoo Linux.

1. Create an account at Freenet6 by visiting this URL and signing up:

   ```
   http://gogonet.gogo6.com
   ```

2. After creating the account, go to this URL, sign in, and create a user ID and password for the IPv6 broker:

   ```
   http://gogonet.gogo6.com/page/freenet6-registration
   ```

3. As `root`, install `gogoc`:

   ```
   shell> emerge gogoc
   ```

4. Edit `/etc/gogoc/gogoc.conf` to set the `userid` and `password` values. For example:

   ```
   userid=gogouser
   passwd=gogopass
   ```

5. Start `gogoc`:

   ```
   shell> /etc/init.d/gogoc start
   ```

   To start `gogoc` each time your system boots, execute this command:

   ```
   shell> rc-update add gogoc default
   ```

6. Use `ping6` to try to ping a host:

   ```
   shell> ping6 ipv6.google.com
   ```

7. To see your IPv6 address:

   ```
   shell> ifconfig tun
   ```

5.1.10 Server-Side Help

MySQL Server supports a `HELP` statement that returns information from the MySQL Reference manual (see Section 13.8.3, “HELP Syntax”). Several tables in the `mysql` system database contain the information needed to support this statement (see Section 5.3, “The mysql System Database”). The proper operation of this statement requires that these help tables be initialized, which is done by processing the contents of the `fill_help_tables.sql` script.

If you install MySQL using a binary or source distribution on Unix, help table content initialization occurs when you initialize the data directory (see Section 2.10.1, “Initializing the Data Directory”). For an RPM distribution on Linux or binary distribution on Windows, content initialization occurs as part of the MySQL installation process.

If you upgrade MySQL using a binary distribution, help table content is not upgraded automatically, but you can upgrade it manually. Locate the `fill_help_tables.sql` file in the `share` or `share/mysql` directory. Change location into that directory and process the file with the `mysql` client as follows:

```
shell> mysql -u root mysql < fill_help_tables.sql
```

You can also obtain the latest `fill_help_tables.sql` at any time to upgrade your help tables. Download the proper file for your version of MySQL from http://dev.mysql.com/doc/index-other.html. After downloading and uncompressing the file, process it with `mysql` as described previously.

If you are working with Git and a MySQL development source tree, you must use a downloaded copy of the `fill_help_tables.sql` file because the source tree contains only a "stub" version.

Note

For a server that participates in replication, the help table content upgrade process involves multiple servers. For details, see Section 17.4.1.26, "Replication of Server-Side Help Tables".

5.1.11 Server Response to Signals

On Unix, signals can be sent to processes. `mysqld` responds to signals sent to it as follows:

- `SIGTERM` causes the server to shut down.
- `SIGHUP` causes the server to reload the grant tables and to flush tables, logs, the thread cache, and the host cache. These actions are like various forms of the `FLUSH` statement. The server also writes a status report to the error log that has this format:

```
Status information:

Current dir: /var/mysql/data/
Running threads: 0  Stack size: 196608
Current locks:

Key caches:
default
Buffer_size:       8388600
Block_size:           1024
Division_limit:        100
Age_limit:             300
blocks used:             0
not flushed:             0
w_requests:              0
writes:                  0
r_requests:              0
reads:                   0

handler status:
read_key:            0
read_next:           0
read_rnd             0
read_first:          1
write:               0
delete               0
update:              0

Table status:
Opened tables:          5
Open tables:            0
Open files:             7
Open streams:           0

Alarm status:
Active alarms:   1
Max used alarms: 2
Next alarm time: 67
```

5.1.12 The Server Shutdown Process

The server shutdown process takes place as follows:

1. The shutdown process is initiated.

   This can occur initiated several ways. For example, a user with the `SHUTDOWN` privilege can execute a `mysqladmin shutdown` command. `mysqladmin` can be used on any platform supported by MySQL. Other operating system-specific shutdown initiation methods are possible as well: The server shuts down on Unix when it receives a `SIGTERM` signal. A server running as a service on Windows shuts down when the services manager tells it to.

2. The server creates a shutdown thread if necessary.

   Depending on how shutdown was initiated, the server might create a thread to handle the shutdown process. If shutdown was requested by a client, a shutdown thread is created. If shutdown is the result of receiving a `SIGTERM` signal, the signal thread might handle shutdown itself, or it might create a separate thread to do so. If the server tries to create a shutdown thread and cannot (for example, if memory is exhausted), it issues a diagnostic message that appears in the error log:

   ```
   Error: Can't create thread to kill server
   ```

3. The server stops accepting new connections.

   To prevent new activity from being initiated during shutdown, the server stops accepting new client connections by closing the handlers for the network interfaces to which it normally listens for connections: the TCP/IP port, the Unix socket file, the Windows named pipe, and shared memory on Windows.

4. The server terminates current activity.

   For each thread associated with a client connection, the server breaks the connection to the client and marks the thread as killed. Threads die when they notice that they are so marked. Threads for idle connections die quickly. Threads that currently are processing statements check their state periodically and take longer to die. For additional information about thread termination, see Section 13.7.6.4, “KILL Syntax”, in particular for the instructions about killed `REPAIR TABLE` or `OPTIMIZE TABLE` operations on `MyISAM` tables.

   For threads that have an open transaction, the transaction is rolled back. If a thread is updating a nontransactional table, an operation such as a multiple-row `UPDATE` or `INSERT` may leave the table partially updated because the operation can terminate before completion.

   If the server is a master replication server, it treats threads associated with currently connected slaves like other client threads. That is, each one is marked as killed and exits when it next checks its state.

   If the server is a slave replication server, it stops the I/O and SQL threads, if they are active, before marking client threads as killed. The SQL thread is permitted to finish its current statement (to avoid causing replication problems), and then stops. If the SQL thread is in the middle of a transaction at this point, the server waits until the current replication event group (if any) has finished executing, or until the user issues a `KILL QUERY` or `KILL CONNECTION` statement. See also Section 13.4.2.6, “STOP SLAVE Syntax”.

   If the slave is updating a nontransactional table when it is forcibly killed, the slave's data may become inconsistent with the master.

5. The server shuts down or closes storage engines.

   At this stage, the server flushes the table cache and closes all open tables.

   Each storage engine performs any actions necessary for tables that it manages. For example, `MyISAM` flushes any pending index writes for a table. `InnoDB` flushes its buffer pool to disk (unless

`innodb_fast_shutdown` is 2), writes the current LSN to the tablespace, and terminates its own internal threads.

6. The server exits.

5.2 The MySQL Data Directory

Information managed by the MySQL server is stored under a directory known as the data directory. The following list briefly describes the items typically found in the data directory, with cross references for additional information:

- Data directory subdirectories. Each subdirectory of the data directory is a database directory and corresponds to a database managed by the server. All MySQL installations have certain standard databases:
  - The `mysql` directory corresponds to the `mysql` system database, which contains information required by the MySQL server as it runs. See Section 5.3, “The mysql System Database”.
  - The `performance_schema` directory corresponds to the Performance Schema, which provides information used to inspect the internal execution of the server at runtime. See Chapter 22, *MySQL Performance Schema*.
  - The `ndbinfo` directory corresponds to the `ndbinfo` database that stores information specific to NDB Cluster (present only for installations built to include NDB Cluster). See Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”.

  Other subdirectories correspond to databases created by users or applications.

Note

`INFORMATION_SCHEMA` is a standard database, but its implementation uses no corresponding database directory.

- Log files written by the server. See Section 5.4, “MySQL Server Logs”.
- `InnoDB` tablespace and log files. See Chapter 14, *The InnoDB Storage Engine*.
- The server process ID file (while the server is running).

Some items in the preceding list can be relocated elsewhere by reconfiguring the server. In addition, the `--datadir` option enables the location of the data directory itself to be changed. For a given MySQL installation, check the server configuration to determine whether items have been moved.

5.3 The mysql System Database

The `mysql` database is the system database. It contains tables that store information required by the MySQL server as it runs.

Tables in the `mysql` database fall into these categories:

- Grant System Tables
- Object Information System Tables
- Log System Tables
- Server-Side Help System Tables
- Time Zone System Tables
- Replication System Tables

- Miscellaneous System Tables

The remainder of this section enumerates the tables in each category, with cross references for additional information. System tables use the `MyISAM` storage engine.

Grant System Tables

These system tables contain grant information about user accounts and the privileges held by them:

- `user`: User accounts, global privileges, and other non-privilege columns.
- `db`: Database-level privileges.
- `host`: Obsolete.
- `tables_priv`: Table-level privileges.
- `columns_priv`: Column-level privileges.
- `procs_priv`: Stored procedure and function privileges.
- `proxies_priv`: Proxy-user privileges.

For more information about the structure, contents, and purpose of the grant tables, see Section 6.2.2, “Grant Tables”.

Object Information System Tables

These system tables contain information about stored programs, user-defined functions, and server-side plugins:

- `event`: Information about Event Scheduler events. See Section 20.4, “Using the Event Scheduler”. The server loads events listed in this table during its startup sequence, unless started with the `--skip-grant-tables` option.
- `func`: Information about user-defined functions (UDFs). See Section 24.4, “Adding New Functions to MySQL”. The server loads UDFs listed in this table during its startup sequence, unless started with the `--skip-grant-tables` option.
- `plugin`: Information about server-side plugins. See Section 5.5.1, “Installing and Uninstalling Plugins”, and Section 24.2, “The MySQL Plugin API”. The server loads plugins listed in this table during its startup sequence, unless started with the `--skip-grant-tables` option.
- `proc`: Information about stored procedures and functions. See Section 20.2, “Using Stored Routines (Procedures and Functions)”.

Log System Tables

The server uses these system tables for logging:

- `general_log`: The general query log table.
- `slow_log`: The slow query log table.

Log tables use the `CSV` storage engine.

For more information, see Section 5.4, “MySQL Server Logs”.

Server-Side Help System Tables

These system tables contain server-side help information:

- `help_category`: Information about help categories.
- `help_keyword`: Keywords associated with help topics.
- `help_relation`: Mappings between help keywords and topics.
- `help_topic`: Help topic contents.

For more information, see Section 5.1.10, “Server-Side Help”.

Time Zone System Tables

These system tables contain time zone information:

- `time_zone`: Time zone IDs and whether they use leap seconds.
- `time_zone_leap_second`: When leap seconds occur.
- `time_zone_name`: Mappings between time zone IDs and names.
- `time_zone_transition`, `time_zone_transition_type`: Time zone descriptions.

For more information, see Section 10.6, “MySQL Server Time Zone Support”.

Replication System Tables

The server uses the `ndb_binlog_index` system table to store binary log information for NDB Cluster replication. See Section 18.6.4, “NDB Cluster Replication Schema and Tables”.

Miscellaneous System Tables

Other system tables do not fall into the preceding categories:

- `servers`: Used by the `FEDERATED` storage engine. See Section 15.9.2.2, “Creating a FEDERATED Table Using CREATE SERVER”.

5.4 MySQL Server Logs

MySQL Server has several logs that can help you find out what activity is taking place.

Log Type	Information Written to Log
Error log	Problems encountered starting, running, or stopping `mysqld`
General query log	Established client connections and statements received from clients
Binary log	Statements that change data (also used for replication)
Relay log	Data changes received from a replication master server
Slow query log	Queries that took more than `long_query_time` seconds to execute
DDL log (metadata log)	Metadata operations performed by DDL statements

By default, no logs are enabled, except the error log on Windows. (The DDL log is always created when required, and has no user-configurable options; see Section 5.4.6, “The DDL Log”.) The following log-specific sections provide information about the server options that enable logging.

By default, the server writes files for all enabled logs in the data directory. You can force the server to close and reopen the log files (or in some cases switch to a new log file) by flushing the logs. Log flushing occurs when you issue a `FLUSH LOGS` statement; execute `mysqladmin` with a `flush-logs` or `refresh` argument; or execute `mysqldump` with a `--flush-logs` or `--master-data` option. See Section 13.7.6.3, “FLUSH Syntax”, Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”, and Section 4.5.4, “`mysqldump` — A Database Backup Program”. In addition, the binary log is flushed when its size reaches the value of the `max_binlog_size` system variable.

You can control the general query and slow query logs during runtime. You can enable or disable logging, or change the log file name. You can tell the server to write general query and slow query entries to log tables, log files, or both. For details, see Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”, Section 5.4.3, “The General Query Log”, and Section 5.4.5, “The Slow Query Log”.

The relay log is used only on slave replication servers, to hold data changes from the master server that must also be made on the slave. For discussion of relay log contents and configuration, see Section 17.2.2.1, “The Slave Relay Log”.

For information about log maintenance operations such as expiration of old log files, see Section 5.4.7, “Server Log Maintenance”.

For information about keeping logs secure, see Section 6.1.2.3, “Passwords and Logging”.

5.4.1 Selecting General Query and Slow Query Log Output Destinations

MySQL Server provides flexible control over the destination of output to the general query log and the slow query log, if those logs are enabled. Possible destinations for log entries are log files or the `general_log` and `slow_log` tables in the `mysql` database. Either or both destinations can be selected.

Log control at server startup. The `--log-output` option specifies the destination for log output. This option does not in itself enable the logs. Its syntax is `--log-output[=value,...]`:

- If `--log-output` is given with a value, the value should be a comma-separated list of one or more of the words `TABLE` (log to tables), `FILE` (log to files), or `NONE` (do not log to tables or files). `NONE`, if present, takes precedence over any other specifiers.
- If `--log-output` is omitted, the default logging destination is `FILE`.

The `general_log` system variable controls logging to the general query log for the selected log destinations. If specified at server startup, `general_log` takes an optional argument of 1 or 0 to enable or disable the log. To specify a file name other than the default for file logging, set the `general_log_file` variable. Similarly, the `slow_query_log` variable controls logging to the slow query log for the selected destinations and setting `slow_query_log_file` specifies a file name for file logging. If either log is enabled, the server opens the corresponding log file and writes startup messages to it. However, further logging of queries to the file does not occur unless the `FILE` log destination is selected.

Examples:

- To write general query log entries to the log table and the log file, use `--log-output=TABLE,FILE` to select both log destinations and `--general_log` to enable the general query log.
- To write general and slow query log entries only to the log tables, use `--log-output=TABLE` to select tables as the log destination and `--general_log` and `--slow_query_log` to enable both logs.
- To write slow query log entries only to the log file, use `--log-output=FILE` to select files as the log destination and `--slow_query_log` to enable the slow query log. (In this case, because the default log destination is `FILE`, you could omit the `--log-output` option.)

Log control at runtime. The system variables associated with log tables and files enable runtime control over logging:

- The global `log_output` system variable indicates the current logging destination. It can be modified at runtime to change the destination.
- The global `general_log` and `slow_query_log` variables indicate whether the general query log and slow query log are enabled (`ON`) or disabled (`OFF`). You can set these variables at runtime to control whether the logs are enabled.

- The global `general_log_file` and `slow_query_log_file` variables indicate the names of the general query log and slow query log files. You can set these variables at server startup or at runtime to change the names of the log files.
- To disable or enable general query logging for the current connection, set the session `sql_log_off` variable to `ON` or `OFF`.

The use of tables for log output offers the following benefits:

- Log entries have a standard format. To display the current structure of the log tables, use these statements:

```
SHOW CREATE TABLE mysql.general_log;
SHOW CREATE TABLE mysql.slow_log;
```

- Log contents are accessible through SQL statements. This enables the use of queries that select only those log entries that satisfy specific criteria. For example, to select log contents associated with a particular client (which can be useful for identifying problematic queries from that client), it is easier to do this using a log table than a log file.
- Logs are accessible remotely through any client that can connect to the server and issue queries (if the client has the appropriate log table privileges). It is not necessary to log in to the server host and directly access the file system.

The log table implementation has the following characteristics:

- In general, the primary purpose of log tables is to provide an interface for users to observe the runtime execution of the server, not to interfere with its runtime execution.
- `CREATE TABLE`, `ALTER TABLE`, and `DROP TABLE` are valid operations on a log table. For `ALTER TABLE` and `DROP TABLE`, the log table cannot be in use and must be disabled, as described later.
- By default, the log tables use the `CSV` storage engine that writes data in comma-separated values format. For users who have access to the `.CSV` files that contain log table data, the files are easy to import into other programs such as spreadsheets that can process CSV input.

  The log tables can be altered to use the `MyISAM` storage engine. You cannot use `ALTER TABLE` to alter a log table that is in use. The log must be disabled first. No engines other than `CSV` or `MyISAM` are legal for the log tables.
- To disable logging so that you can alter (or drop) a log table, you can use the following strategy. The example uses the general query log; the procedure for the slow query log is similar but uses the `slow_log` table and `slow_query_log` system variable.

```
SET @old_log_state = @@global.general_log;
SET GLOBAL general_log = 'OFF';
ALTER TABLE mysql.general_log ENGINE = MyISAM;
SET GLOBAL general_log = @old_log_state;
```

- `TRUNCATE TABLE` is a valid operation on a log table. It can be used to expire log entries.
- `RENAME TABLE` is a valid operation on a log table. You can atomically rename a log table (to perform log rotation, for example) using the following strategy:

```
USE mysql;
DROP TABLE IF EXISTS general_log2;
CREATE TABLE general_log2 LIKE general_log;
RENAME TABLE general_log TO general_log_backup, general_log2 TO general_log;
```

- `CHECK TABLE` is a valid operation on a log table.
- `LOCK TABLES` cannot be used on a log table.

- `INSERT`, `DELETE`, and `UPDATE` cannot be used on a log table. These operations are permitted only internally to the server itself.
- `FLUSH TABLES WITH READ LOCK` and the state of the `read_only` system variable have no effect on log tables. The server can always write to the log tables.
- Entries written to the log tables are not written to the binary log and thus are not replicated to slave servers.
- To flush the log tables or log files, use `FLUSH TABLES` or `FLUSH LOGS`, respectively.
- Partitioning of log tables is not permitted.
- Before MySQL 5.5.25, `mysqldump` does not dump the `general_log` or `slow_query_log` tables for dumps of the `mysql` database. As of 5.5.25, the dump includes statements to recreate those tables so that they are not missing after reloading the dump file. Log table contents are not dumped.

5.4.2 The Error Log

This section discusses how to configure the MySQL server for logging of diagnostic messages to the error log. For information about selecting the error message character set or language, see Section 10.1.6, “Error Message Character Set”, or Section 10.2, “Setting the Error Message Language”.

The error log contains a record of `mysqld` startup and shutdown times. It also contains diagnostic messages such as errors, warnings, and notes that occur during server startup and shutdown, and while the server is running. For example, if `mysqld` notices that a table needs to be automatically checked or repaired, it writes a message to the error log.

On some operating systems, the error log contains a stack trace if `mysqld` exits abnormally. The trace can be used to determine where `mysqld` exited. See Section 24.5, “Debugging and Porting MySQL”.

If used to start `mysqld`, `mysqld_safe` may write messages to the error log. For example, when `mysqld_safe` notices abnormal `mysqld` exits, it restarts `mysqld` and writes a `mysqld restarted` message to the error log.

The following sections discuss aspects of configuring error logging. In the discussion, “console” means `stderr`, the standard error output. This is your terminal or console window unless the standard error output has been redirected to a different destination.

The server interprets options that determine where to write error messages somewhat differently for Windows and Unix systems. Be sure to configure error logging using the information appropriate to your platform.

5.4.2.1 Error Logging on Windows

On Windows, `mysqld` uses the `--log-error`, `--pid-file`, and `--console` options to determine whether `mysqld` writes the error log to the console or a file, and, if to a file, the file name:

- If `--console` is given, `mysqld` writes the error log to the console, unless `--log-error` is also given. `--log-error` takes precedence over `--console` if both are given.
- If `--log-error` is not given, or is given without naming a file, `mysqld` writes the error log to a file named *`host_name`*`.err` in the data directory, unless the `--pid-file` option is specified. In that case, the file name is the PID file base name with a suffix of `.err` in the data directory.
- If `--log-error` is given to name a file, `mysqld` writes the error log to that file (with an `.err` suffix added if the name has no suffix), located under the data directory unless an absolute path name is given to specify a different location.

If the server writes the error log to a file, the `log_error` system variable indicates the error log file name.

In addition, the server by default writes events and error messages to the Windows Event Log within the Application log:

- Entries marked as `Error`, `Warning`, and `Note` are written to the Event Log, but not messages such as information statements from individual storage engines.
- Event Log entries have a source of `MySQL`.
- You cannot disable writing information to the Windows Event Log.

5.4.2.2 Error Logging on Unix and Unix-Like Systems

On Unix and Unix-like systems, `mysqld` uses the `--log-error` option to determine whether `mysqld` writes the error log to the console or a file, and, if to a file, the file name:

- If `--log-error` is not given, `mysqld` writes the error log to the console.
- If `--log-error` is given without naming a file, `mysqld` writes the error log to a file named *`host_name`*`.err` in the data directory.
- If `--log-error` is given to name a file, `mysqld` writes the error log to that file (with an `.err` suffix added if the name has no suffix), located under the data directory unless an absolute path name is given to specify a different location.
- If `--log-error` is given in an option file in a `[mysqld]`, `[server]`, or `[mysqld_safe]` section, `mysqld_safe` finds and uses the option, and passes it to `mysqld`.

Note

It is common for Yum or APT package installations to configure an error log file location under `/var/log` with an option like `log-error=/var/log/mysqld.log` in a server configuration file. Removing the file name from the option causes the *`host_name`*`.err` file in the data directory to be used.

If the server writes the error log to a file, the `log_error` system variable indicates the error log file name.

5.4.2.3 Error Logging to the System Log

If you use `mysqld_safe` to start `mysqld`, `mysqld_safe` arranges for `mysqld` to write error messages to a log file or to `syslog`. `mysqld_safe` has three error-logging options, `--syslog`, `--skip-syslog`, and `--log-error`. The default with no logging options or with `--skip-syslog` is to use the default log file. To explicitly specify use of an error log file, specify `--log-error=`*`file_name`* to `mysqld_safe`, which then arranges for `mysqld` to write messages to a log file. To use `syslog` instead, specify the `--syslog` option.

5.4.2.4 Error Log Filtering

The `--log-warnings` option or `log_warnings` system variable controls warning logging to the error log. The default value is enabled (1). To disable warning logging, set `--log-warnings` or `log_warnings` to 0. If the value is greater than 1, aborted connections are written to the error log, and access-denied errors for new connection attempts are written. See Section B.5.2.11, “Communication Errors and Aborted Connections”.

5.4.2.5 Error Log File Flushing and Renaming

If you flush the logs using `FLUSH ERROR LOGS`, `FLUSH LOGS`, or `mysqladmin flush-logs`, the server closes and reopens any error log file to which it is writing. To rename an error log file, do so manually before flushing. Flushing the logs then opens a new file with the original file name. For example, assuming a log file name of *`host_name`*`.err`, to rename the file and create a new one, use the following commands:

```
mv host_name.err host_name.err-old
mysqladmin flush-logs
mv host_name.err-old backup-directory
```

On Windows, use `rename` rather than `mv`.

If the location of the error file is not writable by the server, the log-flushing operation fails to create a new log file. For example, on Linux, the server might write the error log as `/var/log/mysqld.log`, where `/var/log` is owned by `root` and not writable by `mysqld`. For information about handling this case, see Section 5.4.7, “Server Log Maintenance”.

If the server is not writing to a named error log file, no error log file renaming occurs when the logs are flushed.

5.4.3 The General Query Log

The general query log is a general record of what `mysqld` is doing. The server writes information to this log when clients connect or disconnect, and it logs each SQL statement received from clients. The general query log can be very useful when you suspect an error in a client and want to know exactly what the client sent to `mysqld`.

`mysqld` writes statements to the query log in the order that it receives them, which might differ from the order in which they are executed. This logging order is in contrast with that of the binary log, for which statements are written after they are executed but before any locks are released. In addition, the query log may contain statements that only select data while such statements are never written to the binary log.

When using statement-based binary logging on a replication master server, statements received by its slaves are written to the query log of each slave. Statements are written to the query log of the master server if a client reads events with the `mysqlbinlog` utility and passes them to the server.

However, when using row-based binary logging, updates are sent as row changes rather than SQL statements, and thus these statements are never written to the query log when `binlog_format` is `ROW`. A given update also might not be written to the query log when this variable is set to `MIXED`, depending on the statement used. See Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”, for more information.

By default, the general query log is disabled. To specify the initial general query log state explicitly, use `--general_log[={0|1}]`. With no argument or an argument of 1, `--general_log` enables the log. With an argument of 0, this option disables the log. To specify a log file name, use `--general_log_file=file_name`. To specify the log destination, use `--log-output` (as described in Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”). The older options to enable the general query log, `--log` and `-l`, are deprecated.

If you specify no name for the general query log file, the default name is `host_name.log`. The server creates the file in the data directory unless an absolute path name is given to specify a different directory.

To disable or enable the general query log or change the log file name at runtime, use the global `general_log` and `general_log_file` system variables. Set `general_log` to 0 (or `OFF`) to disable the log or to 1 (or `ON`) to enable it. Set `general_log_file` to specify the name of the log file. If a log file already is open, it is closed and the new file is opened.

When the general query log is enabled, the server writes output to any destinations specified by the `--log-output` option or `log_output` system variable. If you enable the log, the server opens the log file and writes startup messages to it. However, further logging of queries to the file does not occur unless the `FILE` log destination is selected. If the destination is `NONE`, the server writes no queries even if the general log is enabled. Setting the log file name has no effect on logging if the log destination value does not contain `FILE`.

Server restarts and log flushing do not cause a new general query log file to be generated (although flushing closes and reopens it). To rename the file and create a new one, use the following commands:

```
shell> mv host_name.log host_name-old.log
shell> mysqladmin flush-logs
shell> mv host_name-old.log backup-directory
```

On Windows, use `rename` rather than `mv`.

You can also rename the general query log file at runtime by disabling the log:

```
SET GLOBAL general_log = 'OFF';
```

With the log disabled, rename the log file externally; for example, from the command line. Then enable the log again:

```
SET GLOBAL general_log = 'ON';
```

This method works on any platform and does not require a server restart.

The session `sql_log_off` variable can be set to `ON` or `OFF` to disable or enable general query logging for the current connection.

The general query log should be protected because logged statements might contain passwords. See Section 6.1.2.3, “Passwords and Logging”.

5.4.4 The Binary Log

The binary log contains “events” that describe database changes such as table creation operations or changes to table data. It also contains events for statements that potentially could have made changes (for example, a `DELETE` which matched no rows), unless row-based logging is used. The binary log also contains information about how long each statement took that updated data. The binary log has two important purposes:

- For replication, the binary log on a master replication server provides a record of the data changes to be sent to slave servers. The master server sends the events contained in its binary log to its slaves, which execute those events to make the same data changes that were made on the master. See Section 17.2, “Replication Implementation”.
- Certain data recovery operations require use of the binary log. After a backup has been restored, the events in the binary log that were recorded after the backup was made are re-executed. These events bring databases up to date from the point of the backup. See Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”.

The binary log is not used for statements such as `SELECT` or `SHOW` that do not modify data. To log all statements (for example, to identify a problem query), use the general query log. See Section 5.4.3, “The General Query Log”.

Running a server with binary logging enabled makes performance slightly slower. However, the benefits of the binary log in enabling you to set up replication and for restore operations generally outweigh this minor performance decrement.

The binary log should be protected because logged statements might contain passwords. See Section 6.1.2.3, “Passwords and Logging”.

The following discussion describes some of the server options and variables that affect the operation of binary logging. For a complete list, see Section 17.1.3.4, “Binary Log Options and Variables”.

To enable the binary log, start the server with the `--log-bin[=base_name]` option. If no *`base_name`* value is given, the default name is the value of the `pid-file` option (which by default is

the name of host machine) followed by `-bin`. If the base name is given, the server writes the file in the data directory unless the base name is given with a leading absolute path name to specify a different directory. It is recommended that you specify a base name explicitly rather than using the default of the host name; see Section B.5.7, “Known Issues in MySQL”, for the reason.

If you supply an extension in the log name (for example, `--log-bin=base_name.extension`), the extension is silently removed and ignored.

`mysqld` appends a numeric extension to the binary log base name to generate binary log file names. The number increases each time the server creates a new log file, thus creating an ordered series of files. The server creates a new file in the series each time it starts or flushes the logs. The server also creates a new binary log file automatically after the current log's size reaches `max_binlog_size`. A binary log file may become larger than `max_binlog_size` if you are using large transactions because a transaction is written to the file in one piece, never split between files.

To keep track of which binary log files have been used, `mysqld` also creates a binary log index file that contains the names of all used binary log files. By default, this has the same base name as the binary log file, with the extension `'.index'`. You can change the name of the binary log index file with the `--log-bin-index[=file_name]` option. You should not manually edit this file while `mysqld` is running; doing so would confuse `mysqld`.

The term “binary log file” generally denotes an individual numbered file containing database events. The term “binary log” collectively denotes the set of numbered binary log files plus the index file.

A client that has the `SUPER` privilege can disable binary logging of its own statements by using a `SET sql_log_bin=0` statement. See Section 5.1.5, “Server System Variables”.

The format of the events recorded in the binary log is dependent on the binary logging format. Three format types are supported, row-based logging, statement-based logging and mixed-base logging. The binary logging format used depends on the MySQL version. For general descriptions of the logging formats, see Section 5.4.4.1, “Binary Logging Formats”. For detailed information about the format of the binary log, see MySQL Internals: The Binary Log.

The server evaluates the `--binlog-do-db` and `--binlog-ignore-db` options in the same way as it does the `--replicate-do-db` and `--replicate-ignore-db` options. For information about how this is done, see Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”.

If you are replicating from an NDB Cluster to a standalone MySQL Server, you should be aware that the `NDB` storage engine uses default values for some binary logging options (including options specific to `NDB` such as `--ndb-log-update-as-write`) that differ from those used by other storage engines. If not corrected for, these differences can lead to divergence of the master's and slave's binary logs. For more information, see Replication from NDB to other storage engines. In particular, if you are using a nontransactional storage engine such as `MyISAM` on the slave, see Replication from NDB to a nontransactional storage engine.

A replication slave server by default does not write to its own binary log any data modifications that are received from the replication master. To log these modifications, start the slave with the `--log-slave-updates` option in addition to the `--log-bin` option (see Section 17.1.3.3, “Replication Slave Options and Variables”). This is done when a slave is also to act as a master to other slaves in chained replication.

You can delete all binary log files with the `RESET MASTER` statement, or a subset of them with `PURGE BINARY LOGS`. See Section 13.7.6.6, “RESET Syntax”, and Section 13.4.1.1, “PURGE BINARY LOGS Syntax”.

If you are using replication, you should not delete old binary log files on the master until you are sure that no slave still needs to use them. For example, if your slaves never run more than three days behind, once a day you can execute `mysqladmin flush-logs` on the master and then remove any logs that are more than three days old. You can remove the files manually, but it is preferable to use

`PURGE BINARY LOGS`, which also safely updates the binary log index file for you (and which can take a date argument). See Section 13.4.1.1, “PURGE BINARY LOGS Syntax”.

You can display the contents of binary log files with the `mysqlbinlog` utility. This can be useful when you want to reprocess statements in the log for a recovery operation. For example, you can update a MySQL server from the binary log as follows:

```
shell> mysqlbinlog log_file | mysql -h server_name
```

`mysqlbinlog` also can be used to display replication slave relay log file contents because they are written using the same format as binary log files. For more information on the `mysqlbinlog` utility and how to use it, see Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”. For more information about the binary log and recovery operations, see Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”.

Binary logging is done immediately after a statement or transaction completes but before any locks are released or any commit is done. This ensures that the log is logged in commit order.

Updates to nontransactional tables are stored in the binary log immediately after execution.

Within an uncommitted transaction, all updates (`UPDATE`, `DELETE`, or `INSERT`) that change transactional tables such as `InnoDB` tables are cached until a `COMMIT` statement is received by the server. At that point, `mysqld` writes the entire transaction to the binary log before the `COMMIT` is executed.

Modifications to nontransactional tables cannot be rolled back. If a transaction that is rolled back includes modifications to nontransactional tables, the entire transaction is logged with a `ROLLBACK` statement at the end to ensure that the modifications to those tables are replicated.

When a thread that handles the transaction starts, it allocates a buffer of `binlog_cache_size` to buffer statements. If a statement is bigger than this, the thread opens a temporary file to store the transaction. The temporary file is deleted when the thread ends.

The `Binlog_cache_use` status variable shows the number of transactions that used this buffer (and possibly a temporary file) for storing statements. The `Binlog_cache_disk_use` status variable shows how many of those transactions actually had to use a temporary file. These two variables can be used for tuning `binlog_cache_size` to a large enough value that avoids the use of temporary files.

The `max_binlog_cache_size` system variable (default 4GB, which is also the maximum) can be used to restrict the total size used to cache a multiple-statement transaction. If a transaction is larger than this many bytes, it fails and rolls back. The minimum value is 4096.

If you are using the binary log and row based logging, concurrent inserts are converted to normal inserts for `CREATE ... SELECT` or `INSERT ... SELECT` statements. This is done to ensure that you can re-create an exact copy of your tables by applying the log during a backup operation. If you are using statement-based logging, the original statement is written to the log.

The binary log format has some known limitations that can affect recovery from backups. See Section 17.4.1, “Replication Features and Issues”.

Binary logging for stored programs is done as described in Section 20.7, “Binary Logging of Stored Programs”.

Note that the binary log format differs in MySQL 5.5 from previous versions of MySQL, due to enhancements in replication. See Section 17.4.2, “Replication Compatibility Between MySQL Versions”.

Writes to the binary log file and binary log index file are handled in the same way as writes to `MyISAM` tables. See Section B.5.3.4, “How MySQL Handles a Full Disk”.

By default, the binary log is not synchronized to disk at each write. So if the operating system or machine (not only the MySQL server) crashes, there is a chance that the last statements of the binary log are lost. To prevent this, you can make the binary log be synchronized to disk after every *N* writes to the binary log, with the `sync_binlog` system variable. See Section 5.1.5, "Server System Variables". 1 is the safest value for `sync_binlog`, but also the slowest. Even with `sync_binlog` set to 1, there is still the chance of an inconsistency between the table content and binary log content in case of a crash. For example, if you are using `InnoDB` tables and the MySQL server processes a `COMMIT` statement, it writes the whole transaction to the binary log and then commits this transaction into `InnoDB`. If the server crashes between those two operations, the transaction is rolled back by `InnoDB` at restart but still exists in the binary log. To resolve this, you should set `--innodb_support_xa` to 1. Although this option is related to the support of XA transactions in InnoDB, it also ensures that the binary log and InnoDB data files are synchronized.

For this option to provide a greater degree of safety, the MySQL server should also be configured to synchronize the binary log and the `InnoDB` logs to disk at every transaction. The `InnoDB` logs are synchronized by default, and `sync_binlog=1` can be used to synchronize the binary log. The effect of this option is that at restart after a crash, after doing a rollback of transactions, the MySQL server scans the latest binary log file to collect transaction *`xid`* values and calculate the last valid position in the binary log file. The MySQL server then tells `InnoDB` to complete any prepared transactions that were successfully written to the to the binary log, and truncates the binary log to the last valid position. This ensures that the binary log reflects the exact data of `InnoDB` tables, and so, that the slave remains in synchrony with the master (not receiving a statement which has been rolled back).

If the MySQL server discovers at crash recovery that the binary log is shorter than it should have been, it lacks at least one successfully committed `InnoDB` transaction. This should not happen if `sync_binlog=1` and the disk/file system do an actual sync when they are requested to (some do not), so the server prints an error message `The binary log file_name is shorter than its expected size`. In this case, this binary log is not correct and replication should be restarted from a fresh snapshot of the master's data.

The session values of the following system variables are written to the binary log and honored by the replication slave when parsing the binary log:

- `sql_mode` (except that the `NO_DIR_IN_CREATE` mode is not replicated; see Section 17.4.1.38, "Replication and Variables")
- `foreign_key_checks`
- `unique_checks`
- `character_set_client`
- `collation_connection`
- `collation_database`
- `collation_server`
- `sql_auto_is_null`

5.4.4.1 Binary Logging Formats

The server uses several logging formats to record information in the binary log. The exact format employed depends on the version of MySQL being used. There are three logging formats:

- Replication capabilities in MySQL originally were based on propagation of SQL statements from master to slave. This is called *statement-based logging*. You can cause this format to be used by starting the server with `--binlog-format=STATEMENT`.
- In *row-based logging*, the master writes events to the binary log that indicate how individual table rows are affected. You can cause the server to use row-based logging by starting it with `--binlog-format=ROW`.

- A third option is also available: *mixed logging*. With mixed logging, statement-based logging is used by default, but the logging mode switches automatically to row-based in certain cases as described below. You can cause MySQL to use mixed logging explicitly by starting `mysqld` with the option `--binlog-format=MIXED`.

In MySQL 5.5, the default binary logging format is `STATEMENT`.

The logging format can also be set or limited by the storage engine being used. This helps to eliminate issues when replicating certain statements between a master and slave which are using different storage engines.

With statement-based replication, there may be issues with replicating nondeterministic statements. In deciding whether or not a given statement is safe for statement-based replication, MySQL determines whether it can guarantee that the statement can be replicated using statement-based logging. If MySQL cannot make this guarantee, it marks the statement as potentially unreliable and issues the warning, `Statement may not be safe to log in statement format`.

You can avoid these issues by using MySQL's row-based replication instead.

5.4.4.2 Setting The Binary Log Format

You can select the binary logging format explicitly by starting the MySQL server with `--binlog-format=type`. The supported values for *`type`* are:

- `STATEMENT` causes logging to be statement based.
- `ROW` causes logging to be row based.
- `MIXED` causes logging to use mixed format.

In MySQL 5.5, the default binary logging format is `STATEMENT`. This includes MySQL NDB Cluster 7.2.1 and later MySQL NDB Cluster 7.2 releases, which are based on MySQL 5.5.

The logging format also can be switched at runtime. Set the global value of the `binlog_format` system variable to specify the format for clients that connect subsequent to the change:

```
mysql> SET GLOBAL binlog_format = 'STATEMENT';
mysql> SET GLOBAL binlog_format = 'ROW';
mysql> SET GLOBAL binlog_format = 'MIXED';
```

An individual client can control the logging format for its own statements by setting the session value of `binlog_format`:

```
mysql> SET SESSION binlog_format = 'STATEMENT';
mysql> SET SESSION binlog_format = 'ROW';
mysql> SET SESSION binlog_format = 'MIXED';
```

Note

Each MySQL Server can set its own and only its own binary logging format (true whether `binlog_format` is set with global or session scope). This means that changing the logging format on a replication master does not cause a slave to change its logging format to match. (When using `STATEMENT` mode, the `binlog_format` system variable is not replicated; when using `MIXED` or `ROW` logging mode, it is replicated but is ignored by the slave.) Changing the binary logging format on the master while replication is ongoing, or without also changing it on the slave can cause replication to fail with errors such as `Error executing row event: 'Cannot execute statement: impossible to write to binary log since statement is in row format and BINLOG_FORMAT = STATEMENT.'`

To change the global or session `binlog_format` value, you must have the `SUPER` privilege.

There are several reasons why a client might want to set binary logging on a per-session basis:

- A session that makes many small changes to the database might want to use row-based logging.
- A session that performs updates that match many rows in the `WHERE` clause might want to use statement-based logging because it will be more efficient to log a few statements than many rows.
- Some statements require a lot of execution time on the master, but result in just a few rows being modified. It might therefore be beneficial to replicate them using row-based logging.

There are exceptions when you cannot switch the replication format at runtime:

- From within a stored function or a trigger
- If the `NDBCLUSTER` storage engine is enabled
- If the session is currently in row-based replication mode and has open temporary tables

Trying to switch the format in any of these cases results in an error.

If you are using `InnoDB` tables and the transaction isolation level is `READ COMMITTED` or `READ UNCOMMITTED`, only row-based logging can be used. It is *possible* to change the logging format to `STATEMENT`, but doing so at runtime leads very rapidly to errors because `InnoDB` can no longer perform inserts.

Switching the replication format at runtime is not recommended when any temporary tables exist, because temporary tables are logged only when using statement-based replication, whereas with row-based replication they are not logged. With mixed replication, temporary tables are usually logged; exceptions happen with user-defined functions (UDFs) and with the `UUID()` function.

With the binary log format set to `ROW`, many changes are written to the binary log using the row-based format. Some changes, however, still use the statement-based format. Examples include all DDL (data definition language) statements such as `CREATE TABLE`, `ALTER TABLE`, or `DROP TABLE`.

The `--binlog-row-event-max-size` option is available for servers that are capable of row-based replication. Rows are stored into the binary log in chunks having a size in bytes not exceeding the value of this option. The value must be a multiple of 256. The default value is 1024.

Warning

When using *statement-based logging* for replication, it is possible for the data on the master and slave to become different if a statement is designed in such a way that the data modification is *nondeterministic*; that is, it is left to the will of the query optimizer. In general, this is not a good practice even outside of replication. For a detailed explanation of this issue, see Section B.5.7, “Known Issues in MySQL”.

5.4.4.3 Mixed Binary Logging Format

When running in `MIXED` logging format, the server automatically switches from statement-based to row-based logging under the following conditions:

- When a DML statement updates an `NDBCLUSTER` table.
- When a function contains `UUID()`.
- When one or more tables with `AUTO_INCREMENT` columns are updated and a trigger or stored function is invoked. Like all other unsafe statements, this generates a warning if `binlog_format = STATEMENT`.

For more information, see Section 17.4.1.1, “Replication and AUTO_INCREMENT”.

- When any `INSERT DELAYED` is executed.
- When the body of a view requires row-based replication, the statement creating the view also uses it. For example, this occurs when the statement creating a view uses the `UUID()` function.
- When a call to a UDF is involved.
- If a statement is logged by row and the session that executed the statement has any temporary tables, logging by row is used for all subsequent statements (except for those accessing temporary tables) until all temporary tables in use by that session are dropped.

  This is true whether or not any temporary tables are actually logged.

  Temporary tables cannot be logged using row-based format; thus, once row-based logging is used, all subsequent statements using that table are unsafe. The server approximates this condition by treating all statements executed during the session as unsafe until the session no longer holds any temporary tables.
- When `FOUND_ROWS()` or `ROW_COUNT()` is used. (Bug #12092, Bug #30244)
- When `USER()`, `CURRENT_USER()`, or `CURRENT_USER` is used. (Bug #28086)
- When a statement refers to one or more system variables. (Bug #31168)

  Exception. The following system variables, when used with session scope (only), do not cause the logging format to switch:

  - `auto_increment_increment`
  - `auto_increment_offset`
  - `character_set_client`
  - `character_set_connection`
  - `character_set_database`
  - `character_set_server`
  - `collation_connection`
  - `collation_database`
  - `collation_server`
  - `foreign_key_checks`
  - `identity`
  - `last_insert_id`
  - `lc_time_names`
  - `pseudo_thread_id`
  - `sql_auto_is_null`
  - `time_zone`
  - `timestamp`

  - `unique_checks`

  For information about determining system variable scope, see Section 5.1.6, “Using System Variables”.

  For information about how replication treats `sql_mode`, see Section 17.4.1.38, “Replication and Variables”.

- When one of the tables involved is a log table in the `mysql` database.
- When the `LOAD_FILE()` function is used. (Bug #39701)

Note

A warning is generated if you try to execute a statement using statement-based logging that should be written using row-based logging. The warning is shown both in the client (in the output of `SHOW WARNINGS`) and through the `mysqld` error log. A warning is added to the `SHOW WARNINGS` table each time such a statement is executed. However, only the first statement that generated the warning for each client session is written to the error log to prevent flooding the log.

In addition to the decisions above, individual engines can also determine the logging format used when information in a table is updated. The logging capabilities of an individual engine can be defined as follows:

- If an engine supports row-based logging, the engine is said to be *row-logging capable*.
- If an engine supports statement-based logging, the engine is said to be *statement-logging capable*.

A given storage engine can support either or both logging formats. The following table lists the formats supported by each engine.

Storage Engine	Row Logging Supported	Statement Logging Supported
`ARCHIVE`	Yes	Yes
`BLACKHOLE`	Yes	Yes
`CSV`	Yes	Yes
`EXAMPLE`	Yes	No
`FEDERATED`	Yes	Yes
`HEAP`	Yes	Yes
`InnoDB`	Yes	Yes when the transaction isolation level is `REPEATABLE READ` or `SERIALIZABLE`; No otherwise.
`MyISAM`	Yes	Yes
`MERGE`	Yes	Yes
`NDBCLUSTER`	Yes	No

Whether a statement is to be logged and the logging mode to be used is determined according to the type of statement (safe, unsafe, or binary injected), the binary logging format (`STATEMENT`, `ROW`, or `MIXED`), and the logging capabilities of the storage engine (statement capable, row capable, both, or neither). (Binary injection refers to logging a change that must be logged using `ROW` format.)

Statements may be logged with or without a warning; failed statements are not logged, but generate errors in the log. This is shown in the following decision table, where **SLC** stands for “statement-logging capable” and **RLC** stands for “row-logging capable”.

Condition				Action	
Type	**binlog_format**	**SLC**	**RLC**	**Error / Warning**	**Logged as**
*	*	No	No	Error: Cannot execute statement: Binary logging is impossible since at least one engine is involved that is both row-incapable and statement-incapable.	-
Safe	STATEMENT	Yes	No	-	STATEMENT
Safe	MIXED	Yes	No	-	STATEMENT
Safe	ROW	Yes	No	Error: Cannot execute statement: Binary logging is impossible since BINLOG_FORMAT = ROW and at least one table uses a storage engine that is not capable of row-based logging.	-
Unsafe	STATEMENT	Yes	No	Warning: Unsafe statement binlogged in statement format, since BINLOG_FORMAT = STATEMENT	STATEMENT
Unsafe	MIXED	Yes	No	Error: Cannot execute statement: Binary logging of an unsafe statement is impossible when the storage engine is limited to statement-based logging, even if BINLOG_FORMAT = MIXED.	-
Unsafe	ROW	Yes	No	Error: Cannot execute statement: Binary logging is impossible since	-

Condition				Action	
Type	**binlog_format**	**SLC**	**RLC**	**Error / Warning**	**Logged as**
				BINLOG_FORMAT = ROW and at least one table uses a storage engine that is not capable of row-based logging.	
Row Injection	STATEMENT	Yes	No	Error: Cannot execute row injection: Binary logging is not possible since at least one table uses a storage engine that is not capable of row-based logging.	-
Row Injection	MIXED	Yes	No	Error: Cannot execute row injection: Binary logging is not possible since at least one table uses a storage engine that is not capable of row-based logging.	-
Row Injection	ROW	Yes	No	Error: Cannot execute row injection: Binary logging is not possible since at least one table uses a storage engine that is not capable of row-based logging.	-
Safe	STATEMENT	No	Yes	Error: Cannot execute statement: Binary logging is impossible since BINLOG_FORMAT = STATEMENT and at least one table uses a storage engine that is not capable of statement-based logging.	-
Safe	MIXED	No	Yes	-	ROW
Safe	ROW	No	Yes	-	ROW

Condition				Action	
Type	**binlog_format**	**SLC**	**RLC**	**Error / Warning**	**Logged as**
Unsafe	STATEMENT	No	Yes	Error: Cannot execute statement: Binary logging is impossible since BINLOG_FORMAT = STATEMENT and at least one table uses a storage engine that is not capable of statement-based logging.	-
Unsafe	MIXED	No	Yes	-	ROW
Unsafe	ROW	No	Yes	-	ROW
Row Injection	STATEMENT	No	Yes	Error: Cannot execute row injection: Binary logging is not possible since BINLOG_FORMAT = STATEMENT.	-
Row Injection	MIXED	No	Yes	-	ROW
Row Injection	ROW	No	Yes	-	ROW
Safe	STATEMENT	Yes	Yes	-	STATEMENT
Safe	MIXED	Yes	Yes	-	STATEMENT
Safe	ROW	Yes	Yes	-	ROW
Unsafe	STATEMENT	Yes	Yes	Warning: Unsafe statement binlogged in statement format since BINLOG_FORMAT = STATEMENT.	STATEMENT
Unsafe	MIXED	Yes	Yes	-	ROW
Unsafe	ROW	Yes	Yes	-	ROW
Row Injection	STATEMENT	Yes	Yes	Error: Cannot execute row injection: Binary logging is not possible because BINLOG_FORMAT = STATEMENT.	-
Row Injection	MIXED	Yes	Yes	-	ROW

Condition				Action	
Type	**binlog_format**	**SLC**	**RLC**	**Error / Warning**	**Logged as**
Row Injection	ROW	Yes	Yes	-	ROW

Handling of mixed-format logging in MySQL 5.5.2 and earlier. The decision-making process for binary logging changed in MySQL 5.5.3, due to the fix for Bug #39934. Prior to MySQL 5.5.3, when determining the logging mode to be used, the capabilities of all the tables affected by the event are combined, and the set of affected tables is then marked according to these rules:

- A set of tables is defined as *row-logging restricted* if the tables are row-logging capable but not statement-logging capable.
- A set of tables is defined as *statement-logging restricted* if the tables are statement-logging capable but not row-logging capable.

Once the determination of the possible logging formats required by the statement is complete it is compared to the current `binlog_format` setting. The following table is used in MySQL 5.5.2 and earlier to decide how the information is recorded in the binary log or, if appropriate, whether an error is raised. In the table, a safe operation is defined as one that is deterministic.

In MySQL 5.5.2 and earlier, several rules decide whether the statement is deterministic, as shown in the following table, where **SLR** stands for “statement-logging restricted” and **RLR** stands for “row-logging restricted”. A statement is *statement-logging restricted* if one or more of the tables it accesses is not row-logging capable. Similarly, a statement is *row-logging restricted* if any table accessed by the statement is not statement-logging capable.

Condition				Action	
Safe/ unsafe	**binlog_format**	**SLR**	**RLR**	**Error/Warning**	**Logged as**
Safe	STATEMENT	Yes	Yes	Error: not loggable	
Safe	STATEMENT	Yes	No		STATEMENT
Safe	STATEMENT	No	Yes	Error: not loggable	
Safe	STATEMENT	No	No		STATEMENT
Safe	MIXED	Yes	Yes	Error: not loggable	
Safe	MIXED	Yes	No		STATEMENT
Safe	MIXED	No	Yes		ROW
Safe	MIXED	No	No		STATEMENT
Safe	ROW	Yes	Yes	Error: not loggable	
Safe	ROW	Yes	No	Error: not loggable	
Safe	ROW	No	Yes		ROW
Safe	ROW	No	No		ROW
Unsafe	STATEMENT	Yes	Yes	Error: not loggable	
Unsafe	STATEMENT	Yes	No	Warning: unsafe	STATEMENT

Condition				Action	
Safe/ unsafe	**binlog_format**	**SLR**	**RLR**	**Error/Warning**	**Logged as**
Unsafe	STATEMENT	No	Yes	Error: not loggable	
Unsafe	STATEMENT	No	No	Warning: unsafe	STATEMENT
Unsafe	MIXED	Yes	Yes	Error: not loggable	
Unsafe	MIXED	Yes	No	Error: not loggable	
Unsafe	MIXED	No	Yes		ROW
Unsafe	MIXED	No	No		ROW
Unsafe	ROW	Yes	Yes	Error: not loggable	
Unsafe	ROW	Yes	No	Error: not loggable	
Unsafe	ROW	No	Yes		ROW
Unsafe	ROW	No	No		ROW

In all MySQL 5.5 releases, when a warning is produced by the determination, a standard MySQL warning is produced (and is available using SHOW WARNINGS). The information is also written to the mysqld error log. Only one error for each error instance per client connection is logged to prevent flooding the log. The log message includes the SQL statement that was attempted.

If a slave server was started with --log-warnings enabled, the slave prints messages to the error log to provide information about its status, such as the binary log and relay log coordinates where it starts its job, when it is switching to another relay log, when it reconnects after a disconnect, and so forth.

5.4.4.4 Logging Format for Changes to mysql Database Tables

The contents of the grant tables in the mysql database can be modified directly (for example, with INSERT or DELETE) or indirectly (for example, with GRANT or CREATE USER). Statements that affect mysql database tables are written to the binary log using the following rules:

- Data manipulation statements that change data in mysql database tables directly are logged according to the setting of the binlog_format system variable. This pertains to statements such as INSERT, UPDATE, DELETE, REPLACE, DO, LOAD DATA INFILE, SELECT, and TRUNCATE TABLE.
- Statements that change the mysql database indirectly are logged as statements regardless of the value of binlog_format. This pertains to statements such as GRANT, REVOKE, SET PASSWORD, RENAME USER, CREATE (all forms except CREATE TABLE ... SELECT), ALTER (all forms), and DROP (all forms).

CREATE TABLE ... SELECT is a combination of data definition and data manipulation. The CREATE TABLE part is logged using statement format and the SELECT part is logged according to the value of binlog_format.

5.4.5 The Slow Query Log

The slow query log consists of SQL statements that took more than long_query_time seconds to execute and required at least min_examined_row_limit rows to be examined. The minimum and default values of long_query_time are 0 and 10, respectively. The value can be specified to a

resolution of microseconds. For logging to a file, times are written including the microseconds part. For logging to tables, only integer times are written; the microseconds part is ignored.

By default, administrative statements are not logged, nor are queries that do not use indexes for lookups. This behavior can be changed using `--log-slow-admin-statements` and `log_queries_not_using_indexes`, as described later.

The time to acquire the initial locks is not counted as execution time. `mysqld` writes a statement to the slow query log after it has been executed and after all locks have been released, so log order might differ from execution order.

By default, the slow query log is disabled. To specify the initial slow query log state explicitly, use `--slow_query_log[={0|1}]`. With no argument or an argument of 1, `--slow_query_log` enables the log. With an argument of 0, this option disables the log. To specify a log file name, use `--slow_query_log_file=file_name`. To specify the log destination, use `--log-output` (as described in Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”). The older option to enable the slow query log file, `--log-slow-queries`, is deprecated.

If you specify no name for the slow query log file, the default name is *`host_name`*`-slow.log`. The server creates the file in the data directory unless an absolute path name is given to specify a different directory.

To disable or enable the slow query log or change the log file name at runtime, use the global `slow_query_log` and `slow_query_log_file` system variables. Set `slow_query_log` to 0 (or `OFF`) to disable the log or to 1 (or `ON`) to enable it. Set `slow_query_log_file` to specify the name of the log file. If a log file already is open, it is closed and the new file is opened.

When the slow query log is enabled, the server writes output to any destinations specified by the `--log-output` option or `log_output` system variable. If you enable the log, the server opens the log file and writes startup messages to it. However, further logging of queries to the file does not occur unless the `FILE` log destination is selected. If the destination is `NONE`, the server writes no queries even if the slow query log is enabled. Setting the log file name has no effect on logging if the log destination value does not contain `FILE`.

The server writes less information to the slow query log if you use the `--log-short-format` option.

To include slow administrative statements in the statements written to the slow query log, use the `--log-slow-admin-statements` server option. Administrative statements include `ALTER TABLE`, `ANALYZE TABLE`, `CHECK TABLE`, `CREATE INDEX`, `DROP INDEX`, `OPTIMIZE TABLE`, and `REPAIR TABLE`.

To include queries that do not use indexes for row lookups in the statements written to the slow query log, enable the `log_queries_not_using_indexes` system variable. When such queries are logged, the slow query log may grow quickly.

The server uses the controlling parameters in the following order to determine whether to write a query to the slow query log:

1. The query must either not be an administrative statement, or `--log-slow-admin-statements` must have been specified.
2. The query must have taken at least `long_query_time` seconds, or `log_queries_not_using_indexes` must be enabled and the query used no indexes for row lookups.
3. The query must have examined at least `min_examined_row_limit` rows.

The server does not write queries handled by the query cache to the slow query log, nor queries that would not benefit from the presence of an index because the table has zero rows or one row.

By default, a replication slave does not write replicated queries to the slow query log. To change this, use the `--log-slow-slave-statements` server option.

The slow query log should be protected because logged statements might contain passwords. See Section 6.1.2.3, “Passwords and Logging”.

The slow query log can be used to find queries that take a long time to execute and are therefore candidates for optimization. However, examining a long slow query log can become a difficult task. To make this easier, you can process a slow query log file using the `mysqldumpslow` command to summarize the queries that appear in the log. See Section 4.6.8, “`mysqldumpslow` — Summarize Slow Query Log Files”.

5.4.6 The DDL Log

The DDL log, or metadata log, records metadata operations generated by data definition statements such as `DROP TABLE` and `ALTER TABLE`. MySQL uses this log to recover from crashes occurring in the middle of a metadata operation. When executing the statement `DROP TABLE t1, t2`, we need to ensure that both `t1` and `t2` are dropped, and that each table drop is complete. Another example of this type of SQL statement is `ALTER TABLE t3 DROP PARTITION p2`, where we must make certain that the partition is completely dropped and that its definition is removed from the list of partitions for table `t3`.

A record of metadata operations such as those just described are written to the file `ddl_log.log`, in the MySQL data directory. This is a binary file; it is not intended to be human-readable, and you should not attempt to modify its contents in any way.

`ddl_log.log` is not created until it is actually needed for recording metadata statements, and is removed following a successful start of `mysqld`. Thus, it is possible for this file not to be present on a MySQL server that is functioning in a completely normal manner.

Currently, `ddl_log.log` can hold up to 1048573 entries, equivalent 4 GB in size. Once this limit is exceeded, you must rename or remove the file before it is possible to execute any additional DDL statements. This is a known issue which we are working to resolve (Bug #83708).

There are no user-configurable server options or variables associated with this file.

5.4.7 Server Log Maintenance

As described in Section 5.4, “MySQL Server Logs”, MySQL Server can create several different log files to help you see what activity is taking place. However, you must clean up these files regularly to ensure that the logs do not take up too much disk space.

When using MySQL with logging enabled, you may want to back up and remove old log files from time to time and tell MySQL to start logging to new files. See Section 7.2, “Database Backup Methods”.

On a Linux (Red Hat) installation, you can use the `mysql-log-rotate` script for this. If you installed MySQL from an RPM distribution, this script should have been installed automatically. Be careful with this script if you are using the binary log for replication. You should not remove binary logs until you are certain that their contents have been processed by all slaves.

On other systems, you must install a short script yourself that you start from `cron` (or its equivalent) for handling log files.

For the binary log, you can set the `expire_logs_days` system variable to expire binary log files automatically after a given number of days (see Section 5.1.5, “Server System Variables”). If you are using replication, you should set the variable no lower than the maximum number of days your slaves might lag behind the master. To remove binary logs on demand, use the `PURGE BINARY LOGS` statement (see Section 13.4.1.1, “PURGE BINARY LOGS Syntax”).

You can force MySQL to start using new log files by flushing the logs. Log flushing occurs when you issue a `FLUSH LOGS` statement or execute a `mysqladmin flush-logs`, `mysqladmin refresh`, `mysqldump --flush-logs`, or `mysqldump --master-data` command. See Section 13.7.6.3, “FLUSH Syntax”, Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”, and

Section 4.5.4, “mysqldump — A Database Backup Program”. In addition, the binary log is flushed when its size reaches the value of the max_binlog_size system variable.

FLUSH LOGS supports optional modifiers to enable selective flushing of individual logs (for example, FLUSH BINARY LOGS).

A log-flushing operation does the following:

- If general query logging or slow query logging to a log file is enabled, the server closes and reopens the general query log file or slow query log file.
- If binary logging is enabled, the server closes the current binary log file and opens a new log file with the next sequence number.
- If the server was started with the --log-error option to cause the error log to be written to a file, the server closes and reopens the log file.

The server creates a new binary log file when you flush the logs. However, it just closes and reopens the general and slow query log files. To cause new files to be created on Unix, rename the current log files before flushing them. At flush time, the server opens new log files with the original names. For example, if the general and slow query log files are named mysql.log and mysql-slow.log, you can use a series of commands like this:

```
shell> cd mysql-data-directory
shell> mv mysql.log mysql.old
shell> mv mysql-slow.log mysql-slow.old
shell> mysqladmin flush-logs
```

On Windows, use rename rather than mv.

At this point, you can make a backup of mysql.old and mysql-slow.old and then remove them from disk.

A similar strategy can be used to back up the error log file, if there is one.

You can rename the general query log or slow query log at runtime by disabling the log:

```
SET GLOBAL general_log = 'OFF';
SET GLOBAL slow_query_log = 'OFF';
```

With the logs disabled, rename the log files externally; for example, from the command line. Then enable the logs again:

```
SET GLOBAL general_log = 'ON';
SET GLOBAL slow_query_log = 'ON';
```

This method works on any platform and does not require a server restart.

Note

For the server to recreate a given log file after you have renamed the file externally, the file location must be writable by the server. This may not always be the case. For example, on Linux, the server might write the error log as /var/log/mysqld.log, where /var/log is owned by root and not writable by mysqld. In this case, the log-flushing operation will fail to create a new log file.

To handle this situation, you must manually create the new log file with the proper ownershiop after renaming the original log file. For example, execute these commands as root:

```
shell> mv /var/log/mysqld.log /var/log/mysqld.log.old
shell> install -omysql -gmysql -m0644 /dev/null /var/log/mysqld.log
```

5.5 MySQL Server Plugins

MySQL supports a plugin API that enables creation of server components. Plugins can be loaded at server startup, or loaded and unloaded at runtime without restarting the server. The components supported by this interface include, but are not limited to, storage engines, `INFORMATION_SCHEMA` tables, full-text parser plugins, partitioning support, and server extensions.

MySQL distributions include several plugins that implement server extensions:

- Plugins for authenticating attempts by clients to connect to MySQL Server. Plugins are available for several authentication protocols. See Section 6.3.6, “Pluggable Authentication”.
- Semisynchronous replication plugins implement an interface to replication capabilities that permit the master to proceed as long as at least one slave has responded to each transaction. See Section 17.3.8, “Semisynchronous Replication”.
- MySQL Enterprise Edition includes a thread pool plugin that manages connection threads to increase server performance by efficiently managing statement execution threads for large numbers of client connections. See Section 5.5.3, “MySQL Enterprise Thread Pool”.
- MySQL Enterprise Edition includes an audit plugin for monitoring and logging of connection and query activity. See Section 6.5.2, “MySQL Enterprise Audit”.

The following sections describe how to install and uninstall plugins, and how to determine at runtime which plugins are installed and obtain information about them. For information about writing plugins, see Section 24.2, “The MySQL Plugin API”.

5.5.1 Installing and Uninstalling Plugins

Server plugins must be loaded into the server before they can be used. MySQL supports plugin loading at server startup and runtime. It is also possible to control the activation state of loaded plugins at startup, and to unload them at runtime.

- Installing plugins
- Controlling plugin activation state
- Uninstalling plugins

While a plugin is loaded, information about it is available at runtime from the `INFORMATION_SCHEMA.PLUGINS` table and the `SHOW PLUGINS` statement. See Section 5.5.2, “Obtaining Server Plugin Information”.

Installing Plugins

Before a server plugin can be used, it must be installed using one of the following methods. In the descriptions, *`plugin_name`* stands for a plugin name such as `innodb` or `csv`.

Built-in plugins:

A built-in plugin is known by the server automatically. Normally, the server enables the plugin at startup. Some built-in plugins permit this to be changed with the *`--plugin_name`*`[=`*`activation_state`*`]` option.

Plugins registered in the `mysql.plugin` system table:

The `mysql.plugin` table serves as a registry of plugins (other than built-in plugins, which need not be registered). At startup, the server loads each plugin listed in the table. Normally, for a plugin loaded

from the `mysql.plugin` table, the server also enables the plugin. This can be changed with the `--plugin_name[=activation_state]` option.

If the server is started with the `--skip-grant-tables` option, it does not consult the `mysql.plugin` table and does not load the plugins listed there.

Plugins named with the `--plugin-load` option:

A plugin located in a plugin library file can be loaded at server startup with the `--plugin-load` option. Normally, for a plugin loaded at startup, the server also enables the plugin. This can be changed with the `--plugin_name[=activation_state]` option.

The value of each plugin-loading option is a semicolon-separated list of *`name=plugin_library`* and *`plugin_library`* values. Each *`name`* is the name of a plugin to load, and *`plugin_library`* is the name of the library file that contains the plugin code. If a plugin library is named without any preceding plugin name, the server loads all plugins in the library. The server looks for plugin library files in the directory named by the `plugin_dir` system variable.

Plugin-loading options do not register any plugin in the `mysql.plugin` table. For subsequent restarts, the server loads the plugin again only if `--plugin-load` is given again. That is, the option produces a one-time plugin-installation operation that persists for a single server invocation.

`--plugin-load` enables plugins to be loaded even when `--skip-grant-tables` is given (which causes the server to ignore the `mysql.plugin` table). `--plugin-load` also enables plugins to be loaded at startup under configurations when plugins cannot be loaded at runtime.

Plugins installed with the `INSTALL PLUGIN` statement:

A plugin located in a plugin library file can be loaded at runtime with the `INSTALL PLUGIN` statement. The statement also registers the plugin in the `mysql.plugin` table to cause the server to load it on subsequent restarts. For this reason, `INSTALL PLUGIN` requires the `INSERT` privilege for the `mysql.plugin` table.

The plugin library file base name depends on your platform. Common suffixes are `.so` for Unix and Unix-like systems, `.dll` for Windows.

Example: The `--plugin-load` option installs a plugin at server startup. To install a plugin named `myplugin` from a plugin library file named `somepluglib.so`, use these lines in a `my.cnf` file:

```
[mysqld]
plugin-load=myplugin=somepluglib.so
```

In this case, the plugin is not registered in `mysql.plugin`. Restarting the server without the `--plugin-load` option causes the plugin not to be loaded at startup.

Alternatively, the `INSTALL PLUGIN` statement causes the server to load the plugin code from the library file at runtime:

```
INSTALL PLUGIN myplugin SONAME 'somepluglib.so';
```

`INSTALL PLUGIN` also causes “permanent” plugin registration: The plugin is listed in the `mysql.plugin` table to ensure that the server loads it on subsequent restarts.

Many plugins can be loaded either at server startup or at runtime. However, if a plugin is designed such that it must be loaded and initialized during server startup, attempts to load it at runtime using `INSTALL PLUGIN` produce an error:

```
mysql> INSTALL PLUGIN myplugin SONAME 'somepluglib.so';
ERROR 1721 (HY000): Plugin 'myplugin' is marked as not dynamically
installable. You have to stop the server to install it.
```

In this case, you must use `--plugin-load`.

Many plugins can be loaded either at server startup or at runtime. However, if a plugin is designed such that it must be loaded and initialized during server startup, use `--plugin-load` rather than `INSTALL PLUGIN`.

If a plugin is named both using a `--plugin-load` option and (as a result of an earlier `INSTALL PLUGIN` statement) in the `mysql.plugin` table, the server starts but writes these messages to the error log:

```
[ERROR] Function 'plugin_name' already exists
[Warning] Couldn't load plugin named 'plugin_name'
with soname 'plugin_object_file'.
```

Controlling Plugin Activation State

If the server knows about a plugin when it starts (for example, because the plugin is named using a `--plugin-load` option or is registered in the `mysql.plugin` table), the server loads and enables the plugin by default. It is possible to control activation state for such a plugin using a `--plugin_name[=activation_state]` startup option, where *`plugin_name`* is the name of the plugin to affect, such as `innodb` or `csv`. As with other options, dashes and underscores are interchangeable in option names. Also, activation state values are not case sensitive. For example, `--my_plugin=ON` and `--my-plugin=on` are equivalent.

- `--plugin_name=OFF`

  Tells the server to disable the plugin. This may not be possible for certain built-in plugins, such as `mysql_native_password`.

- `--plugin_name[=ON]`

  Tells the server to enable the plugin. (Specifying the option as `--plugin_name` without a value has the same effect.) If the plugin fails to initialize, the server runs with the plugin disabled.

- `--plugin_name=FORCE`

  Tells the server to enable the plugin, but if plugin initialization fails, the server does not start. In other words, this option forces the server to run with the plugin enabled or not at all.

- `--plugin_name=FORCE_PLUS_PERMANENT`

  Like `FORCE`, but in addition prevents the plugin from being unloaded at runtime. If a user attempts to do so with `UNINSTALL PLUGIN`, an error occurs. This value is available as of MySQL 5.5.7.

Plugin activation states are visible in the `LOAD_OPTION` column of the `INFORMATION_SCHEMA.PLUGINS` table.

Suppose that `CSV`, `BLACKHOLE`, and `ARCHIVE` are built-in pluggable storage engines and that you want the server to load them at startup, subject to these conditions: The server is permitted to run if `CSV` initialization fails, must require that `BLACKHOLE` initialization succeeds, and should disable `ARCHIVE`. To accomplish that, use these lines in an option file:

```
[mysqld]
csv=ON
blackhole=FORCE
archive=OFF
```

The `--enable-plugin_name` option format is a synonym for `--plugin_name=ON`. The `--disable-plugin_name` and `--skip-plugin_name` option formats are synonyms for `--plugin_name=OFF`.

Before MySQL 5.1.36, plugin options are boolean options (see Section 4.2.5, “Program Option Modifiers”). That is, any of these options enable the plugin:

```
--plugin_name
--plugin_name=1
--enable-plugin_name
```

And these options disable the plugin:

```
--plugin_name=0
--disable-plugin_name
--skip-plugin_name
```

If you upgrade to MySQL 5.5 from a version older than 5.1.36 and previously used options of the form `--plugin_name=0` or `--plugin_name=1`, the equivalent options are now `--plugin_name=OFF` and `--plugin_name=ON`, respectively. You also have the choice of requiring plugins to start successfully by using `--plugin_name=FORCE` or `--plugin_name=FORCE_PLUS_PERMANENT`.

If a plugin is disabled, either explicitly with `OFF` or implicitly because it was enabled with `ON` but failed to initialize, aspects of server operation that require the plugin will change. For example, if the plugin implements a storage engine, existing tables for the storage engine become inaccessible, and attempts to create new tables for the storage engine result in tables that use the default storage engine unless the `NO_ENGINE_SUBSTITUTION` SQL mode is enabled to cause an error to occur instead.

Disabling a plugin may require adjustment to other options. For example, if you start the server using `--skip-innodb` to disable `InnoDB`, other `innodb_xxx` options likely will need to be omitted at startup. In addition, because `InnoDB` is the default storage engine, it will not start unless you specify another available storage engine with `--default-storage-engine`.

Uninstalling Plugins

At runtime, the `UNINSTALL PLUGIN` statement disables and uninstalls a plugin known to the server. The statement unloads the plugin and removes it from the `mysql.plugin` table, if it is registered there. For this reason, `UNINSTALL PLUGIN` statement requires the `DELETE` privilege for the `mysql.plugin` table. With the plugin no longer registered in the table, the server will not load the plugin automatically for subsequent restarts.

`UNINSTALL PLUGIN` can unload a plugin regardless of whether it was loaded at runtime with `INSTALL PLUGIN` or at startup with a plugin-loading option, subject to these conditions:

- It cannot unload plugins that are built in to the server. These can be identified as those that have a library name of `NULL` in the output from `INFORMATION_SCHEMA.PLUGINS` or `SHOW PLUGINS`.
- It cannot unload plugins for which the server was started with `--plugin_name=FORCE_PLUS_PERMANENT`, which prevents plugin unloading at runtime. These can be identified from the `LOAD_OPTION` column of the `INFORMATION_SCHEMA.PLUGINS` table.

To uninstall a plugin that currently is loaded at server startup with a plugin-loading option, use this procedure.

1. Remove any options related to the plugin from the `my.cnf` file.
2. Restart the server.
3. Plugins normally are installed using either a plugin-loading option at startup or with `INSTALL PLUGIN` at runtime, but not both. However, removing options for a plugin from the `my.cnf` file may not be sufficient to uninstall it if at some point `INSTALL PLUGIN` has also been used. If the plugin still appears in the output from `INFORMATION_SCHEMA.PLUGINS` or `SHOW PLUGINS`, use `UNINSTALL PLUGIN` to remove it from the `mysql.plugin` table. Then restart the server again.

5.5.2 Obtaining Server Plugin Information

There are several ways to determine which plugins are installed in the server:

- The `INFORMATION_SCHEMA.PLUGINS` table contains a row for each loaded plugin. Any that have a `PLUGIN_LIBRARY` value of `NULL` are built in and cannot be unloaded.

```
mysql> SELECT * FROM information_schema.PLUGINS\G
*************************** 1. row ***************************
           PLUGIN_NAME: binlog
        PLUGIN_VERSION: 1.0
         PLUGIN_STATUS: ACTIVE
           PLUGIN_TYPE: STORAGE ENGINE
   PLUGIN_TYPE_VERSION: 50158.0
        PLUGIN_LIBRARY: NULL
PLUGIN_LIBRARY_VERSION: NULL
         PLUGIN_AUTHOR: MySQL AB
    PLUGIN_DESCRIPTION: This is a pseudo storage engine to represent the binlog in a transaction
        PLUGIN_LICENSE: GPL
           LOAD_OPTION: FORCE
...
*************************** 10. row ***************************
           PLUGIN_NAME: InnoDB
        PLUGIN_VERSION: 1.0
         PLUGIN_STATUS: ACTIVE
           PLUGIN_TYPE: STORAGE ENGINE
   PLUGIN_TYPE_VERSION: 50158.0
        PLUGIN_LIBRARY: ha_innodb_plugin.so
PLUGIN_LIBRARY_VERSION: 1.0
         PLUGIN_AUTHOR: Innobase Oy
    PLUGIN_DESCRIPTION: Supports transactions, row-level locking,
                        and foreign keys
        PLUGIN_LICENSE: GPL
           LOAD_OPTION: ON
...
```

- The `SHOW PLUGINS` statement displays a row for each loaded plugin. Any that have a `Library` value of `NULL` are built in and cannot be unloaded.

```
mysql> SHOW PLUGINS\G
*************************** 1. row ***************************
   Name: binlog
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
...
*************************** 10. row ***************************
   Name: InnoDB
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: ha_innodb_plugin.so
License: GPL
...
```

- The `mysql.plugin` table shows which plugins have been registered with `INSTALL PLUGIN`. The table contains only plugin names and library file names, so it does not provide as much information as the `PLUGINS` table or the `SHOW PLUGINS` statement.

5.5.3 MySQL Enterprise Thread Pool

Note

MySQL Enterprise Thread Pool is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, http://www.mysql.com/products/.

As of MySQL 5.5.16, MySQL Enterprise Edition includes MySQL Enterprise Thread Pool, implemented using a server plugin. The default thread-handling model in MySQL Server executes statements using one thread per client connection. As more clients connect to the server and execute statements, overall

performance degrades. The thread pool plugin provides an alternative thread-handling model designed to reduce overhead and improve performance. The plugin implements a thread pool that increases server performance by efficiently managing statement execution threads for large numbers of client connections.

The thread pool addresses several problems of the one thread per connection model:

- Too many thread stacks make CPU caches almost useless in highly parallel execution workloads. The thread pool promotes thread stack reuse to minimize the CPU cache footprint.
- With too many threads executing in parallel, context switching overhead is high. This also presents a challenging task to the operating system scheduler. The thread pool controls the number of active threads to keep the parallelism within the MySQL server at a level that it can handle and that is appropriate for the server host on which MySQL is executing.
- Too many transactions executing in parallel increases resource contention. In `InnoDB`, this increases the time spent holding central mutexes. The thread pool controls when transactions start to ensure that not too many execute in parallel.

The thread pool plugin is included only in MySQL Enterprise Edition. It is not included in MySQL community distributions.

On Windows, the thread pool plugin requires Windows Vista or newer. On Linux, the plugin requires kernel 2.6.9 or higher.

Additional Resources

Section A.14, “MySQL 5.5 FAQ: MySQL Enterprise Thread Pool”

5.5.3.1 Thread Pool Components

The thread pool feature comprises these components:

- A plugin library file contains a plugin for the thread pool code and plugins for several `INFORMATION_SCHEMA` tables.

  For a detailed description of how the thread pool works, see Section 5.5.3.3, “Thread Pool Operation”.

  The `INFORMATION_SCHEMA` tables are named `TP_THREAD_STATE`, `TP_THREAD_GROUP_STATE`, and `TP_THREAD_GROUP_STATS`. These tables provide information about thread pool operation. For more information, see Section 21.30, “Thread Pool INFORMATION_SCHEMA Tables”.

- Several system variables are related to the thread pool. The `thread_handling` system variable has a value of `loaded-dynamically` when the server successfully loads the thread pool plugin.

  The other related variables are implemented by the thread pool plugin; they are not available unless it is enabled:

  - `thread_pool_algorithm`: The concurrency algorithm to use for scheduling.
  - `thread_pool_high_priority_connection`: How to schedule statement execution for a session.
  - `thread_pool_prio_kickup_timer`: How long before the thread pool moves a statement awaiting execution from the low-priority queue to the high-priority queue.
  - `thread_pool_max_unused_threads`: How many sleeping threads to permit.
  - `thread_pool_size`: The number of thread groups in the thread pool. This is the most important parameter controlling thread pool performance.

- `thread_pool_stall_limit`: The time before an executing statement is considered to be stalled.

If any variable implemented by the plugin is set to an illegal value at startup, plugin initialization fails and the plugin does not load.

For information about setting thread pool parameters, see Section 5.5.3.4, “Thread Pool Tuning”.

- The Performance Schema exposes information about the thread pool and may be used to investigate operational performance. For more information, see Chapter 22, *MySQL Performance Schema*.

5.5.3.2 Thread Pool Installation

This section describes how to install MySQL Enterprise Thread Pool. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

The plugin library file base name is `thread_pool`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).

To enable thread pool capability, load the plugins to be used by starting the server with the `--plugin-load` option. For example, if you name just the plugin library file, the server loads all plugins that it contains (that is, the thread pool plugin and all the `INFORMATION_SCHEMA` tables). To do this, put these lines in your `my.cnf` file (adjust the `.so` suffix for your platform as necessary):

```
[mysqld]
plugin-load=thread_pool.so
```

That is equivalent to loading all thread pool plugins by naming them individually:

```
[mysqld]
plugin-load=thread_pool=thread_pool.so;tp_thread_state=thread_pool.so;tp_thread_group_state=thread_pool
```

If desired, you can load individual plugins from the library file. To load the thread pool plugin but not the `INFORMATION_SCHEMA` tables, use an option like this:

```
[mysqld]
plugin-load=thread_pool=thread_pool.so
```

To load the thread pool plugin and only the `TP_THREAD_STATE INFORMATION_SCHEMA` table, use an option like this:

```
[mysqld]
plugin-load=thread_pool=thread_pool.so;tp_thread_state=thread_pool.so
```

Note

If you do not load all the `INFORMATION_SCHEMA` tables, some or all MySQL Enterprise Monitor thread pool graphs will be empty.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
       FROM INFORMATION_SCHEMA.PLUGINS
       WHERE PLUGIN_NAME LIKE 'thread%' OR PLUGIN_NAME LIKE 'tp%';
```

```
+----------------------+---------------+
| PLUGIN_NAME          | PLUGIN_STATUS |
+----------------------+---------------+
| thread_pool          | ACTIVE        |
| TP_THREAD_STATE      | ACTIVE        |
| TP_THREAD_GROUP_STATE | ACTIVE        |
| TP_THREAD_GROUP_STATS | ACTIVE        |
+----------------------+---------------+
```

If a plugin fails to initialize, check the server error log for diagnostic messages.

If the server loads the thread pool plugin successfully, it sets the `thread_handling` system variable to `dynamically-loaded`.

5.5.3.3 Thread Pool Operation

The thread pool consists of a number of thread groups, each of which manages a set of client connections. As connections are established, the thread pool assigns them to thread groups in round-robin fashion.

The number of thread groups is configurable using the `thread_pool_size` system variable. The default number of groups is 16. For guidelines on setting this variable, see Section 5.5.3.4, “Thread Pool Tuning”.

The maximum number of threads per group is 4096 (or 4095 on some systems where one thread is used internally).

The thread pool separates connections and threads, so there is no fixed relationship between connections and the threads that execute statements received from those connections. This differs from the default thread-handling model that associates one thread with one connection such that the thread executes all statements from the connection.

The thread pool tries to ensure a maximum of one thread executing in each group at any time, but sometimes permits more threads to execute temporarily for best performance. The algorithm works in the following manner:

- Each thread group has a listener thread that listens for incoming statements from the connections assigned to the group. When a statement arrives, the thread group either begins executing it immediately or queues it for later execution:
  - Immediate execution occurs if the statement is the only one received and no statements are queued or currently executing.
  - Queuing occurs if the statement cannot begin executing immediately.
- If immediate execution occurs, execution is performed by the listener thread. (This means that temporarily no thread in the group is listening.) If the statement finishes quickly, the executing thread returns to listening for statements. Otherwise, the thread pool considers the statement stalled and starts another thread as a listener thread (creating it if necessary). To ensure that no thread group becomes blocked by stalled statements, the thread pool has a background thread that regularly monitors thread group states.

  By using the listening thread to execute a statement that can begin immediately, there is no need to create an additional thread if the statement finishes quickly. This ensures the most efficient execution possible in the case of a low number of concurrent threads.

  When the thread pool plugin starts, it creates one thread per group (the listener thread), plus the background thread. Additional threads are created as necessary to execute statements.
- The value of the `thread_pool_stall_limit` system variable determines the meaning of “finishes quickly” in the previous item. The default time before threads are considered stalled is 60ms but can be set to a maximum of 6s. This parameter is configurable to enable you to strike a balance appropriate for the server work load. Short wait values permit threads to start more quickly. Short

values are also better for avoiding deadlock situations. Long wait values are useful for workloads that include long-running statements, to avoid starting too many new statements while the current ones execute.

- The thread pool focuses on limiting the number of concurrent short-running statements. Before an executing statement reaches the stall time, it prevents other statements from beginning to execute. If the statement executes past the stall time, it is permitted to continue but no longer prevents other statements from starting. In this way, the thread pool tries to ensure that in each thread group there is never more than one short-running statement, although there might be multiple long-running statements. It is undesirable to let long-running statements prevent other statements from executing because there is no limit on the amount of waiting that might be necessary. For example, on a replication master, a thread that is sending binary log events to a slave effectively runs forever.

- A statement becomes blocked if it encounters a disk I/O operation or a user level lock (row lock or table lock). The block would cause the thread group to become unused, so there are callbacks to the thread pool to ensure that the thread pool can immediately start a new thread in this group to execute another statement. When a blocked thread returns, the thread pool permits it to restart immediately.

- There are two queues, a high-priority queue and a low-priority queue. The first statement in a transaction goes to the low-priority queue. Any following statements for the transaction go to the high-priority queue if the transaction is ongoing (statements for it have begun executing), or to the low-priority queue otherwise. Queue assignment can be affected by enabling the `thread_pool_high_priority_connection` system variable, which causes all queued statements for a session to go into the high-priority queue.

  Statements for a nontransactional storage engine, or a transactional engine if `autocommit` is enabled, are treated as low-priority statements because in this case each statement is a transaction. Thus, given a mix of statements for `InnoDB` and `MyISAM` tables, the thread pool prioritizes those for `InnoDB` over those for `MyISAM` unless `autocommit` is enabled. With `autocommit` enabled, all statements will be low priority.

- When the thread group selects a queued statement for execution, it first looks in the high-priority queue, then in the low-priority queue. If a statement is found, it is removed from its queue and begins to execute.

- If a statement stays in the low-priority queue too long, the thread pool moves to the high-priority queue. The value of the `thread_pool_prio_kickup_timer` system variable controls the time before movement. For each thread group, a maximum of one statement per 10ms or 100 per second will be moved from the low-priority queue to the high-priority queue.

- The thread pool reuses the most active threads to obtain a much better use of CPU caches. This is a small adjustment that has a great impact on performance.

- While a thread executes a statement from a user connection, Performance Schema instrumentation accounts thread activity to the user connection. Otherwise, Performance Schema accounts activity to the thread pool.

Here are examples of conditions under which a thread group might have multiple threads started to execute statements:

- One thread begins executing a statement, but runs long enough to be considered stalled. The thread group permits another thread to begin executing another statement even through the first thread is still executing.

- One thread begins executing a statement, then becomes blocked and reports this back to the thread pool. The thread group permits another thread to begin executing another statement.

- One thread begins executing a statement, becomes blocked, but does not report back that it is blocked because the block does not occur in code that has been instrumented with thread pool callbacks. In this case, the thread appears to the thread group to be still running. If the block lasts

long enough for the statement to be considered stalled, the group permits another thread to begin executing another statement.

The thread pool is designed to be scalable across an increasing number of connections. It is also designed to avoid deadlocks that can arise from limiting the number of actively executing statements. It is important that threads that do not report back to the thread pool do not prevent other statements from executing and thus cause the thread pool to become deadlocked. Examples of such statements follow:

- Long-running statements. These would lead to all resources used by only a few statements and they could prevent all others from accessing the server.
- Binary log dump threads that read the binary log and send it to slaves. This is a kind of long-running "statement" that runs for a very long time, and that should not prevent other statements from executing.
- Statements blocked on a row lock, table lock, sleep, or any other blocking activity that has not been reported back to the thread pool by MySQL Server or a storage engine.

In each case, to prevent deadlock, the statement is moved to the stalled category when it does not complete quickly, so that the thread group can permit another statement to begin executing. With this design, when a thread executes or becomes blocked for an extended time, the thread pool moves the thread to the stalled category and for the rest of the statement's execution, it does not prevent other statements from executing.

The maximum number of threads that can occur is the sum of `max_connections` and `thread_pool_size`. This can happen in a situation where all connections are in execution mode and an extra thread is created per group to listen for more statements. This is not necessarily a state that happens often, but it is theoretically possible.

5.5.3.4 Thread Pool Tuning

This section provides guidelines on setting thread pool system variables for best performance, measured using a metric such as transactions per second.

`thread_pool_size` is the most important parameter controlling thread pool performance. It can be set only at server startup. Our experience in testing the thread pool indicates the following:

- If the primary storage engine is `InnoDB`, the optimal `thread_pool_size` setting is likely to be between 16 and 36, with the most common optimal values tending to be from 24 to 36. We have not seen any situation where the setting has been optimal beyond 36. There may be special cases where a value smaller than 16 is optimal.

  For workloads such as DBT2 and Sysbench, the optimum for `InnoDB` seems to be usually around 36. For very write-intensive workloads, the optimal setting can sometimes be lower.

- If the primary storage engine is `MyISAM`, the `thread_pool_size` setting should be fairly low. We tend to get optimal performance for values from 4 to 8. Higher values tend to have a slightly negative but not dramatic impact on performance.

Another system variable, `thread_pool_stall_limit`, is important for handling of blocked and long-running statements. If all calls that block the MySQL Server are reported to the thread pool, it would always know when execution threads are blocked. However, this may not always be true. For example, blocks could occur in code that has not been instrumented with thread pool callbacks. For such cases, the thread pool must be able to identify threads that appear to be blocked. This is done by means of a timeout, the length of which can be tuned using the `thread_pool_stall_limit` system variable. This parameter ensures that the server does not become completely blocked. The value of `thread_pool_stall_limit` has an upper limit of 6 seconds to prevent the risk of a deadlocked server.

`thread_pool_stall_limit` also enables the thread pool to handle long-running statements. If a long-running statement was permitted to block a thread group, all other connections assigned to the

group would be blocked and unable to start execution until the long-running statement completed. In the worst case, this could take hours or even days.

The value of `thread_pool_stall_limit` should be chosen such that statements that execute longer than its value are considered stalled. Stalled statements generate a lot of extra overhead since they involve extra context switches and in some cases even extra thread creations. On the other hand, setting the `thread_pool_stall_limit` parameter too high means that long-running statements will block a number of short-running statements for longer than necessary. Short wait values permit threads to start more quickly. Short values are also better for avoiding deadlock situations. Long wait values are useful for workloads that include long-running statements, to avoid starting too many new statements while the current ones execute.

Suppose a server executes a workload where 99.9% of the statements complete within 100ms even when the server is loaded, and the remaining statements take between 100ms and 2 hours fairly evenly spread. In this case, it would make sense to set `thread_pool_stall_limit` to 10 (meaning 100ms). The default value of 60ms is okay for servers that primarily execute very simple statements.

The `thread_pool_stall_limit` parameter can be changed at runtime to enable you to strike a balance appropriate for the server work load. Assuming that the `TP_THREAD_GROUP_STATS` table is enabled, you can use the following query to determine the fraction of executed statements that stalled:

```
SELECT SUM(STALLED_QUERIES_EXECUTED) / SUM(QUERIES_EXECUTED)
FROM information_schema.TP_THREAD_GROUP_STATS;
```

This number should be as low as possible. To decrease the likelihood of statements stalling, increase the value of `thread_pool_stall_limit`.

When a statement arrives, what is the maximum time it can be delayed before it actually starts executing? Suppose that the following conditions apply:

- There are 200 statements queued in the low-priority queue.
- There are 10 statements queued in the high-priority queue.
- `thread_pool_prio_kickup_timer` is set to 10000 (10 seconds).
- `thread_pool_stall_limit` is set to 100 (1 second).

In the worst case, the 10 high-priority statements represent 10 transactions that continue executing for a long time. Thus, in the worst case, no statements will be moved to the high-priority queue because it will always already contain statements awaiting execution. After 10 seconds, the new statement is eligible to be moved to the high-priority queue. However, before it can be moved, all the statements before it must be moved as well. This could take another 2 seconds because a maximum of 100 statements per second are moved to the high-priority queue. Now when the statement reaches the high-priority queue, there could potentially be many long-running statements ahead of it. In the worst case, every one of those will become stalled and it will take 1 second for each statement before the next statement is retrieved from the high-priority queue. Thus, in this scenario, it will take 222 seconds before the new statement starts executing.

This example shows a worst case for an application. How to handle it depends on the application. If the application has high requirements for the response time, it should most likely throttle users at a higher level itself. Otherwise, it can use the thread pool configuration parameters to set some kind of a maximum waiting time.

5.6 Running Multiple MySQL Instances on One Machine

In some cases, you might want to run multiple instances of MySQL on a single machine. You might want to test a new MySQL release while leaving an existing production setup undisturbed. Or you might want to give different users access to different `mysqld` servers that they manage themselves. (For example, you might be an Internet Service Provider that wants to provide independent MySQL installations for different customers.)

It is possible to use a different MySQL server binary per instance, or use the same binary for multiple instances, or any combination of the two approaches. For example, you might run a server from MySQL 5.1 and one from MySQL 5.5, to see how different versions handle a given workload. Or you might run multiple instances of the current production version, each managing a different set of databases.

Whether or not you use distinct server binaries, each instance that you run must be configured with unique values for several operating parameters. This eliminates the potential for conflict between instances. Parameters can be set on the command line, in option files, or by setting environment variables. See Section 4.2.3, “Specifying Program Options”. To see the values used by a given instance, connect to it and execute a `SHOW VARIABLES` statement.

The primary resource managed by a MySQL instance is the data directory. Each instance should use a different data directory, the location of which is specified using the `--datadir=dir_name` option. For methods of configuring each instance with its own data directory, and warnings about the dangers of failing to do so, see Section 5.6.1, “Setting Up Multiple Data Directories”.

In addition to using different data directories, several other options must have different values for each server instance:

- `--port=port_num`

  `--port` controls the port number for TCP/IP connections. Alternatively, if the host has multiple network addresses, you can use `--bind-address` to cause each server to listen to a different address.

- `--socket={file_name|pipe_name}`

  `--socket` controls the Unix socket file path on Unix or the named pipe name on Windows. On Windows, it is necessary to specify distinct pipe names only for those servers configured to permit named-pipe connections.

- `--shared-memory-base-name=name`

  This option is used only on Windows. It designates the shared-memory name used by a Windows server to permit clients to connect using shared memory. It is necessary to specify distinct shared-memory names only for those servers configured to permit shared-memory connections.

- `--pid-file=file_name`

  This option indicates the path name of the file in which the server writes its process ID.

If you use the following log file options, their values must differ for each server:

- `--general_log_file=file_name`
- `--log-bin[=file_name]`
- `--slow_query_log_file=file_name`
- `--log-error[=file_name]`

For further discussion of log file options, see Section 5.4, “MySQL Server Logs”.

To achieve better performance, you can specify the following option differently for each server, to spread the load between several physical disks:

- `--tmpdir=dir_name`

Having different temporary directories also makes it easier to determine which MySQL server created any given temporary file.

If you have multiple MySQL installations in different locations, you can specify the base directory for each installation with the `--basedir=dir_name` option. This causes each instance to automatically

use a different data directory, log files, and PID file because the default for each of those parameters is relative to the base directory. In that case, the only other options you need to specify are the `--socket` and `--port` options. Suppose that you install different versions of MySQL using `tar` file binary distributions. These install in different locations, so you can start the server for each installation using the command `bin/mysqld_safe` under its corresponding base directory. `mysqld_safe` determines the proper `--basedir` option to pass to `mysqld`, and you need specify only the `--socket` and `--port` options to `mysqld_safe`.

As discussed in the following sections, it is possible to start additional servers by specifying appropriate command options or by setting environment variables. However, if you need to run multiple servers on a more permanent basis, it is more convenient to use option files to specify for each server those option values that must be unique to it. The `--defaults-file` option is useful for this purpose.

5.6.1 Setting Up Multiple Data Directories

Each MySQL Instance on a machine should have its own data directory. The location is specified using the `--datadir=`*`dir_name`* option.

There are different methods of setting up a data directory for a new instance:

- Create a new data directory.
- Copy an existing data directory.

The following discussion provides more detail about each method.

Warning

Normally, you should never have two servers that update data in the same databases. This may lead to unpleasant surprises if your operating system does not support fault-free system locking. If (despite this warning) you run multiple servers using the same data directory and they have logging enabled, you must use the appropriate options to specify log file names that are unique to each server. Otherwise, the servers try to log to the same files.

Even when the preceding precautions are observed, this kind of setup works only with `MyISAM` and `MERGE` tables, and not with any of the other storage engines. Also, this warning against sharing a data directory among servers always applies in an NFS environment. Permitting multiple MySQL servers to access a common data directory over NFS is a *very bad idea*. The primary problem is that NFS is the speed bottleneck. It is not meant for such use. Another risk with NFS is that you must devise a way to ensure that two or more servers do not interfere with each other. Usually NFS file locking is handled by the `lockd` daemon, but at the moment there is no platform that performs locking 100% reliably in every situation.

Create a New Data Directory

With this method, the data directory will be in the same state as when you first install MySQL. It will have the default set of MySQL accounts and no user data.

On Unix, initialize the data directory. See Section 2.10, “Postinstallation Setup and Testing”.

On Windows, the data directory is included in the MySQL distribution:

- MySQL Zip archive distributions for Windows contain an unmodified data directory. You can unpack such a distribution into a temporary location, then copy it `data` directory to where you are setting up the new instance.
- As of MySQL 5.5.5, Windows MSI package installers create and set up the data directory that the installed server will use, but also create a pristine “template” data directory named `data` under the

installation directory. After an installation has been performed using an MSI package, the template data directory can be copied to set up additional MySQL instances.

Copy an Existing Data Directory

With this method, any MySQL accounts or user data present in the data directory are carried over to the new data directory.

1. Stop the existing MySQL instance using the data directory. This must be a clean shutdown so that the instance flushes any pending changes to disk.
2. Copy the data directory to the location where the new data directory should be.
3. Copy the `my.cnf` or `my.ini` option file used by the existing instance. This serves as a basis for the new instance.
4. Modify the new option file so that any pathnames referring to the original data directory refer to the new data directory. Also, modify any other options that must be unique per instance, such as the TCP/IP port number and the log files. For a list of parameters that must be unique per instance, see Section 5.6, “Running Multiple MySQL Instances on One Machine”.
5. Start the new instance, telling it to use the new option file.

5.6.2 Running Multiple MySQL Instances on Windows

You can run multiple servers on Windows by starting them manually from the command line, each with appropriate operating parameters, or by installing several servers as Windows services and running them that way. General instructions for running MySQL from the command line or as a service are given in Section 2.3, “Installing MySQL on Microsoft Windows”. The following sections describe how to start each server with different values for those options that must be unique per server, such as the data directory. These options are listed in Section 5.6, “Running Multiple MySQL Instances on One Machine”.

5.6.2.1 Starting Multiple MySQL Instances at the Windows Command Line

The procedure for starting a single MySQL server manually from the command line is described in Section 2.3.7.5, “Starting MySQL from the Windows Command Line”. To start multiple servers this way, you can specify the appropriate options on the command line or in an option file. It is more convenient to place the options in an option file, but it is necessary to make sure that each server gets its own set of options. To do this, create an option file for each server and tell the server the file name with a `--defaults-file` option when you run it.

Suppose that you want to run one instance of `mysqld` on port 3307 with a data directory of `C:\mydata1`, and another instance on port 3308 with a data directory of `C:\mydata2`. Use this procedure:

1. Make sure that each data directory exists, including its own copy of the `mysql` database that contains the grant tables.
2. Create two option files. For example, create one file named `C:\my-opts1.cnf` that looks like this:

```
[mysqld]
datadir = C:/mydata1
port = 3307
```

   Create a second file named `C:\my-opts2.cnf` that looks like this:

```
[mysqld]
datadir = C:/mydata2
port = 3308
```

3. Use the `--defaults-file` option to start each server with its own option file:

```
C:\> C:\mysql\bin\mysqld --defaults-file=C:\my-opts1.cnf
C:\> C:\mysql\bin\mysqld --defaults-file=C:\my-opts2.cnf
```

   Each server starts in the foreground (no new prompt appears until the server exits later), so you will need to issue those two commands in separate console windows.

To shut down the servers, connect to each using the appropriate port number:

```
C:\> C:\mysql\bin\mysqladmin --port=3307 --host=127.0.0.1 --user=root --password shutdown
C:\> C:\mysql\bin\mysqladmin --port=3308 --host=127.0.0.1 --user=root --password shutdown
```

Servers configured as just described permit clients to connect over TCP/IP. If your version of Windows supports named pipes and you also want to permit named-pipe connections, specify options that enable the named pipe and specify its name. Each server that supports named-pipe connections must use a unique pipe name. For example, the `C:\my-opts1.cnf` file might be written like this:

```
[mysqld]
datadir = C:/mydata1
port = 3307
enable-named-pipe
socket = mypipe1
```

Modify `C:\my-opts2.cnf` similarly for use by the second server. Then start the servers as described previously.

A similar procedure applies for servers that you want to permit shared-memory connections. Enable such connections with the `--shared-memory` option and specify a unique shared-memory name for each server with the `--shared-memory-base-name` option.

5.6.2.2 Starting Multiple MySQL Instances as Windows Services

On Windows, a MySQL server can run as a Windows service. The procedures for installing, controlling, and removing a single MySQL service are described in Section 2.3.7.7, “Starting MySQL as a Windows Service”.

To set up multiple MySQL services, you must make sure that each instance uses a different service name in addition to the other parameters that must be unique per instance.

For the following instructions, suppose that you want to run the `mysqld` server from two different versions of MySQL that are installed at `C:\mysql-5.1.55` and `C:\mysql-5.5.60`, respectively. (This might be the case if you are running 5.1.55 as your production server, but also want to conduct tests using 5.5.60.)

To install MySQL as a Windows service, use the `--install` or `--install-manual` option. For information about these options, see Section 2.3.7.7, “Starting MySQL as a Windows Service”.

Based on the preceding information, you have several ways to set up multiple services. The following instructions describe some examples. Before trying any of them, shut down and remove any existing MySQL services.

- **Approach 1:** Specify the options for all services in one of the standard option files. To do this, use a different service name for each server. Suppose that you want to run the 5.1.55 `mysqld` using the service name of `mysqld1` and the 5.5.60 `mysqld` using the service name `mysqld2`. In this case, you can use the `[mysqld1]` group for 5.1.55 and the `[mysqld2]` group for 5.5.60. For example, you can set up `C:\my.cnf` like this:

```
# options for mysqld1 service
[mysqld1]
```

```
basedir = C:/mysql-5.1.55
port = 3307
enable-named-pipe
socket = mypipe1

# options for mysqld2 service
[mysqld2]
basedir = C:/mysql-5.5.60
port = 3308
enable-named-pipe
socket = mypipe2
```

Install the services as follows, using the full server path names to ensure that Windows registers the correct executable program for each service:

```
C:\> C:\mysql-5.1.55\bin\mysqld --install mysqld1
C:\> C:\mysql-5.5.60\bin\mysqld --install mysqld2
```

To start the services, use the services manager, or use `NET START` with the appropriate service names:

```
C:\> NET START mysqld1
C:\> NET START mysqld2
```

To stop the services, use the services manager, or use `NET STOP` with the appropriate service names:

```
C:\> NET STOP mysqld1
C:\> NET STOP mysqld2
```

- **Approach 2:** Specify options for each server in separate files and use `--defaults-file` when you install the services to tell each server what file to use. In this case, each file should list options using a `[mysqld]` group.

  With this approach, to specify options for the 5.1.55 `mysqld`, create a file `C:\my-opts1.cnf` that looks like this:

  ```
  [mysqld]
  basedir = C:/mysql-5.1.55
  port = 3307
  enable-named-pipe
  socket = mypipe1
  ```

  For the 5.5.60 `mysqld`, create a file `C:\my-opts2.cnf` that looks like this:

  ```
  [mysqld]
  basedir = C:/mysql-5.5.60
  port = 3308
  enable-named-pipe
  socket = mypipe2
  ```

  Install the services as follows (enter each command on a single line):

  ```
  C:\> C:\mysql-5.1.55\bin\mysqld --install mysqld1
            --defaults-file=C:\my-opts1.cnf
  C:\> C:\mysql-5.5.60\bin\mysqld --install mysqld2
            --defaults-file=C:\my-opts2.cnf
  ```

  When you install a MySQL server as a service and use a `--defaults-file` option, the service name must precede the option.

  After installing the services, start and stop them the same way as in the preceding example.

To remove multiple services, use `mysqld --remove` for each one, specifying a service name following the `--remove` option. If the service name is the default (`MySQL`), you can omit it.

5.6.3 Running Multiple MySQL Instances on Unix

One way is to run multiple MySQL instances on Unix is to compile different servers with different default TCP/IP ports and Unix socket files so that each one listens on different network interfaces. Compiling in different base directories for each installation also results automatically in a separate, compiled-in data directory, log file, and PID file location for each server.

Assume that an existing 5.1 server is configured for the default TCP/IP port number (3306) and Unix socket file (`/tmp/mysql.sock`). To configure a new 5.5.60 server to have different operating parameters, use a `CMake` command something like this:

```
shell> cmake . -DMYSQL_TCP_PORT=port_number \
             -DMYSQL_UNIX_ADDR=file_name \
             -DCMAKE_INSTALL_PREFIX=/usr/local/mysql-5.5.60
```

Here, *`port_number`* and *`file_name`* must be different from the default TCP/IP port number and Unix socket file path name, and the `CMAKE_INSTALL_PREFIX` value should specify an installation directory different from the one under which the existing MySQL installation is located.

If you have a MySQL server listening on a given port number, you can use the following command to find out what operating parameters it is using for several important configurable variables, including the base directory and Unix socket file name:

```
shell> mysqladmin --host=host_name --port=port_number variables
```

With the information displayed by that command, you can tell what option values *not* to use when configuring an additional server.

If you specify `localhost` as the host name, `mysqladmin` defaults to using a Unix socket file connection rather than TCP/IP. To explicitly specify the connection protocol, use the `--protocol={TCP|SOCKET|PIPE|MEMORY}` option.

You need not compile a new MySQL server just to start with a different Unix socket file and TCP/IP port number. It is also possible to use the same server binary and start each invocation of it with different parameter values at runtime. One way to do so is by using command-line options:

```
shell> mysqld_safe --socket=file_name --port=port_number
```

To start a second server, provide different `--socket` and `--port` option values, and pass a `--datadir=dir_name` option to `mysqld_safe` so that the server uses a different data directory.

Alternatively, put the options for each server in a different option file, then start each server using a `--defaults-file` option that specifies the path to the appropriate option file. For example, if the option files for two server instances are named `/usr/local/mysql/my.cnf` and `/usr/local/mysql/my.cnf2`, start the servers like this: command:

```
shell> mysqld_safe --defaults-file=/usr/local/mysql/my.cnf
shell> mysqld_safe --defaults-file=/usr/local/mysql/my.cnf2
```

Another way to achieve a similar effect is to use environment variables to set the Unix socket file name and TCP/IP port number:

```
shell> MYSQL_UNIX_PORT=/tmp/mysqld-new.sock
shell> MYSQL_TCP_PORT=3307
shell> export MYSQL_UNIX_PORT MYSQL_TCP_PORT
shell> mysql_install_db --user=mysql
shell> mysqld_safe --datadir=/path/to/datadir &
```

This is a quick way of starting a second server to use for testing. The nice thing about this method is that the environment variable settings apply to any client programs that you invoke from the same shell. Thus, connections for those clients are automatically directed to the second server.

Section 4.9, “MySQL Program Environment Variables”, includes a list of other environment variables you can use to affect MySQL programs.

On Unix, the `mysqld_multi` script provides another way to start multiple servers. See Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”.

5.6.4 Using Client Programs in a Multiple-Server Environment

To connect with a client program to a MySQL server that is listening to different network interfaces from those compiled into your client, you can use one of the following methods:

- Start the client with `--host=host_name --port=port_number` to connect using TCP/IP to a remote server, with `--host=127.0.0.1 --port=port_number` to connect using TCP/IP to a local server, or with `--host=localhost --socket=file_name` to connect to a local server using a Unix socket file or a Windows named pipe.
- Start the client with `--protocol=TCP` to connect using TCP/IP, `--protocol=SOCKET` to connect using a Unix socket file, `--protocol=PIPE` to connect using a named pipe, or `--protocol=MEMORY` to connect using shared memory. For TCP/IP connections, you may also need to specify `--host` and `--port` options. For the other types of connections, you may need to specify a `--socket` option to specify a Unix socket file or Windows named-pipe name, or a `--shared-memory-base-name` option to specify the shared-memory name. Shared-memory connections are supported only on Windows.
- On Unix, set the `MYSQL_UNIX_PORT` and `MYSQL_TCP_PORT` environment variables to point to the Unix socket file and TCP/IP port number before you start your clients. If you normally use a specific socket file or port number, you can place commands to set these environment variables in your `.login` file so that they apply each time you log in. See Section 4.9, “MySQL Program Environment Variables”.
- Specify the default Unix socket file and TCP/IP port number in the `[client]` group of an option file. For example, you can use `C:\my.cnf` on Windows, or the `.my.cnf` file in your home directory on Unix. See Section 4.2.6, “Using Option Files”.
- In a C program, you can specify the socket file or port number arguments in the `mysql_real_connect()` call. You can also have the program read option files by calling `mysql_options()`. See Section 23.8.7, “C API Function Descriptions”.
- If you are using the Perl `DBD::mysql` module, you can read options from MySQL option files. For example:

```
$dsn = "DBI:mysql:test;mysql_read_default_group=client;"
       . "mysql_read_default_file=/usr/local/mysql/data/my.cnf";
$dbh = DBI->connect($dsn, $user, $password);
```

See Section 23.10, “MySQL Perl API”.

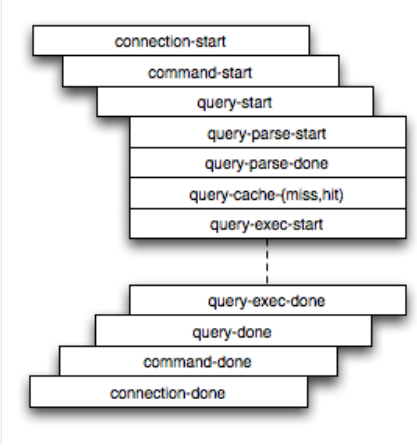
Other programming interfaces may provide similar capabilities for reading option files.

5.7 Tracing mysqld Using DTrace

The DTrace probes in the MySQL server are designed to provide information about the execution of queries within MySQL and the different areas of the system being utilized during that process. The organization and triggering of the probes means that the execution of an entire query can be monitored with one level of probes (`query-start` and `query-done`) but by monitoring other probes you can get successively more detailed information about the execution of the query in terms of the locks used, sort methods and even row-by-row and storage-engine level execution information.

The DTrace probes are organized so that you can follow the entire query process, from the point of connection from a client, through the query execution, row-level operations, and back out again. You can think of the probes as being fired within a specific sequence during a typical client connect/execute/disconnect sequence, as shown in the following figure.

Figure 5.1 The MySQL Architecture Using Pluggable Storage Engines



Global information is provided in the arguments to the DTrace probes at various levels. Global information, that is, the connection ID and user/host and where relevant the query string, is provided at key levels (`connection-start`, `command-start`, `query-start`, and `query-exec-start`). As you go deeper into the probes, it is assumed either you are only interested in the individual executions (row-level probes provide information on the database and table name only), or that you will combine the row-level probes with the notional parent probes to provide the information about a specific query. Examples of this will be given as the format and arguments of each probe are provided.

MySQL includes support for DTrace probes on these platforms:

- Solaris 10 Update 5 (Solaris 5/08) on SPARC, x86 and x86_64 platforms
- OS X 10.4 and higher

Enabling the probes should be automatic on these platforms. To explicitly enable or disable the probes during building, use the `-DENABLE_DTRACE=1` or `-DENABLE_DTRACE=0` option to `CMake`.

If a non-Solaris platform includes DTrace support, building `mysqld` on that platform will include DTrace support.

Additional Resources

- For more information on DTrace and writing DTrace scripts, read the DTrace User Guide.
- For an introduction to DTrace, see the MySQL Dev Zone article Getting started with DTracing MySQL.

5.7.1 mysqld DTrace Probe Reference

MySQL supports the following static probes, organized into groups of functionality.

Table 5.5 MySQL DTrace Probes

Group	Probes
Connection	`connection-start`, `connection-done`
Command	`command-start`, `command-done`
Query	`query-start`, `query-done`
Query Parsing	`query-parse-start`, `query-parse-done`

Group	Probes
Query Cache	`query-cache-hit`, `query-cache-miss`
Query Execution	`query-exec-start`, `query-exec-done`
Row Level	`insert-row-start`, `insert-row-done`
	`update-row-start`, `update-row-done`
	`delete-row-start`, `delete-row-done`
Row Reads	`read-row-start`, `read-row-done`
Index Reads	`index-read-row-start`, `index-read-row-done`
Lock	`handler-rdlock-start`, `handler-rdlock-done`
	`handler-wrlock-start`, `handler-wrlock-done`
	`handler-unlock-start`, `handler-unlock-done`
Filesort	`filesort-start`, `filesort-done`
Statement	`select-start`, `select-done`
	`insert-start`, `insert-done`
	`insert-select-start`, `insert-select-done`
	`update-start`, `update-done`
	`multi-update-start`, `multi-update-done`
	`delete-start`, `delete-done`
	`multi-delete-start`, `multi-delete-done`
Network	`net-read-start`, `net-read-done`, `net-write-start`, `net-write-done`
Keycache	`keycache-read-start`, `keycache-read-block`, `keycache-read-done`, `keycache-read-hit`, `keycache-read-miss`, `keycache-write-start`, `keycache-write-block`, `keycache-write-done`

Note

When extracting the argument data from the probes, each argument is available as `argN`, starting with `arg0`. To identify each argument within the definitions they are provided with a descriptive name, but you must access the information using the corresponding `argN` parameter.

5.7.1.1 Connection Probes

The `connection-start` and `connection-done` probes enclose a connection from a client, regardless of whether the connection is through a socket or network connection.

```
connection-start(connectionid, user, host)
connection-done(status, connectionid)
```

- `connection-start`: Triggered after a connection and successful login/authentication have been completed by a client. The arguments contain the connection information:
  - `connectionid`: An `unsigned long` containing the connection ID. This is the same as the process ID shown as the `Id` value in the output from `SHOW PROCESSLIST`.
  - `user`: The username used when authenticating. The value will be blank for the anonymous user.
  - `host`: The host of the client connection. For a connection made using Unix sockets, the value will be blank.
- `connection-done`: Triggered just as the connection to the client has been closed. The arguments are:

- `status`: The status of the connection when it was closed. A logout operation will have a value of 0; any other termination of the connection has a nonzero value.
- `connectionid`: The connection ID of the connection that was closed.

The following D script will quantify and summarize the average duration of individual connections, and provide a count, dumping the information every 60 seconds:

```
#!/usr/sbin/dtrace -s


mysql*:::connection-start
{
  self->start = timestamp;
}

mysql*:::connection-done
/self->start/
{
  @ = quantize(((timestamp - self->start)/1000000));
  self->start = 0;
}

tick-60s
{
  printa(@);
}
```

When executed on a server with a large number of clients you might see output similar to this:

```
  1  57413                      :tick-60s

           value  ------------- Distribution ------------- count
              -1 |                                         0
               0 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@ 30011
               1 |                                         59
               2 |                                         5
               4 |                                         20
               8 |                                         29
              16 |                                         18
              32 |                                         27
              64 |                                         30
             128 |                                         11
             256 |                                         10
             512 |                                         1
            1024 |                                         6
            2048 |                                         8
            4096 |                                         9
            8192 |                                         8
           16384 |                                         2
           32768 |                                         1
           65536 |                                         1
          131072 |                                         0
          262144 |                                         1
          524288 |                                         0
```

5.7.1.2 Command Probes

The command probes are executed before and after a client command is executed, including any SQL statement that might be executed during that period. Commands include operations such as the initialization of the DB, use of the `COM_CHANGE_USER` operation (supported by the MySQL protocol), and manipulation of prepared statements. Many of these commands are used only by the MySQL client API from various connectors such as PHP and Java.

```
command-start(connectionid, command, user, host)
command-done(status)
```

- `command-start`: Triggered when a command is submitted to the server.

- `connectionid`: The connection ID of the client executing the command.
- `command`: An integer representing the command that was executed. Possible values are shown in the following table.

Value	Name	Description
00	COM_SLEEP	Internal thread state
01	COM_QUIT	Close connection
02	COM_INIT_DB	Select database (`USE ...`)
03	COM_QUERY	Execute a query
04	COM_FIELD_LIST	Get a list of fields
05	COM_CREATE_DB	Create a database (deprecated)
06	COM_DROP_DB	Drop a database (deprecated)
07	COM_REFRESH	Refresh connection
08	COM_SHUTDOWN	Shutdown server
09	COM_STATISTICS	Get statistics
10	COM_PROCESS_INFO	Get processes (`SHOW PROCESSLIST`)
11	COM_CONNECT	Initialize connection
12	COM_PROCESS_KILL	Kill process
13	COM_DEBUG	Get debug information
14	COM_PING	Ping
15	COM_TIME	Internal thread state
16	COM_DELAYED_INSERT	Internal thread state
17	COM_CHANGE_USER	Change user
18	COM_BINLOG_DUMP	Used by a replication slave or `mysqlbinlog` to initiate a binary log read
19	COM_TABLE_DUMP	Used by a replication slave to get the master table information
20	COM_CONNECT_OUT	Used by a replication slave to log a connection to the server
21	COM_REGISTER_SLAVE	Used by a replication slave during registration
22	COM_STMT_PREPARE	Prepare a statement
23	COM_STMT_EXECUTE	Execute a statement
24	COM_STMT_SEND_LONG_DATA	Used by a client when requesting extended data
25	COM_STMT_CLOSE	Close a prepared statement
26	COM_STMT_RESET	Reset a prepared statement
27	COM_SET_OPTION	Set a server option
28	COM_STMT_FETCH	Fetch a prepared statement

  - `user`: The user executing the command.
  - `host`: The client host.
- `command-done`: Triggered when the command execution completes. The `status` argument contains 0 if the command executed successfully, or 1 if the statement was terminated before normal completion.

The `command-start` and `command-done` probes are best used when combined with the statement probes to get an idea of overall execution time.

5.7.1.3 Query Probes

The `query-start` and `query-done` probes are triggered when a specific query is received by the server and when the query has been completed and the information has been successfully sent to the client.

```
query-start(query, connectionid, database, user, host)
query-done(status)
```

- `query-start`: Triggered after the query string has been received from the client. The arguments are:
  - `query`: The full text of the submitted query.
  - `connectionid`: The connection ID of the client that submitted the query. The connection ID equals the connection ID returned when the client first connects and the `Id` value in the output from `SHOW PROCESSLIST`.
  - `database`: The database name on which the query is being executed.
  - `user`: The username used to connect to the server.
  - `host`: The hostname of the client.
- `query-done`: Triggered once the query has been executed and the information has been returned to the client. The probe includes a single argument, `status`, which returns 0 when the query is successfully executed and 1 if there was an error.

You can get a simple report of the execution time for each query using the following D script:

```
#!/usr/sbin/dtrace -s

#pragma D option quiet

dtrace:::BEGIN
{
   printf("%-20s %-20s %-40s %-9s\n", "Who", "Database", "Query", "Time(ms)");
}

mysql*:::query-start
{
   self->query = copyinstr(arg0);
   self->connid = arg1;
   self->db    = copyinstr(arg2);
   self->who   = strjoin(copyinstr(arg3),strjoin("@",copyinstr(arg4)));
   self->querystart = timestamp;
}

mysql*:::query-done
{
   printf("%-20s %-20s %-40s %-9d\n",self->who,self->db,self->query,
          (timestamp - self->querystart) / 1000000);
}
```

When executing the above script you should get a basic idea of the execution time of your queries:

```
shell> ./query.d
Who                 Database            Query                                    Time(ms)
root@localhost      test                select * from t1 order by i limit 10     0
root@localhost      test                set global query_cache_size=0            0
root@localhost      test                select * from t1 order by i limit 10     776
root@localhost      test                select * from t1 order by i limit 10     773
root@localhost      test                select * from t1 order by i desc limit 10 795
```

5.7.1.4 Query Parsing Probes

The query parsing probes are triggered before the original SQL statement is parsed and when the parsing of the statement and determination of the execution model required to process the statement has been completed:

```
query-parse-start(query)
query-parse-done(status)
```

- `query-parse-start`: Triggered just before the statement is parsed by the MySQL query parser. The single argument, `query`, is a string containing the full text of the original query.
- `query-parse-done`: Triggered when the parsing of the original statement has been completed. The `status` is an integer describing the status of the operation. A `0` indicates that the query was successfully parsed. A `1` indicates that the parsing of the query failed.

For example, you could monitor the execution time for parsing a given query using the following D script:

```
#!/usr/sbin/dtrace -s

#pragma D option quiet

mysql*:::query-parse-start
{
   self->parsestart = timestamp;
   self->parsequery = copyinstr(arg0);
}

mysql*:::query-parse-done
/arg0 == 0/
{
   printf("Parsing %s: %d microseconds\n", self->parsequery,((timestamp - self->parsestart)/1000));
}

mysql*:::query-parse-done
/arg0 != 0/
{
   printf("Error parsing %s: %d microseconds\n", self->parsequery,((timestamp - self->parsestart)/1000));
}
```

In the above script a predicate is used on `query-parse-done` so that different output is generated based on the status value of the probe.

When running the script and monitoring the execution:

```
shell> ./query-parsing.d
Error parsing select from t1 join (t2) on (t1.i = t2.i) order by t1.s,t1.i limit 10: 36 ms
Parsing select * from t1 join (t2) on (t1.i = t2.i) order by t1.s,t1.i limit 10: 176 ms
```

5.7.1.5 Query Cache Probes

The query cache probes are fired when executing any query. The `query-cache-hit` query is triggered when a query exists in the query cache and can be used to return the query cache information. The arguments contain the original query text and the number of rows returned from the query cache for the query. If the query is not within the query cache, or the query cache is not enabled, then the `query-cache-miss` probe is triggered instead.

```
query-cache-hit(query, rows)
query-cache-miss(query)
```

- `query-cache-hit`: Triggered when the query has been found within the query cache. The first argument, `query`, contains the original text of the query. The second argument, `rows`, is an integer containing the number of rows in the cached query.
- `query-cache-miss`: Triggered when the query is not found within the query cache. The first argument, `query`, contains the original text of the query.

The query cache probes are best combined with a probe on the main query so that you can determine the differences in times between using or not using the query cache for specified queries. For example, in the following D script, the query and query cache information are combined into the information output during monitoring:

```
#!/usr/sbin/dtrace -s

#pragma D option quiet

dtrace:::BEGIN
{
   printf("%-20s %-20s %-40s %2s %-9s\n", "Who", "Database", "Query", "QC", "Time(ms)");
}

mysql*:::query-start
{
   self->query = copyinstr(arg0);
   self->connid = arg1;
   self->db    = copyinstr(arg2);
   self->who   = strjoin(copyinstr(arg3),strjoin("@",copyinstr(arg4)));
   self->querystart = timestamp;
   self->qc = 0;
}

mysql*:::query-cache-hit
{
   self->qc = 1;
}

mysql*:::query-cache-miss
{
   self->qc = 0;
}

mysql*:::query-done
{
   printf("%-20s %-20s %-40s %-2s %-9d\n",self->who,self->db,self->query,(self->qc ? "Y" : "N"),
          (timestamp - self->querystart) / 1000000);
}
```

When executing the script you can see the effects of the query cache. Initially the query cache is disabled. If you set the query cache size and then execute the query multiple times you should see that the query cache is being used to return the query data:

```
shell> ./query-cache.d
root@localhost       test                select * from t1 order by i limit 10     N  1072
root@localhost                           set global query_cache_size=262144       N  0
root@localhost       test                select * from t1 order by i limit 10     N  781
root@localhost       test                select * from t1 order by i limit 10     Y  0
```

5.7.1.6 Query Execution Probes

The query execution probe is triggered when the actual execution of the query starts, after the parsing and checking the query cache but before any privilege checks or optimization. By comparing the difference between the start and done probes you can monitor the time actually spent servicing the query (instead of just handling the parsing and other elements of the query).

```
query-exec-start(query, connectionid, database, user, host, exec_type)
query-exec-done(status)
```

Note

The information provided in the arguments for `query-start` and `query-exec-start` are almost identical and designed so that you can choose to monitor either the entire query process (using `query-start`) or only the execution (using `query-exec-start`) while exposing the core information about the user, client, and query being executed.

- `query-exec-start`: Triggered when the execution of a individual query is started. The arguments are:
  - `query`: The full text of the submitted query.
  - `connectionid`: The connection ID of the client that submitted the query. The connection ID equals the connection ID returned when the client first connects and the `Id` value in the output from `SHOW PROCESSLIST`.
  - `database`: The database name on which the query is being executed.
  - `user`: The username used to connect to the server.
  - `host`: The hostname of the client.
  - `exec_type`: The type of execution. Execution types are determined based on the contents of the query and where it was submitted. The values for each type are shown in the following table.

Value	Description
0	Executed query from sql_parse, top-level query.
1	Executed prepared statement
2	Executed cursor statement
3	Executed query in stored procedure

- `query-exec-done`: Triggered when the execution of the query has completed. The probe includes a single argument, `status`, which returns 0 when the query is successfully executed and 1 if there was an error.

5.7.1.7 Row-Level Probes

The `*row-{start,done}` probes are triggered each time a row operation is pushed down to a storage engine. For example, if you execute an `INSERT` statement with 100 rows of data, then the `insert-row-start` and `insert-row-done` probes will be triggered 100 times each, for each row insert.

```
insert-row-start(database, table)
insert-row-done(status)

update-row-start(database, table)
update-row-done(status)

delete-row-start(database, table)
delete-row-done(status)
```

- `insert-row-start`: Triggered before a row is inserted into a table.
- `insert-row-done`: Triggered after a row is inserted into a table.
- `update-row-start`: Triggered before a row is updated in a table.
- `update-row-done`: Triggered before a row is updated in a table.
- `delete-row-start`: Triggered before a row is deleted from a table.
- `delete-row-done`: Triggered before a row is deleted from a table.

The arguments supported by the probes are consistent for the corresponding `start` and `done` probes in each case:

- `database`: The database name.
- `table`: The table name.

- `status`: The status; 0 for success or 1 for failure.

Because the row-level probes are triggered for each individual row access, these probes can be triggered many thousands of times each second, which may have a detrimental effect on both the monitoring script and MySQL. The DTrace environment should limit the triggering on these probes to prevent the performance being adversely affected. Either use the probes sparingly, or use counter or aggregation functions to report on these probes and then provide a summary when the script terminates or as part of a `query-done` or `query-exec-done` probes.

The following example script summarizes the duration of each row operation within a larger query:

```
#!/usr/sbin/dtrace -s

#pragma D option quiet

dtrace:::BEGIN
{
   printf("%-2s %-10s %-10s %9s %9s %-s \n",
          "St", "Who", "DB", "ConnID", "Dur ms", "Query");
}

mysql*:::query-start
{
   self->query = copyinstr(arg0);
   self->who   = strjoin(copyinstr(arg3),strjoin("@",copyinstr(arg4)));
   self->db    = copyinstr(arg2);
   self->connid = arg1;
   self->querystart = timestamp;
   self->rowdur = 0;
}

mysql*:::query-done
{
   this->elapsed = (timestamp - self->querystart) /1000000;
   printf("%2d %-10s %-10s %9d %9d %s\n",
          arg0, self->who, self->db,
          self->connid, this->elapsed, self->query);
}

mysql*:::query-done
/ self->rowdur /
{
   printf("%34s %9d %s\n", "", (self->rowdur/1000000), "-> Row ops");
}

mysql*:::insert-row-start
{
   self->rowstart = timestamp;
}

mysql*:::delete-row-start
{
   self->rowstart = timestamp;
}

mysql*:::update-row-start
{
   self->rowstart = timestamp;
}

mysql*:::insert-row-done
{
   self->rowdur += (timestamp-self->rowstart);
}

mysql*:::delete-row-done
{
   self->rowdur += (timestamp-self->rowstart);
}

mysql*:::update-row-done
```

```
{
   self->rowdur += (timestamp-self->rowstart);
}
```

Running the above script with a query that inserts data into a table, you can monitor the exact time spent performing the raw row insertion:

```
St Who        DB            ConnID    Dur ms Query
 0 @localhost test              13     20767 insert into t1(select * from t2)
                                        4827 -> Row ops
```

5.7.1.8 Read Row Probes

The read row probes are triggered at a storage engine level each time a row read operation occurs. These probes are specified within each storage engine (as opposed to the `*row-start` probes which are in the storage engine interface). These probes can therefore be used to monitor individual storage engine row-level operations and performance. Because these probes are triggered around the storage engine row read interface, they may be hit a significant number of times during a basic query.

```
read-row-start(database, table, scan_flag)
read-row-done(status)
```

- `read-row-start`: Triggered when a row is read by the storage engine from the specified `database` and `table`. The `scan_flag` is set to 1 (true) when the read is part of a table scan (that is, a sequential read), or 0 (false) when the read is of a specific record.
- `read-row-done`: Triggered when a row read operation within a storage engine completes. The `status` returns 0 on success, or a positive value on failure.

5.7.1.9 Index Probes

The index probes are triggered each time a row is read using one of the indexes for the specified table. The probe is triggered within the corresponding storage engine for the table.

```
index-read-row-start(database, table)
index-read-row-done(status)
```

- `index-read-row-start`: Triggered when a row is read by the storage engine from the specified `database` and `table`.
- `index-read-row-done`: Triggered when an indexed row read operation within a storage engine completes. The `status` returns 0 on success, or a positive value on failure.

5.7.1.10 Lock Probes

The lock probes are called whenever an external lock is requested by MySQL for a table using the corresponding lock mechanism on the table as defined by the table's engine type. There are three different types of lock, the read lock, write lock, and unlock operations. Using the probes you can determine the duration of the external locking routine (that is, the time taken by the storage engine to implement the lock, including any time waiting for another lock to become free) and the total duration of the lock/unlock process.

```
handler-rdlock-start(database, table)
handler-rdlock-done(status)

handler-wrlock-start(database, table)
handler-wrlock-done(status)

handler-unlock-start(database, table)
handler-unlock-done(status)
```

- `handler-rdlock-start`: Triggered when a read lock is requested on the specified `database` and `table`.

- `handler-wrlock-start`: Triggered when a write lock is requested on the specified `database` and `table`.
- `handler-unlock-start`: Triggered when an unlock request is made on the specified `database` and `table`.
- `handler-rdlock-done`: Triggered when a read lock request completes. The `status` is 0 if the lock operation succeeded, or `>0` on failure.
- `handler-wrlock-done`: Triggered when a write lock request completes. The `status` is 0 if the lock operation succeeded, or `>0` on failure.
- `handler-unlock-done`: Triggered when an unlock request completes. The `status` is 0 if the unlock operation succeeded, or `>0` on failure.

You can use arrays to monitor the locking and unlocking of individual tables and then calculate the duration of the entire table lock using the following script:

```
#!/usr/sbin/dtrace -s

#pragma D option quiet

mysql*:::handler-rdlock-start
{
   self->rdlockstart = timestamp;
   this->lockref = strjoin(copyinstr(arg0),strjoin("@",copyinstr(arg1)));
   self->lockmap[this->lockref] = self->rdlockstart;
   printf("Start: Lock->Read   %s.%s\n",copyinstr(arg0),copyinstr(arg1));
}

mysql*:::handler-wrlock-start
{
   self->wrlockstart = timestamp;
   this->lockref = strjoin(copyinstr(arg0),strjoin("@",copyinstr(arg1)));
   self->lockmap[this->lockref] = self->rdlockstart;
   printf("Start: Lock->Write  %s.%s\n",copyinstr(arg0),copyinstr(arg1));
}

mysql*:::handler-unlock-start
{
   self->unlockstart = timestamp;
   this->lockref = strjoin(copyinstr(arg0),strjoin("@",copyinstr(arg1)));
   printf("Start: Lock->Unlock %s.%s (%d ms lock duration)\n",
          copyinstr(arg0),copyinstr(arg1),
          (timestamp - self->lockmap[this->lockref])/1000000);
}

mysql*:::handler-rdlock-done
{
   printf("End:   Lock->Read   %d ms\n",
          (timestamp - self->rdlockstart)/1000000);
}

mysql*:::handler-wrlock-done
{
   printf("End:   Lock->Write  %d ms\n",
          (timestamp - self->wrlockstart)/1000000);
}

mysql*:::handler-unlock-done
{
   printf("End:   Lock->Unlock %d ms\n",
          (timestamp - self->unlockstart)/1000000);
}
```

When executed, you should get information both about the duration of the locking process itself, and of the locks on a specific table:

```
Start: Lock->Read   test.t2
```

```
End:   Lock->Read   0 ms
Start: Lock->Unlock test.t2 (25743 ms lock duration)
End:   Lock->Unlock 0 ms
Start: Lock->Read   test.t2
End:   Lock->Read   0 ms
Start: Lock->Unlock test.t2 (1 ms lock duration)
End:   Lock->Unlock 0 ms
Start: Lock->Read   test.t2
End:   Lock->Read   0 ms
Start: Lock->Unlock test.t2 (1 ms lock duration)
End:   Lock->Unlock 0 ms
Start: Lock->Read   test.t2
End:   Lock->Read   0 ms
```

5.7.1.11 Filesort Probes

The filesort probes are triggered whenever a filesort operation is applied to a table. For more information on filesort and the conditions under which it occurs, see Section 8.2.1.10, “ORDER BY Optimization”.

```
filesort-start(database, table)
filesort-done(status, rows)
```

- `filesort-start`: Triggered when the filesort operation starts on a table. The two arguments to the probe, `database` and `table`, will identify the table being sorted.
- `filesort-done`: Triggered when the filesort operation completes. Two arguments are supplied, the `status` (0 for success, 1 for failure), and the number of rows sorted during the filesort process.

An example of this is in the following script, which tracks the duration of the filesort process in addition to the duration of the main query:

```
#!/usr/sbin/dtrace -s

#pragma D option quiet

dtrace:::BEGIN
{
   printf("%-2s %-10s %-10s %9s %18s %-s \n",
          "St", "Who", "DB", "ConnID", "Dur microsec", "Query");
}

mysql*:::query-start
{
   self->query = copyinstr(arg0);
   self->who   = strjoin(copyinstr(arg3),strjoin("@",copyinstr(arg4)));
   self->db    = copyinstr(arg2);
   self->connid = arg1;
   self->querystart = timestamp;
   self->filesort = 0;
   self->fsdb = "";
   self->fstable = "";
}

mysql*:::filesort-start
{
  self->filesort = timestamp;
  self->fsdb = copyinstr(arg0);
  self->fstable = copyinstr(arg1);
}

mysql*:::filesort-done
{
   this->elapsed = (timestamp - self->filesort) /1000;
   printf("%2d %-10s %-10s %9d %18d Filesort on %s\n",
          arg0, self->who, self->fsdb,
          self->connid, this->elapsed, self->fstable);
}

mysql*:::query-done
```

```
{
   this->elapsed = (timestamp - self->querystart) /1000;
   printf("%2d %-10s %-10s %9d %18d %s\n",
          arg0, self->who, self->db,
          self->connid, this->elapsed, self->query);
}
```

Executing a query on a large table with an `ORDER BY` clause that triggers a filesort, and then creating an index on the table and then repeating the same query, you can see the difference in execution speed:

```
St Who        DB            ConnID       Dur microsec Query
 0 @localhost test             14          11335469 Filesort on t1
 0 @localhost test             14          11335787 select * from t1 order by i limit 100
 0 @localhost test             14         466734378 create index t1a on t1 (i)
 0 @localhost test             14             26472 select * from t1 order by i limit 100
```

5.7.1.12 Statement Probes

The individual statement probes are provided to give specific information about different statement types. For the start probes the string of the query is provided as a the only argument. Depending on the statement type, the information provided by the corresponding done probe will differ. For all done probes the status of the operation (`0` for success, `>0` for failure) is provided. For `SELECT`, `INSERT`, `INSERT ... (SELECT FROM ...)`, `DELETE`, and `DELETE FROM t1,t2` operations the number of rows affected is returned.

For `UPDATE` and `UPDATE t1,t2 ...` statements the number of rows matched and the number of rows actually changed is provided. This is because the number of rows actually matched by the corresponding `WHERE` clause, and the number of rows changed can differ. MySQL does not update the value of a row if the value already matches the new setting.

```
select-start(query)
select-done(status,rows)

insert-start(query)
insert-done(status,rows)

insert-select-start(query)
insert-select-done(status,rows)

update-start(query)
update-done(status,rowsmatched,rowschanged)

multi-update-start(query)
multi-update-done(status,rowsmatched,rowschanged)

delete-start(query)
delete-done(status,rows)

multi-delete-start(query)
multi-delete-done(status,rows)
```

- `select-start`: Triggered before a `SELECT` statement.
- `select-done`: Triggered at the end of a `SELECT` statement.
- `insert-start`: Triggered before a `INSERT` statement.
- `insert-done`: Triggered at the end of an `INSERT` statement.
- `insert-select-start`: Triggered before an `INSERT ... SELECT` statement.
- `insert-select-done`: Triggered at the end of an `INSERT ... SELECT` statement.
- `update-start`: Triggered before an `UPDATE` statement.
- `update-done`: Triggered at the end of an `UPDATE` statement.

- `multi-update-start`: Triggered before an `UPDATE` statement involving multiple tables.
- `multi-update-done`: Triggered at the end of an `UPDATE` statement involving multiple tables.
- `delete-start`: Triggered before a `DELETE` statement.
- `delete-done`: Triggered at the end of a `DELETE` statement.
- `multi-delete-start`: Triggered before a `DELETE` statement involving multiple tables.
- `multi-delete-done`: Triggered at the end of a `DELETE` statement involving multiple tables.

The arguments for the statement probes are:

- `query`: The query string.
- `status`: The status of the query. `0` for success, and `>0` for failure.
- `rows`: The number of rows affected by the statement. This returns the number rows found for `SELECT`, the number of rows deleted for `DELETE`, and the number of rows successfully inserted for `INSERT`.
- `rowsmatched`: The number of rows matched by the `WHERE` clause of an `UPDATE` operation.
- `rowschanged`: The number of rows actually changed during an `UPDATE` operation.

You use these probes to monitor the execution of these statement types without having to monitor the user or client executing the statements. A simple example of this is to track the execution times:

```
#!/usr/sbin/dtrace -s

#pragma D option quiet

dtrace:::BEGIN
{
   printf("%-60s %-8s %-8s %-8s\n", "Query", "RowsU", "RowsM", "Dur (ms)");
}

mysql*:::update-start, mysql*:::insert-start,
mysql*:::delete-start, mysql*:::multi-delete-start,
mysql*:::multi-delete-done, mysql*:::select-start,
mysql*:::insert-select-start, mysql*:::multi-update-start
{
    self->query = copyinstr(arg0);
    self->querystart = timestamp;
}

mysql*:::insert-done, mysql*:::select-done,
mysql*:::delete-done, mysql*:::multi-delete-done, mysql*:::insert-select-done
/ self->querystart /
{
    this->elapsed = ((timestamp - self->querystart)/1000000);
    printf("%-60s %-8d %-8d %d\n",
           self->query,
           0,
           arg1,
           this->elapsed);
    self->querystart = 0;
}

mysql*:::update-done, mysql*:::multi-update-done
/ self->querystart /
{
    this->elapsed = ((timestamp - self->querystart)/1000000);
    printf("%-60s %-8d %-8d %d\n",
           self->query,
           arg1,
           arg2,
           this->elapsed);
```

```
    self->querystart = 0;
}
```

When executed you can see the basic execution times and rows matches:

```
Query                                                   RowsU    RowsM    Dur (ms)
select * from t2                                        0        275      0
insert into t2 (select * from t2)                       0        275      9
update t2 set i=5 where i > 75                          110      110      8
update t2 set i=5 where i < 25                          254      134      12
delete from t2 where i < 5                              0        0        0
```

Another alternative is to use the aggregation functions in DTrace to aggregate the execution time of individual statements together:

```
#!/usr/sbin/dtrace -s

#pragma D option quiet


mysql*:::update-start, mysql*:::insert-start,
mysql*:::delete-start, mysql*:::multi-delete-start,
mysql*:::multi-delete-done, mysql*:::select-start,
mysql*:::insert-select-start, mysql*:::multi-update-start
{
    self->querystart = timestamp;
}

mysql*:::select-done
{
        @statements["select"] = sum(((timestamp - self->querystart)/1000000));
}

mysql*:::insert-done, mysql*:::insert-select-done
{
        @statements["insert"] = sum(((timestamp - self->querystart)/1000000));
}

mysql*:::update-done, mysql*:::multi-update-done
{
        @statements["update"] = sum(((timestamp - self->querystart)/1000000));
}

mysql*:::delete-done, mysql*:::multi-delete-done
{
        @statements["delete"] = sum(((timestamp - self->querystart)/1000000));
}

tick-30s
{
        printa(@statements);
}
```

The script just shown aggregates the times spent doing each operation, which could be used to help benchmark a standard suite of tests.

```
 delete                                                          0
  update                                                         0
  insert                                                        23
  select                                                      2484

  delete                                                         0
  update                                                         0
  insert                                                        39
  select                                                     10744

  delete                                                         0
  update                                                        26
  insert                                                        56
  select                                                     10944
```

```
  delete                                                        0
  update                                                       26
  insert                                                     2287
  select                                                    15985
```

5.7.1.13 Network Probes

The network probes monitor the transfer of information from the MySQL server and clients of all types over the network. The probes are defined as follows:

```
net-read-start()
net-read-done(status, bytes)
net-write-start(bytes)
net-write-done(status)
```

- `net-read-start`: Triggered when a network read operation is started.
- `net-read-done`: Triggered when the network read operation completes. The `status` is an `integer` representing the return status for the operation, `0` for success and `1` for failure. The `bytes` argument is an integer specifying the number of bytes read during the process.
- `net-start-bytes`: Triggered when data is written to a network socket. The single argument, `bytes`, specifies the number of bytes written to the network socket.
- `net-write-done`: Triggered when the network write operation has completed. The single argument, `status`, is an integer representing the return status for the operation, `0` for success and `1` for failure.

You can use the network probes to monitor the time spent reading from and writing to network clients during execution. The following D script provides an example of this. Both the cumulative time for the read or write is calculated, and the number of bytes. Note that the dynamic variable size has been increased (using the `dynvarsize` option) to cope with the rapid firing of the individual probes for the network reads/writes.

```
#!/usr/sbin/dtrace -s

#pragma D option quiet
#pragma D option dynvarsize=4m

dtrace:::BEGIN
{
   printf("%-2s %-30s %-10s %9s %18s %-s \n",
          "St", "Who", "DB", "ConnID", "Dur microsec", "Query");
}

mysql*:::query-start
{
   self->query = copyinstr(arg0);
   self->who   = strjoin(copyinstr(arg3),strjoin("@",copyinstr(arg4)));
   self->db    = copyinstr(arg2);
   self->connid = arg1;
   self->querystart = timestamp;
   self->netwrite = 0;
   self->netwritecum = 0;
   self->netwritebase = 0;
   self->netread = 0;
   self->netreadcum = 0;
   self->netreadbase = 0;
}

mysql*:::net-write-start
{
   self->netwrite += arg0;
   self->netwritebase = timestamp;
}

mysql*:::net-write-done
{
```

```
   self->netwritecum += (timestamp - self->netwritebase);
   self->netwritebase = 0;
}

mysql*:::net-read-start
{
   self->netreadbase = timestamp;
}

mysql*:::net-read-done
{
   self->netread += arg1;
   self->netreadcum += (timestamp - self->netreadbase);
   self->netreadbase = 0;
}

mysql*:::query-done
{
   this->elapsed = (timestamp - self->querystart) /1000000;
   printf("%2d %-30s %-10s %9d %18d %s\n",
          arg0, self->who, self->db,
          self->connid, this->elapsed, self->query);
   printf("Net read: %d bytes (%d ms) write: %d bytes (%d ms)\n",
               self->netread, (self->netreadcum/1000000),
               self->netwrite, (self->netwritecum/1000000));
}
```

When executing the above script on a machine with a remote client, you can see that approximately a third of the time spent executing the query is related to writing the query results back to the client.

```
St Who                             DB            ConnID       Dur microsec Query
 0 root@::ffff:198.51.100.108      test              31              3495 select * from t1 limit 10000
Net read: 0 bytes (0 ms) write: 10000075 bytes (1220 ms)
```

5.7.1.14 Keycache Probes

The keycache probes are triggered when using the index key cache used with the MyISAM storage engine. Probes exist to monitor when data is read into the keycache, cached key data is written from the cache into a cached file, or when accessing the keycache.

Keycache usage indicates when data is read or written from the index files into the cache, and can be used to monitor how efficient the memory allocated to the keycache is being used. A high number of keycache reads across a range of queries may indicate that the keycache is too small for size of data being accessed.

```
keycache-read-start(filepath, bytes, mem_used, mem_free)
keycache-read-block(bytes)
keycache-read-hit()
keycache-read-miss()
keycache-read-done(mem_used, mem_free)
keycache-write-start(filepath, bytes, mem_used, mem_free)
keycache-write-block(bytes)
keycache-write-done(mem_used, mem_free)
```

When reading data from the index files into the keycache, the process first initializes the read operation (indicated by `keycache-read-start`), then loads blocks of data (`keycache-read-block`), and then the read block is either matches the data being identified (`keycache-read-hit`) or more data needs to be read (`keycache-read-miss`). Once the read operation has completed, reading stops with the `keycache-read-done`.

Data will be read from the index file into the keycache only when the specified key is not already within the keycache.

- `keycache-read-start`: Triggered when the keycache read operation is started. Data is read from the specified `filepath`, reading the specified number of `bytes`. The `mem_used` and `mem_avail` indicate memory currently used by the keycache and the amount of memory available within the keycache.

- `keycache-read-block`: Triggered when the keycache reads a block of data, of the specified number of `bytes`, from the index file into the keycache.
- `keycache-read-hit`: Triggered when the block of data read from the index file matches the key data requested.
- `keycache-read-miss`: Triggered when the block of data read from the index file does not match the key data needed.
- `keycache-read-done`: Triggered when the keycache read operation has completed. The `mem_used` and `mem_avail` indicate memory currently used by the keycache and the amount of memory available within the keycache.

Keycache writes occur when the index information is updated during an `INSERT`, `UPDATE`, or `DELETE` operation, and the cached key information is flushed back to the index file.

- `keycache-write-start`: Triggered when the keycache write operation is started. Data is written to the specified `filepath`, reading the specified number of `bytes`. The `mem_used` and `mem_avail` indicate memory currently used by the keycache and the amount of memory available within the keycache.
- `keycache-write-block`: Triggered when the keycache writes a block of data, of the specified number of `bytes`, to the index file from the keycache.
- `keycache-write-done`: Triggered when the keycache write operation has completed. The `mem_used` and `mem_avail` indicate memory currently used by the keycache and the amount of memory available within the keycache.

Chapter 6 Security

Table of Contents

6.1 General Security Issues 698
6.1.1 Security Guidelines 698
6.1.2 Keeping Passwords Secure 699
6.1.3 Making MySQL Secure Against Attackers 707
6.1.4 Security-Related mysqld Options and Variables 709
6.1.5 How to Run MySQL as a Normal User 709
6.1.6 Security Issues with LOAD DATA LOCAL 710
6.1.7 Client Programming Security Guidelines 712
6.2 The MySQL Access Privilege System 713
6.2.1 Privileges Provided by MySQL 714
6.2.2 Grant Tables 718
6.2.3 Specifying Account Names 724
6.2.4 Access Control, Stage 1: Connection Verification 726
6.2.5 Access Control, Stage 2: Request Verification 728
6.2.6 When Privilege Changes Take Effect 730
6.2.7 Troubleshooting Problems Connecting to MySQL 731
6.3 MySQL User Account Management 736
6.3.1 User Names and Passwords 736
6.3.2 Adding User Accounts 738
6.3.3 Removing User Accounts 739
6.3.4 Setting Account Resource Limits 739
6.3.5 Assigning Account Passwords 741
6.3.6 Pluggable Authentication 743
6.3.7 Proxy Users 745
6.3.8 SQL-Based MySQL Account Activity Auditing 750
6.4 Using Encrypted Connections 751
6.4.1 Configuring MySQL to Use Encrypted Connections 752
6.4.2 Command Options for Encrypted Connections 754
6.4.3 Creating SSL Certificates and Keys Using openssl 757
6.4.4 OpenSSL Versus yaSSL 762
6.4.5 Building MySQL with Support for Encrypted Connections 762
6.4.6 Encrypted Connection Protocols and Ciphers 763
6.4.7 Connecting to MySQL Remotely from Windows with SSH 765
6.5 Security Plugins 765
6.5.1 Authentication Plugins 765
6.5.2 MySQL Enterprise Audit 784

When thinking about security within a MySQL installation, you should consider a wide range of possible topics and how they affect the security of your MySQL server and related applications:

- General factors that affect security. These include choosing good passwords, not granting unnecessary privileges to users, ensuring application security by preventing SQL injections and data corruption, and others. See Section 6.1, “General Security Issues”.
- Security of the installation itself. The data files, log files, and the all the application files of your installation should be protected to ensure that they are not readable or writable by unauthorized parties. For more information, see Section 2.10, “Postinstallation Setup and Testing”.
- Access control and security within the database system itself, including the users and databases granted with access to the databases, views and stored programs in use within the database. For more information, see Section 6.2, “The MySQL Access Privilege System”, and Section 6.3, “MySQL User Account Management”.

- The features offered by security-related plugins. See Section 6.5, “Security Plugins”.
- Network security of MySQL and your system. The security is related to the grants for individual users, but you may also wish to restrict MySQL so that it is available only locally on the MySQL server host, or to a limited set of other hosts.
- Ensure that you have adequate and appropriate backups of your database files, configuration and log files. Also be sure that you have a recovery solution in place and test that you are able to successfully recover the information from your backups. See Chapter 7, *Backup and Recovery*.

6.1 General Security Issues

This section describes general security issues to be aware of and what you can do to make your MySQL installation more secure against attack or misuse. For information specifically about the access control system that MySQL uses for setting up user accounts and checking database access, see Section 2.10, “Postinstallation Setup and Testing”.

For answers to some questions that are often asked about MySQL Server security issues, see Section A.9, “MySQL 5.5 FAQ: Security”.

6.1.1 Security Guidelines

Anyone using MySQL on a computer connected to the Internet should read this section to avoid the most common security mistakes.

In discussing security, it is necessary to consider fully protecting the entire server host (not just the MySQL server) against all types of applicable attacks: eavesdropping, altering, playback, and denial of service. We do not cover all aspects of availability and fault tolerance here.

MySQL uses security based on Access Control Lists (ACLs) for all connections, queries, and other operations that users can attempt to perform. There is also support for SSL-encrypted connections between MySQL clients and servers. Many of the concepts discussed here are not specific to MySQL at all; the same general ideas apply to almost all applications.

When running MySQL, follow these guidelines:

- **Do not ever give anyone (except MySQL `root` accounts) access to the `user` table in the `mysql` database!** This is critical.
- Learn how the MySQL access privilege system works (see Section 6.2, “The MySQL Access Privilege System”). Use the `GRANT` and `REVOKE` statements to control access to MySQL. Do not grant more privileges than necessary. Never grant privileges to all hosts.

  Checklist:

  - Try `mysql -u root`. If you are able to connect successfully to the server without being asked for a password, anyone can connect to your MySQL server as the MySQL `root` user with full privileges! Review the MySQL installation instructions, paying particular attention to the information about setting a `root` password. See Section 2.10.4, “Securing the Initial MySQL Accounts”.
  - Use the `SHOW GRANTS` statement to check which accounts have access to what. Then use the `REVOKE` statement to remove those privileges that are not necessary.
- Do not store cleartext passwords in your database. If your computer becomes compromised, the intruder can take the full list of passwords and use them. Instead, use `SHA2()` or some other one-way hashing function and store the hash value.

  To prevent password recovery using rainbow tables, do not use these functions on a plain password; instead, choose some string to be used as a salt, and use hash(hash(password)+salt) values.

- Do not choose passwords from dictionaries. Special programs exist to break passwords. Even passwords like “xfish98” are very bad. Much better is “duag98” which contains the same word “fish” but typed one key to the left on a standard QWERTY keyboard. Another method is to use a password that is taken from the first characters of each word in a sentence (for example, “Four score and seven years ago” results in a password of “Fsasya”). The password is easy to remember and type, but difficult to guess for someone who does not know the sentence. In this case, you can additionally substitute digits for the number words to obtain the phrase “4 score and 7 years ago”, yielding the password “4sa7ya” which is even more difficult to guess.
- Invest in a firewall. This protects you from at least 50% of all types of exploits in any software. Put MySQL behind the firewall or in a demilitarized zone (DMZ).

  Checklist:

  - Try to scan your ports from the Internet using a tool such as `nmap`. MySQL uses port 3306 by default. This port should not be accessible from untrusted hosts. As a simple way to check whether your MySQL port is open, try the following command from some remote machine, where *`server_host`* is the host name or IP address of the host on which your MySQL server runs:

    ```
    shell> telnet server_host 3306
    ```

    If `telnet` hangs or the connection is refused, the port is blocked, which is how you want it to be. If you get a connection and some garbage characters, the port is open, and should be closed on your firewall or router, unless you really have a good reason to keep it open.
- Applications that access MySQL should not trust any data entered by users, and should be written using proper defensive programming techniques. See Section 6.1.7, “Client Programming Security Guidelines”.
- Do not transmit plain (unencrypted) data over the Internet. This information is accessible to everyone who has the time and ability to intercept it and use it for their own purposes. Instead, use an encrypted protocol such as SSL or SSH. MySQL supports internal SSL connections. Another technique is to use SSH port-forwarding to create an encrypted (and compressed) tunnel for the communication.
- Learn to use the `tcpdump` and `strings` utilities. In most cases, you can check whether MySQL data streams are unencrypted by issuing a command like the following:

  ```
  shell> tcpdump -l -i eth0 -w - src or dst port 3306 | strings
  ```

  This works under Linux and should work with small modifications under other systems.

  Warning

  If you do not see cleartext data, this does not always mean that the information actually is encrypted. If you need high security, consult with a security expert.

6.1.2 Keeping Passwords Secure

Passwords occur in several contexts within MySQL. The following sections provide guidelines that enable end users and administrators to keep these passwords secure and avoid exposing them. There is also a discussion of how MySQL uses password hashing internally.

6.1.2.1 End-User Guidelines for Password Security

MySQL users should use the following guidelines to keep passwords secure.

When you run a client program to connect to the MySQL server, it is inadvisable to specify your password in a way that exposes it to discovery by other users. The methods you can use to specify

your password when you run client programs are listed here, along with an assessment of the risks of each method. In short, the safest methods are to have the client program prompt for the password or to specify the password in a properly protected option file.

- Use a `-pyour_pass` or `--password=your_pass` option on the command line. For example:

```
shell> mysql -u francis -pfrank db_name
```

Warning

This is convenient *but insecure*. On some systems, your password becomes visible to system status programs such as `ps` that may be invoked by other users to display command lines. MySQL clients typically overwrite the command-line password argument with zeros during their initialization sequence. However, there is still a brief interval during which the value is visible. Also, on some systems this overwriting strategy is ineffective and the password remains visible to `ps`. (SystemV Unix systems and perhaps others are subject to this problem.)

If your operating environment is set up to display your current command in the title bar of your terminal window, the password remains visible as long as the command is running, even if the command has scrolled out of view in the window content area.

- Use the `-p` or `--password` option on the command line with no password value specified. In this case, the client program solicits the password interactively:

```
shell> mysql -u francis -p db_name
Enter password: ********
```

The `*` characters indicate where you enter your password. The password is not displayed as you enter it.

It is more secure to enter your password this way than to specify it on the command line because it is not visible to other users. However, this method of entering a password is suitable only for programs that you run interactively. If you want to invoke a client from a script that runs noninteractively, there is no opportunity to enter the password from the keyboard. On some systems, you may even find that the first line of your script is read and interpreted (incorrectly) as your password.

- Store your password in an option file. For example, on Unix, you can list your password in the `[client]` section of the `.my.cnf` file in your home directory:

```
[client]
password=your_pass
```

To keep the password safe, the file should not be accessible to anyone but yourself. To ensure this, set the file access mode to `400` or `600`. For example:

```
shell> chmod 600 .my.cnf
```

To name from the command line a specific option file containing the password, use the `--defaults-file=file_name` option, where `file_name` is the full path name to the file. For example:

```
shell> mysql --defaults-file=/home/francis/mysql-opts
```

Section 4.2.6, “Using Option Files”, discusses option files in more detail.

- Store your password in the `MYSQL_PWD` environment variable. See Section 4.9, “MySQL Program Environment Variables”.

This method of specifying your MySQL password must be considered *extremely insecure* and should not be used. Some versions of `ps` include an option to display the environment of running processes. On some systems, if you set `MYSQL_PWD`, your password is exposed to any other user who runs `ps`. Even on systems without such a version of `ps`, it is unwise to assume that there are no other methods by which users can examine process environments.

On Unix, the `mysql` client writes a record of executed statements to a history file (see Section 4.5.1.3, "mysql Logging"). By default, this file is named `.mysql_history` and is created in your home directory. Passwords can be written as plain text in SQL statements such as `CREATE USER`, `GRANT`, and `SET PASSWORD`, so if you use these statements, they are logged in the history file. To keep this file safe, use a restrictive access mode, the same way as described earlier for the `.my.cnf` file.

If your command interpreter is configured to maintain a history, any file in which the commands are saved will contain MySQL passwords entered on the command line. For example, `bash` uses `~/.bash_history`. Any such file should have a restrictive access mode.

6.1.2.2 Administrator Guidelines for Password Security

Database administrators should use the following guidelines to keep passwords secure.

MySQL stores passwords for user accounts in the `mysql.user` table. Access to this table should never be granted to any nonadministrative accounts.

A user who has access to modify the plugin directory (the value of the `plugin_dir` system variable) or the `my.cnf` file that specifies the plugin directory location can replace plugins and modify the capabilities provided by plugins, including authentication plugins.

Files such as log files to which passwords might be written should be protected. See Section 6.1.2.3, "Passwords and Logging".

6.1.2.3 Passwords and Logging

Passwords can be written as plain text in SQL statements such as `CREATE USER`, `GRANT`, `SET PASSWORD`, and statements that invoke the `PASSWORD()` function. If such statements are logged by the MySQL server as written, passwords in them become visible to anyone with access to the logs. This applies to the general query log, the slow query log, and the binary log (see Section 5.4, "MySQL Server Logs").

Contents of the audit log file produced by the audit log plugin are not encrypted. For security reasons, this file should be written to a directory accessible only to the MySQL server and users with a legitimate reason to view the log. See Section 6.5.2.2, "MySQL Enterprise Audit Security Considerations".

To guard log files against unwarranted exposure, locate them in a directory that restricts access to the server and the database administrator. If the server logs to tables in the `mysql` database, grant access to those tables only to the database administrator.

Replication slaves store the password for the replication master in the `master.info` file. Restrict this file to be accessible only to the database administrator.

Use a restricted access mode to protect database backups that include log tables or log files containing passwords.

6.1.2.4 Password Hashing in MySQL

Note

The information in this section applies only for accounts that use the `mysql_native_password` or `mysql_old_password` authentication plugins.

MySQL lists user accounts in the `user` table of the `mysql` database. Each MySQL account can be assigned a password, although the `user` table does not store the cleartext version of the password, but a hash value computed from it.

MySQL uses passwords in two phases of client/server communication:

- When a client attempts to connect to the server, there is an initial authentication step in which the client must present a password that has a hash value matching the hash value stored in the `user` table for the account the client wants to use.
- After the client connects, it can (if it has sufficient privileges) set or change the password hash for accounts listed in the `user` table. The client can do this by using the `PASSWORD()` function to generate a password hash, or by using a password-generating statement (`CREATE USER`, `GRANT`, or `SET PASSWORD`).

In other words, the server *checks* hash values during authentication when a client first attempts to connect. The server *generates* hash values if a connected client invokes the `PASSWORD()` function or uses a password-generating statement to set or change a password.

Password hashing methods in MySQL have the history described following. These changes are illustrated by changes in the result from the `PASSWORD()` function that computes password hash values and in the structure of the `user` table where passwords are stored.

The Original (Pre-4.1) Hashing Method

The original hashing method produced a 16-byte string. Such hashes look like this:

```
mysql> SELECT PASSWORD('mypass');
+--------------------+
| PASSWORD('mypass') |
+--------------------+
| 6f8c114b58f2ce9e   |
+--------------------+
```

To store account passwords, the `Password` column of the `user` table was at this point 16 bytes long.

The 4.1 Hashing Method

MySQL 4.1 introduced password hashing that provided better security and reduced the risk of passwords being intercepted. There were several aspects to this change:

- Different format of password values produced by the `PASSWORD()` function
- Widening of the `Password` column
- Control over the default hashing method
- Control over the permitted hashing methods for clients attempting to connect to the server

The changes in MySQL 4.1 took place in two stages:

- MySQL 4.1.0 used a preliminary version of the 4.1 hashing method. This method was short lived and the following discussion says nothing more about it.
- In MySQL 4.1.1, the hashing method was modified to produce a longer 41-byte hash value:

```
mysql> SELECT PASSWORD('mypass');
+-------------------------------------------+
| PASSWORD('mypass')                        |
+-------------------------------------------+
| *6C8989366EAF75BB670AD8EA7A7FC1176A95CEF4 |
+-------------------------------------------+
```

The longer password hash format has better cryptographic properties, and client authentication based on long hashes is more secure than that based on the older short hashes.

To accommodate longer password hashes, the `Password` column in the `user` table was changed at this point to be 41 bytes, its current length.

A widened `Password` column can store password hashes in both the pre-4.1 and 4.1 formats. The format of any given hash value can be determined two ways:

- The length: 4.1 and pre-4.1 hashes are 41 and 16 bytes, respectively.
- Password hashes in the 4.1 format always begin with a `*` character, whereas passwords in the pre-4.1 format never do.

To permit explicit generation of pre-4.1 password hashes, two additional changes were made:

- The `OLD_PASSWORD()` function was added, which returns hash values in the 16-byte format.
- For compatibility purposes, the `old_passwords` system variable was added, to enable DBAs and applications control over the hashing method. The default `old_passwords` value of 0 causes hashing to use the 4.1 method (41-byte hash values), but setting `old_passwords=1` causes hashing to use the pre-4.1 method. In this case, `PASSWORD()` produces 16-byte values and is equivalent to `OLD_PASSWORD()`

To permit DBAs control over how clients are permitted to connect, the `secure_auth` system variable was added. Starting the server with this variable disabled or enabled permits or prohibits clients to connect using the older pre-4.1 password hashing method. Before MySQL 5.6.5, `secure_auth` is disabled by default. As of 5.6.5, `secure_auth` is enabled by default to promote a more secure default configuration. (DBAs can disable it at their discretion, but this is not recommended.)

In addition, the `mysql` client supports a `--secure-auth` option that is analogous to `secure_auth`, but from the client side. It can be used to prevent connections to less secure accounts that use pre-4.1 password hashing. This option is disabled by default before MySQL 5.6.7, enabled thereafter.

Compatibility Issues Related to Hashing Methods

The widening of the `Password` column in MySQL 4.1 from 16 bytes to 41 bytes affects installation or upgrade operations as follows:

- If you perform a new installation of MySQL, the `Password` column is made 41 bytes long automatically.
- Upgrades from MySQL 4.1 or later to current versions of MySQL should not give rise to any issues in regard to the `Password` column because both versions use the same column length and password hashing method.
- For upgrades from a pre-4.1 release to 4.1 or later, you must upgrade the system tables after upgrading. (See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.)

The 4.1 hashing method is understood only by MySQL 4.1 (and higher) servers and clients, which can result in some compatibility problems. A 4.1 or higher client can connect to a pre-4.1 server, because the client understands both the pre-4.1 and 4.1 password hashing methods. However, a pre-4.1 client that attempts to connect to a 4.1 or higher server may run into difficulties. For example, a 4.0 `mysql` client may fail with the following error message:

```
shell> mysql -h localhost -u root
Client does not support authentication protocol requested
by server; consider upgrading MySQL client
```

This phenomenon also occurs for attempts to use the older PHP `mysql` extension after upgrading to MySQL 4.1 or higher. (See Common Problems with MySQL and PHP.)

The following discussion describes the differences between the pre-4.1 and 4.1 hashing methods, and what you should do if you upgrade your server but need to maintain backward compatibility with pre-4.1 clients. (However, permitting connections by old clients is not recommended and should be avoided if possible.) Additional information can be found in Section B.5.2.4, “Client does not support authentication protocol”. This information is of particular importance to PHP programmers migrating MySQL databases from versions older than 4.1 to 4.1 or higher.

The differences between short and long password hashes are relevant both for how the server uses passwords during authentication and for how it generates password hashes for connected clients that perform password-changing operations.

The way in which the server uses password hashes during authentication is affected by the width of the `Password` column:

- If the column is short, only short-hash authentication is used.
- If the column is long, it can hold either short or long hashes, and the server can use either format:
  - Pre-4.1 clients can connect, but because they know only about the pre-4.1 hashing method, they can authenticate only using accounts that have short hashes.
  - 4.1 and later clients can authenticate using accounts that have short or long hashes.

Even for short-hash accounts, the authentication process is actually a bit more secure for 4.1 and later clients than for older clients. In terms of security, the gradient from least to most secure is:

- Pre-4.1 client authenticating with short password hash
- 4.1 or later client authenticating with short password hash
- 4.1 or later client authenticating with long password hash

The way in which the server generates password hashes for connected clients is affected by the width of the `Password` column and by the `old_passwords` system variable. A 4.1 or later server generates long hashes only if certain conditions are met: The `Password` column must be wide enough to hold long values and `old_passwords` must not be set to 1.

Those conditions apply as follows:

- The `Password` column must be wide enough to hold long hashes (41 bytes). If the column has not been updated and still has the pre-4.1 width of 16 bytes, the server notices that long hashes cannot fit into it and generates only short hashes when a client performs password-changing operations using the `PASSWORD()` function or a password-generating statement. This is the behavior that occurs if you have upgraded from a version of MySQL older than 4.1 to 4.1 or later but have not yet run the `mysql_upgrade` program to widen the `Password` column.
- If the `Password` column is wide, it can store either short or long password hashes. In this case, the `PASSWORD()` function and password-generating statements generate long hashes unless the server was started with the `old_passwords` system variable set to 1 to force the server to generate short password hashes instead.

The purpose of the `old_passwords` system variable is to permit backward compatibility with pre-4.1 clients under circumstances where the server would otherwise generate long password hashes. The option does not affect authentication (4.1 and later clients can still use accounts that have long password hashes), but it does prevent creation of a long password hash in the `user` table as the result of a password-changing operation. Were that permitted to occur, the account could no longer be used by pre-4.1 clients. With `old_passwords` disabled, the following undesirable scenario is possible:

- An old pre-4.1 client connects to an account that has a short password hash.
- The client changes its own password. With `old_passwords` disabled, this results in the account having a long password hash.

- The next time the old client attempts to connect to the account, it cannot, because the account has a long password hash that requires the 4.1 hashing method during authentication. (Once an account has a long password hash in the user table, only 4.1 and later clients can authenticate for it because pre-4.1 clients do not understand long hashes.)

This scenario illustrates that, if you must support older pre-4.1 clients, it is problematic to run a 4.1 or higher server without `old_passwords` set to 1. By running the server with `old_passwords=1`, password-changing operations do not generate long password hashes and thus do not cause accounts to become inaccessible to older clients. (Those clients cannot inadvertently lock themselves out by changing their password and ending up with a long password hash.)

The downside of `old_passwords=1` is that any passwords created or changed use short hashes, even for 4.1 or later clients. Thus, you lose the additional security provided by long password hashes. To create an account that has a long hash (for example, for use by 4.1 clients) or to change an existing account to use a long password hash, an administrator can set the session value of `old_passwords` set to 0 while leaving the global value set to 1:

```
mysql> SET @@session.old_passwords = 0;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @@session.old_passwords, @@global.old_passwords;
+--------------------------+------------------------+
| @@session.old_passwords | @@global.old_passwords |
+--------------------------+------------------------+
|                        0 |                      1 |
+--------------------------+------------------------+
1 row in set (0.00 sec)

mysql> CREATE USER 'newuser'@'localhost' IDENTIFIED BY 'newpass';
Query OK, 0 rows affected (0.03 sec)

mysql> SET PASSWORD FOR 'existinguser'@'localhost' = PASSWORD('existingpass');
Query OK, 0 rows affected (0.00 sec)
```

The following scenarios are possible in MySQL 4.1 or later. The factors are whether the `Password` column is short or long, and, if long, whether the server is started with `old_passwords` enabled or disabled.

Scenario 1: Short `Password` column in user table:

- Only short hashes can be stored in the `Password` column.
- The server uses only short hashes during client authentication.
- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use short hashes exclusively. Any change to an account's password results in that account having a short password hash.
- The value of `old_passwords` is irrelevant because with a short `Password` column, the server generates only short password hashes anyway.

This scenario occurs when a pre-4.1 MySQL installation has been upgraded to 4.1 or later but `mysql_upgrade` has not been run to upgrade the system tables in the `mysql` database. (This is not a recommended configuration because it does not permit use of more secure 4.1 password hashing.)

Scenario 2: Long `Password` column; server started with `old_passwords=1`:

- Short or long hashes can be stored in the `Password` column.
- 4.1 and later clients can authenticate for accounts that have short or long hashes.
- Pre-4.1 clients can authenticate only for accounts that have short hashes.

- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use short hashes exclusively. Any change to an account's password results in that account having a short password hash.

In this scenario, newly created accounts have short password hashes because `old_passwords=1` prevents generation of long hashes. Also, if you create an account with a long hash before setting `old_passwords` to 1, changing the account's password while `old_passwords=1` results in the account being given a short password, causing it to lose the security benefits of a longer hash.

To create a new account that has a long password hash, or to change the password of any existing account to use a long hash, first set the session value of `old_passwords` set to 0 while leaving the global value set to 1, as described previously.

In this scenario, the server has an up to date `Password` column, but is running with the default password hashing method set to generate pre-4.1 hash values. This is not a recommended configuration but may be useful during a transitional period in which pre-4.1 clients and passwords are upgraded to 4.1 or later. When that has been done, it is preferable to run the server with `old_passwords=0` and `secure_auth=1`.

Scenario 3: Long `Password` column; server started with `old_passwords=0`:

- Short or long hashes can be stored in the `Password` column.
- 4.1 and later clients can authenticate using accounts that have short or long hashes.
- Pre-4.1 clients can authenticate only using accounts that have short hashes.
- For connected clients, password hash-generating operations involving the `PASSWORD()` function or password-generating statements use long hashes exclusively. A change to an account's password results in that account having a long password hash.

As indicated earlier, a danger in this scenario is that it is possible for accounts that have a short password hash to become inaccessible to pre-4.1 clients. A change to such an account's password made using the `PASSWORD()` function or a password-generating statement results in the account being given a long password hash. From that point on, no pre-4.1 client can connect to the server using that account. The client must upgrade to 4.1 or later.

If this is a problem, you can change a password in a special way. For example, normally you use `SET PASSWORD` as follows to change an account password:

```
SET PASSWORD FOR 'some_user'@'some_host' = PASSWORD('password');
```

To change the password but create a short hash, use the `OLD_PASSWORD()` function instead:

```
SET PASSWORD FOR 'some_user'@'some_host' = OLD_PASSWORD('password');
```

`OLD_PASSWORD()` is useful for situations in which you explicitly want to generate a short hash.

The disadvantages for each of the preceding scenarios may be summarized as follows:

In scenario 1, you cannot take advantage of longer hashes that provide more secure authentication.

In scenario 2, `old_passwords=1` prevents accounts with short hashes from becoming inaccessible, but password-changing operations cause accounts with long hashes to revert to short hashes unless you take care to change the session value of `old_passwords` to 0 first.

In scenario 3, accounts with short hashes become inaccessible to pre-4.1 clients if you change their passwords without explicitly using `OLD_PASSWORD()`.

The best way to avoid compatibility problems related to short password hashes is to not use them:

- Upgrade all client programs to MySQL 4.1 or later.

- Run the server with `old_passwords=0`.
- Reset the password for any account with a short password hash to use a long password hash.
- For additional security, run the server with `secure_auth=1`.

6.1.2.5 Implications of Password Hashing Changes in MySQL 4.1 for Application Programs

An upgrade to MySQL version 4.1 or later can cause compatibility issues for applications that use `PASSWORD()` to generate passwords for their own purposes. Applications really should not do this, because `PASSWORD()` should be used only to manage passwords for MySQL accounts. But some applications use `PASSWORD()` for their own purposes anyway.

If you upgrade to 4.1 or later from a pre-4.1 version of MySQL and run the server under conditions where it generates long password hashes, an application using `PASSWORD()` for its own passwords breaks. The recommended course of action in such cases is to modify the application to use another function, such as `SHA2()`, `SHA1()`, or `MD5()`, to produce hashed values. If that is not possible, you can use the `OLD_PASSWORD()` function, which is provided for generate short hashes in the old format. However, you should note that `OLD_PASSWORD()` may one day no longer be supported.

If the server is running with `old_passwords=1`, it generates short hashes and `OLD_PASSWORD()` is equivalent to `PASSWORD()`.

PHP programmers migrating their MySQL databases from version 4.0 or lower to version 4.1 or higher should see MySQL and PHP.

6.1.3 Making MySQL Secure Against Attackers

When you connect to a MySQL server, you should use a password. The password is not transmitted in clear text over the connection. Password handling during the client connection sequence was upgraded in MySQL 4.1.1 to be very secure. If you are still using pre-4.1.1-style passwords, the encryption algorithm is not as strong as the newer algorithm. With some effort, a clever attacker who can sniff the traffic between the client and the server can crack the password. (See Section 6.1.2.4, “Password Hashing in MySQL”, for a discussion of the different password handling methods.)

All other information is transferred as text, and can be read by anyone who is able to watch the connection. If the connection between the client and the server goes through an untrusted network, and you are concerned about this, you can use the compressed protocol to make traffic much more difficult to decipher. You can also use MySQL's internal SSL support to make the connection even more secure. See Section 6.4, “Using Encrypted Connections”. Alternatively, use SSH to get an encrypted TCP/IP connection between a MySQL server and a MySQL client. You can find an Open Source SSH client at http://www.openssh.org/, and a comparison of both Open Source and Commercial SSH clients at http://en.wikipedia.org/wiki/Comparison_of_SSH_clients.

To make a MySQL system secure, you should strongly consider the following suggestions:

- Require all MySQL accounts to have a password. A client program does not necessarily know the identity of the person running it. It is common for client/server applications that the user can specify any user name to the client program. For example, anyone can use the `mysql` program to connect as any other person simply by invoking it as `mysql -u other_user db_name` if `other_user` has no password. If all accounts have a password, connecting using another user's account becomes much more difficult.

  For a discussion of methods for setting passwords, see Section 6.3.5, “Assigning Account Passwords”.

- Make sure that the only Unix user account with read or write privileges in the database directories is the account that is used for running `mysqld`.
- Never run the MySQL server as the Unix `root` user. This is extremely dangerous, because any user with the `FILE` privilege is able to cause the server to create files as `root` (for example,

`~root/.bashrc`). To prevent this, `mysqld` refuses to run as `root` unless that is specified explicitly using the `--user=root` option.

`mysqld` can (and should) be run as an ordinary, unprivileged user instead. You can create a separate Unix account named `mysql` to make everything even more secure. Use this account only for administering MySQL. To start `mysqld` as a different Unix user, add a `user` option that specifies the user name in the `[mysqld]` group of the `my.cnf` option file where you specify server options. For example:

```
[mysqld]
user=mysql
```

This causes the server to start as the designated user whether you start it manually or by using `mysqld_safe` or `mysql.server`. For more details, see Section 6.1.5, “How to Run MySQL as a Normal User”.

Running `mysqld` as a Unix user other than `root` does not mean that you need to change the `root` user name in the `user` table. *User names for MySQL accounts have nothing to do with user names for Unix accounts*.

- Do not grant the `FILE` privilege to nonadministrative users. Any user that has this privilege can write a file anywhere in the file system with the privileges of the `mysqld` daemon. This includes the server's data directory containing the files that implement the privilege tables. To make `FILE`-privilege operations a bit safer, files generated with `SELECT ... INTO OUTFILE` do not overwrite existing files and are writable by everyone.

  The `FILE` privilege may also be used to read any file that is world-readable or accessible to the Unix user that the server runs as. With this privilege, you can read any file into a database table. This could be abused, for example, by using `LOAD DATA` to load `/etc/passwd` into a table, which then can be displayed with `SELECT`.

  To limit the location in which files can be read and written, set the `secure_file_priv` system to a specific directory. See Section 5.1.5, “Server System Variables”.

- Do not grant the `PROCESS` or `SUPER` privilege to nonadministrative users. The output of `mysqladmin processlist` and `SHOW PROCESSLIST` shows the text of any statements currently being executed, so any user who is permitted to see the server process list might be able to see statements issued by other users such as `UPDATE user SET password=PASSWORD('not_secure')`.

  `mysqld` reserves an extra connection for users who have the `SUPER` privilege, so that a MySQL `root` user can log in and check server activity even if all normal connections are in use.

  The `SUPER` privilege can be used to terminate client connections, change server operation by changing the value of system variables, and control replication servers.

- Do not permit the use of symlinks to tables. (This capability can be disabled with the `--skip-symbolic-links` option.) This is especially important if you run `mysqld` as `root`, because anyone that has write access to the server's data directory then could delete any file in the system! See Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”.

- Stored programs and views should be written using the security guidelines discussed in Section 20.6, “Access Control for Stored Programs and Views”.

- If you do not trust your DNS, you should use IP addresses rather than host names in the grant tables. In any case, you should be very careful about creating grant table entries using host name values that contain wildcards.

- If you want to restrict the number of connections permitted to a single account, you can do so by setting the `max_user_connections` variable in `mysqld`. The `GRANT` statement also

supports resource control options for limiting the extent of server use permitted to an account. See Section 13.7.1.3, “GRANT Syntax”.

- If the plugin directory is writable by the server, it may be possible for a user to write executable code to a file in the directory using `SELECT ... INTO DUMPFILE`. This can be prevented by making `plugin_dir` read only to the server or by setting `--secure-file-priv` to a directory where `SELECT` writes can be made safely.

6.1.4 Security-Related mysqld Options and Variables

The following table shows `mysqld` options and system variables that affect security. For descriptions of each of these, see Section 5.1.4, “Server Command Options”, and Section 5.1.5, “Server System Variables”.

Table 6.1 Security Option and Variable Summary

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
allow-suspicious-udfs	Yes	Yes				
automatic_sp_privileges			Yes		Global	Yes
chroot	Yes	Yes				
des-key-file	Yes	Yes				
local_infile			Yes		Global	Yes
old_passwords			Yes		Both	Yes
safe-show-database	Yes	Yes				
safe-user-create	Yes	Yes				
secure-auth	Yes	Yes			Global	Yes
- *Variable*: secure_auth			Yes		Global	Yes
secure-file-priv	Yes	Yes			Global	No
- *Variable*: secure_file_priv			Yes		Global	No
skip-grant-tables	Yes	Yes				
skip-name-resolve	Yes	Yes			Global	No
- *Variable*: skip_name_resolve			Yes		Global	No
skip-networking	Yes	Yes			Global	No
- *Variable*: skip_networking			Yes		Global	No
skip-show-database	Yes	Yes			Global	No
- *Variable*: skip_show_database			Yes		Global	No

6.1.5 How to Run MySQL as a Normal User

On Windows, you can run the server as a Windows service using a normal user account.

On Linux, for installations performed using a MySQL repository, RPM packages, or Debian packages, the MySQL server `mysqld` should be started by the local `mysql` operating system user. Starting

by another operating system user is not supported by the init scripts that are included as part of the installation.

On Unix (or Linux for installations performed using `tar` or `tar.gz` packages) , the MySQL server `mysqld` can be started and run by any user. However, you should avoid running the server as the Unix `root` user for security reasons. To change `mysqld` to run as a normal unprivileged Unix user *`user_name`*, you must do the following:

1. Stop the server if it is running (use `mysqladmin shutdown`).
2. Change the database directories and files so that *`user_name`* has privileges to read and write files in them (you might need to do this as the Unix `root` user):

   ```
   shell> chown -R user_name /path/to/mysql/datadir
   ```

   If you do not do this, the server will not be able to access databases or tables when it runs as *`user_name`*.

   If directories or files within the MySQL data directory are symbolic links, `chown -R` might not follow symbolic links for you. If it does not, you will also need to follow those links and change the directories and files they point to.
3. Start the server as user *`user_name`*. Another alternative is to start `mysqld` as the Unix `root` user and use the `--user=`*`user_name`* option. `mysqld` starts up, then switches to run as the Unix user *`user_name`* before accepting any connections.
4. To start the server as the given user automatically at system startup time, specify the user name by adding a `user` option to the `[mysqld]` group of the `/etc/my.cnf` option file or the `my.cnf` option file in the server's data directory. For example:

   ```
   [mysqld]
   user=user_name
   ```

If your Unix machine itself is not secured, you should assign passwords to the MySQL `root` accounts in the grant tables. Otherwise, any user with a login account on that machine can run the `mysql` client with a `--user=root` option and perform any operation. (It is a good idea to assign passwords to MySQL accounts in any case, but especially so when other login accounts exist on the server host.) See Section 2.10.4, “Securing the Initial MySQL Accounts”.

6.1.6 Security Issues with LOAD DATA LOCAL

The `LOAD DATA` statement can load a file located on the server host, or, if the `LOCAL` keyword is specified, on the client host.

There are two potential security issues with the `LOCAL` version of `LOAD DATA`:

- The transfer of the file from the client host to the server host is initiated by the MySQL server. In theory, a patched server could be built that would tell the client program to transfer a file of the server's choosing rather than the file named by the client in the `LOAD DATA` statement. Such a server could access any file on the client host to which the client user has read access. (A patched server could in fact reply with a file-transfer request to any statement, not just `LOAD DATA LOCAL`, so a more fundamental issue is that clients should not connect to untrusted servers.)
- In a Web environment where the clients are connecting from a Web server, a user could use `LOAD DATA LOCAL` to read any files that the Web server process has read access to (assuming that a user could run any statement against the SQL server). In this environment, the client with respect to the MySQL server actually is the Web server, not a remote program being run by users who connect to the Web server.

To avoid `LOAD DATA` issues, clients should avoid using `LOCAL`. To avoid connecting to untrusted servers, clients can establish a secure connection and verify the server identity by connecting using the `--ssl-verify-server-cert` option and the appropriate CA certificate.

To enable adminstrators and applications to manage the local data loading capability, `LOCAL` configuration works like this:

- On the server side:
  - The `local_infile` system variable controls server-side `LOCAL` capability. Depending on the `local_infile` setting, the server refuses or permits local data loading by clients that have `LOCAL` enabled on the client side. By default, `local_infile` is enabled.
  - To explicitly cause the server to refuse or permit `LOAD DATA LOCAL` statements (regardless of how client programs and libraries are configured at build time or runtime), start `mysqld` with `local_infile` disabled or enabled, respectively. `local_infile` can also be set at runtime.
- On the client side:
  - The `ENABLED_LOCAL_INFILE` `CMake` option controls the compiled-in default `LOCAL` capability for the MySQL client library. Clients that make no explicit arrangements therefore have `LOCAL` capability disabled or enabled according to the `ENABLED_LOCAL_INFILE` setting specified at MySQL build time.

    By default, the client library in MySQL binary distributions is compiled with `ENABLED_LOCAL_INFILE` enabled. If you compile MySQL from source, configure it with `ENABLED_LOCAL_INFILE` disabled or enabled based on whether clients that make no explicit arrangements should have `LOCAL` capability disabled or enabled, respectively.
  - Client programs that use the C API can control load data loading explicitly by invoking `mysql_options()` to disable or enable the `MYSQL_OPT_LOCAL_INFILE` option. See Section 23.8.7.49, “mysql_options()”.
  - For the `mysql` client, local data loading is disabled by default. To disable or enable it explicitly, use the `--local-infile=0` or `--local-infile[=1]` option.
  - For the `mysqlimport` client, local data loading is disabled by default. To disable or enable it explicitly, use the `--local=0` or `--local[=1]` option.
  - If you use `LOAD DATA LOCAL` in Perl scripts or other programs that read the `[client]` group from option files, you can add an `local-infile` option setting to that group. To prevent problems for programs that do not understand this option, specify it using the `loose-` prefix:

    ```
    [client]
    loose-local-infile=0
    ```

    or:

    ```
    [client]
    loose-local-infile=1
    ```
  - In all cases, successful use of a `LOCAL` load operation by a client also requires that the server permits it.

If `LOCAL` capability is disabled, on either the server or client side, a client that attempts to issue a `LOAD DATA LOCAL` statement receives the following error message:

```
ERROR 1148: The used command is not allowed with this MySQL version
```

6.1.7 Client Programming Security Guidelines

Applications that access MySQL should not trust any data entered by users, who can try to trick your code by entering special or escaped character sequences in Web forms, URLs, or whatever application you have built. Be sure that your application remains secure if a user enters something like `; DROP DATABASE mysql;`. This is an extreme example, but large security leaks and data loss might occur as a result of hackers using similar techniques, if you do not prepare for them.

A common mistake is to protect only string data values. Remember to check numeric data as well. If an application generates a query such as `SELECT * FROM table WHERE ID=234` when a user enters the value `234`, the user can enter the value `234 OR 1=1` to cause the application to generate the query `SELECT * FROM table WHERE ID=234 OR 1=1`. As a result, the server retrieves every row in the table. This exposes every row and causes excessive server load. The simplest way to protect from this type of attack is to use single quotation marks around the numeric constants: `SELECT * FROM table WHERE ID='234'`. If the user enters extra information, it all becomes part of the string. In a numeric context, MySQL automatically converts this string to a number and strips any trailing nonnumeric characters from it.

Sometimes people think that if a database contains only publicly available data, it need not be protected. This is incorrect. Even if it is permissible to display any row in the database, you should still protect against denial of service attacks (for example, those that are based on the technique in the preceding paragraph that causes the server to waste resources). Otherwise, your server becomes unresponsive to legitimate users.

Checklist:

- Enable strict SQL mode to tell the server to be more restrictive of what data values it accepts. See Section 5.1.8, “Server SQL Modes”.
- Try to enter single and double quotation marks (`'` and `"`) in all of your Web forms. If you get any kind of MySQL error, investigate the problem right away.
- Try to modify dynamic URLs by adding `%22` (`"`), `%23` (`#`), and `%27` (`'`) to them.
- Try to modify data types in dynamic URLs from numeric to character types using the characters shown in the previous examples. Your application should be safe against these and similar attacks.
- Try to enter characters, spaces, and special symbols rather than numbers in numeric fields. Your application should remove them before passing them to MySQL or else generate an error. Passing unchecked values to MySQL is very dangerous!
- Check the size of data before passing it to MySQL.
- Have your application connect to the database using a user name different from the one you use for administrative purposes. Do not give your applications any access privileges they do not need.

Many application programming interfaces provide a means of escaping special characters in data values. Properly used, this prevents application users from entering values that cause the application to generate statements that have a different effect than you intend:

- MySQL C API: Use the `mysql_real_escape_string()` API call.
- MySQL++: Use the `escape` and `quote` modifiers for query streams.
- PHP: Use either the `mysqli` or `pdo_mysql` extensions, and not the older `ext/mysql` extension. The preferred API's support the improved MySQL authentication protocol and passwords, as well as prepared statements with placeholders. See also Choosing an API.

  If the older `ext/mysql` extension must be used, then for escaping use the `mysql_real_escape_string()` function and not `mysql_escape_string()` or `addslashes()` because only `mysql_real_escape_string()` is character set-aware; the other functions can be “bypassed” when using (invalid) multibyte character sets.

- Perl DBI: Use placeholders or the `quote()` method.
- Ruby DBI: Use placeholders or the `quote()` method.
- Java JDBC: Use a `PreparedStatement` object and placeholders.

Other programming interfaces might have similar capabilities.

6.2 The MySQL Access Privilege System

The primary function of the MySQL privilege system is to authenticate a user who connects from a given host and to associate that user with privileges on a database such as `SELECT`, `INSERT`, `UPDATE`, and `DELETE`. Additional functionality includes the ability to have anonymous users and to grant privileges for MySQL-specific functions such as `LOAD DATA INFILE` and administrative operations.

There are some things that you cannot do with the MySQL privilege system:

- You cannot explicitly specify that a given user should be denied access. That is, you cannot explicitly match a user and then refuse the connection.
- You cannot specify that a user has privileges to create or drop tables in a database but not to create or drop the database itself.
- A password applies globally to an account. You cannot associate a password with a specific object such as a database, table, or routine.

The user interface to the MySQL privilege system consists of SQL statements such as `CREATE USER`, `GRANT`, and `REVOKE`. See Section 13.7.1, “Account Management Statements”.

Internally, the server stores privilege information in the grant tables of the `mysql` database (that is, in the database named `mysql`). The MySQL server reads the contents of these tables into memory when it starts and bases access-control decisions on the in-memory copies of the grant tables.

The MySQL privilege system ensures that all users may perform only the operations permitted to them. As a user, when you connect to a MySQL server, your identity is determined by *the host from which you connect* and *the user name you specify*. When you issue requests after connecting, the system grants privileges according to your identity and *what you want to do*.

MySQL considers both your host name and user name in identifying you because there is no reason to assume that a given user name belongs to the same person on all hosts. For example, the user `joe` who connects from `office.example.com` need not be the same person as the user `joe` who connects from `home.example.com`. MySQL handles this by enabling you to distinguish users on different hosts that happen to have the same name: You can grant one set of privileges for connections by `joe` from `office.example.com`, and a different set of privileges for connections by `joe` from `home.example.com`. To see what privileges a given account has, use the `SHOW GRANTS` statement. For example:

```
SHOW GRANTS FOR 'joe'@'office.example.com';
SHOW GRANTS FOR 'joe'@'home.example.com';
```

MySQL access control involves two stages when you run a client program that connects to the server:

Stage 1: The server accepts or rejects the connection based on your identity and whether you can verify your identity by supplying the correct password.

Stage 2: Assuming that you can connect, the server checks each statement you issue to determine whether you have sufficient privileges to perform it. For example, if you try to select rows from a table in a database or drop a table from the database, the server verifies that you have the `SELECT` privilege for the table or the `DROP` privilege for the database.

For a more detailed description of what happens during each stage, see Section 6.2.4, “Access Control, Stage 1: Connection Verification”, and Section 6.2.5, “Access Control, Stage 2: Request Verification”.

If your privileges are changed (either by yourself or someone else) while you are connected, those changes do not necessarily take effect immediately for the next statement that you issue. For details about the conditions under which the server reloads the grant tables, see Section 6.2.6, “When Privilege Changes Take Effect”.

For general security-related advice, see Section 6.1, “General Security Issues”. For help in diagnosing privilege-related problems, see Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”.

6.2.1 Privileges Provided by MySQL

The privileges granted to a MySQL account determine which operations the account can perform. MySQL privileges differ in the contexts in which they apply and at different levels of operation:

- Administrative privileges enable users to manage operation of the MySQL server. These privileges are global because they are not specific to a particular database.
- Database privileges apply to a database and to all objects within it. These privileges can be granted for specific databases, or globally so that they apply to all databases.
- Privileges for database objects such as tables, indexes, views, and stored routines can be granted for specific objects within a database, for all objects of a given type within a database (for example, all tables in a database), or globally for all objects of a given type in all databases).

Information about account privileges is stored in the `user`, `db`, `host`, `tables_priv`, `columns_priv`, and `procs_priv` tables in the `mysql` system database (see Section 6.2.2, “Grant Tables”). The MySQL server reads the contents of these tables into memory when it starts and reloads them under the circumstances indicated in Section 6.2.6, “When Privilege Changes Take Effect”. Access-control decisions are based on the in-memory copies of the grant tables.

Some MySQL releases introduce changes to the structure of the grant tables to add new privileges or features. To make sure that you can take advantage of any new capabilities, update your grant tables to have the current structure whenever you upgrade MySQL. See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

The following table shows the privilege names used in `GRANT` and `REVOKE` statements, along with the column name associated with each privilege in the grant tables and the context in which the privilege applies.

Table 6.2 Permissible Privileges for GRANT and REVOKE

Privilege	Column	Context
`ALL [PRIVILEGES]`	Synonym for “all privileges”	Server administration
`ALTER`	`Alter_priv`	Tables
`ALTER ROUTINE`	`Alter_routine_priv`	Stored routines
`CREATE`	`Create_priv`	Databases, tables, or indexes
`CREATE ROUTINE`	`Create_routine_priv`	Stored routines
`CREATE TABLESPACE`	`Create_tablespace_priv`	Server administration
`CREATE TEMPORARY TABLES`	`Create_tmp_table_priv`	Tables
`CREATE USER`	`Create_user_priv`	Server administration
`CREATE VIEW`	`Create_view_priv`	Views
`DELETE`	`Delete_priv`	Tables
`DROP`	`Drop_priv`	Databases, tables, or views
`EVENT`	`Event_priv`	Databases

Privilege	Column	Context
EXECUTE	Execute_priv	Stored routines
FILE	File_priv	File access on server host
GRANT OPTION	Grant_priv	Databases, tables, or stored routines
INDEX	Index_priv	Tables
INSERT	Insert_priv	Tables or columns
LOCK TABLES	Lock_tables_priv	Databases
PROCESS	Process_priv	Server administration
PROXY	See proxies_priv table	Server administration
REFERENCES	References_priv	Databases or tables
RELOAD	Reload_priv	Server administration
REPLICATION CLIENT	Repl_client_priv	Server administration
REPLICATION SLAVE	Repl_slave_priv	Server administration
SELECT	Select_priv	Tables or columns
SHOW DATABASES	Show_db_priv	Server administration
SHOW VIEW	Show_view_priv	Views
SHUTDOWN	Shutdown_priv	Server administration
SUPER	Super_priv	Server administration
TRIGGER	Trigger_priv	Tables
UPDATE	Update_priv	Tables or columns
USAGE	Synonym for “no privileges”	Server administration

The following list provides general descriptions of the privileges available in MySQL. Particular SQL statements might have more specific privilege requirements than indicated here. If so, the description for the statement in question provides the details.

- The ALL or ALL PRIVILEGES privilege specifier is shorthand. It stands for “all privileges available at a given privilege level” (except GRANT OPTION). For example, granting ALL at the global or table level grants all global privileges or all table-level privileges.
- The ALTER privilege enables use of the ALTER TABLE statement to change the structure of tables. ALTER TABLE also requires the CREATE and INSERT privileges. Renaming a table requires ALTER and DROP on the old table, CREATE, and INSERT on the new table.
- The ALTER ROUTINE privilege is needed to alter or drop stored routines (procedures and functions).
- The CREATE privilege enables creation of new databases and tables.
- The CREATE ROUTINE privilege is needed to create stored routines (procedures and functions).
- The CREATE TABLESPACE privilege is needed to create, alter, or drop tablespaces and log file groups.
- The CREATE TEMPORARY TABLES privilege enables the creation of temporary tables using the CREATE TEMPORARY TABLE statement.

  However, other operations on a temporary table, such as INSERT, UPDATE, or SELECT, require additional privileges for those operations for the database containing the temporary table, or for the nontemporary table of the same name. For more information, see Section 13.1.17.3, “CREATE TEMPORARY TABLE Syntax”.
- The CREATE USER privilege enables use of the CREATE USER, DROP USER, RENAME USER, and REVOKE ALL PRIVILEGES statements.

- The `CREATE VIEW` privilege enables use of the `CREATE VIEW` statement.
- The `DELETE` privilege enables rows to be deleted from tables in a database.
- The `DROP` privilege enables you to drop (remove) existing databases, tables, and views. The `DROP` privilege is required in order to use the statement `ALTER TABLE ... DROP PARTITION` on a partitioned table. The `DROP` privilege is also required for `TRUNCATE TABLE`. *If you grant the `DROP` privilege for the `mysql` database to a user, that user can drop the database in which the MySQL access privileges are stored.*
- The `EVENT` privilege is required to create, alter, drop, or see events for the Event Scheduler.
- The `EXECUTE` privilege is required to execute stored routines (procedures and functions).
- The `FILE` privilege gives you permission to read and write files on the server host using the `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE` statements and the `LOAD_FILE()` function. A user who has the `FILE` privilege can read any file on the server host that is either world-readable or readable by the MySQL server. (This implies the user can read any file in any database directory, because the server can access any of those files.) The `FILE` privilege also enables the user to create new files in any directory where the MySQL server has write access. This includes the server's data directory containing the files that implement the privilege tables. As a security measure, the server will not overwrite existing files. As of MySQL 5.5.54, the `FILE` privilege is required to use the `DATA DIRECTORY` or `INDEX DIRECTORY` table option for the `CREATE TABLE` statement.

  To limit the location in which files can be read and written, set the `secure_file_priv` system to a specific directory. See Section 5.1.5, “Server System Variables”.
- The `GRANT OPTION` privilege enables you to give to other users or remove from other users those privileges that you yourself possess.
- The `INDEX` privilege enables you to create or drop (remove) indexes. `INDEX` applies to existing tables. If you have the `CREATE` privilege for a table, you can include index definitions in the `CREATE TABLE` statement.
- The `INSERT` privilege enables rows to be inserted into tables in a database. `INSERT` is also required for the `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` table-maintenance statements.
- The `LOCK TABLES` privilege enables the use of explicit `LOCK TABLES` statements to lock tables for which you have the `SELECT` privilege. This includes the use of write locks, which prevents other sessions from reading the locked table.
- The `PROCESS` privilege pertains to display of information about the threads executing within the server (that is, information about the statements being executed by sessions). The privilege enables use of `SHOW PROCESSLIST` or `mysqladmin processlist` to see threads belonging to other accounts; you can always see your own threads. The `PROCESS` privilege also enables use of `SHOW ENGINE`.
- The `PROXY` privilege enables a user to impersonate or become known as another user. See Section 6.3.7, “Proxy Users”.
- The `REFERENCES` privilege is unused before MySQL 5.5.41. As of 5.5.41, creation of a foreign key constraint requires at least one of the `SELECT`, `INSERT`, `UPDATE`, `DELETE`, or `REFERENCES` privileges for the parent table.
- The `RELOAD` privilege enables use of the `FLUSH` statement. It also enables `mysqladmin` commands that are equivalent to `FLUSH` operations: `flush-hosts`, `flush-logs`, `flush-privileges`, `flush-status`, `flush-tables`, `flush-threads`, `refresh`, and `reload`.

  The `reload` command tells the server to reload the grant tables into memory. `flush-privileges` is a synonym for `reload`. The `refresh` command closes and reopens the log files and flushes all tables. The other `flush-xxx` commands perform functions similar to `refresh`, but are more

specific and may be preferable in some instances. For example, if you want to flush just the log files, `flush-logs` is a better choice than `refresh`.

- The `REPLICATION CLIENT` privilege enables the use of the `SHOW MASTER STATUS` and `SHOW SLAVE STATUS` statements. In MySQL 5.5.25 and later, it also enables the use of the `SHOW BINARY LOGS` statement.
- The `REPLICATION SLAVE` privilege should be granted to accounts that are used by slave servers to connect to the current server as their master. Without this privilege, the slave cannot request updates that have been made to databases on the master server.
- The `SELECT` privilege enables you to select rows from tables in a database. `SELECT` statements require the `SELECT` privilege only if they actually retrieve rows from a table. Some `SELECT` statements do not access tables and can be executed without permission for any database. For example, you can use `SELECT` as a simple calculator to evaluate expressions that make no reference to tables:

  ```
  SELECT 1+1;
  SELECT PI()*2;
  ```

  The `SELECT` privilege is also needed for other statements that read column values. For example, `SELECT` is needed for columns referenced on the right hand side of *`col_name`*=*`expr`* assignment in `UPDATE` statements or for columns named in the `WHERE` clause of `DELETE` or `UPDATE` statements.

  The `SELECT` privilege is also needed for tables or views being used with `EXPLAIN`, including any underlying tables of views.
- The `SHOW DATABASES` privilege enables the account to see database names by issuing the `SHOW DATABASE` statement. Accounts that do not have this privilege see only databases for which they have some privileges, and cannot use the statement at all if the server was started with the `--skip-show-database` option. Note that *any* global privilege is a privilege for the database.
- The `SHOW VIEW` privilege enables use of the `SHOW CREATE VIEW` statement. This privilege is also needed for views being used with `EXPLAIN`.
- The `SHUTDOWN` privilege enables use of the `mysqladmin shutdown` command and the `mysql_shutdown()` C API function. There is no corresponding SQL statement.
- The `SUPER` privilege enables these operations and server behaviors:
  - Enables configuration changes by modifying global system variables. For some system variables, setting the session value also requires the `SUPER` privilege; if so, it is indicated in the variable description. Examples include `binlog_format`, `sql_log_bin`, and `sql_log_off`.
  - Enables changes to the global transaction isolation level (see Section 13.3.6, “SET TRANSACTION Syntax”).
  - Enables starting and stopping replication on slave servers.
  - Enables use of the `CHANGE MASTER TO` statement.
  - Enables binary log control by means of the `PURGE BINARY LOGS` and `BINLOG` statements.
  - Enables setting the effective authorization ID when executing a view or stored program. A user with this privilege can specify any account in the `DEFINER` attribute of a view or stored program.
  - Enables use of the `CREATE SERVER`, `ALTER SERVER`, and `DROP SERVER` statements.
  - Enables use of the `mysqladmin debug` command.
  - Enables reading the DES key file by the `DES_ENCRYPT()` function.

- Enables control over client connections not permitted to non-SUPER accounts:
  - Enables use of the KILL statement or mysqladmin kill command to kill threads belonging to other accounts. (You can always kill your own threads.)
  - The server accepts one connection from a SUPER client even if the connection limit controlled by the max_connections system variable is reached.
  - Updates can be performed even when the read_only system variable is enabled. This applies to table updates and use of account-management statements such as GRANT and REVOKE.
  - The server does not execute init_connect system variable content when SUPER clients connect.

  You may also need the SUPER privilege to create or alter stored functions if binary logging is enabled, as described in Section 20.7, “Binary Logging of Stored Programs”.
- The TRIGGER privilege enables trigger operations. You must have this privilege for a table to create, drop, execute, or display triggers for that table.

  When a trigger is activated (by a user who has privileges to execute INSERT, UPDATE, or DELETE statements for the table associated with the trigger), trigger execution requires that the user who defined the trigger still have the TRIGGER privilege.
- The UPDATE privilege enables rows to be updated in tables in a database.
- The USAGE privilege specifier stands for “no privileges.” It is used at the global level with GRANT to modify account attributes such as resource limits or SSL characteristics without naming specific account privileges. SHOW GRANTS displays USAGE to indicate that an account has no privileges at a privilege level.

It is a good idea to grant to an account only those privileges that it needs. You should exercise particular caution in granting the FILE and administrative privileges:

- The FILE privilege can be abused to read into a database table any files that the MySQL server can read on the server host. This includes all world-readable files and files in the server's data directory. The table can then be accessed using SELECT to transfer its contents to the client host.
- The GRANT OPTION privilege enables users to give their privileges to other users. Two users that have different privileges and with the GRANT OPTION privilege are able to combine privileges.
- The ALTER privilege may be used to subvert the privilege system by renaming tables.
- The SHUTDOWN privilege can be abused to deny service to other users entirely by terminating the server.
- The PROCESS privilege can be used to view the plain text of currently executing statements, including statements that set or change passwords.
- The SUPER privilege can be used to terminate other sessions or change how the server operates.
- Privileges granted for the mysql database itself can be used to change passwords and other access privilege information. Passwords are stored encrypted, so a malicious user cannot simply read them to know the plain text password. However, a user with write access to the user table Password column can change an account's password, and then connect to the MySQL server using that account.

6.2.2 Grant Tables

The mysql system database includes several grant tables that contain information about user accounts and the privileges held by them. This section describes those tables. For information about other tables in the system database, see Section 5.3, “The mysql System Database”.

Normally, to manipulate the contents of grant tables, you modify them indirectly by using account-management statements such as `CREATE USER`, `GRANT`, and `REVOKE` to set up accounts and control the privileges available to each one. See Section 13.7.1, “Account Management Statements”. The discussion here describes the underlying structure of the grant tables and how the server uses their contents when interacting with clients.

Note

Direct modification of grant tables using statements such as `INSERT`, `UPDATE`, or `DELETE` is discouraged and done at your own risk. The server is free to ignore rows that become malformed as a result of such modifications.

As of MySQL 5.5.55, for any operation that modifies a grant table, the server checks whether the table has the expected structure and produces an error if not. `mysql_upgrade` must be run to update the tables to the expected structure.

These `mysql` database tables contain grant information:

- `user`: User accounts, global privileges, and other non-privilege columns
- `db`: Database-level privileges
- `host`: Obsolete
- `tables_priv`: Table-level privileges
- `columns_priv`: Column-level privileges
- `procs_priv`: Stored procedure and function privileges
- `proxies_priv`: Proxy-user privileges

Each grant table contains scope columns and privilege columns:

- Scope columns determine the scope of each row in the tables; that is, the context in which the row applies. For example, a `user` table row with `Host` and `User` values of `'h1.example.net'` and `'bob'` applies to authenticating connections made to the server from the host `h1.example.net` by a client that specifies a user name of `bob`. Similarly, a `db` table row with `Host`, `User`, and `Db` column values of `'h1.example.net'`, `'bob'` and `'reports'` applies when `bob` connects from the host `h1.example.net` to access the `reports` database. The `tables_priv` and `columns_priv` tables contain scope columns indicating tables or table/column combinations to which each row applies. The `procs_priv` scope columns indicate the stored routine to which each row applies.
- Privilege columns indicate which privileges a table row grants; that is, which operations it permits to be performed. The server combines the information in the various grant tables to form a complete description of a user's privileges. Section 6.2.5, “Access Control, Stage 2: Request Verification”, describes the rules for this.

The server uses the grant tables in the following manner:

- The `user` table scope columns determine whether to reject or permit incoming connections. For permitted connections, any privileges granted in the `user` table indicate the user's global privileges. Any privileges granted in this table apply to *all* databases on the server.

Caution

Because any global privilege is considered a privilege for all databases, any global privilege enables a user to see all database names with `SHOW DATABASES` or by examining the `SCHEMATA` table of `INFORMATION_SCHEMA`.

- The `db` table scope columns determine which users can access which databases from which hosts. The privilege columns determine the permitted operations. A privilege granted at the database level applies to the database and to all objects in the database, such as tables and stored programs.
- The `host` table is used in conjunction with the `db` table when you want a given `db` table row to apply to several hosts. For example, if you want a user to be able to use a database from several hosts in your network, leave the `Host` value empty in the user's `db` table row, then populate the `host` table with a row for each of those hosts. This mechanism is described more detail in Section 6.2.5, “Access Control, Stage 2: Request Verification”.

Note

The `host` table must be modified directly with statements such as `INSERT`, `UPDATE`, and `DELETE`. It is not affected by statements such as `GRANT` and `REVOKE` that modify the grant tables indirectly. Most MySQL installations need not use this table at all.

- The `tables_priv` and `columns_priv` tables are similar to the `db` table, but are more fine-grained: They apply at the table and column levels rather than at the database level. A privilege granted at the table level applies to the table and to all its columns. A privilege granted at the column level applies only to a specific column.
- The `procs_priv` table applies to stored routines (procedures and functions). A privilege granted at the routine level applies only to a single procedure or function.
- The `proxies_priv` table indicates which users can act as proxies for other users and whether a user can grant the `PROXY` privilege to other users.

The server uses the `user`, `db`, and `host` tables in the `mysql` database at both the first and second stages of access control (see Section 6.2, “The MySQL Access Privilege System”). The columns in the `user` and `db` tables are shown here. The `host` table is similar to the `db` table but has a specialized use as described in Section 6.2.5, “Access Control, Stage 2: Request Verification”.

Table 6.3 user and db Table Columns

Table Name	`user`	`db`
Scope columns	`Host`	`Host`
	`User`	`Db`
	`Password`	`User`
Privilege columns	`Select_priv`	`Select_priv`
	`Insert_priv`	`Insert_priv`
	`Update_priv`	`Update_priv`
	`Delete_priv`	`Delete_priv`
	`Index_priv`	`Index_priv`
	`Alter_priv`	`Alter_priv`
	`Create_priv`	`Create_priv`
	`Drop_priv`	`Drop_priv`
	`Grant_priv`	`Grant_priv`
	`Create_view_priv`	`Create_view_priv`
	`Show_view_priv`	`Show_view_priv`
	`Create_routine_priv`	`Create_routine_priv`
	`Alter_routine_priv`	`Alter_routine_priv`
	`Execute_priv`	`Execute_priv`

Table Name	user	db
	Trigger_priv	Trigger_priv
	Event_priv	Event_priv
	Create_tmp_table_priv	Create_tmp_table_priv
	Lock_tables_priv	Lock_tables_priv
	References_priv	References_priv
	Reload_priv	
	Shutdown_priv	
	Process_priv	
	File_priv	
	Show_db_priv	
	Super_priv	
	Repl_slave_priv	
	Repl_client_priv	
	Create_user_priv	
	Create_tablespace_priv	
Security columns	ssl_type	
	ssl_cipher	
	x509_issuer	
	x509_subject	
	plugin	
	authentication_string	
Resource control columns	max_questions	
	max_updates	
	max_connections	
	max_user_connections	

The user table plugin, Password, and authentication_string columns store authentication plugin and credential information.

If an account row names a plugin in the plugin column, the server uses it to authenticate connection attempts for the account. It is up to the plugin whether it uses the Password and authentication_string column values.

If the plugin column for an account row is empty, the server authenticates the account using either the mysql_native_password or mysql_old_password plugin, depending on whether the password hash value in the Password column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the Password column of the account row.

Prior to MySQL 5.5.11, the length of the plugin column was 60 characters. This was increased to 64 characters in MySQL 5.5.11 for compatibility with the mysql.plugin table's name column. (Bug #11766610, Bug #59752)

During the second stage of access control, the server performs request verification to ensure that each client has sufficient privileges for each request that it issues. In addition to the user, db, and host grant tables, the server may also consult the tables_priv and columns_priv tables for requests that involve tables. The latter tables provide finer privilege control at the table and column levels. They have the columns shown in the following table.

Table 6.4 tables_priv and columns_priv Table Columns

Table Name	`tables_priv`	`columns_priv`
Scope columns	`Host`	`Host`
	`Db`	`Db`
	`User`	`User`
	`Table_name`	`Table_name`
		`Column_name`
Privilege columns	`Table_priv`	`Column_priv`
	`Column_priv`	
Other columns	`Timestamp`	`Timestamp`
	`Grantor`	

The `Timestamp` and `Grantor` columns are set to the current timestamp and the `CURRENT_USER` value, respectively, but are otherwise unused.

For verification of requests that involve stored routines, the server may consult the `procs_priv` table, which has the columns shown in the following table.

Table 6.5 procs_priv Table Columns

Table Name	`procs_priv`
Scope columns	`Host`
	`Db`
	`User`
	`Routine_name`
	`Routine_type`
Privilege columns	`Proc_priv`
Other columns	`Timestamp`
	`Grantor`

The `Routine_type` column is an `ENUM` column with values of `'FUNCTION'` or `'PROCEDURE'` to indicate the type of routine the row refers to. This column enables privileges to be granted separately for a function and a procedure with the same name.

The `Timestamp` and `Grantor` columns are unused.

The `proxies_priv` table records information about proxy accounts. It has these columns:

- `Host`, `User`: The proxy account; that is, the account that has the `PROXY` privilege for the proxied account.
- `Proxied_host`, `Proxied_user`: The proxied account.
- `Grantor`, `Timestamp`: Unused.
- `With_grant`: Whether the proxy account can grant the `PROXY` privilege to other accounts.

For an account to be able to grant the `PROXY` privilege to other accounts, it must have a row in the `proxies_priv` table with `With_grant` set to 1 and `Proxied_host` and `Proxied_user` set to indicate the account or accounts for which the privilege can be granted. For example, the `'root'@'localhost'` account created during MySQL installation has a row in the `proxies_priv` table that enables granting the `PROXY` privilege for `''@''`, that is, for all users and all hosts. This

enables `root` to set up proxy users, as well as to delegate to other accounts the authority to set up proxy users. See Section 6.3.7, “Proxy Users”.

Scope columns in the grant tables contain strings. The default value for each is the empty string. The following table shows the number of characters permitted in each column.

Table 6.6 Grant Table Scope Column Lengths

Column Name	Maximum Permitted Characters
`Host`, `Proxied_host`	60
`User`, `Proxied_user`	16
`Password`	41
`Db`	64
`Table_name`	64
`Column_name`	64
`Routine_name`	64

For access-checking purposes, comparisons of `User`, `Proxied_user`, `Password`, `Db`, and `Table_name` values are case sensitive. Comparisons of `Host`, `Proxied_host`, `Column_name`, and `Routine_name` values are not case sensitive.

The `user`, `db`, and `host` tables list each privilege in a separate column that is declared as `ENUM('N','Y') DEFAULT 'N'`. In other words, each privilege can be disabled or enabled, with the default being disabled.

The `tables_priv`, `columns_priv`, and `procs_priv` tables declare the privilege columns as `SET` columns. Values in these columns can contain any combination of the privileges controlled by the table. Only those privileges listed in the column value are enabled.

Table 6.7 Set-Type Privilege Column Values

Table Name	Column Name	Possible Set Elements
`tables_priv`	`Table_priv`	`'Select', 'Insert', 'Update', 'Delete', 'Create', 'Drop', 'Grant', 'References', 'Index', 'Alter', 'Create View', 'Show view', 'Trigger'`
`tables_priv`	`Column_priv`	`'Select', 'Insert', 'Update', 'References'`
`columns_priv`	`Column_priv`	`'Select', 'Insert', 'Update', 'References'`
`procs_priv`	`Proc_priv`	`'Execute', 'Alter Routine', 'Grant'`

Only the `user` table specifies administrative privileges, such as `RELOAD` and `SHUTDOWN`. Administrative operations are operations on the server itself and are not database-specific, so there is no reason to list these privileges in the other grant tables. Consequently, the server need consult only the `user` table to determine whether a user can perform an administrative operation.

The `FILE` privilege also is specified only in the `user` table. It is not an administrative privilege as such, but a user's ability to read or write files on the server host is independent of the database being accessed.

The server reads the contents of the grant tables into memory when it starts. You can tell it to reload the tables by issuing a `FLUSH PRIVILEGES` statement or executing a `mysqladmin flush-privileges` or `mysqladmin reload` command. Changes to the grant tables take effect as indicated in Section 6.2.6, “When Privilege Changes Take Effect”.

When you modify an account, it is a good idea to verify that your changes have the intended effect. To check the privileges for a given account, use the `SHOW GRANTS` statement. For example, to determine the privileges that are granted to an account with user name and host name values of `bob` and `pc84.example.com`, use this statement:

```
SHOW GRANTS FOR 'bob'@'pc84.example.com';
```

6.2.3 Specifying Account Names

MySQL account names consist of a user name and a host name. This enables creation of accounts for users with the same name who can connect from different hosts. This section describes how to write account names, including special values and wildcard rules.

In SQL statements such as `CREATE USER`, `GRANT`, and `SET PASSWORD`, account names follow these rules:

- Account name syntax is `'user_name'@'host_name'`.
- An account name consisting only of a user name is equivalent to `'user_name'@'%'`. For example, `'me'` is equivalent to `'me'@'%'`.
- The user name and host name need not be quoted if they are legal as unquoted identifiers. Quotes are necessary to specify a *`user_name`* string containing special characters (such as space or `-`), or a *`host_name`* string containing special characters or wildcard characters (such as `.` or `%`); for example, `'test-user'@'%.com'`.
- Quote user names and host names as identifiers or as strings, using either backticks (`` ` ``), single quotation marks (`'`), or double quotation marks (`"`). For string-quoting and identifier-quoting guidelines, see Section 9.1.1, “String Literals”, and Section 9.2, “Schema Object Names”.
- The user name and host name parts, if quoted, must be quoted separately. That is, write `'me'@'localhost'`, not `'me@localhost'`; the latter is actually equivalent to `'me@localhost'@'%'`.
- A reference to the `CURRENT_USER` or `CURRENT_USER()` function is equivalent to specifying the current client's user name and host name literally.

MySQL stores account names in grant tables in the `mysql` system database using separate columns for the user name and host name parts:

- The `user` table contains one row for each account. The `User` and `Host` columns store the user name and host name. This table also indicates which global privileges the account has.
- Other grant tables indicate privileges an account has for databases and objects within databases. These tables have `User` and `Host` columns to store the account name. Each row in these tables associates with the account in the `user` table that has the same `User` and `Host` values.
- For access-checking purposes, comparisons of User values are case sensitive. Comparisons of Host values are not case sensitive.

For additional detail about grant table structure, see Section 6.2.2, “Grant Tables”.

User names and host names have certain special values or wildcard conventions, as described following.

The user name part of an account name is either a nonblank value that literally matches the user name for incoming connection attempts, or a blank value (empty string) that matches any user name. An account with a blank user name is an anonymous user. To specify an anonymous user in SQL statements, use a quoted empty user name part, such as `''@'localhost'`.

The host name part of an account name can take many forms, and wildcards are permitted:

- A host value can be a host name or an IP address (IPv4 or IPv6). The name `'localhost'` indicates the local host. The IP address `'127.0.0.1'` indicates the IPv4 loopback interface. The IP address `'::1'` indicates the IPv6 loopback interface.

- The `%` and `_` wildcard characters are permitted in host name or IP address values. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator. For example, a host value of `'%'` matches any host name, whereas a value of `'%.mysql.com'` matches any host in the `mysql.com` domain. `'198.51.100.%'` matches any host in the 198.51.100 class C network.

  Because IP wildcard values are permitted in host values (for example, `'198.51.100.%'` to match every host on a subnet), someone could try to exploit this capability by naming a host `198.51.100.somewhere.com`. To foil such attempts, MySQL does not perform matching on host names that start with digits and a dot. For example, if a host is named `1.2.example.com`, its name never matches the host part of account names. An IP wildcard value can match only IP addresses, not host names.

- For a host value specified as an IPv4 address, a netmask can be given to indicate how many address bits to use for the network number. Netmask notation cannot be used for IPv6 addresses.

  The syntax is *`host_ip/netmask`*. For example:

  ```
  CREATE USER 'david'@'198.51.100.0/255.255.255.0';
  ```

  This enables `david` to connect from any client host having an IP address *`client_ip`* for which the following condition is true:

  ```
  client_ip & netmask = host_ip
  ```

  That is, for the `CREATE USER` statement just shown:

  ```
  client_ip & 255.255.255.0 = 198.51.100.0
  ```

  IP addresses that satisfy this condition range from `198.51.100.0` to `198.51.100.255`.

  A netmask typically begins with bits set to 1, followed by bits set to 0. Examples:

  - `198.0.0.0/255.0.0.0`: Any host on the 198 class A network
  - `198.51.100.0/255.255.0.0`: Any host on the 198.51 class B network
  - `198.51.100.0/255.255.255.0`: Any host on the 198.51.100 class C network
  - `198.51.100.1`: Only the host with this specific IP address

The server performs matching of host values in account names against the client host using the value returned by the system DNS resolver for the client host name or IP address. Except in the case that the account host value is specified using netmask notation, the server performs this comparison as a string match, even for an account host value given as an IP address. This means that you should specify account host values in the same format used by DNS. Here are examples of problems to watch out for:

- Suppose that a host on the local network has a fully qualified name of `host1.example.com`. If DNS returns name lookups for this host as `host1.example.com`, use that name in account host values. If DNS returns just `host1`, use `host1` instead.

- If DNS returns the IP address for a given host as `198.51.100.2`, that will match an account host value of `198.51.100.2` but not `198.051.100.2`. Similarly, it will match an account host pattern like `198.51.100.%` but not `198.051.100.%`.

To avoid problems like these, it is advisable to check the format in which your DNS returns host names and addresses. Use values in the same format in MySQL account names.

6.2.4 Access Control, Stage 1: Connection Verification

When you attempt to connect to a MySQL server, the server accepts or rejects the connection based on your identity and whether you can verify your identity by supplying the correct password. If not, the server denies access to you completely. Otherwise, the server accepts the connection, and then enters Stage 2 and waits for requests.

Credential checking is performed using the three `user` table scope columns (`Host`, `User`, and `Password`). The server accepts the connection only if the `Host` and `User` columns in some `user` table row match the client host name and user name and the client supplies the password specified in that row. The rules for permissible `Host` and `User` values are given in Section 6.2.3, “Specifying Account Names”.

Your identity is based on two pieces of information:

- The client host from which you connect
- Your MySQL user name

If the `User` column value is nonblank, the user name in an incoming connection must match exactly. If the `User` value is blank, it matches any user name. If the `user` table row that matches an incoming connection has a blank user name, the user is considered to be an anonymous user with no name, not a user with the name that the client actually specified. This means that a blank user name is used for all further access checking for the duration of the connection (that is, during Stage 2).

The `Password` column can be blank. This is not a wildcard and does not mean that any password matches. It means that the user must connect without specifying a password. If the server authenticates a client using a plugin, the authentication method that the plugin implements may or may not use the password in the `Password` column. In this case, it is possible that an external password is also used to authenticate to the MySQL server.

Nonblank `Password` values in the `user` table represent encrypted passwords. MySQL does not store passwords in cleartext form for anyone to see. Rather, the password supplied by a user who is attempting to connect is encrypted (using the `PASSWORD()` function). The encrypted password then is used during the connection process when checking whether the password is correct. This is done without the encrypted password ever traveling over the connection. See Section 6.3.1, “User Names and Passwords”.

From MySQL's point of view, the encrypted password is the *real* password, so you should never give anyone access to it. In particular, *do not give nonadministrative users read access to tables in the `mysql` database*.

The following table shows how various combinations of `User` and `Host` values in the `user` table apply to incoming connections.

`User` Value	`Host` Value	Permissible Connections
`'fred'`	`'h1.example.net'`	`fred`, connecting from `h1.example.net`
`''`	`'h1.example.net'`	Any user, connecting from `h1.example.net`
`'fred'`	`'%'`	`fred`, connecting from any host
`''`	`'%'`	Any user, connecting from any host
`'fred'`	`'%.example.net'`	`fred`, connecting from any host in the `example.net` domain
`'fred'`	`'x.example.%'`	`fred`, connecting from `x.example.net`, `x.example.com`, `x.example.edu`, and so on; this is probably not useful

`User` Value	`Host` Value	Permissible Connections
`'fred'`	`'198.51.100.177'`	`fred`, connecting from the host with IP address `198.51.100.177`
`'fred'`	`'198.51.100.%'`	`fred`, connecting from any host in the `198.51.100` class C subnet
`'fred'`	`'198.51.100.0/255.255.255.0'`	Same as previous example

It is possible for the client host name and user name of an incoming connection to match more than one row in the `user` table. The preceding set of examples demonstrates this: Several of the entries shown match a connection from `h1.example.net` by `fred`.

When multiple matches are possible, the server must determine which of them to use. It resolves this issue as follows:

- Whenever the server reads the `user` table into memory, it sorts the rows.
- When a client attempts to connect, the server looks through the rows in sorted order.
- The server uses the first row that matches the client host name and user name.

The server uses sorting rules that order rows with the most-specific `Host` values first. Literal host names and IP addresses are the most specific. (The specificity of a literal IP address is not affected by whether it has a netmask, so `198.51.100.13` and `198.51.100.0/255.255.255.0` are considered equally specific.) The pattern `'%'` means “any host” and is least specific. The empty string `''` also means “any host” but sorts after `'%'`. Rows with the same `Host` value are ordered with the most-specific `User` values first (a blank `User` value means “any user” and is least specific). For rows with equally-specific `Host` and `User` values, the order is indeterminate.

To see how this works, suppose that the `user` table looks like this:

```
+-----------+----------+-
| Host      | User     | ...
+-----------+----------+-
| %         | root     | ...
| %         | jeffrey  | ...
| localhost | root     | ...
| localhost |          | ...
+-----------+----------+-
```

When the server reads the table into memory, it sorts the rows using the rules just described. The result after sorting looks like this:

```
+-----------+----------+-
| Host      | User     | ...
+-----------+----------+-
| localhost | root     | ...
| localhost |          | ...
| %         | jeffrey  | ...
| %         | root     | ...
+-----------+----------+-
```

When a client attempts to connect, the server looks through the sorted rows and uses the first match found. For a connection from `localhost` by `jeffrey`, two of the rows from the table match: the one with `Host` and `User` values of `'localhost'` and `''`, and the one with values of `'%'` and `'jeffrey'`. The `'localhost'` row appears first in sorted order, so that is the one the server uses.

Here is another example. Suppose that the `user` table looks like this:

```
+----------------+----------+-
| Host           | User     | ...
```

```
+---------------+----------+-
| %             | jeffrey  | ...
| h1.example.net |          | ...
+---------------+----------+-
```

The sorted table looks like this:

```
+---------------+----------+-
| Host          | User     | ...
+---------------+----------+-
| h1.example.net |          | ...
| %             | jeffrey  | ...
+---------------+----------+-
```

A connection by `jeffrey` from `h1.example.net` is matched by the first row, whereas a connection by `jeffrey` from any host is matched by the second.

Note

It is a common misconception to think that, for a given user name, all rows that explicitly name that user are used first when the server attempts to find a match for the connection. This is not true. The preceding example illustrates this, where a connection from `h1.example.net` by `jeffrey` is first matched not by the row containing `'jeffrey'` as the `User` column value, but by the row with no user name. As a result, `jeffrey` is authenticated as an anonymous user, even though he specified a user name when connecting.

If you are able to connect to the server, but your privileges are not what you expect, you probably are being authenticated as some other account. To find out what account the server used to authenticate you, use the `CURRENT_USER()` function. (See Section 12.14, “Information Functions”.) It returns a value in *`user_name@host_name`* format that indicates the `User` and `Host` values from the matching `user` table row. Suppose that `jeffrey` connects and issues the following query:

```
mysql> SELECT CURRENT_USER();
+----------------+
| CURRENT_USER() |
+----------------+
| @localhost     |
+----------------+
```

The result shown here indicates that the matching `user` table row had a blank `User` column value. In other words, the server is treating `jeffrey` as an anonymous user.

Another way to diagnose authentication problems is to print out the `user` table and sort it by hand to see where the first match is being made.

6.2.5 Access Control, Stage 2: Request Verification

After you establish a connection, the server enters Stage 2 of access control. For each request that you issue through that connection, the server determines what operation you want to perform, then checks whether you have sufficient privileges to do so. This is where the privilege columns in the grant tables come into play. These privileges can come from any of the `user`, `db`, `host`, `tables_priv`, `columns_priv`, or `procs_priv` tables. (You may find it helpful to refer to Section 6.2.2, “Grant Tables”, which lists the columns present in each of the grant tables.)

The `user` table grants privileges that are assigned to you on a global basis and that apply no matter what the default database is. For example, if the `user` table grants you the `DELETE` privilege, you can delete rows from any table in any database on the server host! It is wise to grant privileges in the `user` table only to people who need them, such as database administrators. For other users, you should leave all privileges in the `user` table set to `'N'` and grant privileges at more specific levels only. You can grant privileges for particular databases, tables, columns, or routines.

The `db` and `host` tables grant database-specific privileges. Values in the scope columns of these tables can take the following forms:

- A blank `User` value in the `db` table matches the anonymous user. A nonblank value matches literally; there are no wildcards in user names.
- The wildcard characters `%` and `_` can be used in the `Host` and `Db` columns of either table. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator. If you want to use either character literally when granting privileges, you must escape it with a backslash. For example, to include the underscore character (_) as part of a database name, specify it as `\_` in the `GRANT` statement.
- A `'%'` `Host` value in the `db` table means “any host.” A blank `Host` value in the `db` table means “consult the `host` table for further information” (a process that is described later in this section).
- A `'%'` or blank `Host` value in the `host` table means “any host.”
- A `'%'` or blank `Db` value in either table means “any database.”

The server reads the `db` and `host` tables into memory and sorts them at the same time that it reads the `user` table. The server sorts the `db` table based on the `Host`, `Db`, and `User` scope columns, and sorts the `host` table based on the `Host` and `Db` scope columns. As with the `user` table, sorting puts the most-specific values first and least-specific values last, and when the server looks for matching rows, it uses the first match that it finds.

The `tables_priv`, `columns_priv`, and `procs_priv` tables grant table-specific, column-specific, and routine-specific privileges. Values in the scope columns of these tables can take the following forms:

- The wildcard characters `%` and `_` can be used in the `Host` column. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator.
- A `'%'` or blank `Host` value means “any host.”
- The `Db`, `Table_name`, `Column_name`, and `Routine_name` columns cannot contain wildcards or be blank.

The server sorts the `tables_priv`, `columns_priv`, and `procs_priv` tables based on the `Host`, `Db`, and `User` columns. This is similar to `db` table sorting, but simpler because only the `Host` column can contain wildcards.

The server uses the sorted tables to verify each request that it receives. For requests that require administrative privileges such as `SHUTDOWN` or `RELOAD`, the server checks only the `user` table row because that is the only table that specifies administrative privileges. The server grants access if the row permits the requested operation and denies access otherwise. For example, if you want to execute `mysqladmin shutdown` but your `user` table row does not grant the `SHUTDOWN` privilege to you, the server denies access without even checking the `db` or `host` tables. (They contain no `Shutdown_priv` column, so there is no need to do so.)

For database-related requests (`INSERT`, `UPDATE`, and so on), the server first checks the user's global privileges by looking in the `user` table row. If the row permits the requested operation, access is granted. If the global privileges in the `user` table are insufficient, the server determines the user's database-specific privileges by checking the `db` and `host` tables:

1. The server looks in the `db` table for a match on the `Host`, `Db`, and `User` columns. The `Host` and `User` columns are matched to the connecting user's host name and MySQL user name. The `Db` column is matched to the database that the user wants to access. If there is no row for the `Host` and `User`, access is denied.
2. If there is a matching `db` table row and its `Host` column is not blank, that row defines the user's database-specific privileges.

3. If the matching `db` table row's `Host` column is blank, it signifies that the `host` table enumerates which hosts should be permitted access to the database. In this case, a further lookup is done in the `host` table to find a match on the `Host` and `Db` columns. If no `host` table row matches, access is denied. If there is a match, the user's database-specific privileges are computed as the intersection (*not* the union!) of the privileges in the `db` and `host` table rows; that is, the privileges that are `'Y'` in both rows. (This way you can grant general privileges in the `db` table row and then selectively restrict them on a host-by-host basis using the `host` table rows.)

After determining the database-specific privileges granted by the `db` and `host` table rows, the server adds them to the global privileges granted by the `user` table. If the result permits the requested operation, access is granted. Otherwise, the server successively checks the user's table and column privileges in the `tables_priv` and `columns_priv` tables, adds those to the user's privileges, and permits or denies access based on the result. For stored-routine operations, the server uses the `procs_priv` table rather than `tables_priv` and `columns_priv`.

Expressed in boolean terms, the preceding description of how a user's privileges are calculated may be summarized like this:

```
global privileges
OR (database privileges AND host privileges)
OR table privileges
OR column privileges
OR routine privileges
```

It may not be apparent why, if the global `user` row privileges are initially found to be insufficient for the requested operation, the server adds those privileges to the database, table, and column privileges later. The reason is that a request might require more than one type of privilege. For example, if you execute an `INSERT INTO ... SELECT` statement, you need both the `INSERT` and the `SELECT` privileges. Your privileges might be such that the `user` table row grants one privilege and the `db` table row grants the other. In this case, you have the necessary privileges to perform the request, but the server cannot tell that from either table by itself; the privileges granted by the rows in both tables must be combined.

The `host` table is not affected by the `GRANT` or `REVOKE` statements, so it is unused in most MySQL installations. If you modify it directly, you can use it for some specialized purposes, such as to maintain a list of secure servers on the local network that are granted all privileges.

You can also use the `host` table to indicate hosts that are *not* secure. Suppose that you have a machine `public.example.org` that is located in a public area that you do not consider secure. You can enable access to all hosts on your network except that machine by using `host` table rows like this:

```
+--------------------+----+-
| Host               | Db | ...
+--------------------+----+-
| public.example.org | %  | ... (all privileges set to 'N')
| %.example.org      | %  | ... (all privileges set to 'Y')
+--------------------+----+-
```

6.2.6 When Privilege Changes Take Effect

When `mysqld` starts, it reads all grant table contents into memory. The in-memory tables become effective for access control at that point.

If you modify the grant tables indirectly using account-management statements such as `GRANT`, `REVOKE`, `SET PASSWORD`, or `RENAME USER`, the server notices these changes and loads the grant tables into memory again immediately.

If you modify the grant tables directly using statements such as `INSERT`, `UPDATE`, or `DELETE`, your changes have no effect on privilege checking until you either restart the server or tell it to reload

the tables. If you change the grant tables directly but forget to reload them, your changes have *no effect* until you restart the server. This may leave you wondering why your changes seem to make no difference!

To tell the server to reload the grant tables, perform a flush-privileges operation. This can be done by issuing a `FLUSH PRIVILEGES` statement or by executing a `mysqladmin flush-privileges` or `mysqladmin reload` command.

A grant table reload affects privileges for each existing client connection as follows:

- Table and column privilege changes take effect with the client's next request.
- Database privilege changes take effect the next time the client executes a `USE db_name` statement.

Note

Client applications may cache the database name; thus, this effect may not be visible to them without actually changing to a different database.

- Global privileges and passwords are unaffected for a connected client. These changes take effect only for subsequent connections.

If the server is started with the `--skip-grant-tables` option, it does not read the grant tables or implement any access control. Anyone can connect and do anything, *which is insecure.* To cause a server thus started to read the tables and enable access checking, flush the privileges.

6.2.7 Troubleshooting Problems Connecting to MySQL

If you encounter problems when you try to connect to the MySQL server, the following items describe some courses of action you can take to correct the problem.

- Make sure that the server is running. If it is not, clients cannot connect to it. For example, if an attempt to connect to the server fails with a message such as one of those following, one cause might be that the server is not running:

```
shell> mysql
ERROR 2003: Can't connect to MySQL server on 'host_name' (111)
shell> mysql
ERROR 2002: Can't connect to local MySQL server through socket
'/tmp/mysql.sock' (111)
```

- It might be that the server is running, but you are trying to connect using a TCP/IP port, named pipe, or Unix socket file different from the one on which the server is listening. To correct this when you invoke a client program, specify a `--port` option to indicate the proper port number, or a `--socket` option to indicate the proper named pipe or Unix socket file. To find out where the socket file is, you can use this command:

```
shell> netstat -ln | grep mysql
```

- Make sure that the server has not been configured to ignore network connections or (if you are attempting to connect remotely) that it has not been configured to listen only locally on its network interfaces. If the server was started with `--skip-networking`, it will not accept TCP/IP connections at all. If the server was started with `--bind-address=127.0.0.1`, it will listen for TCP/IP connections only locally on the loopback interface and will not accept remote connections.
- Check to make sure that there is no firewall blocking access to MySQL. Your firewall may be configured on the basis of the application being executed, or the port number used by MySQL for communication (3306 by default). Under Linux or Unix, check your IP tables (or similar) configuration to ensure that the port has not been blocked. Under Windows, applications such as ZoneAlarm or the Windows XP personal firewall may need to be configured not to block the MySQL port.

- The grant tables must be properly set up so that the server can use them for access control. For some distribution types (such as binary distributions on Windows, or RPM distributions on Linux), the installation process initializes the MySQL data directory, including the `mysql` database containing the grant tables. For distributions that do not do this, you must initialize the data directory manually. For details, see Section 2.10, “Postinstallation Setup and Testing”.

  To determine whether you need to initialize the grant tables, look for a `mysql` directory under the data directory. (The data directory normally is named `data` or `var` and is located under your MySQL installation directory.) Make sure that you have a file named `user.MYD` in the `mysql` database directory. If not, initialize the data directory. After doing so and starting the server, test the initial privileges by executing this command:

  ```
  shell> mysql -u root
  ```

  The server should let you connect without error.

- After a fresh installation, you should connect to the server and set up your users and their access permissions:

  ```
  shell> mysql -u root mysql
  ```

  The server should let you connect because the MySQL `root` user has no password initially. That is also a security risk, so setting the password for the `root` accounts is something you should do while you're setting up your other MySQL accounts. For instructions on setting the initial passwords, see Section 2.10.4, “Securing the Initial MySQL Accounts”.

- If you have updated an existing MySQL installation to a newer version, did you run the `mysql_upgrade` script? If not, do so. The structure of the grant tables changes occasionally when new capabilities are added, so after an upgrade you should always make sure that your tables have the current structure. For instructions, see Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

- If a client program receives the following error message when it tries to connect, it means that the server expects passwords in a newer format than the client is capable of generating:

  ```
  shell> mysql
  Client does not support authentication protocol requested
  by server; consider upgrading MySQL client
  ```

  For information on how to deal with this, see Section 6.1.2.4, “Password Hashing in MySQL”, and Section B.5.2.4, “Client does not support authentication protocol”.

- Remember that client programs use connection parameters specified in option files or environment variables. If a client program seems to be sending incorrect default connection parameters when you have not specified them on the command line, check any applicable option files and your environment. For example, if you get `Access denied` when you run a client without any options, make sure that you have not specified an old password in any of your option files!

  You can suppress the use of option files by a client program by invoking it with the `--no-defaults` option. For example:

  ```
  shell> mysqladmin --no-defaults -u root version
  ```

  The option files that clients use are listed in Section 4.2.6, “Using Option Files”. Environment variables are listed in Section 4.9, “MySQL Program Environment Variables”.

- If you get the following error, it means that you are using an incorrect `root` password:

  ```
  shell> mysqladmin -u root -pxxxx ver
  ```

```
Access denied for user 'root'@'localhost' (using password: YES)
```

If the preceding error occurs even when you have not specified a password, it means that you have an incorrect password listed in some option file. Try the `--no-defaults` option as described in the previous item.

For information on changing passwords, see Section 6.3.5, “Assigning Account Passwords”.

If you have lost or forgotten the `root` password, see Section B.5.3.2, “How to Reset the Root Password”.

- If you change a password by using `SET PASSWORD`, `INSERT`, or `UPDATE`, you must encrypt the password using the `PASSWORD()` function. If you do not use `PASSWORD()` for these statements, the password will not work. For example, the following statement assigns a password, but fails to encrypt it, so the user is not able to connect afterward:

  ```
  SET PASSWORD FOR 'abe'@'host_name' = 'eagle';
  ```

  Instead, set the password like this:

  ```
  SET PASSWORD FOR 'abe'@'host_name' = PASSWORD('eagle');
  ```

  The `PASSWORD()` function is unnecessary when you specify a password using the `CREATE USER` or `GRANT` statements or the `mysqladmin password` command. Each of those automatically uses `PASSWORD()` to encrypt the password. See Section 6.3.5, “Assigning Account Passwords”, and Section 13.7.1.1, “CREATE USER Syntax”.

- `localhost` is a synonym for your local host name, and is also the default host to which clients try to connect if you specify no host explicitly.

  You can use a `--host=127.0.0.1` option to name the server host explicitly. This will make a TCP/IP connection to the local `mysqld` server. You can also use TCP/IP by specifying a `--host` option that uses the actual host name of the local host. In this case, the host name must be specified in a `user` table row on the server host, even though you are running the client program on the same host as the server.

- The `Access denied` error message tells you who you are trying to log in as, the client host from which you are trying to connect, and whether you were using a password. Normally, you should have one row in the `user` table that exactly matches the host name and user name that were given in the error message. For example, if you get an error message that contains `using password: NO`, it means that you tried to log in without a password.

- If you get an `Access denied` error when trying to connect to the database with `mysql -u user_name`, you may have a problem with the `user` table. Check this by executing `mysql -u root mysql` and issuing this SQL statement:

  ```
  SELECT * FROM user;
  ```

  The result should include a row with the `Host` and `User` columns matching your client's host name and your MySQL user name.

- If the following error occurs when you try to connect from a host other than the one on which the MySQL server is running, it means that there is no row in the `user` table with a `Host` value that matches the client host:

  ```
  Host ... is not allowed to connect to this MySQL server
  ```

  You can fix this by setting up an account for the combination of client host name and user name that you are using when trying to connect.

If you do not know the IP address or host name of the machine from which you are connecting, you should put a row with `'%'` as the `Host` column value in the `user` table. After trying to connect from the client machine, use a `SELECT USER()` query to see how you really did connect. Then change the `'%'` in the `user` table row to the actual host name that shows up in the log. Otherwise, your system is left insecure because it permits connections from any host for the given user name.

On Linux, another reason that this error might occur is that you are using a binary MySQL version that is compiled with a different version of the `glibc` library than the one you are using. In this case, you should either upgrade your operating system or `glibc`, or download a source distribution of MySQL version and compile it yourself. A source RPM is normally trivial to compile and install, so this is not a big problem.

- If you specify a host name when trying to connect, but get an error message where the host name is not shown or is an IP address, it means that the MySQL server got an error when trying to resolve the IP address of the client host to a name:

```
shell> mysqladmin -u root -pxxxx -h some_hostname ver
Access denied for user 'root'@'' (using password: YES)
```

If you try to connect as `root` and get the following error, it means that you do not have a row in the `user` table with a `User` column value of `'root'` and that `mysqld` cannot resolve the host name for your client:

```
Access denied for user ''@'unknown'
```

These errors indicate a DNS problem. To fix it, execute `mysqladmin flush-hosts` to reset the internal DNS host cache. See Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”.

Some permanent solutions are:

- Determine what is wrong with your DNS server and fix it.
- Specify IP addresses rather than host names in the MySQL grant tables.
- Put an entry for the client machine name in `/etc/hosts` on Unix or `\windows\hosts` on Windows.
- Start `mysqld` with the `--skip-name-resolve` option.
- Start `mysqld` with the `--skip-host-cache` option.
- On Unix, if you are running the server and the client on the same machine, connect to `localhost`. For connections to `localhost`, MySQL programs attempt to connect to the local server by using a Unix socket file, unless there are connection parameters specified to ensure that the client makes a TCP/IP connection. For more information, see Section 4.2.2, “Connecting to the MySQL Server”.
- On Windows, if you are running the server and the client on the same machine and the server supports named pipe connections, connect to the host name `.` (period). Connections to `.` use a named pipe rather than TCP/IP.

- If `mysql -u root` works but `mysql -h your_hostname -u root` results in `Access denied` (where *`your_hostname`* is the actual host name of the local host), you may not have the correct name for your host in the `user` table. A common problem here is that the `Host` value in the `user` table row specifies an unqualified host name, but your system's name resolution routines return a fully qualified domain name (or vice versa). For example, if you have a row with host `'pluto'` in the `user` table, but your DNS tells MySQL that your host name is `'pluto.example.com'`, the row does not work. Try adding a row to the `user` table that contains the IP address of your host as the `Host` column value. (Alternatively, you could add a row to the `user` table with a `Host` value

that contains a wildcard; for example, `'pluto.%'`. However, use of `Host` values ending with `%` is *insecure* and is *not* recommended!)

- If `mysql -u user_name` works but `mysql -u user_name some_db` does not, you have not granted access to the given user for the database named *`some_db`*.
- If `mysql -u user_name` works when executed on the server host, but `mysql -h host_name -u user_name` does not work when executed on a remote client host, you have not enabled access to the server for the given user name from the remote host.
- If you cannot figure out why you get `Access denied`, remove from the `user` table all rows that have `Host` values containing wildcards (rows that contain `'%'` or `'_'` characters). A very common error is to insert a new row with `Host='%'` and `User='some_user'`, thinking that this enables you to specify `localhost` to connect from the same machine. The reason that this does not work is that the default privileges include a row with `Host='localhost'` and `User=''`. Because that row has a `Host` value `'localhost'` that is more specific than `'%'`, it is used in preference to the new row when connecting from `localhost`! The correct procedure is to insert a second row with `Host='localhost'` and `User='some_user'`, or to delete the row with `Host='localhost'` and `User=''`. After deleting the row, remember to issue a `FLUSH PRIVILEGES` statement to reload the grant tables. See also Section 6.2.4, “Access Control, Stage 1: Connection Verification”.
- If you are able to connect to the MySQL server, but get an `Access denied` message whenever you issue a `SELECT ... INTO OUTFILE` or `LOAD DATA INFILE` statement, your row in the `user` table does not have the `FILE` privilege enabled.
- If you change the grant tables directly (for example, by using `INSERT`, `UPDATE`, or `DELETE` statements) and your changes seem to be ignored, remember that you must execute a `FLUSH PRIVILEGES` statement or a `mysqladmin flush-privileges` command to cause the server to reload the privilege tables. Otherwise, your changes have no effect until the next time the server is restarted. Remember that after you change the `root` password with an `UPDATE` statement, you will not need to specify the new password until after you flush the privileges, because the server will not know you've changed the password yet!
- If your privileges seem to have changed in the middle of a session, it may be that a MySQL administrator has changed them. Reloading the grant tables affects new client connections, but it also affects existing connections as indicated in Section 6.2.6, “When Privilege Changes Take Effect”.
- If you have access problems with a Perl, PHP, Python, or ODBC program, try to connect to the server with `mysql -u user_name db_name` or `mysql -u user_name -pyour_pass db_name`. If you are able to connect using the `mysql` client, the problem lies with your program, not with the access privileges. (There is no space between `-p` and the password; you can also use the `--password=your_pass` syntax to specify the password. If you use the `-p` or `--password` option with no password value, MySQL prompts you for the password.)
- For testing purposes, start the `mysqld` server with the `--skip-grant-tables` option. Then you can change the MySQL grant tables and use the `mysqlaccess` script to check whether your modifications have the desired effect. When you are satisfied with your changes, execute `mysqladmin flush-privileges` to tell the `mysqld` server to reload the privileges. This enables you to begin using the new grant table contents without stopping and restarting the server.
- If you get the following error, you may have a problem with the `db` or `host` table:

```
Access to database denied
```

  If the row selected from the `db` table has an empty value in the `Host` column, make sure that there are one or more corresponding rows in the `host` table specifying which hosts the `db` table row applies to. This problem occurs infrequently because the `host` table is rarely used.

- If everything else fails, start the `mysqld` server with a debugging option (for example, `--debug=d,general,query`). This prints host and user information about attempted connections, as well as information about each command issued. See Section 24.5.3, “The DBUG Package”.
- If you have any other problems with the MySQL grant tables and feel you must post the problem to the mailing list, always provide a dump of the MySQL grant tables. You can dump the tables with the `mysqldump mysql` command. To file a bug report, see the instructions at Section 1.6, “How to Report Bugs or Problems”. In some cases, you may need to restart `mysqld` with `--skip-grant-tables` to run `mysqldump`.

6.3 MySQL User Account Management

This section describes how to set up accounts for clients of your MySQL server. It discusses the following topics:

- The meaning of account names and passwords as used in MySQL and how that compares to names and passwords used by your operating system
- How to set up new accounts and remove existing accounts
- How to change passwords
- Guidelines for using passwords securely

See also Section 13.7.1, “Account Management Statements”, which describes the syntax and use for all user-management SQL statements.

6.3.1 User Names and Passwords

MySQL stores accounts in the `user` table of the `mysql` system database. An account is defined in terms of a user name and the client host or hosts from which the user can connect to the server. For information about account representation in the `user` table, see Section 6.2.2, “Grant Tables”.

The account may also have a password. MySQL supports authentication plugins, so it is possible that an account authenticates using some external authentication method. See Section 6.3.6, “Pluggable Authentication”.

There are several distinctions between the way user names and passwords are used by MySQL and your operating system:

- User names, as used by MySQL for authentication purposes, have nothing to do with user names (login names) as used by Windows or Unix. On Unix, most MySQL clients by default try to log in using the current Unix user name as the MySQL user name, but that is for convenience only. The default can be overridden easily, because client programs permit any user name to be specified with a `-u` or `--user` option. This means that anyone can attempt to connect to the server using any user name, so you cannot make a database secure in any way unless all MySQL accounts have passwords. Anyone who specifies a user name for an account that has no password is able to connect successfully to the server.
- MySQL user names can be up to 16 characters long. Operating system user names may be of a different maximum length. For example, Unix user names typically are limited to eight characters.

Warning

The limit on MySQL user name length is hardcoded in MySQL servers and clients, and trying to circumvent it by modifying the definitions of the tables in the `mysql` database *does not work*.

You should never alter the structure of tables in the `mysql` database in any manner whatsoever except by means of the procedure that is described in Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

> Attempting to redefine MySQL's system tables in any other fashion results in undefined (and unsupported!) behavior. The server is free to ignore rows that become malformed as a result of such modifications.

- To authenticate client connections for accounts that use MySQL native authentication (implemented by the `mysql_native_password` authentication plugin), the server uses passwords stored in the `user` table. These passwords are distinct from passwords for logging in to your operating system. There is no necessary connection between the “external” password you use to log in to a Windows or Unix machine and the password you use to access the MySQL server on that machine.

  If the server authenticates a client using some other plugin, the authentication method that the plugin implements may or may not use a password stored in the `user` table. In this case, it is possible that an external password is also used to authenticate to the MySQL server.

- Passwords stored in the `user` table are encrypted using plugin-specific algorithms. For information about MySQL native password hashing, see Section 6.1.2.4, “Password Hashing in MySQL”.

- If the user name and password contain only ASCII characters, it is possible to connect to the server regardless of character set settings. To connect when the user name or password contain non-ASCII characters, the client should call the `mysql_options()` C API function with the `MYSQL_SET_CHARSET_NAME` option and appropriate character set name as arguments. This causes authentication to take place using the specified character set. Otherwise, authentication will fail unless the server default character set is the same as the encoding in the authentication defaults.

  Standard MySQL client programs support a `--default-character-set` option that causes `mysql_options()` to be called as just described. In addition, character set autodetection is supported as described in Section 10.1.4, “Connection Character Sets and Collations”. For programs that use a connector that is not based on the C API, the connector may provide an equivalent to `mysql_options()` that can be used instead. Check the connector documentation.

  The preceding notes do not apply for `ucs2`, `utf16`, and `utf32`, which are not permitted as client character sets.

The MySQL installation process populates the grant tables with an initial account or accounts. The names and access privileges for these accounts are described in Section 2.10.4, “Securing the Initial MySQL Accounts”, which also discusses how to assign passwords to them. Thereafter, you normally set up, modify, and remove MySQL accounts using statements such as `CREATE USER`, `DROP USER`, `GRANT`, and `REVOKE`. See Section 13.7.1, “Account Management Statements”.

To connect to a MySQL server with a command-line client, specify user name and password options as necessary for the account that you want to use:

```
shell> mysql --user=finley --password db_name
```

If you prefer short options, the command looks like this:

```
shell> mysql -u finley -p db_name
```

If you omit the password value following the `--password` or `-p` option on the command line (as just shown), the client prompts for one. Alternatively, the password can be specified on the command line:

```
shell> mysql --user=finley --password=password db_name
shell> mysql -u finley -ppassword db_name
```

If you use the `-p` option, there must be *no space* between `-p` and the following password value.

Specifying a password on the command line should be considered insecure. See Section 6.1.2.1, “End-User Guidelines for Password Security”. You can use an option file to avoid giving the password on the command line. See Section 4.2.6, “Using Option Files”.

For additional information about specifying user names, passwords, and other connection parameters, see Section 4.2.2, “Connecting to the MySQL Server”.

6.3.2 Adding User Accounts

You can create MySQL accounts two ways:

- By using account-management statements intended for creating accounts and establishing their privileges, such as `CREATE USER` and `GRANT`. These statements cause the server to make appropriate modifications to the underlying grant tables.
- By manipulating the MySQL grant tables directly with statements such as `INSERT`, `UPDATE`, or `DELETE`.

The preferred method is to use account-management statements because they are more concise and less error-prone than manipulating the grant tables directly. All such statements are described in Section 13.7.1, “Account Management Statements”. Direct grant table manipulation is discouraged, and is not described here. The server is free to ignore rows that become malformed as a result of such modifications.

Another option for creating accounts is to use the GUI tool MySQL Workbench. Also, several third-party programs offer capabilities for MySQL account administration. `phpMyAdmin` is one such program.

The following examples show how to use the `mysql` client program to set up new accounts. These examples assume that privileges have been set up according to the defaults described in Section 2.10.4, “Securing the Initial MySQL Accounts”. This means that to make changes, you must connect to the MySQL server as the MySQL `root` user, which has the `CREATE USER` privilege.

First, use the `mysql` program to connect to the server as the MySQL `root` user:

```
shell> mysql --user=root mysql
```

If you have assigned a password to the `root` account, you must also supply a `--password` or `-p` option.

After connecting to the server as `root`, you can add new accounts. The following example uses `CREATE USER` and `GRANT` statements to set up four accounts:

```
mysql> CREATE USER 'finley'@'localhost' IDENTIFIED BY 'password';
mysql> GRANT ALL PRIVILEGES ON *.* TO 'finley'@'localhost'
    ->     WITH GRANT OPTION;
mysql> CREATE USER 'finley'@'%' IDENTIFIED BY 'password';
mysql> GRANT ALL PRIVILEGES ON *.* TO 'finley'@'%'
    ->     WITH GRANT OPTION;
mysql> CREATE USER 'admin'@'localhost' IDENTIFIED BY 'password';
mysql> GRANT RELOAD,PROCESS ON *.* TO 'admin'@'localhost';
mysql> CREATE USER 'dummy'@'localhost';
```

The accounts created by those statements have the following properties:

- Two accounts have a user name of `finley`. Both are superuser accounts with full privileges to do anything. The `'finley'@'localhost'` account can be used only when connecting from the local host. The `'finley'@'%'` account uses the `'%'` wildcard for the host part, so it can be used to connect from any host.

  The `'finley'@'localhost'` account is necessary if there is an anonymous-user account for `localhost`. Without the `'finley'@'localhost'` account, that anonymous-user account takes precedence when `finley` connects from the local host and `finley` is treated as an anonymous user. The reason for this is that the anonymous-user account has a more specific `Host` column value than the `'finley'@'%'` account and thus comes earlier in the `user` table sort order. (`user` table sorting is discussed in Section 6.2.4, “Access Control, Stage 1: Connection Verification”.)

- The `'admin'@'localhost'` account can be used only by `admin` to connect from the local host. It is granted the `RELOAD` and `PROCESS` administrative privileges. These privileges enable the `admin` user to execute the `mysqladmin reload`, `mysqladmin refresh`, and `mysqladmin flush-xxx` commands, as well as `mysqladmin processlist` . No privileges are granted for accessing any databases. You could add such privileges using `GRANT` statements.

- The `'dummy'@'localhost'` account has no password (which is insecure and not recommended). This account can be used only to connect from the local host. No privileges are granted. It is assumed that you will grant specific privileges to the account using `GRANT` statements.

To see the privileges for an account, use `SHOW GRANTS`:

```
mysql> SHOW GRANTS FOR 'admin'@'localhost';
+-----------------------------------------------------+
| Grants for admin@localhost                          |
+-----------------------------------------------------+
| GRANT RELOAD, PROCESS ON *.* TO 'admin'@'localhost' |
+-----------------------------------------------------+
```

The next examples create three accounts and grant them access to specific databases. Each of them has a user name of `custom` and password of *`password`*:

```
mysql> CREATE USER 'custom'@'localhost' IDENTIFIED BY 'password';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON bankaccount.*
    ->     TO 'custom'@'localhost';
mysql> CREATE USER 'custom'@'host47.example.com' IDENTIFIED BY 'password';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON expenses.*
    ->     TO 'custom'@'host47.example.com';
mysql> CREATE USER 'custom'@'%.example.com' IDENTIFIED BY 'password';
mysql> GRANT SELECT,INSERT,UPDATE,DELETE,CREATE,DROP
    ->     ON customer.*
    ->     TO 'custom'@'%.example.com';
```

The three accounts can be used as follows:

- The first account can access the `bankaccount` database, but only from the local host.

- The second account can access the `expenses` database, but only from the host `host47.example.com`.

- The third account can access the `customer` database, from any host in the `example.com` domain. This account has access from all machines in the domain due to use of the `%` wildcard character in the host part of the account name.

6.3.3 Removing User Accounts

To remove an account, use the `DROP USER` statement, which is described in Section 13.7.1.2, “DROP USER Syntax”. For example:

```
mysql> DROP USER 'jeffrey'@'localhost';
```

6.3.4 Setting Account Resource Limits

One means of restricting client use of MySQL server resources is to set the global `max_user_connections` system variable to a nonzero value. This limits the number of simultaneous connections that can be made by any given account, but places no limits on what a client can do once connected. In addition, setting `max_user_connections` does not enable management of individual accounts. Both types of control are of interest to MySQL administrators.

To address such concerns, MySQL permits limits for individual accounts on use of these server resources:

- The number of queries an account can issue per hour
- The number of updates an account can issue per hour
- The number of times an account can connect to the server per hour
- The number of simultaneous connections to the server by an account

Any statement that a client can issue counts against the query limit, unless its results are served from the query cache. Only statements that modify databases or tables count against the update limit.

An “account” in this context corresponds to a row in the `mysql.user` table. That is, a connection is assessed against the `User` and `Host` values in the `user` table row that applies to the connection. For example, an account `'usera'@'%.example.com'` corresponds to a row in the `user` table that has `User` and `Host` values of `usera` and `%.example.com`, to permit `usera` to connect from any host in the `example.com` domain. In this case, the server applies resource limits in this row collectively to all connections by `usera` from any host in the `example.com` domain because all such connections use the same account.

Before MySQL 5.0.3, an “account” was assessed against the actual host from which a user connects. This older method of accounting may be selected by starting the server with the `--old-style-user-limits` option. In this case, if `usera` connects simultaneously from `host1.example.com` and `host2.example.com`, the server applies the account resource limits separately to each connection. If `usera` connects again from `host1.example.com`, the server applies the limits for that connection together with the existing connection from that host.

To establish resource limits for an account, use the `GRANT` statement (see Section 13.7.1.3, “GRANT Syntax”). Provide a `WITH` clause that names each resource to be limited. The default value for each limit is zero (no limit). For example, to create a new account that can access the `customer` database, but only in a limited fashion, issue these statements:

```
mysql> CREATE USER 'francis'@'localhost' IDENTIFIED BY 'frank';
mysql> GRANT ALL ON customer.* TO 'francis'@'localhost'
    ->     WITH MAX_QUERIES_PER_HOUR 20
    ->          MAX_UPDATES_PER_HOUR 10
    ->          MAX_CONNECTIONS_PER_HOUR 5
    ->          MAX_USER_CONNECTIONS 2;
```

The limit types need not all be named in the `WITH` clause, but those named can be present in any order. The value for each per-hour limit should be an integer representing a count per hour. For `MAX_USER_CONNECTIONS`, the limit is an integer representing the maximum number of simultaneous connections by the account. If this limit is set to zero, the global `max_user_connections` system variable value determines the number of simultaneous connections. If `max_user_connections` is also zero, there is no limit for the account.

To modify limits for an existing account, use a `GRANT USAGE` statement at the global level (`ON *.*`). The following statement changes the query limit for `francis` to 100:

```
mysql> GRANT USAGE ON *.* TO 'francis'@'localhost'
    ->     WITH MAX_QUERIES_PER_HOUR 100;
```

The statement modifies only the limit value specified and leaves the account otherwise unchanged.

To remove a limit, set its value to zero. For example, to remove the limit on how many times per hour `francis` can connect, use this statement:

```
mysql> GRANT USAGE ON *.* TO 'francis'@'localhost'
    ->     WITH MAX_CONNECTIONS_PER_HOUR 0;
```

As mentioned previously, the simultaneous-connection limit for an account is determined from the MAX_USER_CONNECTIONS limit and the max_user_connections system variable. Suppose that the global max_user_connections value is 10 and three accounts have individual resource limits specified as follows:

```
GRANT ... TO 'user1'@'localhost' WITH MAX_USER_CONNECTIONS 0;
GRANT ... TO 'user2'@'localhost' WITH MAX_USER_CONNECTIONS 5;
GRANT ... TO 'user3'@'localhost' WITH MAX_USER_CONNECTIONS 20;
```

user1 has a connection limit of 10 (the global max_user_connections value) because it has a MAX_USER_CONNECTIONS limit of zero. user2 and user3 have connection limits of 5 and 20, respectively, because they have nonzero MAX_USER_CONNECTIONS limits.

The server stores resource limits for an account in the user table row corresponding to the account. The max_questions, max_updates, and max_connections columns store the per-hour limits, and the max_user_connections column stores the MAX_USER_CONNECTIONS limit. (See Section 6.2.2, “Grant Tables”.)

Resource-use counting takes place when any account has a nonzero limit placed on its use of any of the resources.

As the server runs, it counts the number of times each account uses resources. If an account reaches its limit on number of connections within the last hour, the server rejects further connections for the account until that hour is up. Similarly, if the account reaches its limit on the number of queries or updates, the server rejects further queries or updates until the hour is up. In all such cases, the server issues appropriate error messages.

Resource counting occurs per account, not per client. For example, if your account has a query limit of 50, you cannot increase your limit to 100 by making two simultaneous client connections to the server. Queries issued on both connections are counted together.

The current per-hour resource-use counts can be reset globally for all accounts, or individually for a given account:

- To reset the current counts to zero for all accounts, issue a FLUSH USER_RESOURCES statement. The counts also can be reset by reloading the grant tables (for example, with a FLUSH PRIVILEGES statement or a mysqladmin reload command).
- The counts for an individual account can be reset to zero by setting any of its limits again. Specify a limit value equal to the value currently assigned to the account.

Per-hour counter resets do not affect the MAX_USER_CONNECTIONS limit.

All counts begin at zero when the server starts. Counts do not carry over through server restarts.

For the MAX_USER_CONNECTIONS limit, an edge case can occur if the account currently has open the maximum number of connections permitted to it: A disconnect followed quickly by a connect can result in an error (ER_TOO_MANY_USER_CONNECTIONS or ER_USER_LIMIT_REACHED) if the server has not fully processed the disconnect by the time the connect occurs. When the server finishes disconnect processing, another connection will once more be permitted.

6.3.5 Assigning Account Passwords

Required credentials for clients that connect to the MySQL server can include a password. This section describes how to assign passwords for MySQL accounts.

MySQL stores credentials in the user table in the mysql system database. Operations that assign or modify passwords are permitted only to users with the CREATE USER privilege, or, alternatively, privileges for the mysql database (INSERT privilege to create new accounts, UPDATE privilege to modify existing accounts). If the read_only system variable is enabled, use of account-modification statements such as CREATE USER or SET PASSWORD additionally requires the SUPER privilege.

The discussion here summarizes syntax only for the most common password-assignment statements. For complete details on other possibilities, see Section 13.7.1.1, “CREATE USER Syntax”, Section 13.7.1.3, “GRANT Syntax”, and Section 13.7.1.6, “SET PASSWORD Syntax”.

MySQL uses plugins to perform client authentication; see Section 6.3.6, “Pluggable Authentication”. In password-assigning statements, the authentication plugin associated with an account performs any hashing required of a cleartext password specified. This enables MySQL to obfuscate passwords prior to storing them in the `mysql.user` table. For most statements described here, MySQL automatically hashes the password specified. An exception is `SET PASSWORD ... = PASSWORD('auth_string')`, for which you use the `PASSWORD()` function explicitly to hash the password. There are also syntaxes for `CREATE USER`, `GRANT`, and `SET PASSWORD` that permit hashed values to be specified literally. For details, see the descriptions of those statements.

To assign a password when you create a new account, use `CREATE USER` and include an `IDENTIFIED BY` clause:

```
CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'password';
```

`CREATE USER` also supports syntax for specifying the account authentication plugin. See Section 13.7.1.1, “CREATE USER Syntax”.

To assign or change a password for an existing account, use `SET PASSWORD` with the `PASSWORD()` function:

```
SET PASSWORD FOR 'jeffrey'@'localhost' = PASSWORD('password');
```

If you are not connected as an anonymous user, you can change your own password by omitting the `FOR` clause:

```
SET PASSWORD = PASSWORD('password');
```

The `PASSWORD()` function hashes the password using the hashing method determined by the value of the `old_passwords` system variable value. If `SET PASSWORD` rejects the hashed password value returned by `PASSWORD()` as not being in the correct format, it may be necessary to change `old_passwords` to change the hashing method. See Section 13.7.1.6, “SET PASSWORD Syntax”.

Use a `GRANT USAGE` statement at the global level (`ON *.*`) to change an account password without affecting the account's current privileges:

```
GRANT USAGE ON *.* TO 'jeffrey'@'localhost' IDENTIFIED BY 'password';
```

To change an account password from the command line, use the `mysqladmin` command:

```
mysqladmin -u user_name -h host_name password "password"
```

The account for which this command sets the password is the one with a `mysql.user` table row that matches *`user_name`* in the `User` column and the client host *from which you connect* in the `Host` column.

Warning

Setting a password using `mysqladmin` should be considered *insecure*. On some systems, your password becomes visible to system status programs such as `ps` that may be invoked by other users to display command lines. MySQL clients typically overwrite the command-line password argument with zeros during their initialization sequence. However, there is still a brief interval during which the value is visible. Also, on some systems this overwriting strategy is ineffective and the password remains visible to `ps`. (SystemV Unix systems and perhaps others are subject to this problem.)

If you are using MySQL Replication, be aware that, currently, a password used by a replication slave as part of a `CHANGE MASTER TO` statement is effectively limited to 32 characters in length; if the password is longer, any excess characters are truncated. This is not due to any limit imposed by the MySQL Server generally, but rather is an issue specific to MySQL Replication. (For more information, see Bug #43439.)

6.3.6 Pluggable Authentication

When a client connects to the MySQL server, the server uses the user name provided by the client and the client host to select the appropriate account row from the `mysql.user` table. The server then consults this row to authenticate the client.

Before MySQL 5.5.7, the server authenticates the password provided by the client against the `Password` column of the account row.

As of MySQL 5.5.7, the server authenticates clients using a plugin. Selection of the proper account row from the `mysql.user` table is based on the user name and client host, as before, but the server authenticates the client by determining from the account row which authentication plugin applies to the client:

- If the account row specifies a plugin, the server invokes it to authenticate the user. If the server cannot find the plugin, an error occurs and the connection attempt is rejected.
- If the account row specifies no plugin name, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row.

The plugin returns a status to the server indicating whether the user is permitted to connect.

Pluggable authentication enables two important capabilities:

- **External authentication:** Pluggable authentication makes it possible for clients to connect to the MySQL server with credentials that are appropriate for authentication methods that store credentials elsewhere than in the `mysql.user` table. For example, plugins can be created to use external authentication methods such as PAM, Windows login IDs, LDAP, or Kerberos.
- **Proxy users:** If a user is permitted to connect, an authentication plugin can return to the server a user name different from the name of the connecting user, to indicate that the connecting user is a proxy for another user (the proxied user). While the connection lasts, the proxy user is treated, for purposes of access control, as having the privileges of the proxied user. In effect, one user impersonates another. For more information, see Section 6.3.7, “Proxy Users”.

Several authentication plugins are available in MySQL:

- Plugins that perform native authentication; that is, authentication based on the password hashing methods in use from before the introduction of pluggable authentication in MySQL. The `mysql_native_password` plugin implements authentication based on the native password hashing method. The `mysql_old_password` plugin implements native authentication based on the older (pre-4.1) password hashing method. See Section 6.5.1.1, “Native Pluggable Authentication”, and Section 6.5.1.2, “Old Native Pluggable Authentication”. Native authentication using `mysql_native_password` is the default for accounts that have no plugin named explicitly in their account row.
- A client-side plugin that sends the password to the server without hashing or encryption. This plugin is used in conjunction with server-side plugins that require access to the password exactly as provided by the client user. See Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”.
- A plugin that performs external authentication using PAM (Pluggable Authentication Modules), enabling MySQL Server to use PAM to authenticate MySQL users. This plugin supports proxy users as well. See Section 6.5.1.4, “PAM Pluggable Authentication”.

- A plugin that performs external authentication on Windows, enabling MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password. This plugin supports proxy users as well. See Section 6.5.1.5, “Windows Pluggable Authentication”.
- A plugin that authenticates clients that connect from the local host through the Unix socket file. See Section 6.5.1.6, “Socket Peer-Credential Pluggable Authentication”.
- A test plugin that checks account credentials and logs success or failure to the server error log. This plugin is intended for testing and development purposes, and as an example of how to write an authentication plugin. See Section 6.5.1.7, “Test Pluggable Authentication”.

Note

For information about current restrictions on the use of pluggable authentication, including which connectors support which plugins, see Section C.9, “Restrictions on Pluggable Authentication”.

Third-party connector developers should read that section to determine the extent to which a connector can take advantage of pluggable authentication capabilities and what steps to take to become more compliant.

If you are interested in writing your own authentication plugins, see Section 24.2.4.9, “Writing Authentication Plugins”.

Authentication Plugin Usage Instructions

This section provides general instructions for installing and using authentication plugins. For instructions specific to a given plugin, see the section that describes that plugin.

In general, pluggable authentication uses corresponding plugins on the server and client sides, so you use a given authentication method like this:

- If necessary, install the plugin library or libraries containing the appropriate plugins. On the server host, install the library containing the server-side plugin, so that the server can use it to authenticate client connections. Similarly, on each client host, install the library containing the client-side plugin for use by client programs. Authentication plugins that are built in need not be installed.
- For each MySQL account that you create, specify the appropriate server-side plugin to use for authentication.
- When a client connects, the server-side plugin tells the client program which client-side plugin to use for authentication.

In the case that an account uses an authentication method that is the default for both the server and the client program, the server need not communicate to the client which client-side plugin to use, and a round trip in client/server negotiation can be avoided. This is true for accounts that use native MySQL authentication (`mysql_native_password` or `mysql_old_password`).

The `--default-auth=`*`plugin_name`* option can be specified on the `mysql` command line as a hint about which client-side plugin the program can expect to use, although the server will override this if the server-side plugin associated with the user account requires a different client-side plugin.

If the client program does not find the client-side plugin, specify a `--plugin-dir=`*`dir_name`* option to indicate where the plugin is located.

Note

If you start the server with the `--skip-grant-tables` option, authentication plugins are not used even if loaded because the server performs no client

authentication and permits any client to connect. Because this is insecure, you might want to use `--skip-grant-tables` in conjunction with `--skip-networking` to prevent remote clients from connecting.

6.3.7 Proxy Users

The MySQL server authenticates client connections using authentication plugins. The plugin that authenticates a given connection may request that the connecting (external) user be treated as a different user for privilege-checking purposes. This enables the external user to be a proxy for the second user; that is, to assume the privileges of the second user:

- The external user is a “proxy user” (a user who can impersonate or become known as another user).
- The second user is a “proxied user” (a user whose identity and privileges can be assumed by a proxy user).

This section describes how the proxy user capability works. For general information about authentication plugins, see Section 6.3.6, “Pluggable Authentication”. For information about specific plugins, see Section 6.5.1, “Authentication Plugins”. For information about writing authentication plugins that support proxy users, see Implementing Proxy User Support in Authentication Plugins.

- Requirements for Proxy User Support
- Granting the Proxy Privilege
- Default Proxy Users
- Default Proxy User and Anonymous User Conflicts
- Proxy User System Variables

Requirements for Proxy User Support

For proxying to occur for a given authentication plugin, these conditions must be satisfied:

- The plugin must support proxying.
- The proxy user account must be set up to be authenticated by the plugin. Use the `CREATE USER` or `GRANT` statement to associate an account with an authentication plugin.
- The proxied user account must be created and granted the privileges to be assumed by the proxy user. Use the `CREATE USER` and `GRANT` statements for this.
- The proxy user account must have the `PROXY` privilege for the proxied account. Use the `GRANT` statement for this.
- For a client connecting to the proxy account to be treated as a proxy user, the authentication plugin must return a user name different from the client user name, to indicate the user name of the proxied account that defines the privileges to be assumed by the proxy user.

The proxy mechanism permits mapping only the client user name to the proxied user name. There is no provision for mapping host names. When a connecting client matches a proxy account, the server attempts to find a match for a proxied account using the user name returned by the authentication plugin and the host name of the proxy account.

Consider the following account definitions:

```
-- create proxy account
CREATE USER 'employee_ext'@'localhost'
  IDENTIFIED WITH my_auth_plugin AS 'my_auth_string';
```

```
-- create proxied account and grant its privileges
CREATE USER 'employee'@'localhost'
  IDENTIFIED BY 'employee_pass';
GRANT ALL ON employees.*
  TO 'employee'@'localhost';

-- grant PROXY privilege to proxy account for proxied account
GRANT PROXY
  ON 'employee'@'localhost'
  TO 'employee_ext'@'localhost';
```

When a client connects as `employee_ext` from the local host, MySQL uses the plugin named `my_auth_plugin` to perform authentication. Suppose that `my_auth_plugin` returns a user name of `employee` to the server, based on the content of `'my_auth_string'` and perhaps by consulting some external authentication system. The name `employee` differs from `employee_ext`, so returning `employee` serves as a request to the server to treat the `employee_ext` client, for purposes of privilege checking, as the `employee` local user.

In this case, `employee_ext` is the proxy user and `employee` is the proxied user.

The server verifies that proxy authentication for `employee` is possible for the `employee_ext` user by checking whether `employee_ext` (the proxy user) has the `PROXY` privilege for `employee` (the proxied user). If this privilege has not been granted, an error occurs. Otherwise, `employee_ext` assumes the privileges of `employee`. The server checks statements executed during the client session by `employee_ext` against the privileges granted to `employee`. In this case, `employee_ext` can access tables in the `employees` database.

When proxying occurs, the `USER()` and `CURRENT_USER()` functions can be used to see the difference between the connecting user (the proxy user) and the account whose privileges apply during the current session (the proxied user). For the example just described, those functions return these values:

```
mysql> SELECT USER(), CURRENT_USER();
+------------------------+--------------------+
| USER()                 | CURRENT_USER()     |
+------------------------+--------------------+
| employee_ext@localhost | employee@localhost |
+------------------------+--------------------+
```

In the `CREATE USER` statement that creates the proxy user account, the `IDENTIFIED WITH` clause that names the authentication plugin is optionally followed by an `AS 'auth_string'` clause specifying a string that the server passes to the plugin when the user connects. If present, the string provides information that helps the plugin determine how to map the external client user name to a proxied user name. It is up to each plugin whether it requires the `AS` clause. If so, the format of the authentication string depends on how the plugin intends to use it. Consult the documentation for a given plugin for information about the authentication string values it accepts.

Granting the Proxy Privilege

The `PROXY` privilege is needed to enable an external user to connect as and have the privileges of another user. To grant this privilege, use the `GRANT` statement. For example:

```
GRANT PROXY ON 'proxied_user' TO 'proxy_user';
```

The statement creates a row in the `mysql.proxies_priv` grant table.

At connection time, *`proxy_user`* must represent a valid externally authenticated MySQL user, and *`proxied_user`* must represent a valid locally authenticated user. Otherwise, the connection attempt fails.

The corresponding `REVOKE` syntax is:

```
```

```
REVOKE PROXY ON 'proxied_user' FROM 'proxy_user';
```

MySQL `GRANT` and `REVOKE` syntax extensions work as usual. For example:

```
GRANT PROXY ON 'a' TO 'b', 'c', 'd';
GRANT PROXY ON 'a' TO 'd' IDENTIFIED BY ...;
GRANT PROXY ON 'a' TO 'd' WITH GRANT OPTION;
GRANT PROXY ON 'a' TO ''@'';
REVOKE PROXY ON 'a' FROM 'b', 'c', 'd';
```

The `PROXY` privilege can be granted in these cases:

- By a user that has `GRANT PROXY ... WITH GRANT OPTION` for *`proxied_user`*.
- By *`proxied_user`* for itself: The value of `USER()` must exactly match `CURRENT_USER()` and *`proxied_user`*, for both the user name and host name parts of the account name.

The initial `root` account created during MySQL installation has the `PROXY ... WITH GRANT OPTION` privilege for `''@''`, that is, for all users and all hosts. This enables `root` to set up proxy users, as well as to delegate to other accounts the authority to set up proxy users. For example, `root` can do this:

```
CREATE USER 'admin'@'localhost' IDENTIFIED BY 'test';
GRANT PROXY ON ''@'' TO 'admin'@'localhost' WITH GRANT OPTION;
```

Those statements create an `admin` user that can manage all `GRANT PROXY` mappings. For example, `admin` can do this:

```
GRANT PROXY ON sally TO joe;
```

Default Proxy Users

To specify that some or all users should connect using a given authentication plugin, create a “blank” MySQL account (`''@''`), associate it with that plugin, and let the plugin return the real authenticated user name (if different from the blank user). For example, suppose that there exists a plugin named `ldap_auth` that implements LDAP authentication and maps connecting users onto either a developer or manager account. To set up proxying of users onto these accounts, use the following statements:

```
-- create default proxy account
CREATE USER ''@'' IDENTIFIED WITH ldap_auth AS 'O=Oracle, OU=MySQL';

-- create proxied accounts
CREATE USER 'developer'@'localhost' IDENTIFIED BY 'developer_pass';
CREATE USER 'manager'@'localhost' IDENTIFIED BY 'manager_pass';

-- grant PROXY privilege to default proxy account for proxied accounts
GRANT PROXY ON 'manager'@'localhost' TO ''@'';
GRANT PROXY ON 'developer'@'localhost' TO ''@'';
```

Now assume that a client connects as follows:

```
shell> mysql --user=myuser --password ...
Enter password: myuser_pass
```

The server will not find `myuser` defined as a MySQL user. But because there is a blank user account (`''@''`) that matches the client user name and host name, the server authenticates the client against that account: The server invokes the `ldap_auth` authentication plugin and passes `myuser` and `myuser_pass` to it as the user name and password.

If the `ldap_auth` plugin finds in the LDAP directory that `myuser_pass` is not the correct password for `myuser`, authentication fails and the server rejects the connection.

If the password is correct and `ldap_auth` finds that `myuser` is a developer, it returns the user name `developer` to the MySQL server, rather than `myuser`. Returning a user name different from the client user name of `myuser` signals to the server that it should treat `myuser` as a proxy. The server verifies that `''@''` can authenticate as `developer` (because that account has the `PROXY` privilege to do so) and accepts the connection. The session proceeds with `myuser` having the privileges of `developer`, the proxied user. (These privileges should be set up by the DBA using `GRANT` statements, not shown.) The `USER()` and `CURRENT_USER()` functions return these values:

```
mysql> SELECT USER(), CURRENT_USER();
+------------------+--------------------+
| USER()           | CURRENT_USER()     |
+------------------+--------------------+
| myuser@localhost | developer@localhost |
+------------------+--------------------+
```

If the plugin instead finds in the LDAP directory that `myuser` is a manager, it returns `manager` as the user name and the session proceeds with `myuser` having the privileges of `manager`.

```
mysql> SELECT USER(), CURRENT_USER();
+------------------+------------------+
| USER()           | CURRENT_USER()   |
+------------------+------------------+
| myuser@localhost | manager@localhost |
+------------------+------------------+
```

For simplicity, external authentication cannot be multilevel: Neither the credentials for `developer` nor those for `manager` are taken into account in the preceding example. However, they are still used if a client tries to connect and authenticate directly as the `developer` or `manager` account, which is why those accounts should be assigned passwords.

Default Proxy User and Anonymous User Conflicts

If you intend to create a default proxy user, check for other existing “match any user” accounts that take precedence over the default proxy user because they can prevent that user from working as intended.

In the preceding discussion, the default proxy user account has `''` in the host part, which matches any host. If you set up a default proxy user, take care to also check whether nonproxy accounts exist with the same user part and `'%'` in the host part, because `'%'` also matches any host, but has precedence over `''` by the rules that the server uses to sort account rows internally (see Section 6.2.4, “Access Control, Stage 1: Connection Verification”).

Suppose that a MySQL installation includes these two accounts:

```
-- create default proxy account
CREATE USER ''@''
  IDENTIFIED WITH some_plugin AS 'some_auth_string';
-- create anonymous account
CREATE USER ''@'%'
  IDENTIFIED BY 'some_password';
```

The first account (`''@''`) is intended as the default proxy user, used to authenticate connections for users who do not otherwise match a more-specific account. The second account (`''@'%'`) is an anonymous-user account, which might have been created, for example, to enable users without their own account to connect anonymously.

Both accounts have the same user part (`''`), which matches any user. And each account has a host part that matches any host. Nevertheless, there is a priority in account matching for connection attempts because the matching rules sort a host of `'%'` ahead of `''`. For accounts that do not match any more-specific account, the server attempts to authenticate them against `''@'%'` (the anonymous user) rather than `''@''` (the default proxy user). The result is that the default proxy account is never used.

To avoid this problem, use one of the following strategies:

- Remove the anonymous account so that it does not conflict with the default proxy user. This might be a good idea anyway if you want to associate every connection with a named user.
- Use a more-specific default proxy user that matches ahead of the anonymous user. For example, to permit only `localhost` proxy connections, use `''@'localhost'`:

```
CREATE USER ''@'localhost'
  IDENTIFIED WITH some_plugin AS 'some_auth_string';
```

  In addition, modify any `GRANT PROXY` statements to name `''@'localhost'` rather than `''@''` as the proxy user.

  Be aware that this strategy prevents anonymous-user connections from `localhost`.

- Create multiple proxy users, one for local connections and one for “everything else” (remote connections). This can be useful particularly when local users should have different privileges from remote users.

  Create the proxy users:

```
-- create proxy user for local connections
CREATE USER ''@'localhost'
  IDENTIFIED WITH some_plugin AS 'some_auth_string';
-- create proxy user for remote connections
CREATE USER ''@'%'
  IDENTIFIED WITH some_plugin AS 'some_auth_string';
```

  Create the proxied users:

```
-- create proxied user for local connections
CREATE USER 'developer'@'localhost'
  IDENTIFIED BY 'some_password';
-- create proxied user for remote connections
CREATE USER 'developer'@'%'
  IDENTIFIED BY 'some_password';
```

  Grant the proxy privilege to each proxy user for the corresponding proxied user:

```
GRANT PROXY ON 'developer'@'localhost' TO ''@'localhost';
GRANT PROXY ON 'developer'@'%' TO ''@'%';
```

  Finally, grant appropriate privileges to the local and remote proxied users (not shown).

  Assume that the `some_plugin`/`'some_auth_string'` combination causes `some_plugin` to map the client user name to `developer`. Local connections match the `''@'localhost'` proxy user, which maps to the `'developer'@'localhost'` proxied user. Remote connections match the `''@'%'` proxy user, which maps to the `'developer'@'%'` proxied user.

Proxy User System Variables

Two system variables help trace the proxy login process:

- `proxy_user`: This value is `NULL` if proxying is not used. Otherwise, it indicates the proxy user account. For example, if a client authenticates through the `''@''` proxy account, this variable is set as follows:

```
mysql> SELECT @@proxy_user;
+--------------+
| @@proxy_user |
```

```
+--------------+
| ''@''        |
+--------------+
```

- `external_user`: Sometimes the authentication plugin may use an external user to authenticate to the MySQL server. For example, when using Windows native authentication, a plugin that authenticates using the windows API does not need the login ID passed to it. However, it still uses a Windows user ID to authenticate. The plugin may return this external user ID (or the first 512 UTF-8 bytes of it) to the server using the `external_user` read-only session variable. If the plugin does not set this variable, its value is `NULL`.

6.3.8 SQL-Based MySQL Account Activity Auditing

Applications can use the following guidelines to perform SQL-based auditing that ties database activity to MySQL accounts.

MySQL accounts correspond to rows in the `mysql.user` table. When a client connects successfully, the server authenticates the client to a particular row in this table. The `User` and `Host` column values in this row uniquely identify the account and correspond to the *`'user_name'@'host_name'`* format in which account names are written in SQL statements.

The account used to authenticate a client determines which privileges the client has. Normally, the `CURRENT_USER()` function can be invoked to determine which account this is for the client user. Its value is constructed from the `User` and `Host` columns of the `user` table row for the account.

However, there are circumstances under which the `CURRENT_USER()` value corresponds not to the client user but to a different account. This occurs in contexts when privilege checking is not based the client's account:

- Stored routines (procedures and functions) defined with the `SQL SECURITY DEFINER` characteristic
- Views defined with the `SQL SECURITY DEFINER` characteristic
- Triggers and events

In those contexts, privilege checking is done against the `DEFINER` account and `CURRENT_USER()` refers to that account, not to the account for the client who invoked the stored routine or view or who caused the trigger to activate. To determine the invoking user, you can call the `USER()` function, which returns a value indicating the actual user name provided by the client and the host from which the client connected. However, this value does not necessarily correspond directly to an account in the `user` table, because the `USER()` value never contains wildcards, whereas account values (as returned by `CURRENT_USER()`) may contain user name and host name wildcards.

For example, a blank user name matches any user, so an account of `''@'localhost'` enables clients to connect as an anonymous user from the local host with any user name. In this case, if a client connects as `user1` from the local host, `USER()` and `CURRENT_USER()` return different values:

```
mysql> SELECT USER(), CURRENT_USER();
+-----------------+----------------+
| USER()          | CURRENT_USER() |
+-----------------+----------------+
| user1@localhost | @localhost     |
+-----------------+----------------+
```

The host name part of an account can contain wildcards, too. If the host name contains a `'%'` or `'_'` pattern character or uses netmask notation, the account can be used for clients connecting from multiple hosts and the `CURRENT_USER()` value will not indicate which one. For example, the account `'user2'@'%.example.com'` can be used by `user2` to connect from any host in the `example.com` domain. If `user2` connects from `remote.example.com`, `USER()` and `CURRENT_USER()` return different values:

```
mysql> SELECT USER(), CURRENT_USER();
+-------------------------+--------------------+
| USER()                  | CURRENT_USER()     |
+-------------------------+--------------------+
| user2@remote.example.com | user2@%.example.com |
+-------------------------+--------------------+
```

If an application must invoke `USER()` for user auditing (for example, if it does auditing from within triggers) but must also be able to associate the `USER()` value with an account in the `user` table, it is necessary to avoid accounts that contain wildcards in the `User` or `Host` column. Specifically, do not permit `User` to be empty (which creates an anonymous-user account), and do not permit pattern characters or netmask notation in `Host` values. All accounts must have a nonempty `User` value and literal `Host` value.

With respect to the previous examples, the `''@'localhost'` and `'user2'@'%.example.com'` accounts should be changed not to use wildcards:

```
RENAME USER ''@'localhost' TO 'user1'@'localhost';
RENAME USER 'user2'@'%.example.com' TO 'user2'@'remote.example.com';
```

If `user2` must be able to connect from several hosts in the `example.com` domain, there should be a separate account for each host.

To extract the user name or host name part from a `CURRENT_USER()` or `USER()` value, use the `SUBSTRING_INDEX()` function:

```
mysql> SELECT SUBSTRING_INDEX(CURRENT_USER(),'@',1);
+--------------------------------------+
| SUBSTRING_INDEX(CURRENT_USER(),'@',1) |
+--------------------------------------+
| user1                                |
+--------------------------------------+

mysql> SELECT SUBSTRING_INDEX(CURRENT_USER(),'@',-1);
+---------------------------------------+
| SUBSTRING_INDEX(CURRENT_USER(),'@',-1) |
+---------------------------------------+
| localhost                             |
+---------------------------------------+
```

6.4 Using Encrypted Connections

With an unencrypted connection between the MySQL client and the server, someone with access to the network could watch all your traffic and inspect the data being sent or received between client and server.

When you must move information over a network in a secure fashion, an unencrypted connection is unacceptable. To make any kind of data unreadable, use encryption. Encryption algorithms must include security elements to resist many kinds of known attacks such as changing the order of encrypted messages or replaying data twice.

MySQL supports encrypted connections between clients and the server using the TLS (Transport Layer Security) protocol. TLS is sometimes referred to as SSL (Secure Sockets Layer) but MySQL does not actually use the SSL protocol for encrypted connections because its encryption is weak (see Section 6.4.6, “Encrypted Connection Protocols and Ciphers”).

TLS uses encryption algorithms to ensure that data received over a public network can be trusted. It has mechanisms to detect data change, loss, or replay. TLS also incorporates algorithms that provide identity verification using the X509 standard.

X509 makes it possible to identify someone on the Internet. In basic terms, there should be some entity called a “Certificate Authority” (or CA) that assigns electronic certificates to anyone who needs them. Certificates rely on asymmetric encryption algorithms that have two encryption keys (a public key and

a secret key). A certificate owner can present the certificate to another party as proof of identity. A certificate consists of its owner's public key. Any data encrypted using this public key can be decrypted only using the corresponding secret key, which is held by the owner of the certificate.

MySQL can be compiled for encrypted-connection support using OpenSSL or yaSSL. For a comparison of the two packages, see Section 6.4.4, “OpenSSL Versus yaSSL” For information about the encryption protocols and ciphers each package supports, see Section 6.4.6, “Encrypted Connection Protocols and Ciphers”.

MySQL programs attempt to connect using encryption if the proper options are given and the server supports encrypted connections. For information about options that affect use of encrypted connections, see Section 6.4.1, “Configuring MySQL to Use Encrypted Connections” and Section 6.4.2, “Command Options for Encrypted Connections”.

MySQL performs encryption on a per-connection basis, and use of encryption for a given user can be optional or mandatory. This enables you to choose an encrypted or unencrypted connection according to the requirements of individual applications. For information on how to require users to use encrypted connections, see the discussion of the `REQUIRE` clause of the `GRANT` statement in Section 13.7.1.3, “GRANT Syntax”.

Encrypted connections are not used by default. For applications that require the security provided by encrypted connections, the extra computation to encrypt the data is worthwhile.

Encrypted connections can be used between master and slave replication servers. See Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”.

For information about using encrypted connections from the MySQL C API, see Section 23.8.15, “C API Encrypted Connection Support”.

It is also possible to connect using encryption from within an SSH connection to the MySQL server host. For an example, see Section 6.4.7, “Connecting to MySQL Remotely from Windows with SSH”.

6.4.1 Configuring MySQL to Use Encrypted Connections

To enable encrypted connections, your MySQL distribution must be built with SSL support, as described in Section 6.4.5, “Building MySQL with Support for Encrypted Connections”. In addition, several options are available to indicate whether to use encrypted connections, and to specify the appropriate certificate and key files. This section provides general guidance about configuring the server and clients for encrypted connections:

- Server-Side Configuration for Encrypted Connections
- Client-Side Configuration for Encrypted Connections

For a complete list of options related to establishment of encrypted connections, see Section 6.4.2, “Command Options for Encrypted Connections”. If you need to create the required certificate and key files, see Section 6.4.3, “Creating SSL Certificates and Keys Using openssl”.

Encrypted connections can be used between master and slave replication servers. See Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”.

Encrypted connections are available through the MySQL C API. See Section 23.8.15, “C API Encrypted Connection Support”.

Note

If the server is compiled against OpenSSL, clients from MySQL 5.5 versions older than 5.5.37 are not able to connect to the server using encrypted connections if the client library is compiled using yaSSL. Either use a client and server compiled using the same SSL package, or upgrade to clients compiled against a client library version from MySQL 5.5.37 or higher.

Server-Side Configuration for Encrypted Connections

These options on the server side identify the certificate and key files the server uses when permitting clients to establish encrypted connections:

- `--ssl-ca`: The path name of the Certificate Authority (CA) certificate file. (`--ssl-capath` is similar but specifies the path name of a directory of CA certificate files.)
- `--ssl-cert`: The path name of the server public key certificate file. This can be sent to the client and authenticated against the CA certificate that it has.
- `--ssl-key`: The path name of the server private key file.

For example, to enable the server for encrypted connections, start it with these lines in the `my.cnf` file, changing the file names as necessary:

```
[mysqld]
ssl-ca=ca.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

Each option names a file in PEM format. If you have a MySQL source distribution, you can test your setup using the demonstration certificate and key files in its `mysql-test/std_data` directory.

Client-Side Configuration for Encrypted Connections

These options on the client side identify the certificate and key files clients use when establishing encrypted connections to the server. They are similar to the options used on the server side, but `--ssl-cert` and `--ssl-key` identify the client public and private key:

- `--ssl-ca`: The path name of the Certificate Authority (CA) certificate file. This option, if used, must specify the same certificate used by the server. (`--ssl-capath` is similar but specifies the path name of a directory of CA certificate files.)
- `--ssl-cert`: The path name of the client public key certificate file.
- `--ssl-key`: The path name of the client private key file.

For additional security relative to that provided by the default encryption, clients can supply a CA certificate matching the one used by the server and enable host name identity verification. In this way, the server and client place their trust in the same CA certificate and the client verifies that the host to which it connected is the one intended:

- To specify the CA certificate, use `--ssl-ca` (or `--ssl-capath`).
- To enable host name identity verification as well, specify `--ssl-verify-server-cert`.
- To require an encrypted connection, specify `--ssl-mode=REQUIRED`.

Depending on the encryption requirements of the MySQL account used by a client, the client may be required to specify certain options to connect using encryption to a MySQL server that supports encrypted connections.

Suppose that you want to connect using an account that has no special encryption requirements or was created using a `GRANT` statement that includes the `REQUIRE SSL` option. As a recommended set of encrypted-connection options, start the server with at least `--ssl-cert` and `--ssl-key`, and invoke the client with `--ssl-ca` (or `--ssl-capath`). A client can connect using encryption like this:

```
mysql --ssl-ca=ca.pem
```

To require that a client certificate also be specified, create the account using the `REQUIRE X509` option. Then the client must also specify the proper client key and certificate files or the server will reject the connection:

```
mysql --ssl-ca=ca.pem \
      --ssl-cert=client-cert.pem \
      --ssl-key=client-key.pem
```

For additional information about the `REQUIRE` clause, see the discussion in Section 13.7.1.3, “GRANT Syntax”.

To prevent use of encryption and override other `--ssl-xxx` options, invoke the client program with `--ssl=0` or a synonym (`--skip-ssl`, `--disable-ssl`):

```
mysql --ssl=0
```

To determine whether the current connection with the server uses encryption, check the value of the `Ssl_cipher` status variable. If the value is empty, the connection is not encrypted. Otherwise, the connection is encrypted and the value indicates the encryption cipher. For example:

```
mysql> SHOW SESSION STATUS LIKE 'Ssl_cipher';
+---------------+--------------------+
| Variable_name | Value              |
+---------------+--------------------+
| Ssl_cipher    | DHE-RSA-AES256-SHA |
+---------------+--------------------+
```

For the `mysql` client, an alternative is to use the `STATUS` or `\s` command and check the `SSL` line:

```
mysql> \s
...
SSL: Not in use
...
```

Or:

```
mysql> \s
...
SSL: Cipher in use is DHE-RSA-AES256-SHA
...
```

6.4.2 Command Options for Encrypted Connections

This section describes options that specify whether to use encrypted connections, the names of certificate and key files, and other parameters related to encrypted-connection support. These options can be given on the command line or in an option file. They are not available unless MySQL has been built with SSL support. See Section 6.4.5, “Building MySQL with Support for Encrypted Connections”. For examples of suggested use and how to check whether a connection is encrypted, see Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”.

For information about using encrypted connections from the MySQL C API, see Section 23.8.15, “C API Encrypted Connection Support”.

Table 6.8 Encrypted-Connection Option Summary

Format	Description	Introduced
--skip-ssl	Do not use encrypted connection	
--ssl	Enable encrypted connection	
--ssl-ca	File that contains list of trusted SSL Certificate Authorities	
--ssl-capath	Directory that contains trusted SSL Certificate Authority certificate files	
--ssl-cert	File that contains X509 certificate	

Format	Description	Introduced
--ssl-cipher	List of permitted ciphers for connection encryption	
--ssl-key	File that contains X509 key	
--ssl-mode	Security state of connection to server	5.5.49
--ssl-verify-server-cert	Verify host name against server certificate Common Name identity	

- `--ssl`

  For the MySQL server, this option specifies that the server permits but does not require encrypted connections.

  For MySQL client programs, this option permits but does not require the client to connect to the server using encryption. Therefore, this option is not sufficient in itself to cause an encrypted connection to be used. For example, if you specify this option for a client program but the server has not been configured to support encrypted connections, the client falls back to an unencrypted connection.

  As a recommended set of options to enable encrypted connections, use at least `--ssl-cert` and `--ssl-key` on the server side and `--ssl-ca` on the client side. See Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”.

  `--ssl` may be implied by other `--ssl-xxx` options, as indicated in the descriptions for those options.

  The `--ssl` option in negated form indicates that encryption should *not* be used and overrides other `--ssl-xxx` options. Specify the option as `--ssl=0` or a synonym (`--skip-ssl`, `--disable-ssl`). For example, you might have options specified in the `[client]` group of your option file to use encrypted connections by default when you invoke MySQL client programs. To use an unencrypted connection instead, invoke the client program with `--ssl=0` on the command line to override the options in the option file.

  To require use of encrypted connections by a MySQL account, use a `GRANT` statement for the account that includes a `REQUIRE SSL` clause. Connection attempts by clients that use the account will be rejected unless MySQL supports encrypted connections and an encrypted connection can be established.

  The `REQUIRE` clause permits other encryption-related options, which can be used to enforce security requirements stricter than `REQUIRE SSL`. For additional details about which command options may or must be specified by clients that connect using accounts configured using the various `REQUIRE` options, see the description of `REQUIRE` in Section 13.7.1.3, “GRANT Syntax”.

- `--ssl-ca=file_name`

  The path name of the Certificate Authority (CA) certificate file in PEM format. This option implies `--ssl`.

  To tell the client not to authenticate the server certificate when establishing an encrypted connection to the server, specify neither `--ssl-ca` nor `--ssl-capath`. The server still verifies the client according to any applicable requirements established for the client account, and it still uses any `--ssl-ca` or `--ssl-capath` option values specified on the server side.

- `--ssl-capath=dir_name`

  The path name of the directory that contains trusted SSL certificate authority (CA) certificate files in PEM format. This option implies `--ssl`.

  To tell the client not to authenticate the server certificate when establishing an encrypted connection to the server, specify neither `--ssl-ca` nor `--ssl-capath`. The server still verifies the client

according to any applicable requirements established for the client account, and it still uses any `--ssl-ca` or `--ssl-capath` option values specified on the server side.

MySQL distributions compiled using OpenSSL support the `--ssl-capath` option (see Section 6.4.4, “OpenSSL Versus yaSSL”). Distributions compiled using yaSSL do not because yaSSL does not look in any directory and does not follow a chained certificate tree. yaSSL requires that all components of the CA certificate tree be contained within a single CA certificate tree and that each certificate in the file has a unique SubjectName value. To work around this yaSSL limitation, concatenate the individual certificate files comprising the certificate tree into a new file and specify that file as the value of the `--ssl-ca` option.

- `--ssl-cert=file_name`

  The path name of the SSL public key certificate file in PEM format. On the client side, this is the client public key certificate. On the server side, this is the server public key certificate. This option implies `--ssl`.

- `--ssl-cipher=cipher_list`

  The list of permitted ciphers for connection encryption. If no cipher in the list is supported, encrypted connections will not work. This option implies `--ssl`.

  For greatest portability, *`cipher_list`* should be a list of one or more cipher names, separated by colons. This format is understood both by OpenSSL and yaSSL. Examples:

  ```
  --ssl-cipher=AES128-SHA
  --ssl-cipher=DHE-RSA-AES256-SHA:AES128-SHA
  ```

  OpenSSL supports a more flexible syntax for specifying ciphers, as described in the OpenSSL documentation at https://www.openssl.org/docs/manmaster/man1/ciphers.html. yaSSL does not, so attempts to use that extended syntax fail for a MySQL distribution compiled using yaSSL.

  For information about which encryption ciphers MySQL supports, see Section 6.4.6, “Encrypted Connection Protocols and Ciphers”.

- `--ssl-key=file_name`

  The path name of the SSL private key file in PEM format. On the client side, this is the client private key. On the server side, this is the server private key. This option implies `--ssl`.

  If the MySQL distribution was compiled using OpenSSL and the key file is protected by a passphrase, the program prompts the user for the passphrase. The password must be given interactively; it cannot be stored in a file. If the passphrase is incorrect, the program continues as if it could not read the key. If the MySQL distribution was built using yaSSL and the key file is protected by a passphrase, an error occurs.

- `--ssl-mode=mode`

  This option is available only for client programs, not the server. It specifies the security state of the connection to the server:

  - If this option is not specified, the default is to establish an unencrypted connection. This is like the `--ssl=0` option or its synonyms (`--skip-ssl`, `--disable-ssl`).
  - If this option is specified, the only permitted value is `REQUIRED` (establish an encrypted connection if the server supports encrypted connections). The connection attempt fails if an encrypted connection cannot be established.

  The `--ssl-mode` option was added in MySQL 5.5.49.

Note

To require encrypted connections in MySQL 5.5, the standard MySQL client programs check whether the connection is encrypted if `--ssl-mode=REQUIRED` was specified. If not, the client exits with an error. Third-party applications that must be able to require encrypted connections can use the same technique. For details, see Section 23.8.7.67, “mysql_ssl_set()”.

- `--ssl-verify-server-cert`

  This option is available only for client programs, not the server. It causes the client to perform host name identify verification by checking the server's Common Name identity in the certificate that the server sends to the client. The client verifies the Common Name against the host name the client uses for connecting to the server, and the connection fails if there is a mismatch. For encrypted connections, this option helps prevent man-in-the-middle attacks. Host name identity verification is disabled by default.

6.4.3 Creating SSL Certificates and Keys Using openssl

This section describes how to use the `openssl` command to set up SSL certificate and key files for use by MySQL servers and clients. The first example shows a simplified procedure such as you might use from the command line. The second shows a script that contains more detail. The first two examples are intended for use on Unix and both use the `openssl` command that is part of OpenSSL. The third example describes how to set up SSL files on Windows.

Important

Whatever method you use to generate the certificate and key files, the Common Name value used for the server and client certificates/keys must each differ from the Common Name value used for the CA certificate. Otherwise, the certificate and key files will not work for servers compiled using OpenSSL. A typical error in this case is:

```
ERROR 2026 (HY000): SSL connection error:
error:00000001:lib(0):func(0):reason(1)
```

- Example 1: Creating SSL Files from the Command Line on Unix
- Example 2: Creating SSL Files Using a Script on Unix
- Example 3: Creating SSL Files on Windows

Example 1: Creating SSL Files from the Command Line on Unix

The following example shows a set of commands to create MySQL server and client certificate and key files. You will need to respond to several prompts by the `openssl` commands. To generate test files, you can press Enter to all prompts. To generate files for production use, you should provide nonempty responses.

```
# Create clean environment
rm -rf newcerts
mkdir newcerts && cd newcerts

# Create CA certificate
openssl genrsa 2048 > ca-key.pem
openssl req -new -x509 -nodes -days 3600 \
        -key ca-key.pem -out ca.pem

# Create server certificate, remove passphrase, and sign it
# server-cert.pem = public key, server-key.pem = private key
openssl req -newkey rsa:2048 -days 3600 \
        -nodes -keyout server-key.pem -out server-req.pem
```

```
openssl rsa -in server-key.pem -out server-key.pem
openssl x509 -req -in server-req.pem -days 3600 \
        -CA ca.pem -CAkey ca-key.pem -set_serial 01 -out server-cert.pem

# Create client certificate, remove passphrase, and sign it
# client-cert.pem = public key, client-key.pem = private key
openssl req -newkey rsa:2048 -days 3600 \
        -nodes -keyout client-key.pem -out client-req.pem
openssl rsa -in client-key.pem -out client-key.pem
openssl x509 -req -in client-req.pem -days 3600 \
        -CA ca.pem -CAkey ca-key.pem -set_serial 01 -out client-cert.pem
```

After generating the certificates, verify them:

```
openssl verify -CAfile ca.pem server-cert.pem client-cert.pem
```

You should see a response like this:

```
server-cert.pem: OK
client-cert.pem: OK
```

Now you have a set of files that can be used as follows:

- `ca.pem`: Use this as the argument to `--ssl-ca` on the server and client sides. (The CA certificate, if used, must be the same on both sides.)
- `server-cert.pem`, `server-key.pem`: Use these as the arguments to `--ssl-cert` and `--ssl-key` on the server side.
- `client-cert.pem`, `client-key.pem`: Use these as the arguments to `--ssl-cert` and `--ssl-key` on the client side.

For additional usage instructions, see Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”.

Example 2: Creating SSL Files Using a Script on Unix

Here is an example script that shows how to set up SSL certificate and key files for MySQL. After executing the script, use the files for SSL connections as described in Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”.

```
DIR=`pwd`/openssl
PRIV=$DIR/private

mkdir $DIR $PRIV $DIR/newcerts
cp /usr/share/ssl/openssl.cnf $DIR
replace ./demoCA $DIR -- $DIR/openssl.cnf

# Create necessary files: $database, $serial and $new_certs_dir
# directory (optional)

touch $DIR/index.txt
echo "01" > $DIR/serial

#
# Generation of Certificate Authority(CA)
#

openssl req -new -x509 -keyout $PRIV/cakey.pem -out $DIR/ca.pem \
    -days 3600 -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# ................++++++
# .........++++++
# writing new private key to '/home/finley/openssl/private/cakey.pem'
```

```
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL admin
# Email Address []:

#
# Create server request and key
#
openssl req -new -keyout $DIR/server-key.pem -out \
    $DIR/server-req.pem -days 3600 -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# ..++++++
# ..........++++++
# writing new private key to '/home/finley/openssl/server-key.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL server
# Email Address []:
#
# Please enter the following 'extra' attributes
# to be sent with your certificate request
# A challenge password []:
# An optional company name []:

#
# Remove the passphrase from the key
#
openssl rsa -in $DIR/server-key.pem -out $DIR/server-key.pem

#
# Sign server cert
#
openssl ca -cert $DIR/ca.pem -policy policy_anything \
    -out $DIR/server-cert.pem -config $DIR/openssl.cnf \
    -infiles $DIR/server-req.pem

# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Enter PEM pass phrase:
# Check that the request matches the signature
# Signature ok
```

```
# The Subjects Distinguished Name is as follows
# countryName           :PRINTABLE:'FI'
# organizationName      :PRINTABLE:'MySQL AB'
# commonName            :PRINTABLE:'MySQL admin'
# Certificate is to be certified until Sep 13 14:22:46 2003 GMT
# (365 days)
# Sign the certificate? [y/n]:y
#
#
# 1 out of 1 certificate requests certified, commit? [y/n]y
# Write out database with 1 new entries
# Data Base Updated

#
# Create client request and key
#
openssl req -new -keyout $DIR/client-key.pem -out \
    $DIR/client-req.pem -days 3600 -config $DIR/openssl.cnf

# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Generating a 1024 bit RSA private key
# ....................................++++++
# ..........................................++++++
# writing new private key to '/home/finley/openssl/client-key.pem'
# Enter PEM pass phrase:
# Verifying password - Enter PEM pass phrase:
# -----
# You are about to be asked to enter information that will be
# incorporated into your certificate request.
# What you are about to enter is what is called a Distinguished Name
# or a DN.
# There are quite a few fields but you can leave some blank
# For some fields there will be a default value,
# If you enter '.', the field will be left blank.
# -----
# Country Name (2 letter code) [AU]:FI
# State or Province Name (full name) [Some-State]:.
# Locality Name (eg, city) []:
# Organization Name (eg, company) [Internet Widgits Pty Ltd]:MySQL AB
# Organizational Unit Name (eg, section) []:
# Common Name (eg, YOUR name) []:MySQL user
# Email Address []:
#
# Please enter the following 'extra' attributes
# to be sent with your certificate request
# A challenge password []:
# An optional company name []:

#
# Remove the passphrase from the key
#
openssl rsa -in $DIR/client-key.pem -out $DIR/client-key.pem

#
# Sign client cert
#

openssl ca -cert $DIR/ca.pem -policy policy_anything \
    -out $DIR/client-cert.pem -config $DIR/openssl.cnf \
    -infiles $DIR/client-req.pem

# Sample output:
# Using configuration from /home/finley/openssl/openssl.cnf
# Enter PEM pass phrase:
# Check that the request matches the signature
# Signature ok
# The Subjects Distinguished Name is as follows
# countryName           :PRINTABLE:'FI'
# organizationName      :PRINTABLE:'MySQL AB'
# commonName            :PRINTABLE:'MySQL user'
# Certificate is to be certified until Sep 13 16:45:17 2003 GMT
```

```
# (365 days)
# Sign the certificate? [y/n]:y
#
#
# 1 out of 1 certificate requests certified, commit? [y/n]y
# Write out database with 1 new entries
# Data Base Updated

#
# Create a my.cnf file that you can use to test the certificates
#

cat <<EOF > $DIR/my.cnf
[client]
ssl-ca=$DIR/ca.pem
ssl-cert=$DIR/client-cert.pem
ssl-key=$DIR/client-key.pem
[mysqld]
ssl-ca=$DIR/ca.pem
ssl-cert=$DIR/server-cert.pem
ssl-key=$DIR/server-key.pem
EOF
```

Example 3: Creating SSL Files on Windows

Download OpenSSL for Windows if it is not installed on your system. An overview of available packages can be seen here:

```
http://www.slproweb.com/products/Win32OpenSSL.html
```

Choose the Win32 OpenSSL Light or Win64 OpenSSL Light package, depending on your architecture (32-bit or 64-bit). The default installation location will be `C:\OpenSSL-Win32` or `C:\OpenSSL-Win64`, depending on which package you downloaded. The following instructions assume a default location of `C:\OpenSSL-Win32`. Modify this as necessary if you are using the 64-bit package.

If a message occurs during setup indicating `'...critical component is missing: Microsoft Visual C++ 2008 Redistributables'`, cancel the setup and download one of the following packages as well, again depending on your architecture (32-bit or 64-bit):

- Visual C++ 2008 Redistributables (x86), available at:

  ```
  http://www.microsoft.com/downloads/details.aspx?familyid=9B2DA534-3E03-4391-8A4D-074B9F2BC1BF
  ```

- Visual C++ 2008 Redistributables (x64), available at:

  ```
  http://www.microsoft.com/downloads/details.aspx?familyid=bd2a6171-e2d6-4230-b809-9a8d7548c1b6
  ```

After installing the additional package, restart the OpenSSL setup procedure.

During installation, leave the default `C:\OpenSSL-Win32` as the install path, and also leave the default option `'Copy OpenSSL DLL files to the Windows system directory'` selected.

When the installation has finished, add `C:\OpenSSL-Win32\bin` to the Windows System Path variable of your server:

1. On the Windows desktop, right-click the **My Computer** icon, and select **Properties**.
2. Select the **Advanced** tab from the **System Properties** menu that appears, and click the **Environment Variables** button.
3. Under **System Variables**, select **Path**, then click the **Edit** button. The **Edit System Variable** dialogue should appear.
4. Add `';C:\OpenSSL-Win32\bin'` to the end (notice the semicolon).

5. Press OK 3 times.

6. Check that OpenSSL was correctly integrated into the Path variable by opening a new command console (`Start>Run>cmd.exe`) and verifying that OpenSSL is available (depending on your version of Windows, the following path-setting instructions might differ slightly):

```
Microsoft Windows [Version ...]
Copyright (c) 2006 Microsoft Corporation. All rights reserved.

C:\Windows\system32>cd \

C:\>openssl
OpenSSL> exit <<< If you see the OpenSSL prompt, installation was successful.

C:\>
```

After OpenSSL has been installed, use instructions similar to those from Example 1 (shown earlier in this section), with the following changes:

- Change the following Unix commands:

```
# Create clean environment
rm -rf newcerts
mkdir newcerts && cd newcerts
```

  On Windows, use these commands instead:

```
# Create clean environment
md c:\newcerts
cd c:\newcerts
```

- When a `'\'` character is shown at the end of a command line, this `'\'` character must be removed and the command lines entered all on a single line.

After generating the certificate and key files, to use them for SSL connections, see Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”.

6.4.4 OpenSSL Versus yaSSL

MySQL can be compiled using OpenSSL or yaSSL, both of which enable encrypted connections based on the OpenSSL API:

- MySQL Enterprise Edition binary distributions are compiled using yaSSL.
- MySQL Community Edition binary distributions are compiled using yaSSL.
- MySQL Community Edition source distributions can be compiled using either OpenSSL or yaSSL (see Section 6.4.5, “Building MySQL with Support for Encrypted Connections”).

OpenSSL and yaSSL offer the same basic functionality, but additional features are available in MySQL distributions compiled using OpenSSL: OpenSSL supports a wider range of encryption ciphers from which to choose for the `--ssl-cipher` option, and supports the `--ssl-capath` option. See Section 6.4.2, “Command Options for Encrypted Connections”.

6.4.5 Building MySQL with Support for Encrypted Connections

To use SSL connections between the MySQL server and client programs, your system must support either OpenSSL or yaSSL:

- MySQL Enterprise Edition binary distributions are compiled using yaSSL.
- MySQL Community Edition binary distributions are compiled using yaSSL.

- MySQL Community Edition source distributions can be compiled using either OpenSSL or yaSSL.

If you compile MySQL from a source distribution, `CMake` configures the distribution to use yaSSL by default. To compile using OpenSSL instead, use this procedure:

1. Ensure OpenSSL 1.0.1 or higher is installed on your system. To obtain OpenSSL, visit http://www.openssl.org.

2. To use OpenSSL, add the `-DWITH_SSL=system` option to the `CMake` command you normally use to configure the MySQL source distribution. For example:

   ```
   cmake . -DWITH_SSL=system
   ```

   That command configures the distribution to use the installed OpenSSL library. See Section 2.9.4, "MySQL Source-Configuration Options".

3. Compile and install the distribution.

To check whether a `mysqld` server supports encrypted connections, examine the value of the `have_ssl` system variable:

```
mysql> SHOW VARIABLES LIKE 'have_ssl';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| have_ssl      | YES   |
+---------------+-------+
```

If the value is `YES`, the server supports encrypted connections. If the value is `DISABLED`, the server is capable of supporting encrypted connections but was not started with the appropriate `--ssl-xxx` options to enable encrypted connections to be used; see Section 6.4.1, "Configuring MySQL to Use Encrypted Connections".

6.4.6 Encrypted Connection Protocols and Ciphers

To determine which encryption protocol and cipher are in use for an encrypted connection, use the following statements to check the values of the `Ssl_version` and `Ssl_cipher` status variables:

```
mysql> SHOW SESSION STATUS LIKE 'Ssl_version';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| Ssl_version   | TLSv1 |
+---------------+-------+
mysql> SHOW SESSION STATUS LIKE 'Ssl_cipher';
+---------------+--------------------+
| Variable_name | Value              |
+---------------+--------------------+
| Ssl_cipher    | DHE-RSA-AES256-SHA |
+---------------+--------------------+
```

If the connection is not encrypted, both variables have an empty value.

MySQL supports encrypted connections using the TLSv1 protocol. As of MySQL 5.5.42, it explicitly disables SSL 2.0 and SSL 3.0 because they provide weak encryption.

To determine which ciphers a given server supports, use the following statement to check the value of the `Ssl_cipher_list` status variable:

```
SHOW SESSION STATUS LIKE 'Ssl_cipher_list';
```

The set of available ciphers depends on your MySQL version and whether MySQL was compiled using OpenSSL or yaSSL, and (for OpenSSL) the library version used to compile MySQL.

MySQL passes this cipher list to OpenSSL:

```
AES256-GCM-SHA384
AES256-SHA
AES256-SHA256
CAMELLIA256-SHA
DES-CBC3-SHA
DHE-DSS-AES256-GCM-SHA384
DHE-DSS-AES256-SHA
DHE-DSS-AES256-SHA256
DHE-DSS-CAMELLIA256-SHA
DHE-RSA-AES256-GCM-SHA384
DHE-RSA-AES256-SHA
DHE-RSA-AES256-SHA256
DHE-RSA-CAMELLIA256-SHA
ECDH-ECDSA-AES256-GCM-SHA384
ECDH-ECDSA-AES256-SHA
ECDH-ECDSA-AES256-SHA384
ECDH-ECDSA-DES-CBC3-SHA
ECDH-RSA-AES256-GCM-SHA384
ECDH-RSA-AES256-SHA
ECDH-RSA-AES256-SHA384
ECDH-RSA-DES-CBC3-SHA
ECDHE-ECDSA-AES128-GCM-SHA256
ECDHE-ECDSA-AES128-SHA
ECDHE-ECDSA-AES128-SHA256
ECDHE-ECDSA-AES256-GCM-SHA384
ECDHE-ECDSA-AES256-SHA
ECDHE-ECDSA-AES256-SHA384
ECDHE-ECDSA-DES-CBC3-SHA
ECDHE-RSA-AES128-GCM-SHA256
ECDHE-RSA-AES128-SHA
ECDHE-RSA-AES128-SHA256
ECDHE-RSA-AES256-GCM-SHA384
ECDHE-RSA-AES256-SHA
ECDHE-RSA-AES256-SHA384
ECDHE-RSA-DES-CBC3-SHA
EDH-DSS-DES-CBC3-SHA
EDH-RSA-DES-CBC3-SHA
PSK-3DES-EDE-CBC-SHA
PSK-AES256-CBC-SHA
SRP-DSS-3DES-EDE-CBC-SHA
SRP-DSS-AES-128-CBC-SHA
SRP-DSS-AES-256-CBC-SHA
SRP-RSA-3DES-EDE-CBC-SHA
SRP-RSA-AES-128-CBC-S
SRP-RSA-AES-256-CBC-SHA
```

MySQL passes this cipher list to yaSSL:

```
AES128-RMD
AES128-SHA
AES256-RMD
AES256-SHA
DES-CBC-SHA
DES-CBC3-RMD
DES-CBC3-SHA
DHE-RSA-AES128-RMD
DHE-RSA-AES128-SHA
DHE-RSA-AES256-RMD
DHE-RSA-AES256-SHA
DHE-RSA-DES-CBC3-RMD
EDH-RSA-DES-CBC-SHA
EDH-RSA-DES-CBC3-SHA
RC4-MD5
RC4-SHA
```

6.4.7 Connecting to MySQL Remotely from Windows with SSH

This section describes how to get an encrypted connection to a remote MySQL server with SSH. The information was provided by David Carlson <dcarlson@mplcomm.com>.

1. Install an SSH client on your Windows machine. For a comparison of SSH clients, see http://en.wikipedia.org/wiki/Comparison_of_SSH_clients.
2. Start your Windows SSH client. Set `Host_Name = yourmysqlserver_URL_or_IP`. Set `userid=your_userid` to log in to your server. This `userid` value might not be the same as the user name of your MySQL account.
3. Set up port forwarding. Either do a remote forward (Set `local_port: 3306`, `remote_host: yourmysqlservername_or_ip`, `remote_port: 3306`) or a local forward (Set `port: 3306`, `host: localhost`, `remote port: 3306`).
4. Save everything, otherwise you will have to redo it the next time.
5. Log in to your server with the SSH session you just created.
6. On your Windows machine, start some ODBC application (such as Access).
7. Create a new file in Windows and link to MySQL using the ODBC driver the same way you normally do, except type in `localhost` for the MySQL host server, not `yourmysqlservername`.

At this point, you should have an ODBC connection to MySQL, encrypted using SSH.

6.5 Security Plugins

MySQL includes several plugins that implement security features:

- Plugins for authenticating attempts by clients to connect to MySQL Server. Plugins are available for several authentication protocols. For general discussion of the authentication process, see Section 6.3.6, “Pluggable Authentication”. For characteristics of specific authentication plugins, see Section 6.5.1, “Authentication Plugins”.
- (MySQL Enterprise Edition only) MySQL Enterprise Audit, implemented using a server plugin, uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines.

6.5.1 Authentication Plugins

The following sections describe pluggable authentication methods available in MySQL and the plugins that implement these methods. For general discussion of the authentication process, see Section 6.3.6, “Pluggable Authentication”.

6.5.1.1 Native Pluggable Authentication

MySQL includes two plugins that implement native authentication; that is, authentication based on the password hashing methods in use from before the introduction of pluggable authentication. This section describes `mysql_native_password`, which implements authentication against the `mysql.user` table using the native password hashing method. For information about `mysql_old_password`, which implements authentication using the older (pre-4.1) native password hashing method, see Section 6.5.1.2, “Old Native Pluggable Authentication”. For information about these password hashing methods, see Section 6.1.2.4, “Password Hashing in MySQL”.

The `mysql_native_password` native authentication plugin is backward compatible. Older clients that do not support authentication *plugins* do use the native authentication *protocol*, so they can connect to servers that support pluggable authentication.

The following table shows the plugin names on the server and client sides.

Table 6.9 Plugin and Library Names for Native Password Authentication

Server-side plugin name	`mysql_native_password`
Client-side plugin name	`mysql_native_password`
Library file name	None (plugins are built in)

The following sections provide installation and usage information specific to native pluggable authentication:

- Installing Native Pluggable Authentication
- Using Native Pluggable Authentication

For general information about pluggable authentication in MySQL, see Section 6.3.6, “Pluggable Authentication”.

Installing Native Pluggable Authentication

The `mysql_native_password` plugin exists in server and client forms:

- The server-side plugin is built into the server, need not be loaded explicitly, and cannot be disabled by unloading it.
- The client-side plugin is built into the `libmysqlclient` client library and is available to any program linked against `libmysqlclient`.

Using Native Pluggable Authentication

MySQL client programs use `mysql_native_password` by default. The `--default-auth` option can be used as a hint about which client-side plugin the program can expect to use:

```
shell> mysql --default-auth=mysql_native_password ...
```

If an account row specifies no plugin name, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row.

6.5.1.2 Old Native Pluggable Authentication

MySQL includes two plugins that implement native authentication; that is, authentication based on the password hashing methods in use from before the introduction of pluggable authentication. This section describes `mysql_old_password`, which implements authentication against the `mysql.user` table using the older (pre-4.1) native password hashing method. For information about `mysql_native_password`, which implements authentication using the native password hashing method, see Section 6.5.1.1, “Native Pluggable Authentication”. For information about these password hashing methods, see Section 6.1.2.4, “Password Hashing in MySQL”.

Note

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

The `mysql_old_password` native authentication plugin is backward compatible. Older clients that do not support authentication *plugins* do use the native authentication *protocol*, so they can connect to servers that support pluggable authentication.

The following table shows the plugin names on the server and client sides.

Table 6.10 Plugin and Library Names for Old Native Password Authentication

Server-side plugin name	`mysql_old_password`
Client-side plugin name	`mysql_old_password`
Library file name	None (plugins are built in)

The following sections provide installation and usage information specific to old native pluggable authentication:

- Installing Old Native Pluggable Authentication
- Using Old Native Pluggable Authentication

For general information about pluggable authentication in MySQL, see Section 6.3.6, “Pluggable Authentication”.

Installing Old Native Pluggable Authentication

The `mysql_old_password` plugin exists in server and client forms:

- The server-side plugin is built into the server, need not be loaded explicitly, and cannot be disabled by unloading it.
- The client-side plugin is built into the `libmysqlclient` client library and is available to any program linked against `libmysqlclient`.

Using Old Native Pluggable Authentication

MySQL client programs can use the `--default-auth` option to specify the `mysql_old_password` plugin as a hint about which client-side plugin the program can expect to use:

```
shell> mysql --default-auth=mysql_old_password ...
```

If an account row specifies no plugin name, the server authenticates the account using either the `mysql_native_password` or `mysql_old_password` plugin, depending on whether the password hash value in the `Password` column used native hashing or the older pre-4.1 hashing method. Clients must match the password in the `Password` column of the account row.

6.5.1.3 Client-Side Cleartext Pluggable Authentication

As of MySQL 5.5.10, a client-side authentication plugin is available that sends the password to the server without hashing or encryption. This plugin is built into the MySQL client library.

The following table shows the plugin name.

Table 6.11 Plugin and Library Names for Cleartext Authentication

Server-side plugin name	None, see discussion
Client-side plugin name	`mysql_clear_password`
Library file name	None (plugin is built in)

With many MySQL authentication methods, the client performs hashing or encryption of the password before sending it to the server. This enables the client to avoid sending the password in clear text.

Hashing or encryption cannot be done for authentication schemes that require the server to receive the password as entered on the client side. In such cases, the client-side `mysql_clear_password` plugin is used to send the password to the server in clear text. There is no corresponding server-side plugin. Rather, the client-side plugin can be used by any server-side plugin that needs a cleartext password. (The PAM authentication plugin is one such; see Section 6.5.1.4, “PAM Pluggable Authentication”.)

The following discussion provides usage information specific to clear text pluggable authentication. For For general information about pluggable authentication in MySQL, see Section 6.3.6, “Pluggable Authentication”.

Note

Sending passwords in clear text may be a security problem in some configurations. To avoid problems if there is any possibility that the password would be intercepted, clients should connect to MySQL Server using a method that protects the password. Possibilities include SSL (see Section 6.4, “Using Encrypted Connections”), IPsec, or a private network.

As of MySQL 5.5.27, to make inadvertent use of the `mysql_clear_password` plugin less likely, MySQL clients must explicitly enable it. This can be done several ways:

- Set the `LIBMYSQL_ENABLE_CLEARTEXT_PLUGIN` environment variable to a value that begins with `1`, `Y`, or `y`. This enables the plugin for all client connections.
- The `mysql`, `mysqladmin`, and `mysqlslap` client programs (also `mysqlcheck`, `mysqldump`, and `mysqlshow` for MySQL 5.5.47 and later) support an `--enable-cleartext-plugin` option that enables the plugin on a per-invocation basis.
- The `mysql_options()` C API function supports a `MYSQL_ENABLE_CLEARTEXT_PLUGIN` option that enables the plugin on a per-connection basis. Also, any program that uses `libmysqlclient` and reads option files can enable the plugin by including an `enable-cleartext-plugin` option in an option group read by the client library.

6.5.1.4 PAM Pluggable Authentication

Note

PAM pluggable authentication is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see http://www.mysql.com/products/.

As of MySQL 5.5.16, MySQL Enterprise Edition supports an authentication method that enables MySQL Server to use PAM (Pluggable Authentication Modules) to authenticate MySQL users. PAM enables a system to use a standard interface to access various kinds of authentication methods, such as Unix passwords or an LDAP directory.

PAM pluggable authentication provides these capabilities:

- External authentication: PAM authentication enables MySQL Server to accept connections from users defined outside the MySQL grant tables and that authenticate using methods supported by PAM.
- Proxy user support: PAM authentication can return to MySQL a user name different from the login user, based on the groups the external user is in and the authentication string provided. This means that the plugin can return the MySQL user that defines the privileges the external PAM-authenticated user should have. For example, a user named `joe` can connect and have the privileges of the user named `developer`.

PAM pluggable authentication has been tested on Linux and macOS.

The PAM plugin uses the information passed to it by MySQL Server (such as user name, host name, password, and authentication string), plus whatever method is available for PAM lookup. The plugin checks the user credentials against PAM and returns `'Authentication succeeded, Username is user_name'` or `'Authentication failed'`.

The following table shows the plugin and library file names. The file name suffix might differ on your system. The file must be located in the directory named by the `plugin_dir` system variable. For installation information, see Installing PAM Pluggable Authentication.

Table 6.12 Plugin and Library Names for PAM Authentication

Server-side plugin name	`authentication_pam`
Client-side plugin name	`mysql_clear_password`
Library file name	`authentication_pam.so`

The server-side PAM authentication plugin is included only in MySQL Enterprise Edition, and the PAM library file includes only the server-side plugin. The server-side PAM authentication plugin is not included in MySQL community distributions.

As of MySQL 5.5.10, the client-side clear-text plugin that communicates with the server-side PAM plugin is built into the `libmysqlclient` client library and is included in all distributions, including community distributions. Inclusion of the client-side clear-text plugin in all MySQL distributions enables clients from any MySQL 5.5.10 or higher distribution to connect to a server that has the server-side plugin loaded.

The following sections provide installation and usage information specific to PAM pluggable authentication:

- Installing PAM Pluggable Authentication
- Uninstalling PAM Pluggable Authentication
- Using PAM Pluggable Authentication
- Unix Password Authentication without Proxy Users
- LDAP Authentication without Proxy Users
- Unix Password Authentication with Proxy Users and Group Mapping
- PAM Pluggable Authentication Debugging

For general information about pluggable authentication in MySQL, see Section 6.3.6, “Pluggable Authentication”. For information about the `mysql_clear_password` plugin, see Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”. For proxy user information, see Section 6.3.7, “Proxy Users”.

Installing PAM Pluggable Authentication

This section describes how to install the PAM authentication plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

The plugin library file base name is `authentication_pam`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).

To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put these lines in your `my.cnf` file (adjust the `.so` suffix for your platform as necessary):

```
[mysqld]
plugin-load=authentication_pam.so
```

After modifying `my.cnf`, restart the server to cause the new settings to take effect.

Alternatively, to register the plugin at runtime, use this statement (adjust the `.so` suffix as necessary):

```
INSTALL PLUGIN authentication_pam SONAME 'authentication_pam.so';
```

`INSTALL PLUGIN` loads a plugin, and also registers it in the `mysql.plugins` system table to cause the plugin to be loaded for each subsequent normal server startup.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, "Obtaining Server Plugin Information"). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
       FROM INFORMATION_SCHEMA.PLUGINS
       WHERE PLUGIN_NAME LIKE '%pam%';
+--------------------+---------------+
| PLUGIN_NAME        | PLUGIN_STATUS |
+--------------------+---------------+
| authentication_pam | ACTIVE        |
+--------------------+---------------+
```

If the plugin fails to initialize, check the server error log for diagnostic messages.

To associate MySQL accounts with the PAM plugin, see Using PAM Pluggable Authentication.

Uninstalling PAM Pluggable Authentication

The method used to uninstall the PAM authentication plugin depends on how you installed it:

- If you installed the plugin at server startup using a `--plugin-load` option, restart the server without the option.
- If you installed the plugin at runtime using `INSTALL PLUGIN`, it remains installed across server restarts. To uninstall it, use `UNINSTALL PLUGIN`:

```
UNINSTALL PLUGIN authentication_pam;
```

Using PAM Pluggable Authentication

This section describes how to use the PAM authentication plugin to connect from MySQL client programs to the server. It is assumed that the server is running with the server-side plugin enabled, as described in Installing PAM Pluggable Authentication, and that client programs are recent enough to include the client-side plugin.

To refer to the PAM authentication plugin in the `IDENTIFIED WITH` clause of a `CREATE USER` or `GRANT` statement, use the name `authentication_pam`. For example:

```
CREATE USER user
  IDENTIFIED WITH authentication_pam
  AS 'authentication_string';
```

The authentication string specifies the following types of information:

- PAM supports the notion of "service name," which is a name that the system administrator can use to configure the authentication method for a particular application. There can be several such "applications" associated with a single database server instance, so the choice of service name is left to the SQL application developer. When you define an account that should authenticate using PAM, specify the service name in the authentication string.
- PAM provides a way for a PAM module to return to the server a MySQL user name other than the login name supplied at login time. Use the authentication string to control the mapping between login name and MySQL user name. If you want to take advantage of proxy user capabilities, the authentication string must include this kind of mapping.

For example, if the service name is `mysql` and users in the `root` and `users` PAM groups should be mapped to the `developer` and `data_entry` MySQL users, respectively, use a statement like this:

```
```

```
CREATE USER user
  IDENTIFIED WITH authentication_pam
  AS 'mysql, root=developer, users=data_entry';
```

Authentication string syntax for the PAM authentication plugin follows these rules:

- The string consists of a PAM service name, optionally followed by a group mapping list consisting of one or more keyword/value pairs each specifying a group name and a MySQL user name:

  ```
  pam_service_name[,group_name=mysql_user_name]...
  ```

  The plugin parses the authentication string on each login check. To minimize overhead, keep the string as short as possible.

- Each *`group_name=mysql_user_name`* pair must be preceded by a comma.

- Leading and trailing spaces not inside double quotation marks are ignored.

- Unquoted *`pam_service_name`*, *`group_name`*, and *`mysql_user_name`* values can contain anything except equal sign, comma, or space.

- If a *`pam_service_name`*, *`group_name`*, or *`mysql_user_name`* value is quoted with double quotation marks, everything between the quotation marks is part of the value. This is necessary, for example, if the value contains space characters. All characters are legal except double quotation mark and backslash (`\`). To include either character, escape it with a backslash.

If the plugin successfully authenticates a login name, it looks for a group mapping list in the authentication string and, if present, uses it to return a different user name to the MySQL server based on the groups the external user is a member of:

- If the authentication string contains no group mapping list, the plugin returns the login name.

- If the authentication string does contain a group mapping list, the plugin examines each *`group_name=mysql_user_name`* pair in the list from left to right and tries to find a match for the *`group_name`* value in a non-MySQL directory of the groups assigned to the authenticated user and returns *`mysql_user_name`* for the first match it finds. If the plugin finds no match for any group, it returns the login name. If the plugin is not capable of looking up a group in a directory, it ignores the group mapping list and returns the login name.

The following sections describe how to set up several authentication scenarios that use the PAM authentication plugin:

- No proxy users. This uses PAM only to check login names and passwords. Every external user permitted to connect to MySQL Server should have a matching MySQL account that is defined to use external PAM authentication. (For a MySQL account of *`user_name@host_name`* to match the external user, *`user_name`* must be the login name and *`host_name`* must match the host from which the client connects.) Authentication can be performed by various PAM-supported methods. The discussion shows how to use traditional Unix passwords and LDAP.

  PAM authentication, when not done through proxy users or groups, requires the MySQL account to have the same user name as the Unix account. MySQL user names are limited to 16 characters (see Section 6.2.2, “Grant Tables”), which limits PAM nonproxy authentication to Unix accounts with names of at most 16 characters.

- Proxy login only and group mapping. For this scenario, create one or a few MySQL accounts that define different sets of privileges. (Ideally, nobody should connect using those accounts directly.) Then define a default user authenticating through PAM that uses some mapping scheme (usually by the external groups the users are in) to map all the external logins to the few MySQL accounts holding the privilege sets. Any user that logs in is mapped to one of the MySQL accounts and uses its privileges. The discussion shows how to set this up using Unix passwords, but other PAM methods such as LDAP could be used instead.

Variations on these scenarios are possible. For example, you can permit some users to log in directly (without proxying) but require others to connect through proxy users.

The examples make the following assumptions. You might need to make some adjustments if your system is set up differently.

- The PAM configuration directory is `/etc/pam.d`.
- The PAM service name is `mysql`, which means that you must set up a PAM file named `mysql` in the PAM configuration directory (creating the file if it does not exist). If you use a service name different from `mysql`, the file name will differ and you must use a different name in the `AS 'auth_string'` clause of `CREATE USER` and `GRANT` statements.
- The examples use a login name of `antonio` and password of `verysecret`. Change these to correspond to the users you want to authenticate.

The PAM authentication plugin checks at initialization time whether the `AUTHENTICATION_PAM_LOG` environment value is set in the server's startup environment. If so, the plugin enables logging of diagnostic messages to the standard output. Depending on how your server is started, the message might appear on the console or in the error log. These messages can be helpful for debugging PAM-related problems that occur when the plugin performs authentication. For more information, see PAM Pluggable Authentication Debugging.

Unix Password Authentication without Proxy Users

This authentication scenario uses PAM only to check Unix user login names and passwords. Every external user permitted to connect to MySQL Server should have a matching MySQL account that is defined to use external PAM authentication.

1. Verify that Unix authentication in PAM permits you to log in as `antonio` with password `verysecret`.
2. Set up PAM to authenticate the `mysql` service by creating a file named `/etc/pam.d/mysql`. The file contents are system dependent, so check existing login-related files in the `/etc/pam.d` directory to see what they look like. On Linux, the `mysql` file might look like this:

   ```
   #%PAM-1.0
   auth            include         password-auth
   account         include         password-auth
   ```

   For Gentoo Linux, use `system-login` rather than `password-auth`. For macOS, use `login` rather than `password-auth`.

   The PAM file format might differ on some systems. For example, on Ubuntu and other Debian-based systems, use these file contents instead:

   ```
   @include common-auth
   @include common-account
   @include common-session-noninteractive
   ```

3. Create a MySQL account with the same user name as the Unix login name and define it to authenticate using the PAM plugin:

   ```
   CREATE USER 'antonio'@'localhost'
     IDENTIFIED WITH authentication_pam AS 'mysql';
   GRANT ALL PRIVILEGES ON mydb.* TO 'antonio'@'localhost';
   ```

4. Connect to the MySQL server using the `mysql` command-line client. For example:

   ```
   mysql --user=antonio --password --enable-cleartext-plugin mydb
   Enter password: verysecret
   ```

The server should permit the connection and the following query should return output as shown:

```
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user;
+-------------------+-------------------+--------------+
| USER()            | CURRENT_USER()    | @@proxy_user |
+-------------------+-------------------+--------------+
| antonio@localhost | antonio@localhost | NULL         |
+-------------------+-------------------+--------------+
```

This demonstrates that `antonio` uses the privileges granted to the `antonio` MySQL account, and that no proxying has occurred.

Note

The client-side `mysql_clear_password` plugin with which the server-side PAM plugin communicates sends the password to the MySQL server in clear text so it can be passed to PAM. This is necessary to use the server-side PAM library, but may be a security problem in some configurations. These measures minimize the risk:

- To make inadvertent use of the `mysql_clear_password` plugin less likely, MySQL clients must explicitly enable it; for example, with the `--enable-cleartext-plugin` option.
- To avoid password exposure with the `mysql_clear_password` plugin enabled, MySQL clients should connect to the MySQL server using a secure connection.

For additinal information, see Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”, and Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”.

Note

On some systems, Unix authentication uses `/etc/shadow`, a file that typically has restricted access permissions. This can cause MySQL PAM-based authentication to fail. Unfortunately, the PAM implementation does not permit distinguishing “password could not be checked” (due, for example, to inability to read `/etc/shadow`) from “password does not match.” If your system uses `/etc/shadow`, you may be able enable access to it by MySQL using this method (assuming that the MySQL server is run from the `mysql` system account):

1. Create a `shadow` group in `/etc/group`.
2. Add the `mysql` user to the `shadow` group in `/etc/group`.
3. Assign `/etc/group` to the `shadow` group and enable the group read permission:

   ```
   chgrp shadow /etc/shadow
   chmod g+r /etc/shadow
   ```

4. Restart the MySQL server.

LDAP Authentication without Proxy Users

This authentication scenario uses PAM only to check LDAP user login names and passwords. Every external user permitted to connect to MySQL Server should have a matching MySQL account that is defined to use external PAM authentication.

1. Verify that LDAP authentication in PAM permits you to log in as `antonio` with password `verysecret`.

2. Set up PAM to authenticate the `mysql` service through LDAP by creating a file named `/etc/pam.d/mysql`. The file contents are system dependent, so check existing login-related files in the `/etc/pam.d` directory to see what they look like. On Linux, the `mysql` file might look like this:

   ```
   #%PAM-1.0
   auth        required    pam_ldap.so
   account     required    pam_ldap.so
   ```

   If PAM object files have a suffix different from `.so` on your system, substitute the correct suffix.

   The PAM file format might differ on some systems.

3. MySQL account creation and connecting to the server is the same as described in Unix Password Authentication without Proxy Users.

Unix Password Authentication with Proxy Users and Group Mapping

The authentication scheme described here uses proxying and group mapping to map connecting MySQL users who authenticate using PAM onto other MySQL accounts that define different sets of privileges. Users do not connect directly through the accounts that define the privileges. Instead, they connect through a default proxy user authenticated using PAM, such that all the external logins are mapped to the MySQL accounts that hold the privileges. Any user who connects is mapped to one of those MySQL accounts, the privileges for which determine the database operations permitted to the external user.

The procedure shown here uses Unix password authentication. To use LDAP instead, see the early steps of LDAP Authentication without Proxy Users.

Note

For information regarding possible problems related to `/etc/shadow`, see Unix Password Authentication without Proxy Users.

1. Verify that Unix authentication in PAM permits you to log in as `antonio` with password `verysecret` and that `antonio` is a member of the `root` or `users` group.

2. Set up PAM to authenticate the `mysql` service. Put the following in `/etc/pam.d/mysql`:

   ```
   #%PAM-1.0
   auth            include         password-auth
   account         include         password-auth
   ```

   For Gentoo Linux, use `system-login` rather than `password-auth`. For macOS, use `login` rather than `password-auth`.

   The PAM file format might differ on some systems. For example, on Ubuntu and other Debian-based systems, use these file contents instead:

   ```
   @include common-auth
   @include common-account
   @include common-session-noninteractive
   ```

3. Create a default proxy user (`''@''`) that maps the external PAM users to the proxied accounts. It maps external users from the `root` PAM group to the `developer` MySQL account and the external users from the `users` PAM group to the `data_entry` MySQL account:

   ```
   CREATE USER ''@''
   ```

```
  IDENTIFIED WITH authentication_pam
  AS 'mysql, root=developer, users=data_entry';
```

The mapping list following the service name is required when you set up proxy users. Otherwise, the plugin cannot tell how to map the name of PAM groups to the proper proxied user name.

Note

If your MySQL installation has anonymous users, they might conflict with the default proxy user. For more information about this problem, and ways of dealing with it, see Default Proxy User and Anonymous User Conflicts.

4. Create the proxied accounts that will be used to access the databases:

```
CREATE USER 'developer'@'localhost' IDENTIFIED BY 'very secret password';
GRANT ALL PRIVILEGES ON mydevdb.* TO 'developer'@'localhost';
CREATE USER 'data_entry'@'localhost' IDENTIFIED BY 'very secret password';
GRANT ALL PRIVILEGES ON mydb.* TO 'data_entry'@'localhost';
```

If you do not let anyone know the passwords for these accounts, other users cannot use them to connect directly to the MySQL server. Instead, it is expected that users will authenticate using PAM and that they will use the `developer` or `data_entry` account by proxy based on their PAM group.

5. Grant the `PROXY` privilege to the proxy account for the proxied accounts:

```
GRANT PROXY ON 'developer'@'localhost' TO ''@'';
GRANT PROXY ON 'data_entry'@'localhost' TO ''@'';
```

6. Connect to the MySQL server using the `mysql` command-line client. For example:

```
mysql --user=antonio --password --enable-cleartext-plugin mydb
Enter password: verysecret
```

The server authenticates the connection using the `''@''` account. The privileges `antonio` will have depends on what PAM groups he is a member of. If `antonio` is a member of the `root` PAM group, the PAM plugin maps `root` to the `developer` MySQL user name and returns that name to the server. The server verifies that `''@''` has the `PROXY` privilege for `developer` and permits the connection. the following query should return output as shown:

```
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user;
+-------------------+--------------------+--------------+
| USER()            | CURRENT_USER()     | @@proxy_user |
+-------------------+--------------------+--------------+
| antonio@localhost | developer@localhost | ''@''        |
+-------------------+--------------------+--------------+
```

This demonstrates that `antonio` uses the privileges granted to the `developer` MySQL account, and that proxying occurred through the default proxy user account.

If `antonio` is not a member of the `root` PAM group but is a member of the `users` group, a similar process occurs, but the plugin maps `user` group membership to the `data_entry` MySQL user name and returns that name to the server. In this case, `antonio` uses the privileges of the `data_entry` MySQL account:

```
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user;
+-------------------+---------------------+--------------+
| USER()            | CURRENT_USER()      | @@proxy_user |
+-------------------+---------------------+--------------+
| antonio@localhost | data_entry@localhost | ''@''        |
+-------------------+---------------------+--------------+
```

Note

The client-side `mysql_clear_password` plugin with which the server-side PAM plugin communicates sends the password to the MySQL server in clear text so it can be passed to PAM. This is necessary to use the server-side PAM library, but may be a security problem in some configurations. These measures minimize the risk:

- To make inadvertent use of the `mysql_clear_password` plugin less likely, MySQL clients must explicitly enable it; for example, with the `--enable-cleartext-plugin` option.
- To avoid password exposure with the `mysql_clear_password` plugin enabled, MySQL clients should connect to the MySQL server using a secure connection.

For additinal information, see Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”, and Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”.

PAM Pluggable Authentication Debugging

The PAM authentication plugin checks at initialization time whether the `AUTHENTICATION_PAM_LOG` environment value is set (the value does not matter). If so, the plugin enables logging of diagnostic messages to the standard output. These messages may be helpful for debugging PAM-related problems that occur when the plugin performs authentication.

Some messages include reference to PAM plugin source files and line numbers, which enables plugin actions to be tied more closely to the location in the code where they occur.

6.5.1.5 Windows Pluggable Authentication

Note

Windows pluggable authentication is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see http://www.mysql.com/products/.

As of MySQL 5.5.16, MySQL Enterprise Edition for Windows supports an authentication method that performs external authentication on Windows, enabling MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password.

The client and server exchange data packets in the authentication handshake. As a result of this exchange, the server creates a security context object that represents the identity of the client in the Windows OS. This identity includes the name of the client account. Windows pluggable authentication uses the identity of the client to check whether it is a given account or a member of a group. By default, negotiation uses Kerberos to authenticate, then NTLM if Kerberos is unavailable.

Windows pluggable authentication provides these capabilities:

- External authentication: Windows authentication enables MySQL Server to accept connections from users defined outside the MySQL grant tables who have logged in to Windows.
- Proxy user support: Windows authentication can return to MySQL a user name different from the client user. This means that the plugin can return the MySQL user that defines the privileges the external Windows-authenticated user should have. For example, a user named `joe` can connect and have the privileges of the user named `developer`.

The following table shows the plugin and library file names. The file must be located in the directory named by the `plugin_dir` system variable.

Table 6.13 Plugin and Library Names for Windows Authentication

Server-side plugin name	`authentication_windows`
Client-side plugin name	`authentication_windows_client`
Library file name	`authentication_windows.dll`

The library file includes only the server-side plugin. As of MySQL 5.5.13, the client-side plugin is built into the `libmysqlclient` client library.

The server-side Windows authentication plugin is included only in MySQL Enterprise Edition. It is not included in MySQL community distributions. The client-side plugin is included in all distributions, including community distributions. This permits clients from any 5.5.13 or higher distribution to connect to a server that has the server-side plugin loaded.

The Windows authentication plugin is supported on any version of Windows supported by MySQL 5.5 (see http://www.mysql.com/support/supportedplatforms/database.html). It requires MySQL Server 5.5.16 or higher.

The following sections provide installation and usage information specific to Windows pluggable authentication:

- Installing Windows Pluggable Authentication
- Uninstalling Windows Pluggable Authentication
- Using Windows Pluggable Authentication

For general information about pluggable authentication in MySQL, see Section 6.3.6, “Pluggable Authentication”. For proxy user information, see Section 6.3.7, “Proxy Users”.

Installing Windows Pluggable Authentication

This section describes how to install the Windows authentication plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put these lines in your `my.cnf` file:

```
[mysqld]
plugin-load=authentication_windows.dll
```

After modifying `my.cnf`, restart the server to cause the new settings to take effect.

Alternatively, to register the plugin at runtime, use this statement:

```
INSTALL PLUGIN authentication_windows SONAME 'authentication_windows.dll';
```

`INSTALL PLUGIN` loads a plugin, and also registers it in the `mysql.plugins` system table to cause the plugin to be loaded for each subsequent normal server startup.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
       FROM INFORMATION_SCHEMA.PLUGINS
       WHERE PLUGIN_NAME LIKE '%windows%';
+-----------------------+---------------+
```

```
| PLUGIN_NAME            | PLUGIN_STATUS |
+------------------------+---------------+
| authentication_windows | ACTIVE        |
+------------------------+---------------+
```

If the plugin fails to initialize, check the server error log for diagnostic messages.

To associate MySQL accounts with the Windows authentication plugin, see Using Windows Pluggable Authentication.

Uninstalling Windows Pluggable Authentication

The method used to uninstall the Windows authentication plugin depends on how you installed it:

- If you installed the plugin at server startup using a `--plugin-load` option, restart the server without the option.
- If you installed the plugin at runtime using `INSTALL PLUGIN`, it remains installed across server restarts. To uninstall it, use `UNINSTALL PLUGIN`:

```
UNINSTALL PLUGIN authentication_windows;
```

In addition, remove any startup options that set Windows plugin-related system variables.

Using Windows Pluggable Authentication

The Windows authentication plugin supports the use of MySQL accounts such that users who have logged in to Windows can connect to the MySQL server without having to specify an additional password. It is assumed that the server is running with the server-side plugin enabled, as described in Installing Windows Pluggable Authentication, and that client programs are recent enough to include the client-side plugin built into `libmysqlclient` (MySQL 5.5.13 or higher). Once the DBA has enabled the server-side plugin and set up accounts to use it, clients can connect using those accounts with no other setup required on their part.

To refer to the Windows authentication plugin in the `IDENTIFIED WITH` clause of a `CREATE USER` or `GRANT` statement, use the name `authentication_windows`. Suppose that the Windows users `Rafal` and `Tasha` should be permitted to connect to MySQL, as well as any users in the `Administrators` or `Power Users` group. To set this up, create a MySQL account named `sql_admin` that uses the Windows plugin for authentication:

```
CREATE USER sql_admin
  IDENTIFIED WITH authentication_windows
  AS 'Rafal, Tasha, Administrators, "Power Users"';
```

The plugin name is `authentication_windows`. The string following the `AS` keyword is the authentication string. It specifies that the Windows users named `Rafal` or `Tasha` are permitted to authenticate to the server as the MySQL user `sql_admin`, as are any Windows users in the `Administrators` or `Power Users` group. The latter group name contains a space, so it must be quoted with double quote characters.

After you create the `sql_admin` account, a user who has logged in to Windows can attempt to connect to the server using that account:

```
C:\> mysql --user=sql_admin
```

No password is required here. The `authentication_windows` plugin uses the Windows security API to check which Windows user is connecting. If that user is named `Rafal` or `Tasha`, or is in the `Administrators` or `Power Users` group, the server grants access and the client is authenticated as `sql_admin` and has whatever privileges are granted to the `sql_admin` account. Otherwise, the server denies access.

Authentication string syntax for the Windows authentication plugin follows these rules:

- The string consists of one or more user mappings separated by commas.
- Each user mapping associates a Windows user or group name with a MySQL user name:

```
win_user_or_group_name=mysql_user_name
win_user_or_group_name
```

  For the latter syntax, with no *mysql_user_name* value given, the implicit value is the MySQL user created by the CREATE USER statement. Thus, these statements are equivalent:

```
CREATE USER sql_admin
  IDENTIFIED WITH authentication_windows
  AS 'Rafal, Tasha, Administrators, "Power Users"';

CREATE USER sql_admin
  IDENTIFIED WITH authentication_windows
  AS 'Rafal=sql_admin, Tasha=sql_admin, Administrators=sql_admin,
      "Power Users"=sql_admin';
```

- Each backslash (`'\'`) in a value must be doubled because backslash is the escape character in MySQL strings.
- Leading and trailing spaces not inside double quotation marks are ignored.
- Unquoted *win_user_or_group_name* and *mysql_user_name* values can contain anything except equal sign, comma, or space.
- If a *win_user_or_group_name* and or *mysql_user_name* value is quoted with double quotation marks, everything between the quotation marks is part of the value. This is necessary, for example, if the name contains space characters. All characters within double quotes are legal except double quotation mark and backslash. To include either character, escape it with a backslash.
- *win_user_or_group_name* values use conventional syntax for Windows principals, either local or in a domain. Examples (note the doubling of backslashes):

```
domain\\user
.\\user
domain\\group
.\\group
BUILTIN\\WellKnownGroup
```

When invoked by the server to authenticate a client, the plugin scans the authentication string left to right for a user or group match to the Windows user. If there is a match, the plugin returns the corresponding *mysql_user_name* to the MySQL server. If there is no match, authentication fails.

A user name match takes preference over a group name match. Suppose that the Windows user named win_user is a member of win_group and the authentication string looks like this:

```
'win_group = sql_user1, win_user = sql_user2'
```

When win_user connects to the MySQL server, there is a match both to win_group and to win_user. The plugin authenticates the user as sql_user2 because the more-specific user match takes precedence over the group match, even though the group is listed first in the authentication string.

Windows authentication always works for connections from the same computer on which the server is running. For cross-computer connections, both computers must be registered with Windows Active Directory. If they are in the same Windows domain, it is unnecessary to specify a domain name. It is also possible to permit connections from a different domain, as in this example:

```
CREATE USER sql_accounting
  IDENTIFIED WITH authentication_windows
  AS 'SomeDomain\\Accounting';
```

Here `SomeDomain` is the name of the other domain. The backslash character is doubled because it is the MySQL escape character within strings.

MySQL supports the concept of proxy users whereby a client can connect and authenticate to the MySQL server using one account but while connected has the privileges of another account (see Section 6.3.7, “Proxy Users”). Suppose that you want Windows users to connect using a single user name but be mapped based on their Windows user and group names onto specific MySQL accounts as follows:

- The `local_user` and `MyDomain\domain_user` local and domain Windows users should map to the `local_wlad` MySQL account.
- Users in the `MyDomain\Developers` domain group should map to the `local_dev` MySQL account.
- Local machine administrators should map to the `local_admin` MySQL account.

To set this up, create a proxy account for Windows users to connect to, and configure this account so that users and groups map to the appropriate MySQL accounts (`local_wlad`, `local_dev`, `local_admin`). In addition, grant the MySQL accounts the privileges appropriate to the operations they need to perform. The following instructions use `win_proxy` as the proxy account, and `local_wlad`, `local_dev`, and `local_admin` as the proxied accounts.

1. Create the proxy MySQL account:

   ```
   CREATE USER win_proxy
     IDENTIFIED WITH  authentication_windows
     AS 'local_user = local_wlad,
         MyDomain\\domain_user = local_wlad,
         MyDomain\\Developers = local_dev,
         BUILTIN\\Administrators = local_admin';
   ```

   Note

   If your MySQL installation has anonymous users, they might conflict with the default proxy user. For more information about this problem, and ways of dealing with it, see Default Proxy User and Anonymous User Conflicts.

2. For proxying to work, the proxied accounts must exist, so create them:

   ```
   CREATE USER local_wlad IDENTIFIED BY 'wlad_pass';
   CREATE USER local_dev IDENTIFIED BY 'dev_pass';
   CREATE USER local_admin IDENTIFIED BY  'admin_pass';
   ```

   If you do not let anyone know the passwords for these accounts, other users cannot use them to connect directly to the MySQL server.

   You should also issue `GRANT` statements (not shown) that grant each proxied account the privileges it needs.

3. The proxy account must have the `PROXY` privilege for each of the proxied accounts:

   ```
   GRANT PROXY ON local_wlad TO win_proxy;
   GRANT PROXY ON local_dev TO win_proxy;
   GRANT PROXY ON local_admin TO win_proxy;
   ```

Now the Windows users `local_user` and `MyDomain\domain_user` can connect to the MySQL server as `win_proxy` and when authenticated have the privileges of the account given in the

authentication string—in this case, `local_wlad`. A user in the `MyDomain\Developers` group who connects as `win_proxy` has the privileges of the `local_dev` account. A user in the `BUILTIN\Administrators` group has the privileges of the `local_admin` account.

To configure authentication so that all Windows users who do not have their own MySQL account go through a proxy account, substitute the default proxy user (`''@''`) for `win_proxy` in the preceding instructions. For information about the default proxy user, see Section 6.3.7, “Proxy Users”.

To use the Windows authentication plugin with Connector/Net connection strings in Connection/Net 6.4.4 and higher, see Using the Windows Native Authentication Plugin.

Additional control over the Windows authentication plugin is provided by the `authentication_windows_use_principal_name` and `authentication_windows_log_level` system variables. See Section 5.1.5, “Server System Variables”.

6.5.1.6 Socket Peer-Credential Pluggable Authentication

As of MySQL 5.5.10, a server-side `auth_socket` authentication plugin is available that authenticates clients that connect from the local host through the Unix socket file. The plugin uses the `SO_PEERCRED` socket option to obtain information about the user running the client program. Thus, the plugin can be used only on systems that support the `SO_PEERCRED` option, such as Linux.

The source code for this plugin can be examined as a relatively simple example demonstrating how to write a loadable authentication plugin.

The following table shows the plugin and library file names. The file must be located in the directory named by the `plugin_dir` system variable.

Table 6.14 Plugin and Library Names for Socket Peer-Credential Authentication

Server-side plugin name	`auth_socket`
Client-side plugin name	None, see discussion
Library file name	`auth_socket.so`

The following sections provide installation and usage information specific to socket pluggable authentication:

- Installing Socket Pluggable Authentication
- Uninstalling Socket Pluggable Authentication
- Using Socket Pluggable Authentication

For general information about pluggable authentication in MySQL, see Section 6.3.6, “Pluggable Authentication”.

Installing Socket Pluggable Authentication

This section describes how to install the socket authentication plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put these lines in your `my.cnf` file:

```
[mysqld]
```

```
plugin-load=auth_socket.so
```

After modifying `my.cnf`, restart the server to cause the new settings to take effect.

Alternatively, to register the plugin at runtime, use this statement:

```
INSTALL PLUGIN auth_socket SONAME 'auth_socket.so';
```

`INSTALL PLUGIN` loads a plugin, and also registers it in the `mysql.plugins` system table to cause the plugin to be loaded for each subsequent normal server startup.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
       FROM INFORMATION_SCHEMA.PLUGINS
       WHERE PLUGIN_NAME LIKE '%socket%';
+-------------+---------------+
| PLUGIN_NAME | PLUGIN_STATUS |
+-------------+---------------+
| auth_socket | ACTIVE        |
+-------------+---------------+
```

If the plugin fails to initialize, check the server error log for diagnostic messages.

To associate MySQL accounts with the socket plugin, see Using Socket Pluggable Authentication.

Uninstalling Socket Pluggable Authentication

The method used to uninstall the socket authentication plugin depends on how you installed it:

- If you installed the plugin at server startup using a `--plugin-load` option, restart the server without the option.
- If you installed the plugin at runtime using `INSTALL PLUGIN`, it remains installed across server restarts. To uninstall it, use `UNINSTALL PLUGIN`:

  ```
  UNINSTALL PLUGIN auth_socket;
  ```

Using Socket Pluggable Authentication

The socket plugin checks whether the socket user name matches the MySQL user name specified by the client program to the server, and permits the connection only if the names match.

Suppose that a MySQL account is created for a user named `valerie` who is to be authenticated by the `auth_socket` plugin for connections from the local host through the socket file:

```
CREATE USER 'valerie'@'localhost' IDENTIFIED WITH auth_socket;
```

If a user on the local host with a login name of `stefanie` invokes `mysql` with the option `--user=valerie` to connect through the socket file, the server uses `auth_socket` to authenticate the client. The plugin determines that the `--user` option value (`valerie`) differs from the client user's name (`stephanie`) and refuses the connection. If a user named `valerie` tries the same thing, the plugin finds that the user name and the MySQL user name are both `valerie` and permits the connection. However, the plugin refuses the connection even for `valerie` if the connection is made using a different protocol, such as TCP/IP.

6.5.1.7 Test Pluggable Authentication

MySQL includes a test plugin that checks account credentials and logs success or failure to the server error log. This is a loadable plugin (not built in) and must be installed prior to use.

The test plugin source code is separate from the server source, unlike the built-in native plugin, so it can be examined as a relatively simple example demonstrating how to write a loadable authentication plugin.

Note

This plugin is intended for testing and development purposes, and is not for use in production environments or on servers that are exposed to public networks.

The following table shows the plugin and library file names. The file name suffix might differ on your system. The file must be located in the directory named by the `plugin_dir` system variable.

Table 6.15 Plugin and Library Names for Test Authentication

Server-side plugin name	`test_plugin_server`
Client-side plugin name	`auth_test_plugin`
Library file name	`auth_test_plugin.so`

The following sections provide installation and usage information specific to test pluggable authentication:

- Installing Test Pluggable Authentication
- Uninstalling Test Pluggable Authentication
- Using Test Pluggable Authentication

For general information about pluggable authentication in MySQL, see Section 6.3.6, “Pluggable Authentication”.

Installing Test Pluggable Authentication

This section describes how to install the test authentication plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put these lines in your `my.cnf` file (adjust the `.so` suffix for your platform as necessary):

```
[mysqld]
plugin-load=auth_test_plugin.so
```

After modifying `my.cnf`, restart the server to cause the new settings to take effect.

Alternatively, to register the plugin at runtime, use this statement (adjust the `.so` suffix as necessary):

```
INSTALL PLUGIN test_plugin_server SONAME 'auth_test_plugin.so';
```

`INSTALL PLUGIN` loads a plugin, and also registers it in the `mysql.plugins` system table to cause the plugin to be loaded for each subsequent normal server startup.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, “Obtaining Server Plugin Information”). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
       FROM INFORMATION_SCHEMA.PLUGINS
       WHERE PLUGIN_NAME LIKE '%test_plugin%';
```

```
+--------------------+---------------+
| PLUGIN_NAME        | PLUGIN_STATUS |
+--------------------+---------------+
| test_plugin_server | ACTIVE        |
+--------------------+---------------+
```

If the plugin fails to initialize, check the server error log for diagnostic messages.

To associate MySQL accounts with the test plugin, see Using Test Pluggable Authentication.

Uninstalling Test Pluggable Authentication

The method used to uninstall the test authentication plugin depends on how you installed it:

- If you installed the plugin at server startup using a `--plugin-load` option, restart the server without the option.
- If you installed the plugin at runtime using `INSTALL PLUGIN`, it remains installed across server restarts. To uninstall it, use `UNINSTALL PLUGIN`:

```
UNINSTALL PLUGIN test_plugin_server;
```

Using Test Pluggable Authentication

To use the test authentication plugin, create an account and name that plugin in the `IDENTIFIED WITH` clause:

```
CREATE USER 'testuser'@'localhost'
IDENTIFIED WITH test_plugin_server
BY 'testpassword';
```

Then provide the `--user` and `--password` options for that account when you connect to the server. For example:

```
shell> mysql --user=testuser --password
Enter password: testpassword
```

The plugin fetches the password as received from the client and compares it with the value stored in the `authentication_string` column of the account row in the `mysql.user` table. If the two values match, the plugin returns the `authentication_string` value as the new effective user ID.

You can look in the server error log for a message indicating whether authentication succeeded (notice that the password is reported as the “user”):

```
[Note] Plugin test_plugin_server reported:
'successfully authenticated user testpassword'
```

6.5.2 MySQL Enterprise Audit

Note

MySQL Enterprise Audit is an extension included in MySQL Enterprise Edition, a commercial product. To learn more about commercial products, see http://www.mysql.com/products/.

As of MySQL 5.5.28, MySQL Enterprise Edition includes MySQL Enterprise Audit, implemented using a server plugin named `audit_log`. MySQL Enterprise Audit uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines.

When installed, the audit plugin enables MySQL Server to produce a log file containing an audit record of server activity. The log contents include when clients connect and disconnect, and what actions they perform while connected, such as which databases and tables they access.

After you install the plugin (see Section 6.5.2.1, “Installing MySQL Enterprise Audit”), it writes an audit log file. By default, the file is named `audit.log` in the server data directory. To change the name of the file, set the `audit_log_file` system variable at server startup.

Audit log file contents are not encrypted. See Section 6.5.2.2, “MySQL Enterprise Audit Security Considerations”.

The audit log file is written in XML, with auditable events encoded as `<AUDIT_RECORD>` elements. To select the file format, set the `audit_log_format` system variable at server startup. For details on file format and contents, see Section 6.5.2.3, “Audit Log File Formats”.

To control what information the audit log plugin writes to its log file, set the `audit_log_policy` system variable. By default, this variable is set to `ALL` (write all auditable events), but also permits values of `LOGINS` or `QUERIES` to log only login or query events, or `NONE` to disable logging.

For more information about controlling how logging occurs, see Section 6.5.2.4, “Audit Log Logging Control”. For descriptions of the parameters used to configure the audit log plugin, see Section 6.5.2.7, “Audit Log Options and System Variables”.

If the audit log plugin is enabled, the Performance Schema (see Chapter 22, *MySQL Performance Schema*) has instrumentation for it. To identify the relevant instruments, use this query:

```
SELECT NAME FROM performance_schema.setup_instruments
WHERE NAME LIKE '%/alog/%';
```

Changes from Older MySQL Enterprise Audit Versions

Several changes were made to the audit log plugin in MySQL 5.5.34 for better compatibility with Oracle Audit Vault.

MySQL 5.7 changed audit log file output to a new format. This format has been backported to MySQL 5.5 and it is possible to select either the old or new format using the `audit_log_format` system variable, which has permitted values of `OLD` and `NEW` (default `OLD`). The two formats differ as follows:

- Information within `<AUDIT_RECORD>` elements written in the old format using attributes is written in the new format using subelements.
- The new format includes more information in `<AUDIT_RECORD>` elements. Every element includes a `RECORD_ID` value providing a unique identifier. The `TIMESTAMP` value includes time zone information. Query records include `HOST`, `IP`, `OS_LOGIN`, and `USER` information, as well as `COMMAND_CLASS` and `STATUS_CODE` values.

Example of old `<AUDIT_RECORD>` format:

```
<AUDIT_RECORD
 TIMESTAMP="2013-09-15T15:27:27"
 NAME="Query"
 CONNECTION_ID="3"
 STATUS="0"
 SQLTEXT="SELECT 1"
/>
```

Example of new `<AUDIT_RECORD>` format:

```
<AUDIT_RECORD>
 <TIMESTAMP>2013-09-15T15:27:27 UTC</TIMESTAMP>
 <RECORD_ID>3998_2013-09-15T15:27:27</RECORD_ID>
```

```
 <NAME>Query</NAME>
 <CONNECTION_ID>3</CONNECTION_ID>
 <STATUS>0</STATUS>
 <STATUS_CODE>0</STATUS_CODE>
 <USER>root[root] @ localhost [127.0.0.1]</USER>
 <OS_LOGIN></OS_LOGIN>
 <HOST>localhost</HOST>
 <IP>127.0.0.1</IP>
 <COMMAND_CLASS>select</COMMAND_CLASS>
 <SQLTEXT>SELECT 1</SQLTEXT>
</AUDIT_RECORD>
```

When the audit log plugin rotates the audit log file, it uses a different file name format. For a log file named `audit.log`, the plugin previously renamed the file to `audit.log.TIMESTAMP`. The plugin now renames the file to `audit.log.TIMESTAMP.xml` to indicate that it is an XML file.

If you change the value of `audit_log_format`, use this procedure to avoid writing log entries in one format to an existing log file that contains entries in a different format:

1. Stop the server.
2. Rename the current audit log file manually.
3. Restart the server with the new value of `audit_log_format`. The audit log plugin will create a new log file, which will contain log entries in the selected format.

The API for writing audit plugins has also changed. The `mysql_event_general` structure has new members to represent client host name and IP address, command class, and external user. For more information, see Section 24.2.4.8, “Writing Audit Plugins”.

6.5.2.1 Installing MySQL Enterprise Audit

This section describes how to install MySQL Enterprise Audit, which is implemented using the `audit_log` plugin. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

Note

If installed, the `audit_log` plugin involves some minimal overhead even when disabled. To avoid this overhead, do not install MySQL Enterprise Audit unless you plan to use it.

To be usable by the server, the plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

The plugin library file base name is `audit_log`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).

To load the plugin at server startup, use the `--plugin-load` option to name the library file that contains it. With this plugin-loading method, the option must be given each time the server starts. For example, put the following lines in your `my.cnf` file (adjust the `.so` suffix for your platform as necessary):

```
[mysqld]
plugin-load=audit_log.so
```

After modifying `my.cnf`, restart the server to cause the new settings to take effect.

Alternatively, to register the plugin at runtime, use this statement (adjust the suffix as necessary):

```
INSTALL PLUGIN audit_log SONAME 'audit_log.so';
```

`INSTALL PLUGIN` loads the plugin, and also registers it in the `mysql.plugins` system table to cause the plugin to be loaded for each subsequent normal server startup.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, "Obtaining Server Plugin Information"). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
       FROM INFORMATION_SCHEMA.PLUGINS
       WHERE PLUGIN_NAME LIKE 'audit%';
+-------------+---------------+
| PLUGIN_NAME | PLUGIN_STATUS |
+-------------+---------------+
| audit_log   | ACTIVE        |
+-------------+---------------+
```

If the plugin fails to initialize, check the server error log for diagnostic messages.

If the plugin has been previously registered with `INSTALL PLUGIN` or is loaded with `--plugin-load`, you can use the `--audit-log` option at server startup to control plugin activation. For example, to load the plugin at startup and prevent it from being removed at runtime, use these options:

```
[mysqld]
plugin-load=audit_log.so
audit-log=FORCE_PLUS_PERMANENT
```

If it is desired to prevent the server from running without the audit plugin, use `--audit-log` with a value of `FORCE` or `FORCE_PLUS_PERMANENT` to force server startup to fail if the plugin does not initialize successfully.

For additional information about the parameters used to configure operation of the `audit_log` plugin, see Section 6.5.2.7, "Audit Log Options and System Variables".

Audit log file contents are not encrypted. See Section 6.5.2.2, "MySQL Enterprise Audit Security Considerations".

6.5.2.2 MySQL Enterprise Audit Security Considerations

Contents of audit log files produced by the audit log plugin are not encrypted and may contain sensitive information, such as the text of SQL statements. For security reasons, audit log files should be written to a directory accessible only to the MySQL server and to users with a legitimate reason to view the log. The default file name is `audit.log` in the data directory. This can be changed by setting the `audit_log_file` system variable at server startup. Other audit log files may exist due to log rotation.

6.5.2.3 Audit Log File Formats

The MySQL server calls the audit log plugin to write an audit record to its log file whenever an auditable event occurs. Typically the first audit record written after plugin startup contains the server description and startup options. Elements following that one represent events such as client connect and disconnect events, executed SQL statements, and so forth. Only top-level statements are logged, not statements within stored programs such as triggers or stored procedures. Contents of files referenced by statements such as `LOAD DATA INFILE` are not logged.

To select the logging format that the audit log plugin uses to write its log file, set the `audit_log_format` system variable at server startup. These formats are available:

- Old-style XML format (`audit_log_format=OLD`): The original audit logging format used by default in older MySQL series. MySQL 5.5 uses old-style XML format by default.
- New-style XML format (`audit_log_format=NEW`): An XML format that has better compatibility with Oracle Audit Vault than old-style XML format. MySQL 5.7 introduced this format, which was backported to MySQL 5.5 as of MySQL 5.5.34.

Note

Changing the value of `audit_log_format` can result in writing log entries in one format to an existing log file that contains entries in a different format. To avoid this issue, use the procedure described at Audit Log File Format.

Audit log file contents are not encrypted. See Section 6.5.2.2, “MySQL Enterprise Audit Security Considerations”.

The following sections describe the available audit logging formats:

- Old-Style XML Audit Log File Format
- New-Style XML Audit Log File Format

Old-Style XML Audit Log File Format

Here is a sample log file in old-style XML format (`audit_log_format=OLD`), reformatted slightly for readability:

```
<?xml version="1.0" encoding="utf-8"?>
<AUDIT>
  <AUDIT_RECORD
    TIMESTAMP="2017-10-16T14:25:00 UTC"
    RECORD_ID="1_2017-10-16T14:25:00"
    NAME="Audit"
    SERVER_ID="1"
    VERSION="1"
    STARTUP_OPTIONS="--port=3306"
    OS_VERSION="i686-Linux"
    MYSQL_VERSION="5.5.59-log"/>
  <AUDIT_RECORD
    TIMESTAMP="2017-10-16T14:25:24 UTC"
    RECORD_ID="2_2017-10-16T14:25:00"
    NAME="Connect"
    CONNECTION_ID="4"
    STATUS="0"
    STATUS_CODE="0"
    USER="root"
    OS_LOGIN=""
    HOST="localhost"
    IP="127.0.0.1"
    COMMAND_CLASS="connect"
    PRIV_USER="root"
    PROXY_USER=""
    DB="test"/>

...

  <AUDIT_RECORD
    TIMESTAMP="2017-10-16T14:25:24 UTC"
    RECORD_ID="6_2017-10-16T14:25:00"
    NAME="Query"
    CONNECTION_ID="4"
    STATUS="0"
    STATUS_CODE="0"
    USER="root[root] @ localhost [127.0.0.1]"
    OS_LOGIN=""
    HOST="localhost"
    IP="127.0.0.1"
    COMMAND_CLASS="drop_table"
    SQLTEXT="DROP TABLE IF EXISTS t"/>

...

  <AUDIT_RECORD
    TIMESTAMP="2017-10-16T14:25:24 UTC"
    RECORD_ID="8_2017-10-16T14:25:00"
    NAME="Quit"
```

```
    CONNECTION_ID="4"
    STATUS="0"
    STATUS_CODE="0"
    USER="root"
    OS_LOGIN=""
    HOST="localhost"
    IP="127.0.0.1"
    COMMAND_CLASS="connect"
  <AUDIT_RECORD
    TIMESTAMP="2017-10-16T14:25:32 UTC"
    RECORD_ID="12_2017-10-16T14:25:00"
    NAME="NoAudit"
    SERVER_ID="1"/>
</AUDIT>
```

The audit log file is written as XML, using UTF-8 (up to 4 bytes per character). The root element is `<AUDIT>`. The root element contains `<AUDIT_RECORD>` elements, each of which provides information about an audited event. When the audit log plugin begins writing a new log file, it writes the XML declaration and opening `<AUDIT>` root element tag. When the plugin closes a log file, it writes the closing `</AUDIT>` root element tag. The closing tag is not present while the file is open.

Attributes of `<AUDIT_RECORD>` elements have these characteristics:

- Some attributes appear in every `<AUDIT_RECORD>` element. Others are optional and may appear depending on the audit record type.
- Order of attributes within an `<AUDIT_RECORD>` element is not guaranteed.
- Attribute values are not fixed length. Long values may be truncated as indicated in the attribute descriptions given later.
- The `<`, `>`, `"`, and `&` characters are encoded as `<`, `>`, `"`, and `&`, respectively. NUL bytes (U+00) are encoded as the `?` character.
- Characters not valid as XML characters are encoded using numeric character references. Valid XML characters are:

  ```
  #x9 | #xA | #xD | [#x20-#xD7FF] | [#xE000-#xFFFD] | [#x10000-#x10FFFF]
  ```

The following attributes are mandatory in every `<AUDIT_RECORD>` element:

- `NAME`

  A string representing the type of instruction that generated the audit event, such as a command that the server received from a client.

  Example: `NAME="Query"`

  Some common `NAME` values:

  ```
  Audit    When auditing starts, which may be server startup time
  Connect  When a client connects, also known as logging in
  Query    An SQL statement (executed directly)
  Prepare  Preparation of an SQL statement; usually followed by Execute
  Execute  Execution of an SQL statement; usually follows Prepare
  Shutdown Server shutdown
  Quit     When a client disconnects
  NoAudit  Auditing has been turned off
  ```

  The possible values are `Audit`, `Binlog Dump`, `Change user`, `Close stmt`, `Connect Out`, `Connect`, `Create DB`, `Daemon`, `Debug`, `Delayed insert`, `Drop DB`, `Execute`, `Fetch`, `Field List`, `Init DB`, `Kill`, `Long Data`, `NoAudit`, `Ping`, `Prepare`, `Processlist`, `Query`, `Quit`, `Refresh`, `Register Slave`, `Reset stmt`, `Set option`, `Shutdown`, `Sleep`, `Statistics`, `Table Dump`, `Time`.

With the exception of "Audit" and "NoAudit", these values correspond to the COM_*xxx* command values listed in the mysql_com.h header file. For example, "Create DB" and "Change user" correspond to COM_CREATE_DB and COM_CHANGE_USER, respectively.

- RECORD_ID

  A unique identifier for the audit record. The value is composed from a sequence number and timestamp, in the format *SEQ_TIMESTAMP*. When the audit log plugin opens the audit log file, it initializes the sequence number to the size of the audit log file, then increments the sequence by 1 for each record logged. The timestamp is a UTC value in *YYYY-MM-DD*T*hh:mm:ss* format indicating the date and time when the audit log plugin opened the file.

  Example: RECORD_ID="12_2017-10-16T14:25:00"

- TIMESTAMP

  A string representing a UTC value in *YYYY-MM-DD*T*hh:mm:ss* UTC format indicating the date and time when the audit event was generated. For example, the event corresponding to execution of an SQL statement received from a client has a TIMESTAMP value occurring after the statement finishes, not when it was received.

  Example: TIMESTAMP="2017-10-16T14:25:32 UTC"

The following attributes are optional in <AUDIT_RECORD> elements. Many of them occur only for elements with specific values of the NAME attribute.

- COMMAND_CLASS

  A string that indicates the type of action performed.

  Example: COMMAND_CLASS="drop_table"

  The values correspond to the Com_*xxx* status variables that indicate command counts; for example Com_drop_table and Com_select count DROP TABLE and SELECT statements, respectively. The following statement displays the possible names:

```
SELECT LOWER(REPLACE(VARIABLE_NAME, 'COM_', '')) AS name
FROM INFORMATION_SCHEMA.GLOBAL_STATUS
WHERE VARIABLE_NAME LIKE 'COM%'
ORDER BY name;
```

- CONNECTION_ID

  An unsigned integer representing the client connection identifier. This is the same as the value returned by the CONNECTION_ID() function within the session.

  Example: CONNECTION_ID="127"

- DB

  A string representing the default database name.

  Example: DB="test"

- HOST

  A string representing the client host name.

  Example: HOST="localhost"

- IP

A string representing the client IP address.

Example: `IP="127.0.0.1"`

- `MYSQL_VERSION`

  A string representing the MySQL server version. This is the same as the value of the `VERSION()` function or `version` system variable.

  Example: `MYSQL_VERSION="5.5.31-log"`

- `OS_LOGIN`

  A string representing the external user (empty if none). The value may differ from `USER`, for example, if the server authenticates the client using an external authentication method.

  Example: `OS_LOGIN="jeffrey"`

- `OS_VERSION`

  A string representing the operating system on which the server was built or is running.

  Example: `OS_VERSION="x86_64-Linux"`

- `PRIV_USER`

  A string representing the user that the server authenticated the client as. This is the user name that the server uses for privilege checking, and it may differ from the `USER` value.

  Example: `PRIV_USER="jeffrey"`

- `PROXY_USER`

  A string representing the proxy user (see Section 6.3.7, “Proxy Users”). The value is empty if user proxying is not in effect.

  Example: `PROXY_USER="developer"`

- `SERVER_ID`

  An unsigned integer representing the server ID. This is the same as the value of the `server_id` system variable.

  Example: `SERVER_ID="1"`

- `SQLTEXT`

  A string representing the text of an SQL statement. The value can be empty. Long values may be truncated. The string, like the audit log file itself, is written using UTF-8 (up to 4 bytes per character), so the value may be the result of conversion. For example, the original statement might have been received from the client as an SJIS string.

  Example: `SQLTEXT="DELETE FROM t1"`

- `STARTUP_OPTIONS`

  A string representing the options that were given on the command line or in option files when the MySQL server was started.

  Example: `STARTUP_OPTIONS="--port=3306 --log-output=FILE"`

- `STATUS`

An unsigned integer representing the command status: 0 for success, nonzero if an error occurred. This is the same as the value of the `mysql_errno()` C API function. See the description for `STATUS_CODE` for information about how it differs from `STATUS`.

The audit log does not contain the SQLSTATE value or error message. To see the associations between error codes, SQLSTATE values, and messages, see Section B.3, “Server Error Codes and Messages”.

Warnings are not logged.

Example: `STATUS="1051"`

- `STATUS_CODE`

  An unsigned integer representing the command status: 0 for success, 1 if an error occurred.

  The `STATUS_CODE` value differs from the `STATUS` value: `STATUS_CODE` is 0 for success and 1 for error, which is compatible with the EZ_collector consumer for Audit Vault. `STATUS` is the value of the `mysql_errno()` C API function. This is 0 for success and nonzero for error, and thus is not necessarily 1 for error.

  Example: `STATUS_CODE="0"`

- `USER`

  A string representing the user name sent by the client. This may differ from the `PRIV_USER` value.

- `VERSION`

  An unsigned integer representing the version of the audit log file format.

  Example: `VERSION="1"`

New-Style XML Audit Log File Format

Here is a sample log file in new-style XML format (`audit_log_format=NEW`), reformatted slightly for readability:

```
<?xml version="1.0" encoding="utf-8"?>
<AUDIT>
 <AUDIT_RECORD>
  <TIMESTAMP>2017-10-16T14:06:33 UTC</TIMESTAMP>
  <RECORD_ID>1_2017-10-16T14:06:33</RECORD_ID>
  <NAME>Audit</NAME>
  <SERVER_ID>1</SERVER_ID>
  <VERSION>1</VERSION>
  <STARTUP_OPTIONS>/usr/local/mysql/bin/mysqld
    --socket=/usr/local/mysql/mysql.sock
    --port=3306</STARTUP_OPTIONS>
  <OS_VERSION>i686-Linux</OS_VERSION>
  <MYSQL_VERSION>5.5.59-log</MYSQL_VERSION>
 </AUDIT_RECORD>
 <AUDIT_RECORD>
  <TIMESTAMP>2017-10-16T14:09:38 UTC</TIMESTAMP>
  <RECORD_ID>2_2017-10-16T14:06:33</RECORD_ID>
  <NAME>Connect</NAME>
  <CONNECTION_ID>5</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER>root</USER>
  <OS_LOGIN/>
  <HOST>localhost</HOST>
  <IP>127.0.0.1</IP>
  <COMMAND_CLASS>connect</COMMAND_CLASS>
```

```
  <PRIV_USER>root</PRIV_USER>
  <PROXY_USER/>
  <DB>test</DB>
 </AUDIT_RECORD>

...

 <AUDIT_RECORD>
  <TIMESTAMP>2017-10-16T14:09:38 UTC</TIMESTAMP>
  <RECORD_ID>6_2017-10-16T14:06:33</RECORD_ID>
  <NAME>Query</NAME>
  <CONNECTION_ID>5</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER>root[root] @ localhost [127.0.0.1]</USER>
  <OS_LOGIN/>
  <HOST>localhost</HOST>
  <IP>127.0.0.1</IP>
  <COMMAND_CLASS>drop_table</COMMAND_CLASS>
  <SQLTEXT>DROP TABLE IF EXISTS t</SQLTEXT>
 </AUDIT_RECORD>

...

 <AUDIT_RECORD>
  <TIMESTAMP>2017-10-16T14:09:39 UTC</TIMESTAMP>
  <RECORD_ID>8_2017-10-16T14:06:33</RECORD_ID>
  <NAME>Quit</NAME>
  <CONNECTION_ID>5</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER>root</USER>
  <OS_LOGIN/>
  <HOST>localhost</HOST>
  <IP>127.0.0.1</IP>
  <COMMAND_CLASS>connect</COMMAND_CLASS>
 </AUDIT_RECORD>

...

 <AUDIT_RECORD>
  <TIMESTAMP>2017-10-16T14:09:43 UTC</TIMESTAMP>
  <RECORD_ID>11_2017-10-16T14:06:33</RECORD_ID>
  <NAME>Quit</NAME>
  <CONNECTION_ID>6</CONNECTION_ID>
  <STATUS>0</STATUS>
  <STATUS_CODE>0</STATUS_CODE>
  <USER>root</USER>
  <OS_LOGIN/>
  <HOST>localhost</HOST>
  <IP>127.0.0.1</IP>
  <COMMAND_CLASS>connect</COMMAND_CLASS>
 </AUDIT_RECORD>
 <AUDIT_RECORD>
  <TIMESTAMP>2017-10-16T14:09:45 UTC</TIMESTAMP>
  <RECORD_ID>12_2017-10-16T14:06:33</RECORD_ID>
  <NAME>NoAudit</NAME>
  <SERVER_ID>1</SERVER_ID>
 </AUDIT_RECORD>
</AUDIT>
```

The audit log file is written as XML, using UTF-8 (up to 4 bytes per character). The root element is `<AUDIT>`. The root element contains `<AUDIT_RECORD>` elements, each of which provides information about an audited event. When the audit log plugin begins writing a new log file, it writes the XML declaration and opening `<AUDIT>` root element tag. When the plugin closes a log file, it writes the closing `</AUDIT>` root element tag. The closing tag is not present while the file is open.

Elements within `<AUDIT_RECORD>` elements have these characteristics:

- Some elements appear in every `<AUDIT_RECORD>` element. Others are optional and may appear depending on the audit record type.

- Order of elements within an <AUDIT_RECORD> element is not guaranteed.
- Element values are not fixed length. Long values may be truncated as indicated in the element descriptions given later.
- The <, >, ", and & characters are encoded as <, >, ", and &, respectively. NUL bytes (U+00) are encoded as the ? character.
- Characters not valid as XML characters are encoded using numeric character references. Valid XML characters are:

```
#x9 | #xA | #xD | [#x20-#xD7FF] | [#xE000-#xFFFD] | [#x10000-#x10FFFF]
```

The following elements are mandatory in every <AUDIT_RECORD> element:

- <NAME>

  A string representing the type of instruction that generated the audit event, such as a command that the server received from a client.

  Example:

  ```
  <NAME>Query</NAME>
  ```

  Some common <NAME> values:

  ```
  Audit    When auditing starts, which may be server startup time
  Connect  When a client connects, also known as logging in
  Query    An SQL statement (executed directly)
  Prepare  Preparation of an SQL statement; usually followed by Execute
  Execute  Execution of an SQL statement; usually follows Prepare
  Shutdown Server shutdown
  Quit     When a client disconnects
  NoAudit  Auditing has been turned off
  ```

  The possible values are Audit, Binlog Dump, Change user, Close stmt, Connect Out, Connect, Create DB, Daemon, Debug, Delayed insert, Drop DB, Execute, Fetch, Field List, Init DB, Kill, Long Data, NoAudit, Ping, Prepare, Processlist, Query, Quit, Refresh, Register Slave, Reset stmt, Set option, Shutdown, Sleep, Statistics, Table Dump, Time.

  With the exception of Audit and NoAudit, these values correspond to the COM_*xxx* command values listed in the mysql_com.h header file. For example, Create DB and Change user correspond to COM_CREATE_DB and COM_CHANGE_USER, respectively.

- <RECORD_ID>

  A unique identifier for the audit record. The value is composed from a sequence number and timestamp, in the format *SEQ_TIMESTAMP*. When the audit log plugin opens the audit log file, it initializes the sequence number to the size of the audit log file, then increments the sequence by 1 for each record logged. The timestamp is a UTC value in *YYYY-MM-DD*T*hh:mm:ss* format indicating the date and time when the audit log plugin opened the file.

  Example:

  ```
  <RECORD_ID>12_2017-10-16T14:06:33</RECORD_ID>
  ```

- <TIMESTAMP>

  A string representing a UTC value in *YYYY-MM-DD*T*hh:mm:ss* UTC format indicating the date and time when the audit event was generated. For example, the event corresponding to execution of

an SQL statement received from a client has a <TIMESTAMP> value occurring after the statement finishes, not when it was received.

Example:

```
<TIMESTAMP>2017-10-16T14:09:45 UTC</TIMESTAMP>
```

The following elements are optional in <AUDIT_RECORD> elements. Many of them occur only with specific <NAME> element values.

- <COMMAND_CLASS>

  A string that indicates the type of action performed.

  Example:

  ```
  <COMMAND_CLASS>drop_table</COMMAND_CLASS>
  ```

  The values correspond to the Com_*xxx* status variables that indicate command counts; for example Com_drop_table and Com_select count DROP TABLE and SELECT statements, respectively. The following statement displays the possible names:

  ```
  SELECT LOWER(REPLACE(VARIABLE_NAME, 'COM_', '')) AS name
  FROM INFORMATION_SCHEMA.GLOBAL_STATUS
  WHERE VARIABLE_NAME LIKE 'COM%'
  ORDER BY name;
  ```

- <CONNECTION_ID>

  An unsigned integer representing the client connection identifier. This is the same as the value returned by the CONNECTION_ID() function within the session.

  Example:

  ```
  <CONNECTION_ID>127</CONNECTION_ID>
  ```

- <DB>

  A string representing the default database name.

  Example:

  ```
  <DB>test</DB>
  ```

- <HOST>

  A string representing the client host name.

  Example:

  ```
  <HOST>localhost</HOST>
  ```

- <IP>

  A string representing the client IP address.

  Example:

  ```
  <IP>127.0.0.1</IP>
  ```

- `<MYSQL_VERSION>`

  A string representing the MySQL server version. This is the same as the value of the `VERSION()` function or `version` system variable.

  Example:

  ```
  <MYSQL_VERSION>5.5.59-log</MYSQL_VERSION>
  ```

- `<OS_LOGIN>`

  A string representing the external user (empty if none). The value may differ from the `<USER>` value, for example, if the server authenticates the client using an external authentication method.

  Example:

  ```
  <OS_LOGIN>jeffrey</OS_LOGIN>
  ```

- `<OS_VERSION>`

  A string representing the operating system on which the server was built or is running.

  Example:

  ```
  <OS_VERSION>x86_64-Linux</OS_VERSION>
  ```

- `<PRIV_USER>`

  A string representing the user that the server authenticated the client as. This is the user name that the server uses for privilege checking, and may differ from the `<USER>` value.

  Example:

  ```
    <PRIV_USER>jeffrey</PRIV_USER>
  ```

- `<PROXY_USER>`

  A string representing the proxy user (see Section 6.3.7, “Proxy Users”). The value is empty if user proxying is not in effect.

  Example:

  ```
    <PROXY_USER>developer</PROXY_USER>
  ```

- `<SERVER_ID>`

  An unsigned integer representing the server ID. This is the same as the value of the `server_id` system variable.

  Example:

  ```
  <SERVER_ID>1</SERVER_ID>
  ```

- `<SQLTEXT>`

  A string representing the text of an SQL statement. The value can be empty. Long values may be truncated. The string, like the audit log file itself, is written using UTF-8 (up to 4 bytes per character), so the value may be the result of conversion. For example, the original statement might have been received from the client as an SJIS string.

Example:

```
<SQLTEXT>DELETE FROM t1</SQLTEXT>
```

- `<STARTUP_OPTIONS>`

  A string representing the options that were given on the command line or in option files when the MySQL server was started. The first option is the path to the server executable.

  Example:

  ```
  <STARTUP_OPTIONS>/usr/local/mysql/bin/mysqld
    --port=3306 --log-output=FILE</STARTUP_OPTIONS>
  ```

- `<STATUS>`

  An unsigned integer representing the command status: 0 for success, nonzero if an error occurred. This is the same as the value of the `mysql_errno()` C API function. See the description for `<STATUS_CODE>` for information about how it differs from `<STATUS>`.

  The audit log does not contain the SQLSTATE value or error message. To see the associations between error codes, SQLSTATE values, and messages, see Section B.3, “Server Error Codes and Messages”.

  Warnings are not logged.

  Example:

  ```
  <STATUS>1051</STATUS>
  ```

- `<STATUS_CODE>`

  An unsigned integer representing the command status: 0 for success, 1 if an error occurred.

  The `STATUS_CODE` value differs from the `STATUS` value: `STATUS_CODE` is 0 for success and 1 for error, which is compatible with the EZ_collector consumer for Audit Vault. `STATUS` is the value of the `mysql_errno()` C API function. This is 0 for success and nonzero for error, and thus is not necessarily 1 for error.

  Example:

  ```
  <STATUS_CODE>0</STATUS_CODE>
  ```

- `<USER>`

  A string representing the user name sent by the client. This may differ from the `<PRIV_USER>` value.

  Example:

  ```
  <USER>root[root] @ localhost [127.0.0.1]</USER>
  ```

- `<VERSION>`

  An unsigned integer representing the version of the audit log file format.

  Example:

  ```
  <VERSION>1</VERSION>
  ```

6.5.2.4 Audit Log Logging Control

This section describes how to control general characteristics of audit logging, such as the file to which the audit log plugin writes events and the format of written events.

- Audit Log File Name
- Audit Log File Format
- Audit Logging Write Strategy
- Audit Log File Space Management and Name Rotation

For additional information about the system variables that affect audit logging, see Section 6.5.2.7, “Audit Log Options and System Variables”.

Audit Log File Name

To control the audit log file name, set the `audit_log_file` system variable at server startup. By default, the name is `audit.log` in the server data directory. For security reasons, the audit log file should be written to a directory accessible only to the MySQL server and to users with a legitimate reason to view the log.

When the audit plugin initializes, it checks whether a file with the audit log file name already exists. If so, the plugin checks whether the file ends with an `</AUDIT>` tag and truncates the tag before writing any `<AUDIT_RECORD>` elements. If the log file exists but does not end with `</AUDIT>` or the `</AUDIT>` tag cannot be truncated, the plugin considers the file malformed and fails to initialize. This can occur if the server exited unexpectedly with the audit log plugin running. No logging occurs until the problem is rectified. Check the error log for diagnostic information:

```
[ERROR] Plugin 'audit_log' init function returned error.
```

To deal with this problem, either remove or rename the malformed log file and restart the server.

Audit Log File Format

To control the audit log file format, set the `audit_log_format` system variable at server startup. By default, the format is `OLD` (old-style XML format). For information about available formats, see Section 6.5.2.3, “Audit Log File Formats”.

Note

Changing the value of `audit_log_format` can result in writing log entries in one format to an existing log file that contains entries in a different format. To avoid this issue, use the following procedure:

1. Stop the server.
2. Either change the value of the `audit_log_file` system variable so the plugin writes to a different file, or rename the current audit log file manually.
3. Restart the server with the new value of `audit_log_format`. The audit log plugin creates a new log file and writes entries to it in the selected format.

Audit Logging Write Strategy

The audit log plugin can use any of several strategies for log writes. Regardless of strategy, logging occurs on a best-effort basis, with no guarantee of consistency.

To specify a write strategy, set the `audit_log_strategy` system variable at server startup. By default, the strategy value is `ASYNCHRONOUS` and the plugin logs asynchronously to a buffer, waiting

if the buffer is full. It's possible to tell the plugin not to wait (`PERFORMANCE`) or to log synchronously, either using file system caching (`SEMISYNCHRONOUS`) or forcing output with a `sync()` call after each write request (`SYNCHRONOUS`).

For asynchronous write strategy, the `audit_log_buffer_size` system variable is the buffer size in bytes. Set this variable at server startup to change the buffer size. The plugin uses a single buffer, which it allocates when it initializes and removes when it terminates. The plugin does not allocate this buffer for nonasynchronous write strategies.

Asynchronous logging strategy has these characteristics:

- Minimal impact on server performance and scalability.
- Blocking of threads that generate audit events for the shortest possible time; that is, time to allocate the buffer plus time to copy the event to the buffer.
- Output goes to the buffer. A separate thread handles writes from the buffer to the log file.

With asynchronous logging, the integrity of the log file may be compromised if a problem occurs during a write to the file or if the plugin does not shut down cleanly (for example, in the event that the server host exits unexpectedly). To reduce this risk, set `audit_log_strategy` to use synchronous logging.

A disadvantage of `PERFORMANCE` strategy is that it drops events when the buffer is full. For a heavily loaded server, the audit log may have events missing.

Audit Log File Space Management and Name Rotation

The audit log file has the potential to grow very large and consume a lot of disk space. To enable management of the space used by its log files, the audit log plugin provides the `audit_log_rotate_on_size` and `audit_log_flush` system variables, which control audit log file rotation and flushing. Rotation can be done manually, or automatically based on file size.

Manual audit log file rotation. By default, `audit_log_rotate_on_size=0` and there is no log rotation except that which you perform manually. In this case, the audit log plugin closes and reopens the log file when the `audit_log_flush` value changes from disabled to enabled. Log file renaming must be done externally to the server. Suppose that the log file name is `audit.log` and you want to maintain the three most recent log files, cycling through the names `audit.log.1` through `audit.log.3`. On Unix, perform rotation manually like this:

1. From the command line, rename the current log files:

   ```
   mv audit.log.2 audit.log.3
   mv audit.log.1 audit.log.2
   mv audit.log audit.log.1
   ```

   At this point, the plugin is still writing to the current log file, which has been renamed to `audit.log.1`.

2. Connect to the server and flush the log file so the plugin closes it and reopens a new `audit.log` file:

   ```
   SET GLOBAL audit_log_flush = ON;
   ```

Automatic size-based audit log file rotation. If `audit_log_rotate_on_size` is greater than 0, setting `audit_log_flush` has no effect. Instead, whenever a write to the log file causes its size to exceed the `audit_log_rotate_on_size` value, the audit log plugin closes the file, renames it, and opens a new log file.

The renamed file has a timestamp and `.xml` added to the end. For example, if the file name is `audit.log`, the plugin renames it to a value such as `audit.log.15081807937726520.xml`. The

last 7 digits are a fractional second part. The first 10 digits are a Unix timestamp value that can be interpreted using the `FROM_UNIXTIME()` function:

```
mysql> SELECT FROM_UNIXTIME(1508180793);
+---------------------------+
| FROM_UNIXTIME(1508180793) |
+---------------------------+
| 2017-10-16 14:06:33       |
+---------------------------+
```

Note

With size-based log file rotation, renamed log files do not rotate off the end of the name sequence. Instead, they have unique names and accumulate indefinitely. To avoid excessive space use, remove old files periodically, backing them up first as necessary.

6.5.2.5 Audit Log Filtering

The `audit_log_policy` system variable controls what kinds of information the plugin writes. By default, this variable is set to `ALL` (write all auditable events), but also permits values of `LOGINS` or `QUERIES` to log only login or query events, or `NONE` to disable logging.

6.5.2.6 Audit Log Option and Variable Reference

Table 6.16 Audit Log Option and Variable Reference

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
audit-log	Yes	Yes				
audit_log_buffer_size	Yes	Yes	Yes		Global	No
audit_log_file	Yes	Yes	Yes		Global	No
audit_log_flush			Yes		Global	Yes
audit_log_format	Yes	Yes	Yes		Global	No
audit_log_policy	Yes	Yes	Yes		Global	Yes
audit_log_rotate_on_size	Yes	Yes	Yes		Global	Yes
audit_log_strategy	Yes	Yes	Yes		Global	No

6.5.2.7 Audit Log Options and System Variables

This section describes the command options and system variables that control operation of MySQL Enterprise Audit. If values specified at startup time are incorrect, the audit log plugin may fail to initialize properly and the server does not load it. In this case, the server may also produce error messages for other audit log settings because it will not recognize them.

To control the activation of the `audit_log` plugin, use this option:

- `--audit-log[=value]`

Introduced	5.5.28	
Command-Line Format	`--audit-log[=value]`	
Permitted Values	**Type**	enumeration
	Default	`ON`
	Valid Values	`ON`

		OFF
		FORCE
		FORCE_PLUS_PERMANENT

This option controls how the server loads the `audit_log` plugin at startup. It is available only if the plugin has been previously registered with `INSTALL PLUGIN` or is loaded with `--plugin-load`. See Section 6.5.2.1, “Installing MySQL Enterprise Audit”.

The option value should be one of those available for plugin-loading options, as described in Section 5.5.1, “Installing and Uninstalling Plugins”. For example, `--audit-log=FORCE_PLUS_PERMANENT` tells the server to load the plugin at startup and prevents it from being removed while the server is running.

This option was added in MySQL 5.5.28.

If the audit log plugin is enabled, it exposes several system variables that permit control over logging:

```
mysql> SHOW VARIABLES LIKE 'audit_log%';
+--------------------------+--------------+
| Variable_name            | Value        |
+--------------------------+--------------+
| audit_log_buffer_size    | 1048576      |
| audit_log_file           | audit.log    |
| audit_log_flush          | OFF          |
| audit_log_policy         | ALL          |
| audit_log_rotate_on_size | 0            |
| audit_log_strategy       | ASYNCHRONOUS |
+--------------------------+--------------+
```

You can set any of these variables at server startup, and some of them at runtime.

- `audit_log_buffer_size`

Introduced	5.5.28	
Command-Line Format	`--audit-log-buffer-size=value`	
System Variable	**Name**	`audit_log_buffer_size`
	Scope	Global
	Dynamic	No
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`1048576`
	Minimum	`4096`
	Maximum	`4294967295`
Permitted Values (64-bit platforms)	**Type**	integer
	Default	`1048576`
	Minimum	`4096`
	Maximum	`18446744073709547520`

When the audit log plugin writes events to the log asynchronously, it uses a buffer to store event contents prior to writing them. This variable controls the size of that buffer, in bytes. The server adjusts the value to a multiple of 4096. The plugin uses a single buffer, which it allocates when it initializes and removes when it terminates. The plugin allocates this buffer only if logging is asynchronous.

This variable was added in MySQL 5.5.28.

- `audit_log_file`

Introduced	5.5.28	
Command-Line Format	`--audit-log-file=file_name`	
System Variable	**Name**	`audit_log_file`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	file name
	Default	`audit.log`

The name of the file to which the audit log plugin writes events. The default value is `audit.log`. If the file name is a relative path, the server interprets it relative to the data directory. For security reasons, the audit log file should be written to a directory accessible only to the MySQL server and to users with a legitimate reason to view the log.

This variable was added in MySQL 5.5.28.

- `audit_log_flush`

Introduced	5.5.28	
System Variable	**Name**	`audit_log_flush`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

When this variable is set to enabled (1 or `ON`), the audit log plugin closes and reopens its log file to flush it. (The value remains `OFF` so that you need not disable it explicitly before enabling it again to perform another flush.) Enabling this variable has no effect unless `audit_log_rotate_on_size` is 0.

This variable was added in MySQL 5.5.28.

- `audit_log_format`

Introduced	5.5.34	
Command-Line Format	`--audit-log-format=value`	
System Variable	**Name**	`audit_log_format`
	Scope	Global
	Dynamic	No
Permitted Values (>= 5.5.34)	**Type**	enumeration
	Default	`OLD`
	Valid Values	`OLD`
		`NEW`

The audit log file format. Permitted values are `OLD` and `NEW` (default `OLD`). For details about each format, see Section 6.5.2.3, “Audit Log File Formats”.

Changing the value of `audit_log_format` can result in writing log entries in one format to an existing log file that contains entries in a different format. To avoid this issue, use the procedure described at Audit Log File Format.

This variable was added in MySQL 5.5.34.

- `audit_log_policy`

Introduced	5.5.28	
Command-Line Format	`--audit-log-policy=value`	
System Variable	**Name**	`audit_log_policy`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`ALL`
	Valid Values	`ALL`
		`LOGINS`
		`QUERIES`
		`NONE`

The policy controlling the information written by the audit log plugin to its log file. The following table shows the permitted values.

Value	Description
`ALL`	Log all events
`NONE`	Log nothing (disable the audit stream)
`LOGINS`	Log only login events
`QUERIES`	Log only query events

This variable was added in MySQL 5.5.28.

- `audit_log_rotate_on_size`

Introduced	5.5.28	
Command-Line Format	`--audit-log-rotate-on-size=N`	
System Variable	**Name**	`audit_log_rotate_on_size`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`0`

If the `audit_log_rotate_on_size` value is 0, the audit log plugin does not perform automatic log file rotation. Instead, use `audit_log_flush` to close and reopen the log on demand. In this case, manually rename the file externally to the server before flushing it.

If the `audit_log_rotate_on_size` value is greater than 0, automatic size-based log file rotation occurs. Whenever a write to the log file causes its size to exceed the `audit_log_rotate_on_size` value, the audit log plugin closes the current log file, renames it, and opens a new log file.

For more information about audit log file rotation, see Audit Log File Space Management and Name Rotation.

If you set this variable to a value that is not a multiple of 4096, it is truncated to the nearest multiple. (Thus, setting it to a value less than 4096 has the effect of setting it to 0 and no rotation occurs, except manually.)

This variable was added in MySQL 5.5.28.

- `audit_log_strategy`

Introduced	5.5.28	
Command-Line Format	`--audit-log-strategy=value`	
System Variable	**Name**	`audit_log_strategy`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	enumeration
	Default	`ASYNCHRONOUS`
	Valid Values	`ASYNCHRONOUS`
		`PERFORMANCE`
		`SEMISYNCHRONOUS`
		`SYNCHRONOUS`

The logging method used by the audit log plugin. These strategy values are permitted:

- `ASYNCHRONOUS`: Log asynchronously. Wait for space in the output buffer.
- `PERFORMANCE`: Log asynchronously. Drop requests for which there is insufficient space in the output buffer.
- `SEMISYNCHRONOUS`: Log synchronously. Permit caching by the operating system.
- `SYNCHRONOUS`: Log synchronously. Call `sync()` after each request.

This variable was added in MySQL 5.5.28.

6.5.2.8 Audit Log Restrictions

MySQL Enterprise Audit is subject to these general restrictions:

- Only SQL statements are logged. Changes made by no-SQL APIs, such as memcached, Node.JS, and the NDB API, are not logged.
- Only top-level statements are logged, not statements within stored programs such as triggers or stored procedures.
- Contents of files referenced by statements such as `LOAD DATA INFILE` are not logged.

NDB Cluster. It is possible to use MySQL Enterprise Audit with MySQL NDB Cluster, subject to the following conditions:

- All changes to be logged must be done using the SQL interface. Changes using no-SQL interfaces, such as those provided by the NDB API, memcached, or ClusterJ, are not logged.
- The plugin must be installed on each MySQL server that is used to execute SQL on the cluster.
- Audit plugin data must be aggregated amongst all MySQL servers used with the cluster. This aggregation is the responsibility of the application or user.

Chapter 7 Backup and Recovery

Table of Contents

7.1 Backup and Recovery Types 806
7.2 Database Backup Methods 809
7.3 Example Backup and Recovery Strategy 811
7.3.1 Establishing a Backup Policy 811
7.3.2 Using Backups for Recovery 813
7.3.3 Backup Strategy Summary 814
7.4 Using mysqldump for Backups 814
7.4.1 Dumping Data in SQL Format with mysqldump 814
7.4.2 Reloading SQL-Format Backups 815
7.4.3 Dumping Data in Delimited-Text Format with mysqldump 816
7.4.4 Reloading Delimited-Text Format Backups 817
7.4.5 mysqldump Tips 818
7.5 Point-in-Time (Incremental) Recovery Using the Binary Log 820
7.5.1 Point-in-Time Recovery Using Event Times 821
7.5.2 Point-in-Time Recovery Using Event Positions 822
7.6 MyISAM Table Maintenance and Crash Recovery 822
7.6.1 Using myisamchk for Crash Recovery 823
7.6.2 How to Check MyISAM Tables for Errors 824
7.6.3 How to Repair MyISAM Tables 824
7.6.4 MyISAM Table Optimization 827
7.6.5 Setting Up a MyISAM Table Maintenance Schedule 827

It is important to back up your databases so that you can recover your data and be up and running again in case problems occur, such as system crashes, hardware failures, or users deleting data by mistake. Backups are also essential as a safeguard before upgrading a MySQL installation, and they can be used to transfer a MySQL installation to another system or to set up replication slave servers.

MySQL offers a variety of backup strategies from which you can choose the methods that best suit the requirements for your installation. This chapter discusses several backup and recovery topics with which you should be familiar:

- Types of backups: Logical versus physical, full versus incremental, and so forth.
- Methods for creating backups.
- Recovery methods, including point-in-time recovery.
- Backup scheduling, compression, and encryption.
- Table maintenance, to enable recovery of corrupt tables.

Additional Resources

Resources related to backup or to maintaining data availability include the following:

- Customers of MySQL Enterprise Edition can use the MySQL Enterprise Backup product for backups. For an overview of the MySQL Enterprise Backup product, see Section 25.2, “MySQL Enterprise Backup Overview”.
- A forum dedicated to backup issues is available at http://forums.mysql.com/list.php?28.
- Details for `mysqldump`, `mysqlhotcopy`, and other MySQL backup programs can be found in Chapter 4, *MySQL Programs*.
- The syntax of the SQL statements described here is given in Chapter 13, *SQL Statement Syntax*.

- For additional information about `InnoDB` backup procedures, see Section 14.21.1, “InnoDB Backup”.
- Replication enables you to maintain identical data on multiple servers. This has several benefits, such as enabling client query load to be distributed over servers, availability of data even if a given server is taken offline or fails, and the ability to make backups with no impact on the master by using a slave server. See Chapter 17, *Replication*.
- NDB Cluster provides a high-availability, high-redundancy version of MySQL adapted for the distributed computing environment. See Chapter 18, *MySQL NDB Cluster 7.2*. For information specifically about NDB Cluster backup, see Section 18.5.3, “Online Backup of NDB Cluster”.
- Distributed Replicated Block Device (DRBD) is another high-availability solution. It works by replicating a block device from a primary server to a secondary server at the block level. See Chapter 16, *High Availability and Scalability*

7.1 Backup and Recovery Types

This section describes the characteristics of different types of backups.

Physical (Raw) Versus Logical Backups

Physical backups consist of raw copies of the directories and files that store database contents. This type of backup is suitable for large, important databases that need to be recovered quickly when problems occur.

Logical backups save information represented as logical database structure (`CREATE DATABASE`, `CREATE TABLE` statements) and content (`INSERT` statements or delimited-text files). This type of backup is suitable for smaller amounts of data where you might edit the data values or table structure, or recreate the data on a different machine architecture.

Physical backup methods have these characteristics:

- The backup consists of exact copies of database directories and files. Typically this is a copy of all or part of the MySQL data directory.
- Physical backup methods are faster than logical because they involve only file copying without conversion.
- Output is more compact than for logical backup.
- Because backup speed and compactness are important for busy, important databases, the MySQL Enterprise Backup product performs physical backups. For an overview of the MySQL Enterprise Backup product, see Section 25.2, “MySQL Enterprise Backup Overview”.
- Backup and restore granularity ranges from the level of the entire data directory down to the level of individual files. This may or may not provide for table-level granularity, depending on storage engine. For example, `InnoDB` tables can each be in a separate file, or share file storage with other `InnoDB` tables; each `MyISAM` table corresponds uniquely to a set of files.
- In addition to databases, the backup can include any related files such as log or configuration files.
- Data from `MEMORY` tables is tricky to back up this way because their contents are not stored on disk. (The MySQL Enterprise Backup product has a feature where you can retrieve data from `MEMORY` tables during a backup.)
- Backups are portable only to other machines that have identical or similar hardware characteristics.
- Backups can be performed while the MySQL server is not running. If the server is running, it is necessary to perform appropriate locking so that the server does not change database contents during the backup. MySQL Enterprise Backup does this locking automatically for tables that require it.

- Physical backup tools include the `mysqlbackup` of MySQL Enterprise Backup for `InnoDB` or any other tables, file system-level commands (such as `cp`, `scp`, `tar`, `rsync`), or `mysqlhotcopy` for `MyISAM` tables.
- For restore:
  - MySQL Enterprise Backup restores `InnoDB` and other tables that it backed up.
  - `ndb_restore` restores `NDB` tables.
  - Files copied at the file system level or with `mysqlhotcopy` can be copied back to their original locations with file system commands.

Logical backup methods have these characteristics:

- The backup is done by querying the MySQL server to obtain database structure and content information.
- Backup is slower than physical methods because the server must access database information and convert it to logical format. If the output is written on the client side, the server must also send it to the backup program.
- Output is larger than for physical backup, particularly when saved in text format.
- Backup and restore granularity is available at the server level (all databases), database level (all tables in a particular database), or table level. This is true regardless of storage engine.
- The backup does not include log or configuration files, or other database-related files that are not part of databases.
- Backups stored in logical format are machine independent and highly portable.
- Logical backups are performed with the MySQL server running. The server is not taken offline.
- Logical backup tools include the `mysqldump` program and the `SELECT ... INTO OUTFILE` statement. These work for any storage engine, even `MEMORY`.
- To restore logical backups, SQL-format dump files can be processed using the `mysql` client. To load delimited-text files, use the `LOAD DATA INFILE` statement or the `mysqlimport` client.

Online Versus Offline Backups

Online backups take place while the MySQL server is running so that the database information can be obtained from the server. Offline backups take place while the server is stopped. This distinction can also be described as “hot” versus “cold” backups; a “warm” backup is one where the server remains running but locked against modifying data while you access database files externally.

Online backup methods have these characteristics:

- The backup is less intrusive to other clients, which can connect to the MySQL server during the backup and may be able to access data depending on what operations they need to perform.
- Care must be taken to impose appropriate locking so that data modifications do not take place that would compromise backup integrity. The MySQL Enterprise Backup product does such locking automatically.

Offline backup methods have these characteristics:

- Clients can be affected adversely because the server is unavailable during backup. For that reason, such backups are often taken from a replication slave server that can be taken offline without harming availability.
- The backup procedure is simpler because there is no possibility of interference from client activity.

A similar distinction between online and offline applies for recovery operations, and similar characteristics apply. However, it is more likely that clients will be affected for online recovery than for online backup because recovery requires stronger locking. During backup, clients might be able to read data while it is being backed up. Recovery modifies data and does not just read it, so clients must be prevented from accessing data while it is being restored.

Local Versus Remote Backups

A local backup is performed on the same host where the MySQL server runs, whereas a remote backup is done from a different host. For some types of backups, the backup can be initiated from a remote host even if the output is written locally on the server. host.

- `mysqldump` can connect to local or remote servers. For SQL output (`CREATE` and `INSERT` statements), local or remote dumps can be done and generate output on the client. For delimited-text output (with the `--tab` option), data files are created on the server host.
- `mysqlhotcopy` performs only local backups: It connects to the server to lock it against data modifications and then copies local table files.
- `SELECT ... INTO OUTFILE` can be initiated from a local or remote client host, but the output file is created on the server host.
- Physical backup methods typically are initiated locally on the MySQL server host so that the server can be taken offline, although the destination for copied files might be remote.

Snapshot Backups

Some file system implementations enable “snapshots” to be taken. These provide logical copies of the file system at a given point in time, without requiring a physical copy of the entire file system. (For example, the implementation may use copy-on-write techniques so that only parts of the file system modified after the snapshot time need be copied.) MySQL itself does not provide the capability for taking file system snapshots. It is available through third-party solutions such as Veritas, LVM, or ZFS.

Full Versus Incremental Backups

A full backup includes all data managed by a MySQL server at a given point in time. An incremental backup consists of the changes made to the data during a given time span (from one point in time to another). MySQL has different ways to perform full backups, such as those described earlier in this section. Incremental backups are made possible by enabling the server's binary log, which the server uses to record data changes.

Full Versus Point-in-Time (Incremental) Recovery

A full recovery restores all data from a full backup. This restores the server instance to the state that it had when the backup was made. If that state is not sufficiently current, a full recovery can be followed by recovery of incremental backups made since the full backup, to bring the server to a more up-to-date state.

Incremental recovery is recovery of changes made during a given time span. This is also called point-in-time recovery because it makes a server's state current up to a given time. Point-in-time recovery is based on the binary log and typically follows a full recovery from the backup files that restores the server to its state when the backup was made. Then the data changes written in the binary log files are applied as incremental recovery to redo data modifications and bring the server up to the desired point in time.

Table Maintenance

Data integrity can be compromised if tables become corrupt. For `InnoDB` tables, this is not a typical issue. For programs to check `MyISAM` tables and repair them if problems are found, see Section 7.6, “MyISAM Table Maintenance and Crash Recovery”.

Backup Scheduling, Compression, and Encryption

Backup scheduling is valuable for automating backup procedures. Compression of backup output reduces space requirements, and encryption of the output provides better security against unauthorized access of backed-up data. MySQL itself does not provide these capabilities. The MySQL Enterprise Backup product can compress `InnoDB` backups, and compression or encryption of backup output can be achieved using file system utilities. Other third-party solutions may be available.

7.2 Database Backup Methods

This section summarizes some general methods for making backups.

Making a Hot Backup with MySQL Enterprise Backup

Customers of MySQL Enterprise Edition can use the MySQL Enterprise Backup product to do physical backups of entire instances or selected databases, tables, or both. This product includes features for incremental and compressed backups. Backing up the physical database files makes restore much faster than logical techniques such as the `mysqldump` command. `InnoDB` tables are copied using a hot backup mechanism. (Ideally, the `InnoDB` tables should represent a substantial majority of the data.) Tables from other storage engines are copied using a warm backup mechanism. For an overview of the MySQL Enterprise Backup product, see Section 25.2, “MySQL Enterprise Backup Overview”.

Making Backups with mysqldump or mysqlhotcopy

The `mysqldump` program and the `mysqlhotcopy` script can make backups. `mysqldump` is more general because it can back up all kinds of tables. `mysqlhotcopy` works only with some storage engines. (See Section 7.4, “Using mysqldump for Backups”, and Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”.)

For `InnoDB` tables, it is possible to perform an online backup that takes no locks on tables using the `--single-transaction` option to `mysqldump`. See Section 7.3.1, “Establishing a Backup Policy”.

Making Backups by Copying Table Files

For storage engines that represent each table using its own files, tables can be backed up by copying those files. For example, `MyISAM` tables are stored as files, so it is easy to do a backup by copying files (`*.frm`, `*.MYD`, and `*.MYI` files). To get a consistent backup, stop the server or lock and flush the relevant tables:

```
FLUSH TABLES tbl_list WITH READ LOCK;
```

You need only a read lock; this enables other clients to continue to query the tables while you are making a copy of the files in the database directory. The flush is needed to ensure that the all active index pages are written to disk before you start the backup. See Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”, and Section 13.7.6.3, “FLUSH Syntax”.

You can also create a binary backup simply by copying all table files, as long as the server isn't updating anything. The `mysqlhotcopy` script uses this method. (But note that table file copying methods do not work if your database contains `InnoDB` tables. `mysqlhotcopy` does not work for `InnoDB` tables because `InnoDB` does not necessarily store table contents in database directories. Also, even if the server is not actively updating data, `InnoDB` may still have modified data cached in memory and not flushed to disk.)

Making Delimited-Text File Backups

To create a text file containing a table's data, you can use `SELECT * INTO OUTFILE 'file_name' FROM tbl_name`. The file is created on the MySQL server host, not the client host. For this statement,

the output file cannot already exist because permitting files to be overwritten constitutes a security risk. See Section 13.2.9, “SELECT Syntax”. This method works for any kind of data file, but saves only table data, not the table structure.

Another way to create text data files (along with files containing `CREATE TABLE` statements for the backed up tables) is to use `mysqldump` with the `--tab` option. See Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”.

To reload a delimited-text data file, use `LOAD DATA INFILE` or `mysqlimport`.

Making Incremental Backups by Enabling the Binary Log

MySQL supports incremental backups: You must start the server with the `--log-bin` option to enable binary logging; see Section 5.4.4, “The Binary Log”. The binary log files provide you with the information you need to replicate changes to the database that are made subsequent to the point at which you performed a backup. At the moment you want to make an incremental backup (containing all changes that happened since the last full or incremental backup), you should rotate the binary log by using `FLUSH LOGS`. This done, you need to copy to the backup location all binary logs which range from the one of the moment of the last full or incremental backup to the last but one. These binary logs are the incremental backup; at restore time, you apply them as explained in Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”. The next time you do a full backup, you should also rotate the binary log using `FLUSH LOGS`, `mysqldump --flush-logs`, or `mysqlhotcopy --flushlog`. See Section 4.5.4, “`mysqldump` — A Database Backup Program”, and Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”.

Making Backups Using Replication Slaves

If you have performance problems with your master server while making backups, one strategy that can help is to set up replication and perform backups on the slave rather than on the master. See Section 17.3.1, “Using Replication for Backups”.

If you are backing up a slave replication server, you should back up its `master.info` and `relay-log.info` files when you back up the slave's databases, regardless of the backup method you choose. These information files are always needed to resume replication after you restore the slave's data. If your slave is replicating `LOAD DATA INFILE` statements, you should also back up any `SQL_LOAD-*` files that exist in the directory that the slave uses for this purpose. The slave needs these files to resume replication of any interrupted `LOAD DATA INFILE` operations. The location of this directory is the value of the `--slave-load-tmpdir` option. If the server was not started with that option, the directory location is the value of the `tmpdir` system variable.

Recovering Corrupt Tables

If you have to restore `MyISAM` tables that have become corrupt, try to recover them using `REPAIR TABLE` or `myisamchk -r` first. That should work in 99.9% of all cases. If `myisamchk` fails, see Section 7.6, “MyISAM Table Maintenance and Crash Recovery”.

Making Backups Using a File System Snapshot

If you are using a Veritas file system, you can make a backup like this:

1. From a client program, execute `FLUSH TABLES WITH READ LOCK`.
2. From another shell, execute `mount vxfs snapshot`.
3. From the first client, execute `UNLOCK TABLES`.
4. Copy files from the snapshot.
5. Unmount the snapshot.

Similar snapshot capabilities may be available in other file systems, such as LVM or ZFS.

7.3 Example Backup and Recovery Strategy

This section discusses a procedure for performing backups that enables you to recover data after several types of crashes:

- Operating system crash
- Power failure
- File system crash
- Hardware problem (hard drive, motherboard, and so forth)

The example commands do not include options such as `--user` and `--password` for the `mysqldump` and `mysql` client programs. You should include such options as necessary to enable client programs to connect to the MySQL server.

Assume that data is stored in the `InnoDB` storage engine, which has support for transactions and automatic crash recovery. Assume also that the MySQL server is under load at the time of the crash. If it were not, no recovery would ever be needed.

For cases of operating system crashes or power failures, we can assume that MySQL's disk data is available after a restart. The `InnoDB` data files might not contain consistent data due to the crash, but `InnoDB` reads its logs and finds in them the list of pending committed and noncommitted transactions that have not been flushed to the data files. `InnoDB` automatically rolls back those transactions that were not committed, and flushes to its data files those that were committed. Information about this recovery process is conveyed to the user through the MySQL error log. The following is an example log excerpt:

```
InnoDB: Database was not shut down normally.
InnoDB: Starting recovery from log files...
InnoDB: Starting log scan based on checkpoint at
InnoDB: log sequence number 0 13674004
InnoDB: Doing recovery: scanned up to log sequence number 0 13739520
InnoDB: Doing recovery: scanned up to log sequence number 0 13805056
InnoDB: Doing recovery: scanned up to log sequence number 0 13870592
InnoDB: Doing recovery: scanned up to log sequence number 0 13936128
...
InnoDB: Doing recovery: scanned up to log sequence number 0 20555264
InnoDB: Doing recovery: scanned up to log sequence number 0 20620800
InnoDB: Doing recovery: scanned up to log sequence number 0 20664692
InnoDB: 1 uncommitted transaction(s) which must be rolled back
InnoDB: Starting rollback of uncommitted transactions
InnoDB: Rolling back trx no 16745
InnoDB: Rolling back of trx no 16745 completed
InnoDB: Rollback of uncommitted transactions completed
InnoDB: Starting an apply batch of log records to the database...
InnoDB: Apply batch completed
InnoDB: Started
mysqld: ready for connections
```

For the cases of file system crashes or hardware problems, we can assume that the MySQL disk data is *not* available after a restart. This means that MySQL fails to start successfully because some blocks of disk data are no longer readable. In this case, it is necessary to reformat the disk, install a new one, or otherwise correct the underlying problem. Then it is necessary to recover our MySQL data from backups, which means that backups must already have been made. To make sure that is the case, design and implement a backup policy.

7.3.1 Establishing a Backup Policy

To be useful, backups must be scheduled regularly. A full backup (a snapshot of the data at a point in time) can be done in MySQL with several tools. For example, MySQL Enterprise Backup can perform a physical backup of an entire instance, with optimizations to minimize overhead and avoid disruption

when backing up InnoDB data files; mysqldump provides online logical backup. This discussion uses mysqldump.

Assume that we make a full backup of all our InnoDB tables in all databases using the following command on Sunday at 1 p.m., when load is low:

```
shell> mysqldump --all-databases --master-data --single-transaction > backup_sunday_1_PM.sql
```

The resulting .sql file produced by mysqldump contains a set of SQL INSERT statements that can be used to reload the dumped tables at a later time.

This backup operation acquires a global read lock on all tables at the beginning of the dump (using FLUSH TABLES WITH READ LOCK). As soon as this lock has been acquired, the binary log coordinates are read and the lock is released. If long updating statements are running when the FLUSH statement is issued, the backup operation may stall until those statements finish. After that, the dump becomes lock-free and does not disturb reads and writes on the tables.

It was assumed earlier that the tables to back up are InnoDB tables, so --single-transaction uses a consistent read and guarantees that data seen by mysqldump does not change. (Changes made by other clients to InnoDB tables are not seen by the mysqldump process.) If the backup operation includes nontransactional tables, consistency requires that they do not change during the backup. For example, for the MyISAM tables in the mysql database, there must be no administrative changes to MySQL accounts during the backup.

Full backups are necessary, but it is not always convenient to create them. They produce large backup files and take time to generate. They are not optimal in the sense that each successive full backup includes all data, even that part that has not changed since the previous full backup. It is more efficient to make an initial full backup, and then to make incremental backups. The incremental backups are smaller and take less time to produce. The tradeoff is that, at recovery time, you cannot restore your data just by reloading the full backup. You must also process the incremental backups to recover the incremental changes.

To make incremental backups, we need to save the incremental changes. In MySQL, these changes are represented in the binary log, so the MySQL server should always be started with the --log-bin option to enable that log. With binary logging enabled, the server writes each data change into a file while it updates data. Looking at the data directory of a MySQL server that was started with the --log-bin option and that has been running for some days, we find these MySQL binary log files:

```
-rw-rw---- 1 guilhem  guilhem   1277324 Nov 10 23:59 gbichot2-bin.000001
-rw-rw---- 1 guilhem  guilhem         4 Nov 10 23:59 gbichot2-bin.000002
-rw-rw---- 1 guilhem  guilhem        79 Nov 11 11:06 gbichot2-bin.000003
-rw-rw---- 1 guilhem  guilhem       508 Nov 11 11:08 gbichot2-bin.000004
-rw-rw---- 1 guilhem  guilhem 220047446 Nov 12 16:47 gbichot2-bin.000005
-rw-rw---- 1 guilhem  guilhem    998412 Nov 14 10:08 gbichot2-bin.000006
-rw-rw---- 1 guilhem  guilhem       361 Nov 14 10:07 gbichot2-bin.index
```

Each time it restarts, the MySQL server creates a new binary log file using the next number in the sequence. While the server is running, you can also tell it to close the current binary log file and begin a new one manually by issuing a FLUSH LOGS SQL statement or with a mysqladmin flush-logs command. mysqldump also has an option to flush the logs. The .index file in the data directory contains the list of all MySQL binary logs in the directory.

The MySQL binary logs are important for recovery because they form the set of incremental backups. If you make sure to flush the logs when you make your full backup, the binary log files created afterward contain all the data changes made since the backup. Let's modify the previous mysqldump command a bit so that it flushes the MySQL binary logs at the moment of the full backup, and so that the dump file contains the name of the new current binary log:

```
shell> mysqldump --single-transaction --flush-logs --master-data=2 \
         --all-databases > backup_sunday_1_PM.sql
```

After executing this command, the data directory contains a new binary log file, `gbichot2-bin.000007`, because the `--flush-logs` option causes the server to flush its logs. The `--master-data` option causes `mysqldump` to write binary log information to its output, so the resulting `.sql` dump file includes these lines:

```
-- Position to start replication or point-in-time recovery from
-- CHANGE MASTER TO MASTER_LOG_FILE='gbichot2-bin.000007',MASTER_LOG_POS=4;
```

Because the `mysqldump` command made a full backup, those lines mean two things:

- The dump file contains all changes made before any changes written to the `gbichot2-bin.000007` binary log file or higher.
- All data changes logged after the backup are not present in the dump file, but are present in the `gbichot2-bin.000007` binary log file or higher.

On Monday at 1 p.m., we can create an incremental backup by flushing the logs to begin a new binary log file. For example, executing a `mysqladmin flush-logs` command creates `gbichot2-bin.000008`. All changes between the Sunday 1 p.m. full backup and Monday 1 p.m. will be in the `gbichot2-bin.000007` file. This incremental backup is important, so it is a good idea to copy it to a safe place. (For example, back it up on tape or DVD, or copy it to another machine.) On Tuesday at 1 p.m., execute another `mysqladmin flush-logs` command. All changes between Monday 1 p.m. and Tuesday 1 p.m. will be in the `gbichot2-bin.000008` file (which also should be copied somewhere safe).

The MySQL binary logs take up disk space. To free up space, purge them from time to time. One way to do this is by deleting the binary logs that are no longer needed, such as when we make a full backup:

```
shell> mysqldump --single-transaction --flush-logs --master-data=2 \
         --all-databases --delete-master-logs > backup_sunday_1_PM.sql
```

Note

Deleting the MySQL binary logs with `mysqldump --delete-master-logs` can be dangerous if your server is a replication master server, because slave servers might not yet fully have processed the contents of the binary log. The description for the `PURGE BINARY LOGS` statement explains what should be verified before deleting the MySQL binary logs. See Section 13.4.1.1, “PURGE BINARY LOGS Syntax”.

7.3.2 Using Backups for Recovery

Now, suppose that we have a catastrophic crash on Wednesday at 8 a.m. that requires recovery from backups. To recover, first we restore the last full backup we have (the one from Sunday 1 p.m.). The full backup file is just a set of SQL statements, so restoring it is very easy:

```
shell> mysql < backup_sunday_1_PM.sql
```

At this point, the data is restored to its state as of Sunday 1 p.m.. To restore the changes made since then, we must use the incremental backups; that is, the `gbichot2-bin.000007` and `gbichot2-bin.000008` binary log files. Fetch the files if necessary from where they were backed up, and then process their contents like this:

```
shell> mysqlbinlog gbichot2-bin.000007 gbichot2-bin.000008 | mysql
```

We now have recovered the data to its state as of Tuesday 1 p.m., but still are missing the changes from that date to the date of the crash. To not lose them, we would have needed to have the MySQL server store its MySQL binary logs into a safe location (RAID disks, SAN, ...) different from the place

where it stores its data files, so that these logs were not on the destroyed disk. (That is, we can start the server with a `--log-bin` option that specifies a location on a different physical device from the one on which the data directory resides. That way, the logs are safe even if the device containing the directory is lost.) If we had done this, we would have the `gbichot2-bin.000009` file (and any subsequent files) at hand, and we could apply them using `mysqlbinlog` and `mysql` to restore the most recent data changes with no loss up to the moment of the crash:

```
shell> mysqlbinlog gbichot2-bin.000009 ... | mysql
```

For more information about using `mysqlbinlog` to process binary log files, see Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”.

7.3.3 Backup Strategy Summary

In case of an operating system crash or power failure, `InnoDB` itself does all the job of recovering data. But to make sure that you can sleep well, observe the following guidelines:

- Always run the MySQL server with the `--log-bin` option, or even `--log-bin=log_name`, where the log file name is located on some safe media different from the drive on which the data directory is located. If you have such safe media, this technique can also be good for disk load balancing (which results in a performance improvement).
- Make periodic full backups, using the `mysqldump` command shown earlier in Section 7.3.1, “Establishing a Backup Policy”, that makes an online, nonblocking backup.
- Make periodic incremental backups by flushing the logs with `FLUSH LOGS` or `mysqladmin flush-logs`.

7.4 Using mysqldump for Backups

This section describes how to use `mysqldump` to produce dump files, and how to reload dump files. A dump file can be used in several ways:

- As a backup to enable data recovery in case of data loss.
- As a source of data for setting up replication slaves.
- As a source of data for experimentation:
  - To make a copy of a database that you can use without changing the original data.
  - To test potential upgrade incompatibilities.

`mysqldump` produces two types of output, depending on whether the `--tab` option is given:

- Without `--tab`, `mysqldump` writes SQL statements to the standard output. This output consists of `CREATE` statements to create dumped objects (databases, tables, stored routines, and so forth), and `INSERT` statements to load data into tables. The output can be saved in a file and reloaded later using `mysql` to recreate the dumped objects. Options are available to modify the format of the SQL statements, and to control which objects are dumped.
- With `--tab`, `mysqldump` produces two output files for each dumped table. The server writes one file as tab-delimited text, one line per table row. This file is named *`tbl_name`*`.txt` in the output directory. The server also sends a `CREATE TABLE` statement for the table to `mysqldump`, which writes it as a file named *`tbl_name`*`.sql` in the output directory.

7.4.1 Dumping Data in SQL Format with mysqldump

This section describes how to use `mysqldump` to create SQL-format dump files. For information about reloading such dump files, see Section 7.4.2, “Reloading SQL-Format Backups”.

By default, `mysqldump` writes information as SQL statements to the standard output. You can save the output in a file:

```
shell> mysqldump [arguments] > file_name
```

To dump all databases, invoke `mysqldump` with the `--all-databases` option:

```
shell> mysqldump --all-databases > dump.sql
```

To dump only specific databases, name them on the command line and use the `--databases` option:

```
shell> mysqldump --databases db1 db2 db3 > dump.sql
```

The `--databases` option causes all names on the command line to be treated as database names. Without this option, `mysqldump` treats the first name as a database name and those following as table names.

With `--all-databases` or `--databases`, `mysqldump` writes `CREATE DATABASE` and `USE` statements prior to the dump output for each database. This ensures that when the dump file is reloaded, it creates each database if it does not exist and makes it the default database so database contents are loaded into the same database from which they came. If you want to cause the dump file to force a drop of each database before recreating it, use the `--add-drop-database` option as well. In this case, `mysqldump` writes a `DROP DATABASE` statement preceding each `CREATE DATABASE` statement.

To dump a single database, name it on the command line:

```
shell> mysqldump --databases test > dump.sql
```

In the single-database case, it is permissible to omit the `--databases` option:

```
shell> mysqldump test > dump.sql
```

The difference between the two preceding commands is that without `--databases`, the dump output contains no `CREATE DATABASE` or `USE` statements. This has several implications:

- When you reload the dump file, you must specify a default database name so that the server knows which database to reload.
- For reloading, you can specify a database name different from the original name, which enables you to reload the data into a different database.
- If the database to be reloaded does not exist, you must create it first.
- Because the output will contain no `CREATE DATABASE` statement, the `--add-drop-database` option has no effect. If you use it, it produces no `DROP DATABASE` statement.

To dump only specific tables from a database, name them on the command line following the database name:

```
shell> mysqldump test t1 t3 t7 > dump.sql
```

7.4.2 Reloading SQL-Format Backups

To reload a dump file written by `mysqldump` that consists of SQL statements, use it as input to the `mysql` client. If the dump file was created by `mysqldump` with the `--all-databases` or `--databases` option, it contains `CREATE DATABASE` and `USE` statements and it is not necessary to specify a default database into which to load the data:

```
shell> mysql < dump.sql
```

Alternatively, from within `mysql`, use a `source` command:

```
mysql> source dump.sql
```

If the file is a single-database dump not containing `CREATE DATABASE` and `USE` statements, create the database first (if necessary):

```
shell> mysqladmin create db1
```

Then specify the database name when you load the dump file:

```
shell> mysql db1 < dump.sql
```

Alternatively, from within `mysql`, create the database, select it as the default database, and load the dump file:

```
mysql> CREATE DATABASE IF NOT EXISTS db1;
mysql> USE db1;
mysql> source dump.sql
```

Note

For Windows PowerShell users: Because the "<" character is reserved for future use in PowerShell, an alternative approach is required, such as using quotes `cmd.exe /c "mysql < dump.sql"`.

7.4.3 Dumping Data in Delimited-Text Format with mysqldump

This section describes how to use `mysqldump` to create delimited-text dump files. For information about reloading such dump files, see Section 7.4.4, “Reloading Delimited-Text Format Backups”.

If you invoke `mysqldump` with the `--tab=dir_name` option, it uses *`dir_name`* as the output directory and dumps tables individually in that directory using two files for each table. The table name is the base name for these files. For a table named `t1`, the files are named `t1.sql` and `t1.txt`. The `.sql` file contains a `CREATE TABLE` statement for the table. The `.txt` file contains the table data, one line per table row.

The following command dumps the contents of the `db1` database to files in the `/tmp` database:

```
shell> mysqldump --tab=/tmp db1
```

The `.txt` files containing table data are written by the server, so they are owned by the system account used for running the server. The server uses `SELECT ... INTO OUTFILE` to write the files, so you must have the `FILE` privilege to perform this operation, and an error occurs if a given `.txt` file already exists.

The server sends the `CREATE` definitions for dumped tables to `mysqldump`, which writes them to `.sql` files. These files therefore are owned by the user who executes `mysqldump`.

It is best that `--tab` be used only for dumping a local server. If you use it with a remote server, the `--tab` directory must exist on both the local and remote hosts, and the `.txt` files will be written by the server in the remote directory (on the server host), whereas the `.sql` files will be written by `mysqldump` in the local directory (on the client host).

For `mysqldump --tab`, the server by default writes table data to `.txt` files one line per row with tabs between column values, no quotation marks around column values, and newline as the line terminator. (These are the same defaults as for `SELECT ... INTO OUTFILE`.)

To enable data files to be written using a different format, `mysqldump` supports these options:

- `--fields-terminated-by=`*`str`*

  The string for separating column values (default: tab).

- `--fields-enclosed-by=`*`char`*

  The character within which to enclose column values (default: no character).

- `--fields-optionally-enclosed-by=`*`char`*

  The character within which to enclose non-numeric column values (default: no character).

- `--fields-escaped-by=`*`char`*

  The character for escaping special characters (default: no escaping).

- `--lines-terminated-by=`*`str`*

  The line-termination string (default: newline).

Depending on the value you specify for any of these options, it might be necessary on the command line to quote or escape the value appropriately for your command interpreter. Alternatively, specify the value using hex notation. Suppose that you want `mysqldump` to quote column values within double quotation marks. To do so, specify double quote as the value for the `--fields-enclosed-by` option. But this character is often special to command interpreters and must be treated specially. For example, on Unix, you can quote the double quote like this:

```
--fields-enclosed-by='"'
```

On any platform, you can specify the value in hex:

```
--fields-enclosed-by=0x22
```

It is common to use several of the data-formatting options together. For example, to dump tables in comma-separated values format with lines terminated by carriage-return/newline pairs (`\r\n`), use this command (enter it on a single line):

```
shell> mysqldump --tab=/tmp --fields-terminated-by=,
         --fields-enclosed-by='"' --lines-terminated-by=0x0d0a db1
```

Should you use any of the data-formatting options to dump table data, you will need to specify the same format when you reload data files later, to ensure proper interpretation of the file contents.

7.4.4 Reloading Delimited-Text Format Backups

For backups produced with `mysqldump --tab`, each table is represented in the output directory by an `.sql` file containing the `CREATE TABLE` statement for the table, and a `.txt` file containing the table data. To reload a table, first change location into the output directory. Then process the `.sql` file with `mysql` to create an empty table and process the `.txt` file to load the data into the table:

```
shell> mysql db1 < t1.sql
shell> mysqlimport db1 t1.txt
```

An alternative to using `mysqlimport` to load the data file is to use the `LOAD DATA INFILE` statement from within the `mysql` client:

```
mysql> USE db1;
mysql> LOAD DATA INFILE 't1.txt' INTO TABLE t1;
```

If you used any data-formatting options with `mysqldump` when you initially dumped the table, you must use the same options with `mysqlimport` or `LOAD DATA INFILE` to ensure proper interpretation of the data file contents:

```
shell> mysqlimport --fields-terminated-by=,
         --fields-enclosed-by='"' --lines-terminated-by=0x0d0a db1 t1.txt
```

Or:

```
mysql> USE db1;
mysql> LOAD DATA INFILE 't1.txt' INTO TABLE t1
    -> FIELDS TERMINATED BY ',' FIELDS ENCLOSED BY '"'
    -> LINES TERMINATED BY '\r\n';
```

7.4.5 mysqldump Tips

This section surveys techniques that enable you to use `mysqldump` to solve specific problems:

- How to make a copy a database
- How to copy a database from one server to another
- How to dump stored programs (stored procedures and functions, triggers, and events)
- How to dump definitions and data separately

7.4.5.1 Making a Copy of a Database

```
shell> mysqldump db1 > dump.sql
shell> mysqladmin create db2
shell> mysql db2 < dump.sql
```

Do not use `--databases` on the `mysqldump` command line because that causes `USE db1` to be included in the dump file, which overrides the effect of naming `db2` on the `mysql` command line.

7.4.5.2 Copy a Database from one Server to Another

On Server 1:

```
shell> mysqldump --databases db1 > dump.sql
```

Copy the dump file from Server 1 to Server 2.

On Server 2:

```
shell> mysql < dump.sql
```

Use of `--databases` with the `mysqldump` command line causes the dump file to include `CREATE DATABASE` and `USE` statements that create the database if it does exist and make it the default database for the reloaded data.

Alternatively, you can omit `--databases` from the `mysqldump` command. Then you will need to create the database on Server 2 (if necessary) and specify it as the default database when you reload the dump file.

On Server 1:

```
shell> mysqldump db1 > dump.sql
```

On Server 2:

```
shell> mysqladmin create db1
shell> mysql db1 < dump.sql
```

You can specify a different database name in this case, so omitting `--databases` from the `mysqldump` command enables you to dump data from one database and load it into another.

7.4.5.3 Dumping Stored Programs

Several options control how `mysqldump` handles stored programs (stored procedures and functions, triggers, and events):

- `--events`: Dump Event Scheduler events
- `--routines`: Dump stored procedures and functions
- `--triggers`: Dump triggers for tables

The `--triggers` option is enabled by default so that when tables are dumped, they are accompanied by any triggers they have. The other options are disabled by default and must be specified explicitly to dump the corresponding objects. To disable any of these options explicitly, use its skip form: `--skip-events`, `--skip-routines`, or `--skip-triggers`.

7.4.5.4 Dumping Table Definitions and Content Separately

The `--no-data` option tells `mysqldump` not to dump table data, resulting in the dump file containing only statements to create the tables. Conversely, the `--no-create-info` option tells `mysqldump` to suppress `CREATE` statements from the output, so that the dump file contains only table data.

For example, to dump table definitions and data separately for the `test` database, use these commands:

```
shell> mysqldump --no-data test > dump-defs.sql
shell> mysqldump --no-create-info test > dump-data.sql
```

For a definition-only dump, add the `--routines` and `--events` options to also include stored routine and event definitions:

```
shell> mysqldump --no-data --routines --events test > dump-defs.sql
```

7.4.5.5 Using mysqldump to Test for Upgrade Incompatibilities

When contemplating a MySQL upgrade, it is prudent to install the newer version separately from your current production version. Then you can dump the database and database object definitions from the production server and load them into the new server to verify that they are handled properly. (This is also useful for testing downgrades.)

On the production server:

```
shell> mysqldump --all-databases --no-data --routines --events > dump-defs.sql
```

On the upgraded server:

```
shell> mysql < dump-defs.sql
```

Because the dump file does not contain table data, it can be processed quickly. This enables you to spot potential incompatibilities without waiting for lengthy data-loading operations. Look for warnings or errors while the dump file is being processed.

After you have verified that the definitions are handled properly, dump the data and try to load it into the upgraded server.

On the production server:

```
shell> mysqldump --all-databases --no-create-info > dump-data.sql
```

On the upgraded server:

```
shell> mysql < dump-data.sql
```

Now check the table contents and run some test queries.

7.5 Point-in-Time (Incremental) Recovery Using the Binary Log

Point-in-time recovery refers to recovery of data changes made since a given point in time. Typically, this type of recovery is performed after restoring a full backup that brings the server to its state as of the time the backup was made. (The full backup can be made in several ways, such as those listed in Section 7.2, “Database Backup Methods”.) Point-in-time recovery then brings the server up to date incrementally from the time of the full backup to a more recent time.

Note

Many of the examples here use the `mysql` client to process binary log output produced by `mysqlbinlog`. If your binary log contains `\0` (null) characters, that output cannot be parsed by `mysql` unless you invoke it with the `--binary-mode` option (available in MySQL 5.6).

Point-in-time recovery is based on these principles:

- The source of information for point-in-time recovery is the set of incremental backups represented by the binary log files generated subsequent to the full backup operation. Therefore, the server must be started with the `--log-bin` option to enable binary logging (see Section 5.4.4, “The Binary Log”).

  To restore data from the binary log, you must know the name and location of the current binary log files. By default, the server creates binary log files in the data directory, but a path name can be specified with the `--log-bin` option to place the files in a different location. Section 5.4.4, “The Binary Log”.

  To see a listing of all binary log files, use this statement:

  ```
  mysql> SHOW BINARY LOGS;
  ```

  To determine the name of the current binary log file, issue the following statement:

  ```
  mysql> SHOW MASTER STATUS;
  ```

- The `mysqlbinlog` utility converts the events in the binary log files from binary format to text so that they can be executed or viewed. `mysqlbinlog` has options for selecting sections of the binary log based on event times or position of events within the log. See Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”.

- Executing events from the binary log causes the data modifications they represent to be redone. This enables recovery of data changes for a given span of time. To execute events from the binary log, process `mysqlbinlog` output using the `mysql` client:

```
shell> mysqlbinlog binlog_files | mysql -u root -p
```

- Viewing log contents can be useful when you need to determine event times or positions to select partial log contents prior to executing events. To view events from the log, send `mysqlbinlog` output into a paging program:

  ```
  shell> mysqlbinlog binlog_files | more
  ```

  Alternatively, save the output in a file and view the file in a text editor:

  ```
  shell> mysqlbinlog binlog_files > tmpfile
  shell> ... edit tmpfile ...
  ```

- Saving the output in a file is useful as a preliminary to executing the log contents with certain events removed, such as an accidental `DROP DATABASE`. You can delete from the file any statements not to be executed before executing its contents. After editing the file, execute the contents as follows:

  ```
  shell> mysql -u root -p < tmpfile
  ```

If you have more than one binary log to execute on the MySQL server, the safe method is to process them all using a single connection to the server. Here is an example that demonstrates what may be *unsafe*:

```
shell> mysqlbinlog binlog.000001 | mysql -u root -p # DANGER!!
shell> mysqlbinlog binlog.000002 | mysql -u root -p # DANGER!!
```

Processing binary logs this way using different connections to the server causes problems if the first log file contains a `CREATE TEMPORARY TABLE` statement and the second log contains a statement that uses the temporary table. When the first `mysql` process terminates, the server drops the temporary table. When the second `mysql` process attempts to use the table, the server reports "unknown table."

To avoid problems like this, use a *single* connection to execute the contents of all binary logs that you want to process. Here is one way to do so:

```
shell> mysqlbinlog binlog.000001 binlog.000002 | mysql -u root -p
```

Another approach is to write all the logs to a single file and then process the file:

```
shell> mysqlbinlog binlog.000001 >  /tmp/statements.sql
shell> mysqlbinlog binlog.000002 >> /tmp/statements.sql
shell> mysql -u root -p -e "source /tmp/statements.sql"
```

7.5.1 Point-in-Time Recovery Using Event Times

To indicate the start and end times for recovery, specify the `--start-datetime` and `--stop-datetime` options for `mysqlbinlog`, in `DATETIME` format. As an example, suppose that exactly at 10:00 a.m. on April 20, 2005 an SQL statement was executed that deleted a large table. To restore the table and data, you could restore the previous night's backup, and then execute the following command:

```
shell> mysqlbinlog --stop-datetime="2005-04-20 9:59:59" \
        /var/log/mysql/bin.123456 | mysql -u root -p
```

This command recovers all of the data up until the date and time given by the `--stop-datetime` option. If you did not detect the erroneous SQL statement that was entered until hours later, you

will probably also want to recover the activity that occurred afterward. Based on this, you could run `mysqlbinlog` again with a start date and time, like so:

```
shell> mysqlbinlog --start-datetime="2005-04-20 10:01:00" \
        /var/log/mysql/bin.123456 | mysql -u root -p
```

In this command, the SQL statements logged from 10:01 a.m. on will be re-executed. The combination of restoring of the previous night's dump file and the two `mysqlbinlog` commands restores everything up until one second before 10:00 a.m. and everything from 10:01 a.m. on.

To use this method of point-in-time recovery, you should examine the log to be sure of the exact times to specify for the commands. To display the log file contents without executing them, use this command:

```
shell> mysqlbinlog /var/log/mysql/bin.123456 > /tmp/mysql_restore.sql
```

Then open the `/tmp/mysql_restore.sql` file with a text editor to examine it.

Excluding specific changes by specifying times for `mysqlbinlog` does not work well if multiple statements executed at the same time as the one to be excluded.

7.5.2 Point-in-Time Recovery Using Event Positions

Instead of specifying dates and times, the `--start-position` and `--stop-position` options for `mysqlbinlog` can be used for specifying log positions. They work the same as the start and stop date options, except that you specify log position numbers rather than dates. Using positions may enable you to be more precise about which part of the log to recover, especially if many transactions occurred around the same time as a damaging SQL statement. To determine the position numbers, run `mysqlbinlog` for a range of times near the time when the unwanted transaction was executed, but redirect the results to a text file for examination. This can be done like so:

```
shell> mysqlbinlog --start-datetime="2005-04-20 9:55:00" \
        --stop-datetime="2005-04-20 10:05:00" \
        /var/log/mysql/bin.123456 > /tmp/mysql_restore.sql
```

This command creates a small text file in the `/tmp` directory that contains the SQL statements around the time that the deleterious SQL statement was executed. Open this file with a text editor and look for the statement that you do not want to repeat. Determine the positions in the binary log for stopping and resuming the recovery and make note of them. Positions are labeled as `log_pos` followed by a number. After restoring the previous backup file, use the position numbers to process the binary log file. For example, you would use commands something like these:

```
shell> mysqlbinlog --stop-position=368312 /var/log/mysql/bin.123456 \
        | mysql -u root -p

shell> mysqlbinlog --start-position=368315 /var/log/mysql/bin.123456 \
        | mysql -u root -p
```

The first command recovers all the transactions up until the stop position given. The second command recovers all transactions from the starting position given until the end of the binary log. Because the output of `mysqlbinlog` includes `SET TIMESTAMP` statements before each SQL statement recorded, the recovered data and related MySQL logs will reflect the original times at which the transactions were executed.

7.6 MyISAM Table Maintenance and Crash Recovery

This section discusses how to use `myisamchk` to check or repair `MyISAM` tables (tables that have `.MYD` and `.MYI` files for storing data and indexes). For general `myisamchk` background, see

Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”. Other table-repair information can be found at Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”.

You can use myisamchk to check, repair, or optimize database tables. The following sections describe how to perform these operations and how to set up a table maintenance schedule. For information about using myisamchk to get information about your tables, see Section 4.6.3.5, “Obtaining Table Information with myisamchk”.

Even though table repair with myisamchk is quite secure, it is always a good idea to make a backup *before* doing a repair or any maintenance operation that could make a lot of changes to a table.

myisamchk operations that affect indexes can cause FULLTEXT indexes to be rebuilt with full-text parameters that are incompatible with the values used by the MySQL server. To avoid this problem, follow the guidelines in Section 4.6.3.1, “myisamchk General Options”.

MyISAM table maintenance can also be done using the SQL statements that perform operations similar to what myisamchk can do:

- To check MyISAM tables, use CHECK TABLE.
- To repair MyISAM tables, use REPAIR TABLE.
- To optimize MyISAM tables, use OPTIMIZE TABLE.
- To analyze MyISAM tables, use ANALYZE TABLE.

For additional information about these statements, see Section 13.7.2, “Table Maintenance Statements”.

These statements can be used directly or by means of the mysqlcheck client program. One advantage of these statements over myisamchk is that the server does all the work. With myisamchk, you must make sure that the server does not use the tables at the same time so that there is no unwanted interaction between myisamchk and the server.

7.6.1 Using myisamchk for Crash Recovery

This section describes how to check for and deal with data corruption in MySQL databases. If your tables become corrupted frequently, you should try to find the reason why. See Section B.5.3.3, “What to Do If MySQL Keeps Crashing”.

For an explanation of how MyISAM tables can become corrupted, see Section 15.3.4, “MyISAM Table Problems”.

If you run mysqld with external locking disabled (which is the default), you cannot reliably use myisamchk to check a table when mysqld is using the same table. If you can be certain that no one will access the tables through mysqld while you run myisamchk, you only have to execute mysqladmin flush-tables before you start checking the tables. If you cannot guarantee this, you must stop mysqld while you check the tables. If you run myisamchk to check tables that mysqld is updating at the same time, you may get a warning that a table is corrupt even when it is not.

If the server is run with external locking enabled, you can use myisamchk to check tables at any time. In this case, if the server tries to update a table that myisamchk is using, the server will wait for myisamchk to finish before it continues.

If you use myisamchk to repair or optimize tables, you *must* always ensure that the mysqld server is not using the table (this also applies if external locking is disabled). If you do not stop mysqld, you should at least do a mysqladmin flush-tables before you run myisamchk. Your tables *may become corrupted* if the server and myisamchk access the tables simultaneously.

When performing crash recovery, it is important to understand that each MyISAM table *tbl_name* in a database corresponds to the three files in the database directory shown in the following table.

File	Purpose
tbl_name.frm	Definition (format) file
tbl_name.MYD	Data file
tbl_name.MYI	Index file

Each of these three file types is subject to corruption in various ways, but problems occur most often in data files and index files.

myisamchk works by creating a copy of the .MYD data file row by row. It ends the repair stage by removing the old .MYD file and renaming the new file to the original file name. If you use --quick, myisamchk does not create a temporary .MYD file, but instead assumes that the .MYD file is correct and generates only a new index file without touching the .MYD file. This is safe, because myisamchk automatically detects whether the .MYD file is corrupt and aborts the repair if it is. You can also specify the --quick option twice to myisamchk. In this case, myisamchk does not abort on some errors (such as duplicate-key errors) but instead tries to resolve them by modifying the .MYD file. Normally the use of two --quick options is useful only if you have too little free disk space to perform a normal repair. In this case, you should at least make a backup of the table before running myisamchk.

7.6.2 How to Check MyISAM Tables for Errors

To check a MyISAM table, use the following commands:

- myisamchk *tbl_name*

  This finds 99.99% of all errors. What it cannot find is corruption that involves *only* the data file (which is very unusual). If you want to check a table, you should normally run myisamchk without options or with the -s (silent) option.

- myisamchk -m *tbl_name*

  This finds 99.999% of all errors. It first checks all index entries for errors and then reads through all rows. It calculates a checksum for all key values in the rows and verifies that the checksum matches the checksum for the keys in the index tree.

- myisamchk -e *tbl_name*

  This does a complete and thorough check of all data (-e means “extended check”). It does a check-read of every key for each row to verify that they indeed point to the correct row. This may take a long time for a large table that has many indexes. Normally, myisamchk stops after the first error it finds. If you want to obtain more information, you can add the -v (verbose) option. This causes myisamchk to keep going, up through a maximum of 20 errors.

- myisamchk -e -i *tbl_name*

  This is like the previous command, but the -i option tells myisamchk to print additional statistical information.

In most cases, a simple myisamchk command with no arguments other than the table name is sufficient to check a table.

7.6.3 How to Repair MyISAM Tables

The discussion in this section describes how to use myisamchk on MyISAM tables (extensions .MYI and .MYD).

You can also use the CHECK TABLE and REPAIR TABLE statements to check and repair MyISAM tables. See Section 13.7.2.2, “CHECK TABLE Syntax”, and Section 13.7.2.5, “REPAIR TABLE Syntax”.

Symptoms of corrupted tables include queries that abort unexpectedly and observable errors such as these:

- *tbl_name*.frm is locked against change
- Can't find file *tbl_name*.MYI (Errcode: *nnn*)
- Unexpected end of file
- Record file is crashed
- Got error *nnn* from table handler

To get more information about the error, run perror *nnn*, where *nnn* is the error number. The following example shows how to use perror to find the meanings for the most common error numbers that indicate a problem with a table:

```
shell> perror 126 127 132 134 135 136 141 144 145
MySQL error code 126 = Index file is crashed
MySQL error code 127 = Record-file is crashed
MySQL error code 132 = Old database file
MySQL error code 134 = Record was already deleted (or record file crashed)
MySQL error code 135 = No more room in record file
MySQL error code 136 = No more room in index file
MySQL error code 141 = Duplicate unique key or constraint on write or update
MySQL error code 144 = Table is crashed and last repair failed
MySQL error code 145 = Table was marked as crashed and should be repaired
```

Note that error 135 (no more room in record file) and error 136 (no more room in index file) are not errors that can be fixed by a simple repair. In this case, you must use ALTER TABLE to increase the MAX_ROWS and AVG_ROW_LENGTH table option values:

```
ALTER TABLE tbl_name MAX_ROWS=xxx AVG_ROW_LENGTH=yyy;
```

If you do not know the current table option values, use SHOW CREATE TABLE.

For the other errors, you must repair your tables. myisamchk can usually detect and fix most problems that occur.

The repair process involves up to four stages, described here. Before you begin, you should change location to the database directory and check the permissions of the table files. On Unix, make sure that they are readable by the user that mysqld runs as (and to you, because you need to access the files you are checking). If it turns out you need to modify files, they must also be writable by you.

This section is for the cases where a table check fails (such as those described in Section 7.6.2, “How to Check MyISAM Tables for Errors”), or you want to use the extended features that myisamchk provides.

The myisamchk options used for table maintenance with are described in Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”. myisamchk also has variables that you can set to control memory allocation that may improve performance. See Section 4.6.3.6, “myisamchk Memory Usage”.

If you are going to repair a table from the command line, you must first stop the mysqld server. Note that when you do mysqladmin shutdown on a remote server, the mysqld server is still available for a while after mysqladmin returns, until all statement-processing has stopped and all index changes have been flushed to disk.

Stage 1: Checking your tables

Run myisamchk *.MYI or myisamchk -e *.MYI if you have more time. Use the -s (silent) option to suppress unnecessary information.

If the `mysqld` server is stopped, you should use the `--update-state` option to tell `myisamchk` to mark the table as “checked.”

You have to repair only those tables for which `myisamchk` announces an error. For such tables, proceed to Stage 2.

If you get unexpected errors when checking (such as `out of memory` errors), or if `myisamchk` crashes, go to Stage 3.

Stage 2: Easy safe repair

First, try `myisamchk -r -q tbl_name` (`-r -q` means “quick recovery mode”). This attempts to repair the index file without touching the data file. If the data file contains everything that it should and the delete links point at the correct locations within the data file, this should work, and the table is fixed. Start repairing the next table. Otherwise, use the following procedure:

1. Make a backup of the data file before continuing.
2. Use `myisamchk -r tbl_name` (`-r` means “recovery mode”). This removes incorrect rows and deleted rows from the data file and reconstructs the index file.
3. If the preceding step fails, use `myisamchk --safe-recover tbl_name`. Safe recovery mode uses an old recovery method that handles a few cases that regular recovery mode does not (but is slower).

Note

If you want a repair operation to go much faster, you should set the values of the `sort_buffer_size` and `key_buffer_size` variables each to about 25% of your available memory when running `myisamchk`.

If you get unexpected errors when repairing (such as `out of memory` errors), or if `myisamchk` crashes, go to Stage 3.

Stage 3: Difficult repair

You should reach this stage only if the first 16KB block in the index file is destroyed or contains incorrect information, or if the index file is missing. In this case, it is necessary to create a new index file. Do so as follows:

1. Move the data file to a safe place.
2. Use the table description file to create new (empty) data and index files:

```
shell> mysql db_name
mysql> SET autocommit=1;
mysql> TRUNCATE TABLE tbl_name;
mysql> quit
```

3. Copy the old data file back onto the newly created data file. (Do not just move the old file back onto the new file. You want to retain a copy in case something goes wrong.)

Important

If you are using replication, you should stop it prior to performing the above procedure, since it involves file system operations, and these are not logged by MySQL.

Go back to Stage 2. `myisamchk -r -q` should work. (This should not be an endless loop.)

You can also use the `REPAIR TABLE tbl_name USE_FRM` SQL statement, which performs the whole procedure automatically. There is also no possibility of unwanted interaction between

a utility and the server, because the server does all the work when you use `REPAIR TABLE`. See Section 13.7.2.5, “REPAIR TABLE Syntax”.

Stage 4: Very difficult repair

You should reach this stage only if the `.frm` description file has also crashed. That should never happen, because the description file is not changed after the table is created:

1. Restore the description file from a backup and go back to Stage 3. You can also restore the index file and go back to Stage 2. In the latter case, you should start with `myisamchk -r`.
2. If you do not have a backup but know exactly how the table was created, create a copy of the table in another database. Remove the new data file, and then move the `.frm` description and `.MYI` index files from the other database to your crashed database. This gives you new description and index files, but leaves the `.MYD` data file alone. Go back to Stage 2 and attempt to reconstruct the index file.

7.6.4 MyISAM Table Optimization

To coalesce fragmented rows and eliminate wasted space that results from deleting or updating rows, run `myisamchk` in recovery mode:

```
shell> myisamchk -r tbl_name
```

You can optimize a table in the same way by using the `OPTIMIZE TABLE` SQL statement. `OPTIMIZE TABLE` does a table repair and a key analysis, and also sorts the index tree so that key lookups are faster. There is also no possibility of unwanted interaction between a utility and the server, because the server does all the work when you use `OPTIMIZE TABLE`. See Section 13.7.2.4, “OPTIMIZE TABLE Syntax”.

`myisamchk` has a number of other options that you can use to improve the performance of a table:

- `--analyze` or `-a`: Perform key distribution analysis. This improves join performance by enabling the join optimizer to better choose the order in which to join the tables and which indexes it should use.
- `--sort-index` or `-S`: Sort the index blocks. This optimizes seeks and makes table scans that use indexes faster.
- `--sort-records=index_num` or `-R index_num`: Sort data rows according to a given index. This makes your data much more localized and may speed up range-based `SELECT` and `ORDER BY` operations that use this index.

For a full description of all available options, see Section 4.6.3, “`myisamchk` — MyISAM Table-Maintenance Utility”.

7.6.5 Setting Up a MyISAM Table Maintenance Schedule

It is a good idea to perform table checks on a regular basis rather than waiting for problems to occur. One way to check and repair `MyISAM` tables is with the `CHECK TABLE` and `REPAIR TABLE` statements. See Section 13.7.2, “Table Maintenance Statements”.

Another way to check tables is to use `myisamchk`. For maintenance purposes, you can use `myisamchk -s`. The `-s` option (short for `--silent`) causes `myisamchk` to run in silent mode, printing messages only when errors occur.

It is also a good idea to enable automatic `MyISAM` table checking. For example, whenever the machine has done a restart in the middle of an update, you usually need to check each table that could have been affected before it is used further. (These are “expected crashed tables.”) To cause the server to check `MyISAM` tables automatically, start it with the `--myisam-recover-options` option. See Section 5.1.4, “Server Command Options”.

You should also check your tables regularly during normal system operation. For example, you can run a `cron` job to check important tables once a week, using a line like this in a `crontab` file:

```
35 0 * * 0 /path/to/myisamchk --fast --silent /path/to/datadir/*/*.MYI
```

This prints out information about crashed tables so that you can examine and repair them as necessary.

To start with, execute `myisamchk -s` each night on all tables that have been updated during the last 24 hours. As you see that problems occur infrequently, you can back off the checking frequency to once a week or so.

Normally, MySQL tables need little maintenance. If you are performing many updates to `MyISAM` tables with dynamic-sized rows (tables with `VARCHAR`, `BLOB`, or `TEXT` columns) or have tables with many deleted rows you may want to defragment/reclaim space from the tables from time to time. You can do this by using `OPTIMIZE TABLE` on the tables in question. Alternatively, if you can stop the `mysqld` server for a while, change location into the data directory and use this command while the server is stopped:

```
shell> myisamchk -r -s --sort-index --myisam_sort_buffer_size=16M */*.MYI
```

Chapter 8 Optimization

Table of Contents

8.1 Optimization Overview 830
8.2 Optimizing SQL Statements 832
8.2.1 Optimizing SELECT Statements 832
8.2.2 Subquery Optimization 866
8.2.3 Optimizing INFORMATION_SCHEMA Queries 870
8.2.4 Optimizing Data Change Statements 875
8.2.5 Optimizing Database Privileges 876
8.2.6 Other Optimization Tips 876
8.3 Optimization and Indexes 877
8.3.1 How MySQL Uses Indexes 877
8.3.2 Primary Key Optimization 878
8.3.3 Foreign Key Optimization 879
8.3.4 Column Indexes 879
8.3.5 Multiple-Column Indexes 880
8.3.6 Verifying Index Usage 881
8.3.7 InnoDB and MyISAM Index Statistics Collection 882
8.3.8 Comparison of B-Tree and Hash Indexes 883
8.4 Optimizing Database Structure 884
8.4.1 Optimizing Data Size 885
8.4.2 Optimizing MySQL Data Types 886
8.4.3 Optimizing for Many Tables 888
8.4.4 Internal Temporary Table Use in MySQL 890
8.5 Optimizing for InnoDB Tables 891
8.5.1 Optimizing Storage Layout for InnoDB Tables 891
8.5.2 Optimizing InnoDB Transaction Management 892
8.5.3 Optimizing InnoDB Redo Logging 893
8.5.4 Bulk Data Loading for InnoDB Tables 893
8.5.5 Optimizing InnoDB Queries 894
8.5.6 Optimizing InnoDB DDL Operations 894
8.5.7 Optimizing InnoDB Disk I/O 895
8.5.8 Optimizing InnoDB Configuration Variables 897
8.5.9 Optimizing InnoDB for Systems with Many Tables 898
8.6 Optimizing for MyISAM Tables 898
8.6.1 Optimizing MyISAM Queries 898
8.6.2 Bulk Data Loading for MyISAM Tables 900
8.6.3 Optimizing REPAIR TABLE Statements 901
8.7 Optimizing for MEMORY Tables 902
8.8 Understanding the Query Execution Plan 903
8.8.1 Optimizing Queries with EXPLAIN 903
8.8.2 EXPLAIN Output Format 903
8.8.3 Extended EXPLAIN Output Format 914
8.8.4 Estimating Query Performance 916
8.9 Controlling the Query Optimizer 916
8.9.1 Controlling Query Plan Evaluation 916
8.9.2 Switchable Optimizations 917
8.9.3 Index Hints 918
8.10 Buffering and Caching 921
8.10.1 InnoDB Buffer Pool Optimization 921
8.10.2 The MyISAM Key Cache 921
8.10.3 The MySQL Query Cache 925
8.11 Optimizing Locking Operations 932
8.11.1 Internal Locking Methods 932

8.11.2 Table Locking Issues 934
8.11.3 Concurrent Inserts 936
8.11.4 Metadata Locking 936
8.11.5 External Locking 937
8.12 Optimizing the MySQL Server 938
8.12.1 System Factors 938
8.12.2 Optimizing Disk I/O 939
8.12.3 Using Symbolic Links 940
8.12.4 Optimizing Memory Use 943
8.12.5 Optimizing Network Use 947
8.13 Measuring Performance (Benchmarking) 949
8.13.1 Measuring the Speed of Expressions and Functions 949
8.13.2 The MySQL Benchmark Suite 949
8.13.3 Using Your Own Benchmarks 950
8.13.4 Measuring Performance with performance_schema 951
8.14 Examining Thread Information 951
8.14.1 Thread Command Values 951
8.14.2 General Thread States 953
8.14.3 Delayed-Insert Thread States 959
8.14.4 Query Cache Thread States 960
8.14.5 Replication Master Thread States 961
8.14.6 Replication Slave I/O Thread States 961
8.14.7 Replication Slave SQL Thread States 962
8.14.8 Replication Slave Connection Thread States 963
8.14.9 NDB Cluster Thread States 963
8.14.10 Event Scheduler Thread States 964

This chapter explains how to optimize MySQL performance and provides examples. Optimization involves configuring, tuning, and measuring performance, at several levels. Depending on your job role (developer, DBA, or a combination of both), you might optimize at the level of individual SQL statements, entire applications, a single database server, or multiple networked database servers. Sometimes you can be proactive and plan in advance for performance, while other times you might troubleshoot a configuration or code issue after a problem occurs. Optimizing CPU and memory usage can also improve scalability, allowing the database to handle more load without slowing down.

8.1 Optimization Overview

Database performance depends on several factors at the database level, such as tables, queries, and configuration settings. These software constructs result in CPU and I/O operations at the hardware level, which you must minimize and make as efficient as possible. As you work on database performance, you start by learning the high-level rules and guidelines for the software side, and measuring performance using wall-clock time. As you become an expert, you learn more about what happens internally, and start measuring things such as CPU cycles and I/O operations.

Typical users aim to get the best database performance out of their existing software and hardware configurations. Advanced users look for opportunities to improve the MySQL software itself, or develop their own storage engines and hardware appliances to expand the MySQL ecosystem.

- Optimizing at the Database Level
- Optimizing at the Hardware Level
- Balancing Portability and Performance

Optimizing at the Database Level

The most important factor in making a database application fast is its basic design:

- Are the tables structured properly? In particular, do the columns have the right data types, and does each table have the appropriate columns for the type of work? For example, applications that perform frequent updates often have many tables with few columns, while applications that analyze large amounts of data often have few tables with many columns.
- Are the right indexes in place to make queries efficient?
- Are you using the appropriate storage engine for each table, and taking advantage of the strengths and features of each storage engine you use? In particular, the choice of a transactional storage engine such as `InnoDB` or a nontransactional one such as `MyISAM` can be very important for performance and scalability.

Note

`InnoDB` is the default storage engine for new tables. In practice, the advanced `InnoDB` performance features mean that `InnoDB` tables often outperform the simpler `MyISAM` tables, especially for a busy database.

- Does each table use an appropriate row format? This choice also depends on the storage engine used for the table. In particular, compressed tables use less disk space and so require less disk I/O to read and write the data. Compression is available for all kinds of workloads with `InnoDB` tables, and for read-only `MyISAM` tables.
- Does the application use an appropriate locking strategy? For example, by allowing shared access when possible so that database operations can run concurrently, and requesting exclusive access when appropriate so that critical operations get top priority. Again, the choice of storage engine is significant. The `InnoDB` storage engine handles most locking issues without involvement from you, allowing for better concurrency in the database and reducing the amount of experimentation and tuning for your code.
- Are all memory areas used for caching sized correctly? That is, large enough to hold frequently accessed data, but not so large that they overload physical memory and cause paging. The main memory areas to configure are the `InnoDB` buffer pool, the `MyISAM` key cache, and the MySQL query cache.

Optimizing at the Hardware Level

Any database application eventually hits hardware limits as the database becomes more and more busy. A DBA must evaluate whether it is possible to tune the application or reconfigure the server to avoid these bottlenecks, or whether more hardware resources are required. System bottlenecks typically arise from these sources:

- Disk seeks. It takes time for the disk to find a piece of data. With modern disks, the mean time for this is usually lower than 10ms, so we can in theory do about 100 seeks a second. This time improves slowly with new disks and is very hard to optimize for a single table. The way to optimize seek time is to distribute the data onto more than one disk.
- Disk reading and writing. When the disk is at the correct position, we need to read or write the data. With modern disks, one disk delivers at least 10–20MB/s throughput. This is easier to optimize than seeks because you can read in parallel from multiple disks.
- CPU cycles. When the data is in main memory, we must process it to get our result. Having large tables compared to the amount of memory is the most common limiting factor. But with small tables, speed is usually not the problem.
- Memory bandwidth. When the CPU needs more data than can fit in the CPU cache, main memory bandwidth becomes a bottleneck. This is an uncommon bottleneck for most systems, but one to be aware of.

Balancing Portability and Performance

To use performance-oriented SQL extensions in a portable MySQL program, you can wrap MySQL-specific keywords in a statement within `/*! */` comment delimiters. Other SQL servers ignore the commented keywords. For information about writing comments, see Section 9.6, “Comment Syntax”.

8.2 Optimizing SQL Statements

The core logic of a database application is performed through SQL statements, whether issued directly through an interpreter or submitted behind the scenes through an API. The tuning guidelines in this section help to speed up all kinds of MySQL applications. The guidelines cover SQL operations that read and write data, the behind-the-scenes overhead for SQL operations in general, and operations used in specific scenarios such as database monitoring.

8.2.1 Optimizing SELECT Statements

Queries, in the form of `SELECT` statements, perform all the lookup operations in the database. Tuning these statements is a top priority, whether to achieve sub-second response times for dynamic web pages, or to chop hours off the time to generate huge overnight reports.

Besides `SELECT` statements, the tuning techniques for queries also apply to constructs such as `CREATE TABLE...AS SELECT`, `INSERT INTO...SELECT`, and `WHERE` clauses in `DELETE` statements. Those statements have additional performance considerations because they combine write operations with the read-oriented query operations.

In MySQL NDB Cluster 7.2 and later, the `NDB` storage engine supports a join pushdown optimization whereby a qualifying join is sent in its entirety to NDB Cluster data nodes, where it can be distributed among them and executed in parallel. For more information about this optimization, see Conditions for NDB pushdown joins.

The main considerations for optimizing queries are:

- To make a slow `SELECT ... WHERE` query faster, the first thing to check is whether you can add an index. Set up indexes on columns used in the `WHERE` clause, to speed up evaluation, filtering, and the final retrieval of results. To avoid wasted disk space, construct a small set of indexes that speed up many related queries used in your application.

  Indexes are especially important for queries that reference different tables, using features such as joins and foreign keys. You can use the `EXPLAIN` statement to determine which indexes are used for a `SELECT`. See Section 8.3.1, “How MySQL Uses Indexes” and Section 8.8.1, “Optimizing Queries with EXPLAIN”.

- Isolate and tune any part of the query, such as a function call, that takes excessive time. Depending on how the query is structured, a function could be called once for every row in the result set, or even once for every row in the table, greatly magnifying any inefficiency.

- Minimize the number of full table scans in your queries, particularly for big tables.

- Keep table statistics up to date by using the `ANALYZE TABLE` statement periodically, so the optimizer has the information needed to construct an efficient execution plan.

- Learn the tuning techniques, indexing techniques, and configuration parameters that are specific to the storage engine for each table. Both `InnoDB` and `MyISAM` have sets of guidelines for enabling and sustaining high performance in queries. For details, see Section 8.5.5, “Optimizing InnoDB Queries” and Section 8.6.1, “Optimizing MyISAM Queries”.

- Avoid transforming the query in ways that make it hard to understand, especially if the optimizer does some of the same transformations automatically.

- If a performance issue is not easily solved by one of the basic guidelines, investigate the internal details of the specific query by reading the `EXPLAIN` plan and adjusting your indexes, `WHERE`

clauses, join clauses, and so on. (When you reach a certain level of expertise, reading the `EXPLAIN` plan might be your first step for every query.)

- Adjust the size and properties of the memory areas that MySQL uses for caching. With efficient use of the `InnoDB` buffer pool, `MyISAM` key cache, and the MySQL query cache, repeated queries run faster because the results are retrieved from memory the second and subsequent times.
- Even for a query that runs fast using the cache memory areas, you might still optimize further so that they require less cache memory, making your application more scalable. Scalability means that your application can handle more simultaneous users, larger requests, and so on without experiencing a big drop in performance.
- Deal with locking issues, where the speed of your query might be affected by other sessions accessing the tables at the same time.

8.2.1.1 WHERE Clause Optimization

This section discusses optimizations that can be made for processing `WHERE` clauses. The examples use `SELECT` statements, but the same optimizations apply for `WHERE` clauses in `DELETE` and `UPDATE` statements.

Some examples of queries that are very fast:

```
SELECT COUNT(*) FROM tbl_name;

SELECT MIN(key_part1),MAX(key_part1) FROM tbl_name;

SELECT MAX(key_part2) FROM tbl_name
  WHERE key_part1=constant;

SELECT ... FROM tbl_name
  ORDER BY key_part1,key_part2,... LIMIT 10;

SELECT ... FROM tbl_name
  ORDER BY key_part1 DESC, key_part2 DESC, ... LIMIT 10;
```

MySQL resolves the following queries using only the entries from a secondary index, if the indexed columns are numeric:

```
SELECT key_part1,key_part2 FROM tbl_name WHERE key_part1=val;

SELECT COUNT(*) FROM tbl_name
  WHERE key_part1=val1 AND key_part2=val2;

SELECT key_part2 FROM tbl_name GROUP BY key_part1;
```

The following queries use the index data to retrieve the rows in sorted order without a separate sorting pass:

```
SELECT ... FROM tbl_name
  ORDER BY key_part1,key_part2,... ;

SELECT ... FROM tbl_name
  ORDER BY key_part1 DESC, key_part2 DESC, ... ;
```

You might be tempted to rewrite your queries to make arithmetic operations faster, while sacrificing readability. Because MySQL does similar optimizations automatically, you can often avoid this work, and leave the query in a more understandable and maintainable form. Some of the optimizations performed by MySQL follow:

Note

Because work on the MySQL optimizer is ongoing, not all of the optimizations that MySQL performs are documented here.

- Removal of unnecessary parentheses:

```
   ((a AND b) AND c OR (((a AND b) AND (c AND d))))
-> (a AND b AND c) OR (a AND b AND c AND d)
```

- Constant folding:

```
   (a<b AND b=c) AND a=5
-> b>5 AND b=c AND a=5
```

- Constant condition removal (needed because of constant folding):

```
   (B>=5 AND B=5) OR (B=6 AND 5=5) OR (B=7 AND 5=6)
-> B=5 OR B=6
```

- Constant expressions used by indexes are evaluated only once.
- `COUNT(*)` on a single table without a `WHERE` is retrieved directly from the table information for `MyISAM` and `MEMORY` tables. This is also done for any `NOT NULL` expression when used with only one table.
- Early detection of invalid constant expressions. MySQL quickly detects that some `SELECT` statements are impossible and returns no rows.
- `HAVING` is merged with `WHERE` if you do not use `GROUP BY` or aggregate functions (`COUNT()`, `MIN()`, and so on).
- For each table in a join, a simpler `WHERE` is constructed to get a fast `WHERE` evaluation for the table and also to skip rows as soon as possible.
- All constant tables are read first before any other tables in the query. A constant table is any of the following:
  - An empty table or a table with one row.
  - A table that is used with a `WHERE` clause on a `PRIMARY KEY` or a `UNIQUE` index, where all index parts are compared to constant expressions and are defined as `NOT NULL`.

  All of the following tables are used as constant tables:

```
SELECT * FROM t WHERE primary_key=1;
SELECT * FROM t1,t2
  WHERE t1.primary_key=1 AND t2.primary_key=t1.id;
```

- The best join combination for joining the tables is found by trying all possibilities. If all columns in `ORDER BY` and `GROUP BY` clauses come from the same table, that table is preferred first when joining.
- If there is an `ORDER BY` clause and a different `GROUP BY` clause, or if the `ORDER BY` or `GROUP BY` contains columns from tables other than the first table in the join queue, a temporary table is created.
- If you use the `SQL_SMALL_RESULT` modifier, MySQL uses an in-memory temporary table.
- Each table index is queried, and the best index is used unless the optimizer believes that it is more efficient to use a table scan. At one time, a scan was used based on whether the best index spanned more than 30% of the table, but a fixed percentage no longer determines the choice between using an index or a scan. The optimizer now is more complex and bases its estimate on additional factors such as table size, number of rows, and I/O block size.
- In some cases, MySQL can read rows from the index without even consulting the data file. If all columns used from the index are numeric, only the index tree is used to resolve the query.

- Before each row is output, those that do not match the `HAVING` clause are skipped.

8.2.1.2 Range Optimization

The `range` access method uses a single index to retrieve a subset of table rows that are contained within one or several index value intervals. It can be used for a single-part or multiple-part index. The following sections give a detailed description of how intervals are extracted from the `WHERE` clause.

- The Range Access Method for Single-Part Indexes
- The Range Access Method for Multiple-Part Indexes

The Range Access Method for Single-Part Indexes

For a single-part index, index value intervals can be conveniently represented by corresponding conditions in the `WHERE` clause, denoted as *range conditions* rather than "intervals."

The definition of a range condition for a single-part index is as follows:

- For both `BTREE` and `HASH` indexes, comparison of a key part with a constant value is a range condition when using the `=`, `<=>`, `IN()`, `IS NULL`, or `IS NOT NULL` operators.
- Additionally, for `BTREE` indexes, comparison of a key part with a constant value is a range condition when using the `>`, `<`, `>=`, `<=`, `BETWEEN`, `!=`, or `<>` operators, or `LIKE` comparisons if the argument to `LIKE` is a constant string that does not start with a wildcard character.
- For all index types, multiple range conditions combined with `OR` or `AND` form a range condition.

"Constant value" in the preceding descriptions means one of the following:

- A constant from the query string
- A column of a `const` or `system` table from the same join
- The result of an uncorrelated subquery
- Any expression composed entirely from subexpressions of the preceding types

Here are some examples of queries with range conditions in the `WHERE` clause:

```
SELECT * FROM t1
  WHERE key_col > 1
  AND key_col < 10;

SELECT * FROM t1
  WHERE key_col = 1
  OR key_col IN (15,18,20);

SELECT * FROM t1
  WHERE key_col LIKE 'ab%'
  OR key_col BETWEEN 'bar' AND 'foo';
```

Some nonconstant values may be converted to constants during the optimizer constant propagation phase.

MySQL tries to extract range conditions from the `WHERE` clause for each of the possible indexes. During the extraction process, conditions that cannot be used for constructing the range condition are dropped, conditions that produce overlapping ranges are combined, and conditions that produce empty ranges are removed.

Consider the following statement, where `key1` is an indexed column and `nonkey` is not indexed:

```
SELECT * FROM t1 WHERE
  (key1 < 'abc' AND (key1 LIKE 'abcde%' OR key1 LIKE '%b')) OR
  (key1 < 'bar' AND nonkey = 4) OR
  (key1 < 'uux' AND key1 > 'z');
```

The extraction process for key `key1` is as follows:

1. Start with original `WHERE` clause:

   ```
   (key1 < 'abc' AND (key1 LIKE 'abcde%' OR key1 LIKE '%b')) OR
   (key1 < 'bar' AND nonkey = 4) OR
   (key1 < 'uux' AND key1 > 'z')
   ```

2. Remove `nonkey = 4` and `key1 LIKE '%b'` because they cannot be used for a range scan. The correct way to remove them is to replace them with `TRUE`, so that we do not miss any matching rows when doing the range scan. Replacing them with `TRUE` yields:

   ```
   (key1 < 'abc' AND (key1 LIKE 'abcde%' OR TRUE)) OR
   (key1 < 'bar' AND TRUE) OR
   (key1 < 'uux' AND key1 > 'z')
   ```

3. Collapse conditions that are always true or false:

   - `(key1 LIKE 'abcde%' OR TRUE)` is always true
   - `(key1 < 'uux' AND key1 > 'z')` is always false

   Replacing these conditions with constants yields:

   ```
   (key1 < 'abc' AND TRUE) OR (key1 < 'bar' AND TRUE) OR (FALSE)
   ```

   Removing unnecessary `TRUE` and `FALSE` constants yields:

   ```
   (key1 < 'abc') OR (key1 < 'bar')
   ```

4. Combining overlapping intervals into one yields the final condition to be used for the range scan:

   ```
   (key1 < 'bar')
   ```

In general (and as demonstrated by the preceding example), the condition used for a range scan is less restrictive than the `WHERE` clause. MySQL performs an additional check to filter out rows that satisfy the range condition but not the full `WHERE` clause.

The range condition extraction algorithm can handle nested `AND`/`OR` constructs of arbitrary depth, and its output does not depend on the order in which conditions appear in `WHERE` clause.

MySQL does not support merging multiple ranges for the `range` access method for spatial indexes. To work around this limitation, you can use a `UNION` with identical `SELECT` statements, except that you put each spatial predicate in a different `SELECT`.

The Range Access Method for Multiple-Part Indexes

Range conditions on a multiple-part index are an extension of range conditions for a single-part index. A range condition on a multiple-part index restricts index rows to lie within one or several key tuple intervals. Key tuple intervals are defined over a set of key tuples, using ordering from the index.

For example, consider a multiple-part index defined as `key1(key_part1, key_part2, key_part3)`, and the following set of key tuples listed in key order:

```
```

```
key_part1  key_part2  key_part3
  NULL       1          'abc'
  NULL       1          'xyz'
  NULL       2          'foo'
   1         1          'abc'
   1         1          'xyz'
   1         2          'abc'
   2         1          'aaa'
```

The condition `key_part1 = 1` defines this interval:

```
(1,-inf,-inf) <= (key_part1,key_part2,key_part3) < (1,+inf,+inf)
```

The interval covers the 4th, 5th, and 6th tuples in the preceding data set and can be used by the range access method.

By contrast, the condition `key_part3 = 'abc'` does not define a single interval and cannot be used by the range access method.

The following descriptions indicate how range conditions work for multiple-part indexes in greater detail.

- For `HASH` indexes, each interval containing identical values can be used. This means that the interval can be produced only for conditions in the following form:

  ```
      key_part1 cmp const1
  AND key_part2 cmp const2
  AND ...
  AND key_partN cmp constN;
  ```

  Here, `const1`, `const2`, ... are constants, `cmp` is one of the `=`, `<=>`, or `IS NULL` comparison operators, and the conditions cover all index parts. (That is, there are `N` conditions, one for each part of an `N`-part index.) For example, the following is a range condition for a three-part `HASH` index:

  ```
  key_part1 = 1 AND key_part2 IS NULL AND key_part3 = 'foo'
  ```

  For the definition of what is considered to be a constant, see The Range Access Method for Single-Part Indexes.

- For a `BTREE` index, an interval might be usable for conditions combined with `AND`, where each condition compares a key part with a constant value using `=`, `<=>`, `IS NULL`, `>`, `<`, `>=`, `<=`, `!=`, `<>`, `BETWEEN`, or `LIKE 'pattern'` (where `'pattern'` does not start with a wildcard). An interval can be used as long as it is possible to determine a single key tuple containing all rows that match the condition (or two intervals if `<>` or `!=` is used).

  The optimizer attempts to use additional key parts to determine the interval as long as the comparison operator is `=`, `<=>`, or `IS NULL`. If the operator is `>`, `<`, `>=`, `<=`, `!=`, `<>`, `BETWEEN`, or `LIKE`, the optimizer uses it but considers no more key parts. For the following expression, the optimizer uses `=` from the first comparison. It also uses `>=` from the second comparison but considers no further key parts and does not use the third comparison for interval construction:

  ```
  key_part1 = 'foo' AND key_part2 >= 10 AND key_part3 > 10
  ```

  The single interval is:

  ```
  ('foo',10,-inf) < (key_part1,key_part2,key_part3) < ('foo',+inf,+inf)
  ```

  It is possible that the created interval contains more rows than the initial condition. For example, the preceding interval includes the value `('foo', 11, 0)`, which does not satisfy the original condition.

- If conditions that cover sets of rows contained within intervals are combined with `OR`, they form a condition that covers a set of rows contained within the union of their intervals. If the conditions are combined with `AND`, they form a condition that covers a set of rows contained within the intersection of their intervals. For example, for this condition on a two-part index:

```
(key_part1 = 1 AND key_part2 < 2) OR (key_part1 > 5)
```

The intervals are:

```
(1,-inf) < (key_part1,key_part2) < (1,2)
(5,-inf) < (key_part1,key_part2)
```

In this example, the interval on the first line uses one key part for the left bound and two key parts for the right bound. The interval on the second line uses only one key part. The `key_len` column in the `EXPLAIN` output indicates the maximum length of the key prefix used.

In some cases, `key_len` may indicate that a key part was used, but that might be not what you would expect. Suppose that *`key_part1`* and *`key_part2`* can be `NULL`. Then the `key_len` column displays two key part lengths for the following condition:

```
key_part1 >= 1 AND key_part2 < 2
```

But, in fact, the condition is converted to this:

```
key_part1 >= 1 AND key_part2 IS NOT NULL
```

The Range Access Method for Single-Part Indexes, describes how optimizations are performed to combine or eliminate intervals for range conditions on a single-part index. Analogous steps are performed for range conditions on multiple-part indexes.

8.2.1.3 Index Merge Optimization

The *Index Merge* access method retrieves rows with multiple `range` scans and merges their results into one. This access method merges index scans from a single table; it does not merge scans across multiple tables. The merge can produce unions, intersections, or unions-of-intersections of its underlying scans.

Example queries for which Index Merge may be used:

```
SELECT * FROM tbl_name WHERE key1 = 10 OR key2 = 20;

SELECT * FROM tbl_name
  WHERE (key1 = 10 OR key2 = 20) AND non_key = 30;

SELECT * FROM t1, t2
  WHERE (t1.key1 IN (1,2) OR t1.key2 LIKE 'value%')
  AND t2.key1 = t1.some_col;

SELECT * FROM t1, t2
  WHERE t1.key1 = 1
  AND (t2.key1 = t1.some_col OR t2.key2 = t1.some_col2);
```

In `EXPLAIN` output, the Index Merge method appears as `index_merge` in the `type` column. In this case, the `key` column contains a list of indexes used, and `key_len` contains a list of the longest key parts for those indexes.

Note

The Index Merge optimization algorithm has the following known deficiencies:

- If your query has a complex `WHERE` clause with deep `AND`/`OR` nesting and MySQL does not choose the optimal plan, try distributing terms using the following identity transformations:

```
(x AND y) OR z => (x OR z) AND (y OR z)
(x OR y) AND z => (x AND z) OR (y AND z)
```

- Index Merge is not applicable to full-text indexes.
- If a range scan is possible on some key, the optimizer will not consider using Index Merge Union or Index Merge Sort-Union algorithms. For example, consider this query:

```
SELECT * FROM t1 WHERE (goodkey1 < 10 OR goodkey2 < 20) AND badkey < 30;
```

  For this query, two plans are possible:

  - An Index Merge scan using the `(goodkey1 < 10 OR goodkey2 < 20)` condition.
  - A range scan using the `badkey < 30` condition.

  However, the optimizer considers only the second plan.

The Index Merge access method has several algorithms, which are displayed in the `Extra` field of `EXPLAIN` output:

- `Using intersect(...)`
- `Using union(...)`
- `Using sort_union(...)`

The following sections describe these algorithms in greater detail. The optimizer chooses between different possible Index Merge algorithms and other access methods based on cost estimates of the various available options.

Use of Index Merge is subject to the value of the `index_merge`, `index_merge_intersection`, `index_merge_union`, and `index_merge_sort_union` flags of the `optimizer_switch` system variable. See Section 8.9.2, “Switchable Optimizations”. By default, all those flags are `on`. To enable only certain algorithms, set `index_merge` to `off`, and enable only such of the others as should be permitted.

- The Index Merge Intersection Access Algorithm
- The Index Merge Union Access Algorithm
- The Index Merge Sort-Union Access Algorithm

The Index Merge Intersection Access Algorithm

This access algorithm is applicable when a `WHERE` clause is converted to several range conditions on different keys combined with `AND`, and each condition is one of the following:

- An *`N`*-part expression of this form, where the index has exactly *`N`* parts (that is, all index parts are covered):

```
key_part1 = const1 AND key_part2 = const2 ... AND key_partN = constN
```

- Any range condition over a primary key of an `InnoDB` table.

Examples:

```
SELECT * FROM innodb_table
  WHERE primary_key < 10 AND key_col1 = 20;

SELECT * FROM tbl_name
  WHERE (key1_part1 = 1 AND key1_part2 = 2) AND key2 = 2;
```

The Index Merge intersection algorithm performs simultaneous scans on all used indexes and produces the intersection of row sequences that it receives from the merged index scans.

If all columns used in the query are covered by the used indexes, full table rows are not retrieved (`EXPLAIN` output contains `Using index` in `Extra` field in this case). Here is an example of such a query:

```
SELECT COUNT(*) FROM t1 WHERE key1 = 1 AND key2 = 1;
```

If the used indexes do not cover all columns used in the query, full rows are retrieved only when the range conditions for all used keys are satisfied.

If one of the merged conditions is a condition over a primary key of an `InnoDB` table, it is not used for row retrieval, but is used to filter out rows retrieved using other conditions.

The Index Merge Union Access Algorithm

The criteria for this algorithm are similar to those for the Index Merge intersection algorithm. The algorithm is applicable when the table's `WHERE` clause is converted to several range conditions on different keys combined with `OR`, and each condition is one of the following:

- An *N*-part expression of this form, where the index has exactly *N* parts (that is, all index parts are covered):

  ```
  key_part1 = const1 AND key_part2 = const2 ... AND key_partN = constN
  ```

- Any range condition over a primary key of an `InnoDB` table.

- A condition for which the Index Merge intersection algorithm is applicable.

Examples:

```
SELECT * FROM t1
  WHERE key1 = 1 OR key2 = 2 OR key3 = 3;

SELECT * FROM innodb_table
  WHERE (key1 = 1 AND key2 = 2)
     OR (key3 = 'foo' AND key4 = 'bar') AND key5 = 5;
```

The Index Merge Sort-Union Access Algorithm

This access algorithm is applicable when the `WHERE` clause is converted to several range conditions combined by `OR`, but the Index Merge union algorithm is not applicable.

Examples:

```
SELECT * FROM tbl_name
  WHERE key_col1 < 10 OR key_col2 < 20;

SELECT * FROM tbl_name
  WHERE (key_col1 > 10 OR key_col2 = 20) AND nonkey_col = 30;
```

The difference between the sort-union algorithm and the union algorithm is that the sort-union algorithm must first fetch row IDs for all rows and sort them before returning any rows.

8.2.1.4 Engine Condition Pushdown Optimization

This optimization improves the efficiency of direct comparisons between a nonindexed column and a constant. In such cases, the condition is “pushed down” to the storage engine for evaluation. This optimization can be used only by the NDB storage engine.

For NDB Cluster, this optimization can eliminate the need to send nonmatching rows over the network between the cluster's data nodes and the MySQL server that issued the query, and can speed up queries where it is used by a factor of 5 to 10 times over cases where condition pushdown could be but is not used.

Suppose that an NDB Cluster table is defined as follows:

```
CREATE TABLE t1 (
    a INT,
    b INT,
    KEY(a)
) ENGINE=NDB;
```

Condition pushdown can be used with queries such as the one shown here, which includes a comparison between a nonindexed column and a constant:

```
SELECT a, b FROM t1 WHERE b = 10;
```

The use of condition pushdown can be seen in the output of EXPLAIN:

```
mysql> EXPLAIN SELECT a,b FROM t1 WHERE b = 10\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: t1
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 10
        Extra: Using where with pushed condition
```

However, condition pushdown *cannot* be used with either of these two queries:

```
SELECT a,b FROM t1 WHERE a = 10;
SELECT a,b FROM t1 WHERE b + 1 = 10;
```

Condition pushdown is not applicable to the first query because an index exists on column a. (An index access method would be more efficient and so would be chosen in preference to condition pushdown.) Condition pushdown cannot be employed for the second query because the comparison involving the nonindexed column b is indirect. (However, condition pushdown could be applied if you were to reduce b + 1 = 10 to b = 9 in the WHERE clause.)

Condition pushdown may also be employed when an indexed column is compared with a constant using a > or < operator:

```
mysql> EXPLAIN SELECT a, b FROM t1 WHERE a < 2\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: t1
         type: range
possible_keys: a
          key: a
      key_len: 5
```

```
          ref: NULL
         rows: 2
        Extra: Using where with pushed condition
```

Other supported comparisons for condition pushdown include the following:

- *`column`* `[NOT] LIKE` *`pattern`*

  `pattern` must be a string literal containing the pattern to be matched; for syntax, see Section 12.5.1, “String Comparison Functions”.

- *`column`* `IS [NOT] NULL`

- *`column`* `IN (`*`value_list`*`)`

  Each item in the *`value_list`* must be a constant, literal value.

- *`column`* `BETWEEN` *`constant1`* `AND` *`constant2`*

  `constant1` and *`constant2`* must each be a constant, literal value.

In all of the cases in the preceding list, it is possible for the condition to be converted into the form of one or more direct comparisons between a column and a constant.

Engine condition pushdown is enabled by default. To disable it at server startup, set the `optimizer_switch` system variable. For example, in a `my.cnf` file, use these lines:

```
[mysqld]
optimizer_switch=engine_condition_pushdown=off
```

At runtime, disable condition pushdown like this:

```
SET optimizer_switch='engine_condition_pushdown=off';
```

Limitations. Condition pushdown is subject to the following limitations:

- Condition pushdown is supported only by the `NDB` storage engine.
- Columns may be compared with constants only; however, this includes expressions which evaluate to constant values.
- Columns used in comparisons cannot be of any of the `BLOB` or `TEXT` types.
- A string value to be compared with a column must use the same collation as the column.
- Joins are not directly supported; conditions involving multiple tables are pushed separately where possible. Use extended `EXPLAIN` output to determine which conditions are actually pushed down. See Section 8.8.3, “Extended EXPLAIN Output Format”.

8.2.1.5 Nested-Loop Join Algorithms

MySQL executes joins between tables using a nested-loop algorithm or variations on it.

- Nested-Loop Join Algorithm
- Block Nested-Loop Join Algorithm

Nested-Loop Join Algorithm

A simple nested-loop join (NLJ) algorithm reads rows from the first table in a loop one at a time, passing each row to a nested loop that processes the next table in the join. This process is repeated as many times as there remain tables to be joined.

Assume that a join between three tables `t1`, `t2`, and `t3` is to be executed using the following join types:

```
Table   Join Type
t1      range
t2      ref
t3      ALL
```

If a simple NLJ algorithm is used, the join is processed like this:

```
for each row in t1 matching range {
  for each row in t2 matching reference key {
    for each row in t3 {
      if row satisfies join conditions, send to client
    }
  }
}
```

Because the NLJ algorithm passes rows one at a time from outer loops to inner loops, it typically reads tables processed in the inner loops many times.

Block Nested-Loop Join Algorithm

A Block Nested-Loop (BNL) join algorithm uses buffering of rows read in outer loops to reduce the number of times that tables in inner loops must be read. For example, if 10 rows are read into a buffer and the buffer is passed to the next inner loop, each row read in the inner loop can be compared against all 10 rows in the buffer. This reduces by an order of magnitude the number of times the inner table must be read.

MySQL join buffering has these characteristics:

- Join buffering can be used when the join is of type `ALL` or `index` (in other words, when no possible keys can be used, and a full scan is done, of either the data or index rows, respectively), or `range`.
- A join buffer is never allocated for the first nonconstant table, even if it would be of type `ALL` or `index`.
- Only columns of interest to a join are stored in its join buffer, not whole rows.
- The `join_buffer_size` system variable determines the size of each join buffer used to process a query.
- One buffer is allocated for each join that can be buffered, so a given query might be processed using multiple join buffers.
- A join buffer is allocated prior to executing the join and freed after the query is done.

For the example join described previously for the NLJ algorithm (without buffering), the join is done as follows using join buffering:

```
for each row in t1 matching range {
  for each row in t2 matching reference key {
    store used columns from t1, t2 in join buffer
    if buffer is full {
      for each row in t3 {
        for each t1, t2 combination in join buffer {
          if row satisfies join conditions, send to client
        }
      }
      empty join buffer
    }
  }
}
```

```
if buffer is not empty {
  for each row in t3 {
    for each t1, t2 combination in join buffer {
      if row satisfies join conditions, send to client
    }
  }
}
```

If *S* is the size of each stored `t1`, `t2` combination is the join buffer and *C* is the number of combinations in the buffer, the number of times table `t3` is scanned is:

```
(S * C)/join_buffer_size + 1
```

The number of `t3` scans decreases as the value of `join_buffer_size` increases, up to the point when `join_buffer_size` is large enough to hold all previous row combinations. At that point, no speed is gained by making it larger.

8.2.1.6 Nested Join Optimization

The syntax for expressing joins permits nested joins. The following discussion refers to the join syntax described in Section 13.2.9.2, “JOIN Syntax”.

The syntax of *`table_factor`* is extended in comparison with the SQL Standard. The latter accepts only *`table_reference`*, not a list of them inside a pair of parentheses. This is a conservative extension if we consider each comma in a list of *`table_reference`* items as equivalent to an inner join. For example:

```
SELECT * FROM t1 LEFT JOIN (t2, t3, t4)
                 ON (t2.a=t1.a AND t3.b=t1.b AND t4.c=t1.c)
```

Is equivalent to:

```
SELECT * FROM t1 LEFT JOIN (t2 CROSS JOIN t3 CROSS JOIN t4)
                 ON (t2.a=t1.a AND t3.b=t1.b AND t4.c=t1.c)
```

In MySQL, `CROSS JOIN` is syntactically equivalent to `INNER JOIN`; they can replace each other. In standard SQL, they are not equivalent. `INNER JOIN` is used with an `ON` clause; `CROSS JOIN` is used otherwise.

In general, parentheses can be ignored in join expressions containing only inner join operations. Consider this join expression:

```
t1 LEFT JOIN (t2 LEFT JOIN t3 ON t2.b=t3.b OR t2.b IS NULL)
   ON t1.a=t2.a
```

After removing parentheses and grouping operations to the left, that join expression transforms into this expression:

```
(t1 LEFT JOIN t2 ON t1.a=t2.a) LEFT JOIN t3
    ON t2.b=t3.b OR t2.b IS NULL
```

Yet, the two expressions are not equivalent. To see this, suppose that the tables `t1`, `t2`, and `t3` have the following state:

- Table `t1` contains rows `(1)`, `(2)`
- Table `t2` contains row `(1,101)`
- Table `t3` contains row `(101)`

In this case, the first expression returns a result set including the rows `(1,1,101,101)`, `(2,NULL,NULL,NULL)`, whereas the second expression returns the rows `(1,1,101,101)`, `(2,NULL,NULL,101)`:

```
mysql> SELECT *
       FROM t1
            LEFT JOIN
            (t2 LEFT JOIN t3 ON t2.b=t3.b OR t2.b IS NULL)
            ON t1.a=t2.a;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
|    1 |    1 |  101 |  101 |
|    2 | NULL | NULL | NULL |
+------+------+------+------+

mysql> SELECT *
       FROM (t1 LEFT JOIN t2 ON t1.a=t2.a)
            LEFT JOIN t3
            ON t2.b=t3.b OR t2.b IS NULL;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
|    1 |    1 |  101 |  101 |
|    2 | NULL | NULL |  101 |
+------+------+------+------+
```

In the following example, an outer join operation is used together with an inner join operation:

```
t1 LEFT JOIN (t2, t3) ON t1.a=t2.a
```

That expression cannot be transformed into the following expression:

```
t1 LEFT JOIN t2 ON t1.a=t2.a, t3
```

For the given table states, the two expressions return different sets of rows:

```
mysql> SELECT *
       FROM t1 LEFT JOIN (t2, t3) ON t1.a=t2.a;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
|    1 |    1 |  101 |  101 |
|    2 | NULL | NULL | NULL |
+------+------+------+------+

mysql> SELECT *
       FROM t1 LEFT JOIN t2 ON t1.a=t2.a, t3;
+------+------+------+------+
| a    | a    | b    | b    |
+------+------+------+------+
|    1 |    1 |  101 |  101 |
|    2 | NULL | NULL |  101 |
+------+------+------+------+
```

Therefore, if we omit parentheses in a join expression with outer join operators, we might change the result set for the original expression.

More exactly, we cannot ignore parentheses in the right operand of the left outer join operation and in the left operand of a right join operation. In other words, we cannot ignore parentheses for the inner table expressions of outer join operations. Parentheses for the other operand (operand for the outer table) can be ignored.

The following expression:

```
(t1,t2) LEFT JOIN t3 ON P(t2.b,t3.b)
```

Is equivalent to this expression for any tables `t1,t2,t3` and any condition `P` over attributes `t2.b` and `t3.b`:

```
t1, t2 LEFT JOIN t3 ON P(t2.b,t3.b)
```

Whenever the order of execution of join operations in a join expression (*`join_table`*) is not from left to right, we talk about nested joins. Consider the following queries:

```
SELECT * FROM t1 LEFT JOIN (t2 LEFT JOIN t3 ON t2.b=t3.b) ON t1.a=t2.a
  WHERE t1.a > 1

SELECT * FROM t1 LEFT JOIN (t2, t3) ON t1.a=t2.a
  WHERE (t2.b=t3.b OR t2.b IS NULL) AND t1.a > 1
```

Those queries are considered to contain these nested joins:

```
t2 LEFT JOIN t3 ON t2.b=t3.b
t2, t3
```

In the first query, the nested join is formed with a left join operation. In the second query, it is formed with an inner join operation.

In the first query, the parentheses can be omitted: The grammatical structure of the join expression will dictate the same order of execution for join operations. For the second query, the parentheses cannot be omitted, although the join expression here can be interpreted unambiguously without them. In our extended syntax, the parentheses in `(t2, t3)` of the second query are required, although theoretically the query could be parsed without them: We still would have unambiguous syntactical structure for the query because `LEFT JOIN` and `ON` play the role of the left and right delimiters for the expression `(t2,t3)`.

The preceding examples demonstrate these points:

- For join expressions involving only inner joins (and not outer joins), parentheses can be removed and joins evaluated left to right. In fact, tables can be evaluated in any order.
- The same is not true, in general, for outer joins or for outer joins mixed with inner joins. Removal of parentheses may change the result.

Queries with nested outer joins are executed in the same pipeline manner as queries with inner joins. More exactly, a variation of the nested-loop join algorithm is exploited. Recall the algorithm by which the nested-loop join executes a query (see Section 8.2.1.5, “Nested-Loop Join Algorithms”). Suppose that a join query over 3 tables `T1,T2,T3` has this form:

```
SELECT * FROM T1 INNER JOIN T2 ON P1(T1,T2)
                 INNER JOIN T3 ON P2(T2,T3)
  WHERE P(T1,T2,T3)
```

Here, `P1(T1,T2)` and `P2(T3,T3)` are some join conditions (on expressions), whereas `P(T1,T2,T3)` is a condition over columns of tables `T1,T2,T3`.

The nested-loop join algorithm would execute this query in the following manner:

```
FOR each row t1 in T1 {
  FOR each row t2 in T2 such that P1(t1,t2) {
    FOR each row t3 in T3 such that P2(t2,t3) {
      IF P(t1,t2,t3) {
         t:=t1||t2||t3; OUTPUT t;
      }
```

```
    }
  }
}
```

The notation `t1||t2||t3` indicates a row constructed by concatenating the columns of rows `t1`, `t2`, and `t3`. In some of the following examples, `NULL` where a table name appears means a row in which `NULL` is used for each column of that table. For example, `t1||t2||NULL` indicates a row constructed by concatenating the columns of rows `t1` and `t2`, and `NULL` for each column of `t3`. Such a row is said to be `NULL`-complemented.

Now consider a query with nested outer joins:

```
SELECT * FROM T1 LEFT JOIN
             (T2 LEFT JOIN T3 ON P2(T2,T3))
             ON P1(T1,T2)
  WHERE P(T1,T2,T3)
```

For this query, modify the nested-loop pattern to obtain:

```
FOR each row t1 in T1 {
  BOOL f1:=FALSE;
  FOR each row t2 in T2 such that P1(t1,t2) {
    BOOL f2:=FALSE;
    FOR each row t3 in T3 such that P2(t2,t3) {
      IF P(t1,t2,t3) {
        t:=t1||t2||t3; OUTPUT t;
      }
      f2=TRUE;
      f1=TRUE;
    }
    IF (!f2) {
      IF P(t1,t2,NULL) {
        t:=t1||t2||NULL; OUTPUT t;
      }
      f1=TRUE;
    }
  }
  IF (!f1) {
    IF P(t1,NULL,NULL) {
      t:=t1||NULL||NULL; OUTPUT t;
    }
  }
}
```

In general, for any nested loop for the first inner table in an outer join operation, a flag is introduced that is turned off before the loop and is checked after the loop. The flag is turned on when for the current row from the outer table a match from the table representing the inner operand is found. If at the end of the loop cycle the flag is still off, no match has been found for the current row of the outer table. In this case, the row is complemented by `NULL` values for the columns of the inner tables. The result row is passed to the final check for the output or into the next nested loop, but only if the row satisfies the join condition of all embedded outer joins.

In the example, the outer join table expressed by the following expression is embedded:

```
(T2 LEFT JOIN T3 ON P2(T2,T3))
```

For the query with inner joins, the optimizer could choose a different order of nested loops, such as this one:

```
FOR each row t3 in T3 {
  FOR each row t2 in T2 such that P2(t2,t3) {
    FOR each row t1 in T1 such that P1(t1,t2) {
      IF P(t1,t2,t3) {
         t:=t1||t2||t3; OUTPUT t;
```

```
      }
    }
  }
}
```

For queries with outer joins, the optimizer can choose only such an order where loops for outer tables precede loops for inner tables. Thus, for our query with outer joins, only one nesting order is possible. For the following query, the optimizer evaluates two different nestings. In both nestings, `T1` must be processed in the outer loop because it is used in an outer join. `T2` and `T3` are used in an inner join, so that join must be processed in the inner loop. However, because the join is an inner join, `T2` and `T3` can be processed in either order.

```
SELECT * T1 LEFT JOIN (T2,T3) ON P1(T1,T2) AND P2(T1,T3)
  WHERE P(T1,T2,T3)
```

One nesting evaluates `T2`, then `T3`:

```
FOR each row t1 in T1 {
  BOOL f1:=FALSE;
  FOR each row t2 in T2 such that P1(t1,t2) {
    FOR each row t3 in T3 such that P2(t1,t3) {
      IF P(t1,t2,t3) {
        t:=t1||t2||t3; OUTPUT t;
      }
      f1:=TRUE
    }
  }
  IF (!f1) {
    IF P(t1,NULL,NULL) {
      t:=t1||NULL||NULL; OUTPUT t;
    }
  }
}
```

The other nesting evaluates `T3`, then `T2`:

```
FOR each row t1 in T1 {
  BOOL f1:=FALSE;
  FOR each row t3 in T3 such that P2(t1,t3) {
    FOR each row t2 in T2 such that P1(t1,t2) {
      IF P(t1,t2,t3) {
        t:=t1||t2||t3; OUTPUT t;
      }
      f1:=TRUE
    }
  }
  IF (!f1) {
    IF P(t1,NULL,NULL) {
      t:=t1||NULL||NULL; OUTPUT t;
    }
  }
}
```

When discussing the nested-loop algorithm for inner joins, we omitted some details whose impact on the performance of query execution may be huge. We did not mention so-called “pushed-down” conditions. Suppose that our `WHERE` condition `P(T1,T2,T3)` can be represented by a conjunctive formula:

```
P(T1,T2,T2) = C1(T1) AND C2(T2) AND C3(T3).
```

In this case, MySQL actually uses the following nested-loop algorithm for the execution of the query with inner joins:

```
FOR each row t1 in T1 such that C1(t1) {
```

```
  FOR each row t2 in T2 such that P1(t1,t2) AND C2(t2)  {
    FOR each row t3 in T3 such that P2(t2,t3) AND C3(t3) {
      IF P(t1,t2,t3) {
         t:=t1||t2||t3; OUTPUT t;
      }
    }
  }
}
```

You see that each of the conjuncts `C1(T1)`, `C2(T2)`, `C3(T3)` are pushed out of the most inner loop to the most outer loop where it can be evaluated. If `C1(T1)` is a very restrictive condition, this condition pushdown may greatly reduce the number of rows from table `T1` passed to the inner loops. As a result, the execution time for the query may improve immensely.

For a query with outer joins, the `WHERE` condition is to be checked only after it has been found that the current row from the outer table has a match in the inner tables. Thus, the optimization of pushing conditions out of the inner nested loops cannot be applied directly to queries with outer joins. Here we must introduce conditional pushed-down predicates guarded by the flags that are turned on when a match has been encountered.

Recall this example with outer joins:

```
P(T1,T2,T3)=C1(T1) AND C(T2) AND C3(T3)
```

For that example, the nested-loop algorithm using guarded pushed-down conditions looks like this:

```
FOR each row t1 in T1 such that C1(t1) {
  BOOL f1:=FALSE;
  FOR each row t2 in T2
      such that P1(t1,t2) AND (f1?C2(t2):TRUE) {
    BOOL f2:=FALSE;
    FOR each row t3 in T3
        such that P2(t2,t3) AND (f1&&f2?C3(t3):TRUE) {
      IF (f1&&f2?TRUE:(C2(t2) AND C3(t3))) {
        t:=t1||t2||t3; OUTPUT t;
      }
      f2=TRUE;
      f1=TRUE;
    }
    IF (!f2) {
      IF (f1?TRUE:C2(t2) && P(t1,t2,NULL)) {
        t:=t1||t2||NULL; OUTPUT t;
      }
      f1=TRUE;
    }
  }
  IF (!f1 && P(t1,NULL,NULL)) {
      t:=t1||NULL||NULL; OUTPUT t;
  }
}
```

In general, pushed-down predicates can be extracted from join conditions such as `P1(T1,T2)` and `P(T2,T3)`. In this case, a pushed-down predicate is guarded also by a flag that prevents checking the predicate for the `NULL`-complemented row generated by the corresponding outer join operation.

Access by key from one inner table to another in the same nested join is prohibited if it is induced by a predicate from the `WHERE` condition.

8.2.1.7 Left Join and Right Join Optimization

MySQL implements an *`A LEFT JOIN B join_condition`* as follows:

- Table *`B`* is set to depend on table *`A`* and all tables on which *`A`* depends.
- Table *`A`* is set to depend on all tables (except *`B`*) that are used in the `LEFT JOIN` condition.

- The `LEFT JOIN` condition is used to decide how to retrieve rows from table *`B`*. (In other words, any condition in the `WHERE` clause is not used.)
- All standard join optimizations are performed, with the exception that a table is always read after all tables on which it depends. If there is a circular dependency, an error occurs.
- All standard `WHERE` optimizations are performed.
- If there is a row in *`A`* that matches the `WHERE` clause, but there is no row in *`B`* that matches the `ON` condition, an extra *`B`* row is generated with all columns set to `NULL`.
- If you use `LEFT JOIN` to find rows that do not exist in some table and you have the following test: *`col_name`* `IS NULL` in the `WHERE` part, where *`col_name`* is a column that is declared as `NOT NULL`, MySQL stops searching for more rows (for a particular key combination) after it has found one row that matches the `LEFT JOIN` condition.

The `RIGHT JOIN` implementation is analogous to that of `LEFT JOIN` with the table roles reversed. Right joins are converted to equivalent left joins, as described in Section 8.2.1.8, “Outer Join Simplification”.

The join optimizer calculates the order in which to join tables. The table read order forced by `LEFT JOIN` or `STRAIGHT_JOIN` helps the join optimizer do its work much more quickly, because there are fewer table permutations to check. This means that if you execute a query of the following type, MySQL does a full scan on `b` because the `LEFT JOIN` forces it to be read before `d`:

```
SELECT *
  FROM a JOIN b LEFT JOIN c ON (c.key=a.key)
  LEFT JOIN d ON (d.key=a.key)
  WHERE b.key=d.key;
```

The fix in this case is reverse the order in which `a` and `b` are listed in the `FROM` clause:

```
SELECT *
  FROM b JOIN a LEFT JOIN c ON (c.key=a.key)
  LEFT JOIN d ON (d.key=a.key)
  WHERE b.key=d.key;
```

For a `LEFT JOIN`, if the `WHERE` condition is always false for the generated `NULL` row, the `LEFT JOIN` is changed to a normal join. For example, the `WHERE` clause would be false in the following query if `t2.column1` were `NULL`:

```
SELECT * FROM t1 LEFT JOIN t2 ON (column1) WHERE t2.column2=5;
```

Therefore, it is safe to convert the query to a normal join:

```
SELECT * FROM t1, t2 WHERE t2.column2=5 AND t1.column1=t2.column1;
```

Now the optimizer can use table `t2` before table `t1` if doing so would result in a better query plan. To provide a hint about the table join order, use `STRAIGHT_JOIN`; see Section 13.2.9, “SELECT Syntax”.

8.2.1.8 Outer Join Simplification

Table expressions in the `FROM` clause of a query are simplified in many cases.

At the parser stage, queries with right outer join operations are converted to equivalent queries containing only left join operations. In the general case, the conversion is performed such that this right join:

```
```

```
(T1, ...) RIGHT JOIN (T2, ...) ON P(T1, ..., T2, ...)
```

Becomes this equivalent left join:

```
(T2, ...) LEFT JOIN (T1, ...) ON P(T1, ..., T2, ...)
```

All inner join expressions of the form `T1 INNER JOIN T2 ON P(T1,T2)` are replaced by the list `T1,T2`, `P(T1,T2)` being joined as a conjunct to the `WHERE` condition (or to the join condition of the embedding join, if there is any).

When the optimizer evaluates plans for outer join operations, it takes into consideration only plans where, for each such operation, the outer tables are accessed before the inner tables. The optimizer choices are limited because only such plans enable outer joins to be executed using the nested-loop algorithm.

Consider a query of this form, where `R(T2)` greatly narrows the number of matching rows from table `T2`:

```
SELECT * T1 LEFT JOIN T2 ON P1(T1,T2)
  WHERE P(T1,T2) AND R(T2)
```

If the query is executed as written, the optimizer has no choice but to access the less-restricted table `T1` before the more-restricted table `T2`, which may produce a very inefficient execution plan.

Instead, MySQL converts the query to a query with no outer join operation if the `WHERE` condition is null-rejected. (That is, it converts the outer join to an inner join.) A condition is said to be null-rejected for an outer join operation if it evaluates to `FALSE` or `UNKNOWN` for any `NULL`-complemented row generated for the operation.

Thus, for this outer join:

```
T1 LEFT JOIN T2 ON T1.A=T2.A
```

Conditions such as these are null-rejected because they cannot be true for any `NULL`-complemented row (with `T2` columns set to `NULL`):

```
T2.B IS NOT NULL
T2.B > 3
T2.C <= T1.C
T2.B < 2 OR T2.C > 1
```

Conditions such as these are not null-rejected because they might be true for a `NULL`-complemented row:

```
T2.B IS NULL
T1.B < 3 OR T2.B IS NOT NULL
T1.B < 3 OR T2.B > 3
```

The general rules for checking whether a condition is null-rejected for an outer join operation are simple:

- It is of the form `A IS NOT NULL`, where `A` is an attribute of any of the inner tables
- It is a predicate containing a reference to an inner table that evaluates to `UNKNOWN` when one of its arguments is `NULL`
- It is a conjunction containing a null-rejected condition as a conjunct
- It is a disjunction of null-rejected conditions

A condition can be null-rejected for one outer join operation in a query and not null-rejected for another. In this query, the `WHERE` condition is null-rejected for the second outer join operation but is not null-rejected for the first one:

```
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
                 LEFT JOIN T3 ON T3.B=T1.B
  WHERE T3.C > 0
```

If the `WHERE` condition is null-rejected for an outer join operation in a query, the outer join operation is replaced by an inner join operation.

For example, in the preceding query, the second outer join is null-rejected and can be replaced by an inner join:

```
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
                 INNER JOIN T3 ON T3.B=T1.B
  WHERE T3.C > 0
```

For the original query, the optimizer evaluates only plans compatible with the single table-access order `T1,T2,T3`. For the rewritten query, it additionally considers the access order `T3,T1,T2`.

A conversion of one outer join operation may trigger a conversion of another. Thus, the query:

```
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
                 LEFT JOIN T3 ON T3.B=T2.B
  WHERE T3.C > 0
```

Is first converted to the query:

```
SELECT * FROM T1 LEFT JOIN T2 ON T2.A=T1.A
                 INNER JOIN T3 ON T3.B=T2.B
  WHERE T3.C > 0
```

Which is equivalent to the query:

```
SELECT * FROM (T1 LEFT JOIN T2 ON T2.A=T1.A), T3
  WHERE T3.C > 0 AND T3.B=T2.B
```

The remaining outer join operation can also be replaced by an inner join because the condition `T3.B=T2.B` is null-rejected. This results in a query with no outer joins at all:

```
SELECT * FROM (T1 INNER JOIN T2 ON T2.A=T1.A), T3
  WHERE T3.C > 0 AND T3.B=T2.B
```

Sometimes the optimizer succeeds in replacing an embedded outer join operation, but cannot convert the embedding outer join. The following query:

```
SELECT * FROM T1 LEFT JOIN
              (T2 LEFT JOIN T3 ON T3.B=T2.B)
              ON T2.A=T1.A
  WHERE T3.C > 0
```

Is converted to:

```
SELECT * FROM T1 LEFT JOIN
              (T2 INNER JOIN T3 ON T3.B=T2.B)
              ON T2.A=T1.A
  WHERE T3.C > 0
```

That can be rewritten only to the form still containing the embedding outer join operation:

```
SELECT * FROM T1 LEFT JOIN
             (T2,T3)
             ON (T2.A=T1.A AND T3.B=T2.B)
  WHERE T3.C > 0
```

Any attempt to convert an embedded outer join operation in a query must take into account the join condition for the embedding outer join together with the `WHERE` condition. In this query, the `WHERE` condition is not null-rejected for the embedded outer join, but the join condition of the embedding outer join `T2.A=T1.A AND T3.C=T1.C` is null-rejected:

```
SELECT * FROM T1 LEFT JOIN
             (T2 LEFT JOIN T3 ON T3.B=T2.B)
             ON T2.A=T1.A AND T3.C=T1.C
  WHERE T3.D > 0 OR T1.D > 0
```

Consequently, the query can be converted to:

```
SELECT * FROM T1 LEFT JOIN
             (T2, T3)
             ON T2.A=T1.A AND T3.C=T1.C AND T3.B=T2.B
  WHERE T3.D > 0 OR T1.D > 0
```

8.2.1.9 IS NULL Optimization

MySQL can perform the same optimization on *`col_name`* `IS NULL` that it can use for *`col_name`* = *`constant_value`*. For example, MySQL can use indexes and ranges to search for `NULL` with `IS NULL`.

Examples:

```
SELECT * FROM tbl_name WHERE key_col IS NULL;

SELECT * FROM tbl_name WHERE key_col <=> NULL;

SELECT * FROM tbl_name
  WHERE key_col=const1 OR key_col=const2 OR key_col IS NULL;
```

If a `WHERE` clause includes a *`col_name`* `IS NULL` condition for a column that is declared as `NOT NULL`, that expression is optimized away. This optimization does not occur in cases when the column might produce `NULL` anyway; for example, if it comes from a table on the right side of a `LEFT JOIN`.

MySQL can also optimize the combination *`col_name`* `= expr OR` *`col_name`* `IS NULL`, a form that is common in resolved subqueries. `EXPLAIN` shows `ref_or_null` when this optimization is used.

This optimization can handle one `IS NULL` for any key part.

Some examples of queries that are optimized, assuming that there is an index on columns `a` and `b` of table `t2`:

```
SELECT * FROM t1 WHERE t1.a=expr OR t1.a IS NULL;

SELECT * FROM t1, t2 WHERE t1.a=t2.a OR t2.a IS NULL;

SELECT * FROM t1, t2
  WHERE (t1.a=t2.a OR t2.a IS NULL) AND t2.b=t1.b;

SELECT * FROM t1, t2
  WHERE t1.a=t2.a AND (t2.b=t1.b OR t2.b IS NULL);

SELECT * FROM t1, t2
  WHERE (t1.a=t2.a AND t2.a IS NULL AND ...)
  OR (t1.a=t2.a AND t2.a IS NULL AND ...);
```

`ref_or_null` works by first doing a read on the reference key, and then a separate search for rows with a `NULL` key value.

The optimization can handle only one `IS NULL` level. In the following query, MySQL uses key lookups only on the expression `(t1.a=t2.a AND t2.a IS NULL)` and is not able to use the key part on `b`:

```
SELECT * FROM t1, t2
  WHERE (t1.a=t2.a AND t2.a IS NULL)
  OR (t1.b=t2.b AND t2.b IS NULL);
```

8.2.1.10 ORDER BY Optimization

This section describes when MySQL can use an index to satisfy an `ORDER BY` clause, the `filesort` algorithms used when an index cannot be used, and execution plan information available from the optimizer about `ORDER BY`.

- Use of Indexes to Satisfy ORDER BY
- Optimization Using filesort
- The Original filesort Algorithm
- The Modified filesort Algorithm
- Comparison of filesort Algorithms
- Influencing ORDER BY Optimization
- ORDER BY Execution Plan Information Available

Use of Indexes to Satisfy ORDER BY

In some cases, MySQL can use an index to satisfy an `ORDER BY` clause without doing extra sorting.

The index can also be used even if the `ORDER BY` does not match the index exactly, as long as all unused portions of the index and all extra `ORDER BY` columns are constants in the `WHERE` clause. The following queries use the index to resolve the `ORDER BY` part:

```
SELECT * FROM t1
  ORDER BY key_part1, key_part2;

SELECT * FROM t1
  WHERE key_part1 = constant
  ORDER BY key_part2;

SELECT * FROM t1
  ORDER BY key_part1 DESC, key_part2 DESC;

SELECT * FROM t1
  WHERE key_part1 = 1
  ORDER BY key_part1 DESC, key_part2 DESC;

SELECT * FROM t1
  WHERE key_part1 > constant
  ORDER BY key_part1 ASC;

SELECT * FROM t1
  WHERE key_part1 < constant
  ORDER BY key_part1 DESC;

SELECT * FROM t1
  WHERE key_part1 = constant1 AND key_part2 > constant2
  ORDER BY key_part2;
```

In some cases, MySQL *cannot* use indexes to resolve the `ORDER BY`, although it may still use indexes to find the rows that match the `WHERE` clause. Examples:

- The query uses `ORDER BY` on different indexes:

```
SELECT * FROM t1 ORDER BY key1, key2;
```

- The query uses `ORDER BY` on nonconsecutive parts of an index:

```
SELECT * FROM t1 WHERE key2=constant ORDER BY key_part1, key_part3;
```

- The query mixes `ASC` and `DESC`:

```
SELECT * FROM t1 ORDER BY key_part1 DESC, key_part2 ASC;
```

- The index used to fetch the rows differs from the one used in the `ORDER BY`:

```
SELECT * FROM t1 WHERE key2=constant ORDER BY key1;
```

- The query uses `ORDER BY` with an expression that includes terms other than the index column name:

```
SELECT * FROM t1 ORDER BY ABS(key);
SELECT * FROM t1 ORDER BY -key;
```

- The query joins many tables, and the columns in the `ORDER BY` are not all from the first nonconstant table that is used to retrieve rows. (This is the first table in the `EXPLAIN` output that does not have a `const` join type.)
- The query has different `ORDER BY` and `GROUP BY` expressions.
- There is an index on only a prefix of a column named in the `ORDER BY` clause. In this case, the index cannot be used to fully resolve the sort order. For example, if only the first 10 bytes of a `CHAR(20)` column are indexed, the index cannot distinguish values past the 10th byte and a `filesort` is needed.
- The index does not store rows in order. For example, this is true for a `HASH` index in a `MEMORY` table.

Availability of an index for sorting may be affected by the use of column aliases. Suppose that the column `t1.a` is indexed. In this statement, the name of the column in the select list is `a`. It refers to `t1.a`, as does the reference to `a` in the `ORDER BY`, so the index on `t1.a` can be used:

```
SELECT a FROM t1 ORDER BY a;
```

In this statement, the name of the column in the select list is also `a`, but it is the alias name. It refers to `ABS(a)`, as does the reference to `a` in the `ORDER BY`, so the index on `t1.a` cannot be used:

```
SELECT ABS(a) AS a FROM t1 ORDER BY a;
```

In the following statement, the `ORDER BY` refers to a name that is not the name of a column in the select list. But there is a column in `t1` named `a`, so the `ORDER BY` refers to `t1.a` and the index on `t1.a` can be used. (The resulting sort order may be completely different from the order for `ABS(a)`, of course.)

```
SELECT ABS(a) AS b FROM t1 ORDER BY a;
```

By default, MySQL sorts all `GROUP BY col1, col2, ...` queries as if you specified `ORDER BY col1, col2, ...` in the query as well. If you include an explicit `ORDER BY` clause that contains the same column list, MySQL optimizes it away without any speed penalty, although the sorting still occurs.

If a query includes `GROUP BY` but you want to avoid the overhead of sorting the result, you can suppress sorting by specifying `ORDER BY NULL`. For example:

```
INSERT INTO foo
SELECT a, COUNT(*) FROM bar GROUP BY a ORDER BY NULL;
```

The optimizer may still choose to use sorting to implement grouping operations. `ORDER BY NULL` suppresses sorting of the result, not prior sorting done by grouping operations to determine the result.

Note

`GROUP BY` implicitly sorts by default (that is, in the absence of `ASC` or `DESC` designators), but relying on implicit `GROUP BY` sorting is deprecated. To produce a given sort order, use explicit `ASC` or `DESC` designators for `GROUP BY` columns or provide an `ORDER BY` clause. `GROUP BY` sorting is a MySQL extension that may change in a future release; for example, to make it possible for the optimizer to order groupings in whatever manner it deems most efficient and to avoid the sorting overhead.

Optimization Using filesort

MySQL has multiple `filesort` algorithms for sorting and retrieving results. The original algorithm uses only the `ORDER BY` columns. The modified algorithm uses not just the `ORDER BY` columns, but all columns referenced by the query.

The optimizer selects which `filesort` algorithm to use. It normally uses the modified algorithm except when `BLOB` or `TEXT` columns are involved, in which case it uses the original algorithm. For each algorithm, the sort buffer size is the `sort_buffer_size` system variable value.

The Original filesort Algorithm

The original `filesort` algorithm works as follows:

1. Read all rows according to key or by table scanning. Skip rows that do not match the `WHERE` clause.
2. For each row, store in the sort buffer a tuple consisting of a pair of values (the sort key value and the row ID).
3. If all pairs fit into the sort buffer, no temporary file is created. Otherwise, when the sort buffer becomes full, run a quicksort on it in memory and write it to a temporary file. Save a pointer to the sorted block.
4. Repeat the preceding steps until all rows have been read.
5. Do a multi-merge of up to `MERGEBUFF` (7) regions to one block in another temporary file. Repeat until all blocks from the first file are in the second file.
6. Repeat the following until there are fewer than `MERGEBUFF2` (15) blocks left.
7. On the last multi-merge, only the row ID (the last part of the value pair) is written to a result file.
8. Read the rows in sorted order using the row IDs in the result file. To optimize this, read in a large block of row IDs, sort them, and use them to read the rows in sorted order into a row buffer. The row buffer size is the `read_rnd_buffer_size` system variable value. The code for this step is in the `sql/records.cc` source file.

One problem with this approach is that it reads rows twice: Once during `WHERE` clause evaluation, and again after sorting the value pairs. And even if the rows were accessed successively the first time (for example, if a table scan is done), the second time they are accessed randomly. (The sort keys are ordered, but the row positions are not.)

The Modified filesort Algorithm

The modified `filesort` algorithm incorporates an optimization to avoid reading the rows twice: It records the sort key value, but instead of the row ID, it records the columns referenced by the query. The modified `filesort` algorithm works like this:

1. Read the rows that match the `WHERE` clause.
2. For each row, store in the sort buffer a tuple consisting of the sort key value and the columns referenced by the query.
3. When the sort buffer becomes full, sort the tuples by sort key value in memory and write it to a temporary file.
4. After merge-sorting the temporary file, retrieve the rows in sorted order, but read the columns required by the query directly from the sorted tuples rather than by accessing the table a second time.

The tuples used by the modified `filesort` algorithm are longer than the pairs used by the original algorithm, and fewer of them fit in the sort buffer. As a result, it is possible for the extra I/O to make the modified approach slower, not faster. To avoid a slowdown, the optimizer uses the modified algorithm only if the total size of the extra columns in the sort tuple does not exceed the value of the `max_length_for_sort_data` system variable. (A symptom of setting the value of this variable too high is a combination of high disk activity and low CPU activity.)

Comparison of filesort Algorithms

Suppose that a table `t1` has four `VARCHAR` columns `a`, `b`, `c`, and `d` and that the optimizer uses `filesort` for this query:

```
SELECT * FROM t1 ORDER BY a, b;
```

The query sorts by `a` and `b`, but returns all columns, so the columns referenced by the query are `a`, `b`, `c`, and `d`. Depending on which `filesort` algorithm the optimizer chooses, the query executes as follows:

For the original algorithm, sort buffer tuples have these contents:

```
(fixed size a value, fixed size b value,
row ID into t1)
```

The optimizer sorts on the fixed size values. After sorting, the optimizer reads the tuples in order and uses the row ID in each tuple to read rows from `t1` to obtain the select list column values.

For the modified algorithm, sort buffer tuples have these contents:

```
(fixed size a value, fixed size b value,
a value, b value, c value, d value)
```

The optimizer sorts on the fixed size values. After sorting, the optimizer reads the tuples in order and uses the values for `a`, `b`, `c`, and `d` to obtain the select list column values without reading `t1` again.

Influencing ORDER BY Optimization

For slow `ORDER BY` queries for which `filesort` is not used, try lowering `max_length_for_sort_data` to a value that is appropriate to trigger a `filesort`.

To increase `ORDER BY` speed, check whether you can get MySQL to use indexes rather than an extra sorting phase. If this is not possible, you can try the following strategies:

- Increase the `sort_buffer_size` variable value. Ideally, the value should be large enough for the entire result set to fit in the sort buffer (to avoid writes to disk and merge passes), but at minimum the value must be large enough to accommodate fifteen tuples.

  Take into account that the size of column values stored in the sort buffer is affected by the `max_sort_length` system variable value. For example, if tuples store values of long string columns and you increase the value of `max_sort_length`, the size of sort buffer tuples increases as well and may require you to increase `sort_buffer_size`. For column values calculated as a result of string expressions (such as those that invoke a string-valued function), the `filesort` algorithm cannot tell the maximum length of expression values, so it must allocate `max_sort_length` bytes for each tuple.

  To monitor the number of merge passes, check the `Sort_merge_passes` status variable.

- Increase the `read_rnd_buffer_size` variable value.

- Use less RAM per row by declaring columns only as large as they need to be to hold the values stored in them. For example, `CHAR(16)` is better than `CHAR(200)` if values never exceed 16 characters.

- Change the `tmpdir` system variable to point to a dedicated file system with large amounts of free space. The variable value can list several paths that are used in round-robin fashion; you can use this feature to spread the load across several directories. Separate the paths by colon characters (`:`) on Unix and semicolon characters (`;`) on Windows. The paths should name directories in file systems located on different *physical* disks, not different partitions on the same disk.

ORDER BY Execution Plan Information Available

With `EXPLAIN SELECT ... ORDER BY`, you can check whether MySQL can use indexes to resolve the query. It cannot if you see `Using filesort` in the `Extra` column. See Section 8.8.1, “Optimizing Queries with EXPLAIN”. Filesort uses a fixed-length row-storage format similar to that used by the `MEMORY` storage engine. Variable-length types such as `VARCHAR` are stored using a fixed length.

If a `filesort` is done, `EXPLAIN` output includes `Using filesort` in the `Extra` column.

An `ORDER BY` with and without `LIMIT` may return rows in different orders, as discussed in Section 8.2.1.13, “LIMIT Query Optimization”.

8.2.1.11 GROUP BY Optimization

The most general way to satisfy a `GROUP BY` clause is to scan the whole table and create a new temporary table where all rows from each group are consecutive, and then use this temporary table to discover groups and apply aggregate functions (if any). In some cases, MySQL is able to do much better than that and to avoid creation of temporary tables by using index access.

The most important preconditions for using indexes for `GROUP BY` are that all `GROUP BY` columns reference attributes from the same index, and that the index stores its keys in order (for example, this is a `BTREE` index and not a `HASH` index). Whether use of temporary tables can be replaced by index access also depends on which parts of an index are used in a query, the conditions specified for these parts, and the selected aggregate functions.

There are two ways to execute a `GROUP BY` query through index access, as detailed in the following sections. In the first method, the grouping operation is applied together with all range predicates (if any). The second method first performs a range scan, and then groups the resulting tuples.

In MySQL, `GROUP BY` is used for sorting, so the server may also apply `ORDER BY` optimizations to grouping. However, relying on implicit `GROUP BY` sorting is deprecated. See Section 8.2.1.10, “ORDER BY Optimization”.

- Loose Index Scan

- Tight Index Scan

Loose Index Scan

The most efficient way to process `GROUP BY` is when an index is used to directly retrieve the grouping columns. With this access method, MySQL uses the property of some index types that the keys are ordered (for example, `BTREE`). This property enables use of lookup groups in an index without having to consider all keys in the index that satisfy all `WHERE` conditions. This access method considers only a fraction of the keys in an index, so it is called a *loose index scan*. When there is no `WHERE` clause, a loose index scan reads as many keys as the number of groups, which may be a much smaller number than that of all keys. If the `WHERE` clause contains range predicates (see the discussion of the `range` join type in Section 8.8.1, “Optimizing Queries with EXPLAIN”), a loose index scan looks up the first key of each group that satisfies the range conditions, and again reads the least possible number of keys. This is possible under the following conditions:

- The query is over a single table.
- The `GROUP BY` names only columns that form a leftmost prefix of the index and no other columns. (If, instead of `GROUP BY`, the query has a `DISTINCT` clause, all distinct attributes refer to columns that form a leftmost prefix of the index.) For example, if a table `t1` has an index on `(c1,c2,c3)`, loose index scan is applicable if the query has `GROUP BY c1, c2,`. It is not applicable if the query has `GROUP BY c2, c3` (the columns are not a leftmost prefix) or `GROUP BY c1, c2, c4` (`c4` is not in the index).
- The only aggregate functions used in the select list (if any) are `MIN()` and `MAX()`, and all of them refer to the same column. The column must be in the index and must immediately follow the columns in the `GROUP BY`.
- Any other parts of the index than those from the `GROUP BY` referenced in the query must be constants (that is, they must be referenced in equalities with constants), except for the argument of `MIN()` or `MAX()` functions.
- For columns in the index, full column values must be indexed, not just a prefix. For example, with `c1 VARCHAR(20), INDEX (c1(10))`, the index cannot be used for loose index scan.

If loose index scan is applicable to a query, the `EXPLAIN` output shows `Using index for group-by` in the `Extra` column.

Assume that there is an index `idx(c1,c2,c3)` on table `t1(c1,c2,c3,c4)`. The loose index scan access method can be used for the following queries:

```
SELECT c1, c2 FROM t1 GROUP BY c1, c2;
SELECT DISTINCT c1, c2 FROM t1;
SELECT c1, MIN(c2) FROM t1 GROUP BY c1;
SELECT c1, c2 FROM t1 WHERE c1 < const GROUP BY c1, c2;
SELECT MAX(c3), MIN(c3), c1, c2 FROM t1 WHERE c2 > const GROUP BY c1, c2;
SELECT c2 FROM t1 WHERE c1 < const GROUP BY c1, c2;
SELECT c1, c2 FROM t1 WHERE c3 = const GROUP BY c1, c2;
```

The following queries cannot be executed with this quick select method, for the reasons given:

- There are aggregate functions other than `MIN()` or `MAX()`:

  ```
  SELECT c1, SUM(c2) FROM t1 GROUP BY c1;
  ```

- The columns in the `GROUP BY` clause do not form a leftmost prefix of the index:

  ```
  SELECT c1, c2 FROM t1 GROUP BY c2, c3;
  ```

- The query refers to a part of a key that comes after the `GROUP BY` part, and for which there is no equality with a constant:

```
SELECT c1, c3 FROM t1 GROUP BY c1, c2;
```

Were the query to include `WHERE c3 = const`, loose index scan could be used.

The loose index scan access method can be applied to other forms of aggregate function references in the select list, in addition to the `MIN()` and `MAX()` references already supported:

- `AVG(DISTINCT)`, `SUM(DISTINCT)`, and `COUNT(DISTINCT)` are supported. `AVG(DISTINCT)` and `SUM(DISTINCT)` take a single argument. `COUNT(DISTINCT)` can have more than one column argument.
- There must be no `GROUP BY` or `DISTINCT` clause in the query.
- The loose scan limitations described earlier still apply.

Assume that there is an index `idx(c1,c2,c3)` on table `t1(c1,c2,c3,c4)`. The loose index scan access method can be used for the following queries:

```
SELECT COUNT(DISTINCT c1), SUM(DISTINCT c1) FROM t1;

SELECT COUNT(DISTINCT c1, c2), COUNT(DISTINCT c2, c1) FROM t1;
```

Tight Index Scan

A tight index scan may be either a full index scan or a range index scan, depending on the query conditions.

When the conditions for a loose index scan are not met, it still may be possible to avoid creation of temporary tables for `GROUP BY` queries. If there are range conditions in the `WHERE` clause, this method reads only the keys that satisfy these conditions. Otherwise, it performs an index scan. Because this method reads all keys in each range defined by the `WHERE` clause, or scans the whole index if there are no range conditions, we term it a *tight index scan*. With a tight index scan, the grouping operation is performed only after all keys that satisfy the range conditions have been found.

For this method to work, it is sufficient that there is a constant equality condition for all columns in a query referring to parts of the key coming before or in between parts of the `GROUP BY` key. The constants from the equality conditions fill in any “gaps” in the search keys so that it is possible to form complete prefixes of the index. These index prefixes then can be used for index lookups. If we require sorting of the `GROUP BY` result, and it is possible to form search keys that are prefixes of the index, MySQL also avoids extra sorting operations because searching with prefixes in an ordered index already retrieves all the keys in order.

Assume that there is an index `idx(c1,c2,c3)` on table `t1(c1,c2,c3,c4)`. The following queries do not work with the loose index scan access method described earlier, but still work with the tight index scan access method.

- There is a gap in the `GROUP BY`, but it is covered by the condition `c2 = 'a'`:

```
SELECT c1, c2, c3 FROM t1 WHERE c2 = 'a' GROUP BY c1, c3;
```

- The `GROUP BY` does not begin with the first part of the key, but there is a condition that provides a constant for that part:

```
SELECT c1, c2, c3 FROM t1 WHERE c1 = 'a' GROUP BY c2, c3;
```

8.2.1.12 DISTINCT Optimization

`DISTINCT` combined with `ORDER BY` needs a temporary table in many cases.

Because DISTINCT may use GROUP BY, learn how MySQL works with columns in ORDER BY or HAVING clauses that are not part of the selected columns. See Section 12.16.3, “MySQL Handling of GROUP BY”.

In most cases, a DISTINCT clause can be considered as a special case of GROUP BY. For example, the following two queries are equivalent:

```
SELECT DISTINCT c1, c2, c3 FROM t1
WHERE c1 > const;

SELECT c1, c2, c3 FROM t1
WHERE c1 > const GROUP BY c1, c2, c3;
```

Due to this equivalence, the optimizations applicable to GROUP BY queries can be also applied to queries with a DISTINCT clause. Thus, for more details on the optimization possibilities for DISTINCT queries, see Section 8.2.1.11, “GROUP BY Optimization”.

When combining LIMIT *row_count* with DISTINCT, MySQL stops as soon as it finds *row_count* unique rows.

If you do not use columns from all tables named in a query, MySQL stops scanning any unused tables as soon as it finds the first match. In the following case, assuming that t1 is used before t2 (which you can check with EXPLAIN), MySQL stops reading from t2 (for any particular row in t1) when it finds the first row in t2:

```
SELECT DISTINCT t1.a FROM t1, t2 where t1.a=t2.a;
```

8.2.1.13 LIMIT Query Optimization

If you need only a specified number of rows from a result set, use a LIMIT clause in the query, rather than fetching the whole result set and throwing away the extra data.

MySQL sometimes optimizes a query that has a LIMIT *row_count* clause and no HAVING clause:

- If you select only a few rows with LIMIT, MySQL uses indexes in some cases when normally it would prefer to do a full table scan.
- If you combine LIMIT *row_count* with ORDER BY, MySQL stops sorting as soon as it has found the first *row_count* rows of the sorted result, rather than sorting the entire result. If ordering is done by using an index, this is very fast. If a filesort must be done, all rows that match the query without the LIMIT clause are selected, and most or all of them are sorted, before the first *row_count* are found. After the initial rows have been found, MySQL does not sort any remainder of the result set.

  One manifestation of this behavior is that an ORDER BY query with and without LIMIT may return rows in different order, as described later in this section.
- If you combine LIMIT *row_count* with DISTINCT, MySQL stops as soon as it finds *row_count* unique rows.
- In some cases, a GROUP BY can be resolved by reading the index in order (or doing a sort on the index), then calculating summaries until the index value changes. In this case, LIMIT *row_count* does not calculate any unnecessary GROUP BY values.
- As soon as MySQL has sent the required number of rows to the client, it aborts the query unless you are using SQL_CALC_FOUND_ROWS. In that case, the number of rows can be retrieved with SELECT FOUND_ROWS(). See Section 12.14, “Information Functions”.
- LIMIT 0 quickly returns an empty set. This can be useful for checking the validity of a query. It can also be employed to obtain the types of the result columns within applications that use a MySQL API that makes result set metadata available. With the mysql client program, you can use the --column-type-info option to display result column types.

- If the server uses temporary tables to resolve a query, it uses the `LIMIT row_count` clause to calculate how much space is required.

If multiple rows have identical values in the `ORDER BY` columns, the server is free to return those rows in any order, and may do so differently depending on the overall execution plan. In other words, the sort order of those rows is nondeterministic with respect to the nonordered columns.

One factor that affects the execution plan is `LIMIT`, so an `ORDER BY` query with and without `LIMIT` may return rows in different orders. Consider this query, which is sorted by the `category` column but nondeterministic with respect to the `id` and `rating` columns:

```
mysql> SELECT * FROM ratings ORDER BY category;
+----+----------+--------+
| id | category | rating |
+----+----------+--------+
|  1 |        1 |    4.5 |
|  5 |        1 |    3.2 |
|  3 |        2 |    3.7 |
|  4 |        2 |    3.5 |
|  6 |        2 |    3.5 |
|  2 |        3 |    5.0 |
|  7 |        3 |    2.7 |
+----+----------+--------+
```

Including `LIMIT` may affect order of rows within each `category` value. For example, this is a valid query result:

```
mysql> SELECT * FROM ratings ORDER BY category LIMIT 5;
+----+----------+--------+
| id | category | rating |
+----+----------+--------+
|  1 |        1 |    4.5 |
|  5 |        1 |    3.2 |
|  4 |        2 |    3.5 |
|  3 |        2 |    3.7 |
|  6 |        2 |    3.5 |
+----+----------+--------+
```

In each case, the rows are sorted by the `ORDER BY` column, which is all that is required by the SQL standard.

If it is important to ensure the same row order with and without `LIMIT`, include additional columns in the `ORDER BY` clause to make the order deterministic. For example, if `id` values are unique, you can make rows for a given `category` value appear in `id` order by sorting like this:

```
mysql> SELECT * FROM ratings ORDER BY category, id;
+----+----------+--------+
| id | category | rating |
+----+----------+--------+
|  1 |        1 |    4.5 |
|  5 |        1 |    3.2 |
|  3 |        2 |    3.7 |
|  4 |        2 |    3.5 |
|  6 |        2 |    3.5 |
|  2 |        3 |    5.0 |
|  7 |        3 |    2.7 |
+----+----------+--------+

mysql> SELECT * FROM ratings ORDER BY category, id LIMIT 5;
+----+----------+--------+
| id | category | rating |
+----+----------+--------+
|  1 |        1 |    4.5 |
|  5 |        1 |    3.2 |
|  3 |        2 |    3.7 |
|  4 |        2 |    3.5 |
```

```
|  6 |        2 |    3.5 |
+----+----------+--------+
```

8.2.1.14 Function Call Optimization

MySQL functions are tagged internally as deterministic or nondeterministic. A function is nondeterministic if, given fixed values for its arguments, it can return different results for different invocations. Examples of nondeterministic functions: `RAND()`, `UUID()`.

If a function is tagged nondeterministic, a reference to it in a `WHERE` clause is evaluated for every row (when selecting from one table) or combination of rows (when selecting from a multiple-table join).

MySQL also determines when to evaluate functions based on types of arguments, whether the arguments are table columns or constant values. A deterministic function that takes a table column as argument must be evaluated whenever that column changes value.

Nondeterministic functions may affect query performance. For example, some optimizations may not be available, or more locking might be required. The following discussion uses `RAND()` but applies to other nondeterministic functions as well.

Suppose that a table `t` has this definition:

```
CREATE TABLE t (id INT NOT NULL PRIMARY KEY, col_a VARCHAR(100));
```

Consider these two queries:

```
SELECT * FROM t WHERE id = POW(1,2);
SELECT * FROM t WHERE id = FLOOR(1 + RAND() * 49);
```

Both queries appear to use a primary key lookup because of the equality comparison against the primary key, but that is true only for the first of them:

- The first query always produces a maximum of one row because `POW()` with constant arguments is a constant value and is used for index lookup.
- The second query contains an expression that uses the nondeterministic function `RAND()`, which is not constant in the query but in fact has a new value for every row of table `t`. Consequently, the query reads every row of the table, evaluates the predicate for each row, and outputs all rows for which the primary key matches the random value. This might be zero, one, or multiple rows, depending on the `id` column values and the values in the `RAND()` sequence.

The effects of nondeterminism are not limited to `SELECT` statements. This `UPDATE` statement uses a nondeterministic function to select rows to be modified:

```
UPDATE t SET col_a = some_expr WHERE id = FLOOR(1 + RAND() * 49);
```

Presumably the intent is to update at most a single row for which the primary key matches the expression. However, it might update zero, one, or multiple rows, depending on the `id` column values and the values in the `RAND()` sequence.

The behavior just described has implications for performance and replication:

- Because a nondeterministic function does not produce a constant value, the optimizer cannot use strategies that might otherwise be applicable, such as index lookups. The result may be a table scan.
- `InnoDB` might escalate to a range-key lock rather than taking a single row lock for one matching row.
- Updates that do not execute deterministically are unsafe for replication.

The difficulties stem from the fact that the `RAND()` function is evaluated once for every row of the table. To avoid multiple function evaluations, use one of these techniques:

- Move the expression containing the nondeterministic function to a separate statement, saving the value in a variable. In the original statement, replace the expression with a reference to the variable, which the optimizer can treat as a constant value:

```
SET @keyval = FLOOR(1 + RAND() * 49);
UPDATE t SET col_a = some_expr WHERE id = @keyval;
```

- Assign the random value to a variable in a derived table. This technique causes the variable to be assigned a value, once, prior to its use in the comparison in the `WHERE` clause:

```
UPDATE t, (SELECT @keyval := FLOOR(1 + RAND() * 49)) AS dt
SET col_a = some_expr WHERE id = @keyval;
```

As mentioned previously, a nondeterministic expression in the `WHERE` clause might prevent optimizations and result in a table scan. However, it may be possible to partially optimize the `WHERE` clause if other expressions are deterministic. For example:

```
SELECT * FROM t WHERE partial_key=5 AND some_column=RAND();
```

If the optimizer can use `partial_key` to reduce the set of rows selected, `RAND()` is executed fewer times, which diminishes the effect of nondeterminism on optimization.

8.2.1.15 Row Constructor Expression Optimization

Row constructors permit simultaneous comparisons of multiple values. For example, these two statements are semantically equivalent:

```
SELECT * FROM t1 WHERE (column1,column2) = (1,1);
SELECT * FROM t1 WHERE column1 = 1 AND column2 = 1;
```

In addition, the optimizer handles both expressions the same way.

The optimizer is less likely to use available indexes if the row constructor columns do not cover the prefix of an index. Consider the following table, which has a primary key on `(c1, c2, c3)`:

```
CREATE TABLE t1 (
  c1 INT, c2 INT, c3 INT, c4 CHAR(100),
  PRIMARY KEY(c1,c2,c3)
);
```

In this query, the `WHERE` clause uses all columns in the index. However, the row constructor itself does not cover an index prefix, with the result that the optimizer uses only `c1` (`key_len=4`, the size of `c1`):

```
mysql> EXPLAIN SELECT * FROM t1
       WHERE c1=1 AND (c2,c3) > (1,1)\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: t1
   partitions: NULL
         type: ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 4
          ref: const
         rows: 3
        Extra: Using where
```

In such cases, rewriting the row constructor expression using an equivalent nonconstructor expression may result in more complete index use. For the given query, the row constructor and equivalent nonconstructor expressions are:

```
(c2,c3) > (1,1)
c2 > 1 OR ((c2 = 1) AND (c3 > 1))
```

Rewriting the query to use the nonconstructor expression results in the optimizer using all three columns in the index (`key_len=12`):

```
mysql> EXPLAIN SELECT * FROM t1
       WHERE c1 = 1 AND (c2 > 1 OR ((c2 = 1) AND (c3 > 1)))\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: t1
   partitions: NULL
         type: range
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 12
          ref: NULL
         rows: 3
        Extra: Using where
```

Thus, for better results, avoid mixing row constructors with `AND`/`OR` expressions. Use one or the other.

8.2.1.16 Avoiding Full Table Scans

Frequently, a full table scan is a danger sign that a query can be speeded up significantly. For tables with more than a few rows, consider redesigning the query by adding an index for one or more of the columns tested in the `WHERE` clause. Put extra effort into avoiding table scans for queries that perform joins or reference foreign keys. If the nature of the data means there is no way to avoid reading all the rows, then it might not be practical to make the query faster, or making it faster might involve extensive restructuring of your tables that is beyond the scope of this section.

The output from `EXPLAIN` shows `ALL` in the `type` column when MySQL uses a table scan to resolve a query. This usually happens under the following conditions:

- The `ON` or `WHERE` clauses do not reference any indexed columns that the query can use. Consider adding an index, or refining those clauses to refer to an indexed column.
- The table is so small that it is faster to perform a table scan than to bother with a key lookup. This is common for tables with fewer than 10 rows and a short row length. Don't worry in this case.
- You are comparing indexed columns with constant values and MySQL has calculated (based on the index tree) that the constants cover too large a part of the table and that a table scan would be faster. See Section 8.2.1.1, “WHERE Clause Optimization”. For example, to query census data only for males or only for females, MySQL must read most of the data blocks in the table, so locating the rows through the index would add unnecessary overhead. Don't worry if you encounter this condition for occasional big reports. If these reports are frequent or truly time-critical, and the table is huge, you might partition, shard, or create dimension tables using the relevant column.
- You are using a key with low cardinality (many rows match the key value) through another column. In this case, MySQL assumes that by using the key it probably will do many key lookups and that a table scan would be faster.

For small tables, a table scan often is appropriate and the performance impact is negligible. For large tables, try the following techniques to avoid having the optimizer incorrectly choose a table scan:

- Minimize the `OR` keywords in your `WHERE` clauses. If there is no index that helps to locate the values on *both* sides of the `OR`, any row could potentially be part of the result set, so all rows must be tested, and that requires a full table scan. If you have one index that helps to optimize one side of an `OR` query, and a different index that helps to optimize the other side, use a `UNION` operator to run separate fast queries and merge the results afterward.

- With tables that use the `MEMORY` storage engine, if you run queries that examine ranges of values (using operators such as `>`, `<=`, or `BETWEEN` on the indexed columns), create the index with the `USING BTREE` clause. The default (`USING HASH`) is fast for retrieving individual rows with an equality operator (`=` or `<=>`), but is much slower (requiring a full table scan) to examine a range of column values. A `MEMORY` table created with the `USING BTREE` clause is still fast for equality comparisons, so use that clause for your `MEMORY` tables that handle a variety of queries.

- Use `ANALYZE TABLE tbl_name` to update the key distributions for the scanned table. See Section 13.7.2.1, “ANALYZE TABLE Syntax”.

- Use `FORCE INDEX` for the scanned table to tell MySQL that table scans are very expensive compared to using the given index:

```
SELECT * FROM t1, t2 FORCE INDEX (index_for_column)
  WHERE t1.col_name=t2.col_name;
```

  See Section 8.9.3, “Index Hints”.

- Start `mysqld` with the `--max-seeks-for-key=1000` option or use `SET max_seeks_for_key=1000` to tell the optimizer to assume that no key scan causes more than 1,000 key seeks. See Section 5.1.5, “Server System Variables”.

8.2.2 Subquery Optimization

Certain optimizations are applicable to comparisons that use the `IN` operator to test subquery results (or that use `=ANY`, which is equivalent). This section discusses these optimizations, particularly with regard to the challenges that `NULL` values present. The last part of the discussion suggests how you can help the optimizer.

Consider the following subquery comparison:

```
outer_expr IN (SELECT inner_expr FROM ... WHERE subquery_where)
```

MySQL evaluates queries “from outside to inside.” That is, it first obtains the value of the outer expression *`outer_expr`*, and then runs the subquery and captures the rows that it produces.

A very useful optimization is to “inform” the subquery that the only rows of interest are those where the inner expression *`inner_expr`* is equal to *`outer_expr`*. This is done by pushing down an appropriate equality into the subquery's `WHERE` clause to make it more restrictive. The converted comparison looks like this:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where AND outer_expr=inner_expr)
```

After the conversion, MySQL can use the pushed-down equality to limit the number of rows it must examine to evaluate the subquery.

More generally, a comparison of *`N`* values to a subquery that returns *`N`*-value rows is subject to the same conversion. If *`oe_i`* and *`ie_i`* represent corresponding outer and inner expression values, this subquery comparison:

```
(oe_1, ..., oe_N) IN
  (SELECT ie_1, ..., ie_N FROM ... WHERE subquery_where)
```

Becomes:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where
                          AND oe_1 = ie_1
                          AND ...
                          AND oe_N = ie_N)
```

For simplicity, the following discussion assumes a single pair of outer and inner expression values.

The conversion just described has its limitations. It is valid only if we ignore possible `NULL` values. That is, the “pushdown” strategy works as long as both of these conditions are true:

- *`outer_expr`* and *`inner_expr`* cannot be `NULL`.
- You need not distinguish `NULL` from `FALSE` subquery results. If the subquery is a part of an `OR` or `AND` expression in the `WHERE` clause, MySQL assumes that you do not care.

When either or both of those conditions do not hold, optimization is more complex.

Suppose that *`outer_expr`* is known to be a non-`NULL` value but the subquery does not produce a row such that *`outer_expr`* = *`inner_expr`*. Then *`outer_expr`* `IN (SELECT ...)` evaluates as follows:

- `NULL`, if the `SELECT` produces any row where *`inner_expr`* is `NULL`
- `FALSE`, if the `SELECT` produces only non-`NULL` values or produces nothing

In this situation, the approach of looking for rows with *`outer_expr = inner_expr`* is no longer valid. It is necessary to look for such rows, but if none are found, also look for rows where *`inner_expr`* is `NULL`. Roughly speaking, the subquery can be converted to something like this:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where AND
        (outer_expr=inner_expr OR inner_expr IS NULL))
```

The need to evaluate the extra `IS NULL` condition is why MySQL has the `ref_or_null` access method:

```
mysql> EXPLAIN
       SELECT outer_expr IN (SELECT t2.maybe_null_key
                             FROM t2, t3 WHERE ...)
       FROM t1;
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: t1
...
*************************** 2. row ***************************
           id: 2
  select_type: DEPENDENT SUBQUERY
        table: t2
         type: ref_or_null
possible_keys: maybe_null_key
          key: maybe_null_key
      key_len: 5
          ref: func
         rows: 2
        Extra: Using where; Using index
...
```

The `unique_subquery` and `index_subquery` subquery-specific access methods also have “or `NULL`” variants. However, they are not visible in `EXPLAIN` output, so you must use `EXPLAIN EXTENDED` followed by `SHOW WARNINGS` (note the `checking NULL` in the warning message):

```
mysql> EXPLAIN EXTENDED
       SELECT outer_expr IN (SELECT maybe_null_key FROM t2) FROM t1\G
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: t1
...
*************************** 2. row ***************************
           id: 2
  select_type: DEPENDENT SUBQUERY
```

```
        table: t2
         type: index_subquery
possible_keys: maybe_null_key
          key: maybe_null_key
      key_len: 5
          ref: func
         rows: 2
        Extra: Using index

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Note
   Code: 1003
Message: select (`test`.`t1`.`outer_expr`,
         ((`test`.`t1`.`outer_expr`) in t2 on
         maybe_null_key checking NULL))) AS `outer_expr IN (SELECT
         maybe_null_key FROM t2)` from `test`.`t1`
```

The additional `OR ... IS NULL` condition makes query execution slightly more complicated (and some optimizations within the subquery become inapplicable), but generally this is tolerable.

The situation is much worse when *`outer_expr`* can be `NULL`. According to the SQL interpretation of `NULL` as “unknown value,” `NULL IN (SELECT inner_expr ...)` should evaluate to:

- `NULL`, if the `SELECT` produces any rows
- `FALSE`, if the `SELECT` produces no rows

For proper evaluation, it is necessary to be able to check whether the `SELECT` has produced any rows at all, so *`outer_expr = inner_expr`* cannot be pushed down into the subquery. This is a problem because many real world subqueries become very slow unless the equality can be pushed down.

Essentially, there must be different ways to execute the subquery depending on the value of *`outer_expr`*.

The optimizer chooses SQL compliance over speed, so it accounts for the possibility that *`outer_expr`* might be `NULL`:

- If *`outer_expr`* is `NULL`, to evaluate the following expression, it is necessary to execute the `SELECT` to determine whether it produces any rows:

  ```
  NULL IN (SELECT inner_expr FROM ... WHERE subquery_where)
  ```

  It is necessary to execute the original `SELECT` here, without any pushed-down equalities of the kind mentioned earlier.

- On the other hand, when *`outer_expr`* is not `NULL`, it is absolutely essential that this comparison:

  ```
  outer_expr IN (SELECT inner_expr FROM ... WHERE subquery_where)
  ```

  be converted to this expression that uses a pushed-down condition:

  ```
  EXISTS (SELECT 1 FROM ... WHERE subquery_where AND outer_expr=inner_expr)
  ```

  Without this conversion, subqueries will be slow.

To solve the dilemma of whether or not to push down conditions into the subquery, the conditions are wrapped within “trigger” functions. Thus, an expression of the following form:

```
outer_expr IN (SELECT inner_expr FROM ... WHERE subquery_where)
```

is converted into:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where
                          AND trigcond(outer_expr=inner_expr))
```

More generally, if the subquery comparison is based on several pairs of outer and inner expressions, the conversion takes this comparison:

```
(oe_1, ..., oe_N) IN (SELECT ie_1, ..., ie_N FROM ... WHERE subquery_where)
```

and converts it to this expression:

```
EXISTS (SELECT 1 FROM ... WHERE subquery_where
                          AND trigcond(oe_1=ie_1)
                          AND ...
                          AND trigcond(oe_N=ie_N)
       )
```

Each `trigcond(X)` is a special function that evaluates to the following values:

- *X* when the “linked” outer expression *oe_i* is not `NULL`
- `TRUE` when the “linked” outer expression *oe_i* is `NULL`

Note

Trigger functions are *not* triggers of the kind that you create with `CREATE TRIGGER`.

Equalities that are wrapped within `trigcond()` functions are not first class predicates for the query optimizer. Most optimizations cannot deal with predicates that may be turned on and off at query execution time, so they assume any `trigcond(X)` to be an unknown function and ignore it. Triggered equalities can be used by those optimizations:

- Reference optimizations: `trigcond(X=Y [OR Y IS NULL])` can be used to construct `ref`, `eq_ref`, or `ref_or_null` table accesses.
- Index lookup-based subquery execution engines: `trigcond(X=Y)` can be used to construct `unique_subquery` or `index_subquery` accesses.
- Table-condition generator: If the subquery is a join of several tables, the triggered condition is checked as soon as possible.

When the optimizer uses a triggered condition to create some kind of index lookup-based access (as for the first two items of the preceding list), it must have a fallback strategy for the case when the condition is turned off. This fallback strategy is always the same: Do a full table scan. In `EXPLAIN` output, the fallback shows up as `Full scan on NULL key` in the `Extra` column:

```
mysql> EXPLAIN SELECT t1.col1,
       t1.col1 IN (SELECT t2.key1 FROM t2 WHERE t2.col2=t1.col2) FROM t1\G
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: t1
        ...
*************************** 2. row ***************************
           id: 2
  select_type: DEPENDENT SUBQUERY
        table: t2
         type: index_subquery
possible_keys: key1
          key: key1
      key_len: 5
          ref: func
         rows: 2
```

```
        Extra: Using where; Full scan on NULL key
```

If you run `EXPLAIN EXTENDED` followed by `SHOW WARNINGS`, you can see the triggered condition:

```
*************************** 1. row ***************************
  Level: Note
   Code: 1003
Message: select `test`.`t1`.`col1` AS `col1`,
         <in_optimizer>(`test`.`t1`.`col1`,
         <exists>(<index_lookup>(<cache>(`test`.`t1`.`col1`) in t2
         on key1 checking NULL
         where (`test`.`t2`.`col2` = `test`.`t1`.`col2`) having
         trigcond(<is_not_null_test>(`test`.`t2`.`key1`))))) AS
         `t1.col1 IN (select t2.key1 from t2 where t2.col2=t1.col2)`
         from `test`.`t1`
```

The use of triggered conditions has some performance implications. A `NULL IN (SELECT ...)` expression now may cause a full table scan (which is slow) when it previously did not. This is the price paid for correct results (the goal of the trigger-condition strategy is to improve compliance, not speed).

For multiple-table subqueries, execution of `NULL IN (SELECT ...)` is particularly slow because the join optimizer does not optimize for the case where the outer expression is `NULL`. It assumes that subquery evaluations with `NULL` on the left side are very rare, even if there are statistics that indicate otherwise. On the other hand, if the outer expression might be `NULL` but never actually is, there is no performance penalty.

To help the query optimizer better execute your queries, use these suggestions:

- Declare a column as `NOT NULL` if it really is. This also helps other aspects of the optimizer by simplifying condition testing for the column.
- If you need not distinguish a `NULL` from `FALSE` subquery result, you can easily avoid the slow execution path. Replace a comparison that looks like this:

  ```
  outer_expr IN (SELECT inner_expr FROM ...)
  ```

  with this expression:

  ```
  (outer_expr IS NOT NULL) AND (outer_expr IN (SELECT inner_expr FROM ...))
  ```

  Then `NULL IN (SELECT ...)` is never evaluated because MySQL stops evaluating `AND` parts as soon as the expression result is clear.

8.2.3 Optimizing INFORMATION_SCHEMA Queries

Applications that monitor databases may make frequent use of `INFORMATION_SCHEMA` tables. Certain types of queries for `INFORMATION_SCHEMA` tables can be optimized to execute more quickly. The goal is to minimize file operations (for example, scanning a directory or opening a table file) to collect the information that makes up these dynamic tables.

Note

Comparison behavior for database and table names in `INFORMATION_SCHEMA` queries might differ from what you expect. For details, see Section 10.1.8.7, “Using Collation in INFORMATION_SCHEMA Searches”.

1) Try to use constant lookup values for database and table names in the `WHERE` clause

You can take advantage of this principle as follows:

- To look up databases or tables, use expressions that evaluate to a constant, such as literal values, functions that return a constant, or scalar subqueries.

- Avoid queries that use a nonconstant database name lookup value (or no lookup value) because they require a scan of the data directory to find matching database directory names.
- Within a database, avoid queries that use a nonconstant table name lookup value (or no lookup value) because they require a scan of the database directory to find matching table files.

This principle applies to the `INFORMATION_SCHEMA` tables shown in the following table, which shows the columns for which a constant lookup value enables the server to avoid a directory scan. For example, if you are selecting from `TABLES`, using a constant lookup value for `TABLE_SCHEMA` in the `WHERE` clause enables a data directory scan to be avoided.

Table	Column to specify to avoid data directory scan	Column to specify to avoid database directory scan
`COLUMNS`	`TABLE_SCHEMA`	`TABLE_NAME`
`KEY_COLUMN_USAGE`	`TABLE_SCHEMA`	`TABLE_NAME`
`PARTITIONS`	`TABLE_SCHEMA`	`TABLE_NAME`
`REFERENTIAL_CONSTRAINTS`	`CONSTRAINT_SCHEMA`	`TABLE_NAME`
`STATISTICS`	`TABLE_SCHEMA`	`TABLE_NAME`
`TABLES`	`TABLE_SCHEMA`	`TABLE_NAME`
`TABLE_CONSTRAINTS`	`TABLE_SCHEMA`	`TABLE_NAME`
`TRIGGERS`	`EVENT_OBJECT_SCHEMA`	`EVENT_OBJECT_TABLE`
`VIEWS`	`TABLE_SCHEMA`	`TABLE_NAME`

The benefit of a query that is limited to a specific constant database name is that checks need be made only for the named database directory. Example:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test';
```

Use of the literal database name `test` enables the server to check only the `test` database directory, regardless of how many databases there might be. By contrast, the following query is less efficient because it requires a scan of the data directory to determine which database names match the pattern `'test%'`:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA LIKE 'test%';
```

For a query that is limited to a specific constant table name, checks need be made only for the named table within the corresponding database directory. Example:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME = 't1';
```

Use of the literal table name `t1` enables the server to check only the files for the `t1` table, regardless of how many tables there might be in the `test` database. By contrast, the following query requires a scan of the `test` database directory to determine which table names match the pattern `'t%'`:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME LIKE 't%';
```

The following query requires a scan of the database directory to determine matching database names for the pattern `'test%'`, and for each matching database, it requires a scan of the database directory to determine matching table names for the pattern `'t%'`:

```
SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test%' AND TABLE_NAME LIKE 't%';
```

2) Write queries that minimize the number of table files that must be opened

For queries that refer to certain INFORMATION_SCHEMA table columns, several optimizations are available that minimize the number of table files that must be opened. Example:

```
SELECT TABLE_NAME, ENGINE FROM INFORMATION_SCHEMA.TABLES
WHERE TABLE_SCHEMA = 'test';
```

In this case, after the server has scanned the database directory to determine the names of the tables in the database, those names become available with no further file system lookups. Thus, TABLE_NAME requires no files to be opened. The ENGINE (storage engine) value can be determined by opening the table's .frm file, without touching other table files such as the .MYD or .MYI file.

Some values, such as INDEX_LENGTH for MyISAM tables, require opening the .MYD or .MYI file as well.

The file-opening optimization types are denoted thus:

- SKIP_OPEN_TABLE: Table files do not need to be opened. The information has already become available within the query by scanning the database directory.
- OPEN_FRM_ONLY: Only the table's .frm file need be opened.
- OPEN_TRIGGER_ONLY: Only the table's .TRG file need be opened.
- OPEN_FULL_TABLE: The unoptimized information lookup. The .frm, .MYD, and .MYI files must be opened.

The following list indicates how the preceding optimization types apply to INFORMATION_SCHEMA table columns. For tables and columns not named, none of the optimizations apply.

- COLUMNS: OPEN_FRM_ONLY applies to all columns
- KEY_COLUMN_USAGE: OPEN_FULL_TABLE applies to all columns
- PARTITIONS: OPEN_FULL_TABLE applies to all columns
- REFERENTIAL_CONSTRAINTS: OPEN_FULL_TABLE applies to all columns
- STATISTICS:

Column	Optimization type
TABLE_CATALOG	OPEN_FRM_ONLY
TABLE_SCHEMA	OPEN_FRM_ONLY
TABLE_NAME	OPEN_FRM_ONLY
NON_UNIQUE	OPEN_FRM_ONLY
INDEX_SCHEMA	OPEN_FRM_ONLY
INDEX_NAME	OPEN_FRM_ONLY
SEQ_IN_INDEX	OPEN_FRM_ONLY
COLUMN_NAME	OPEN_FRM_ONLY
COLLATION	OPEN_FRM_ONLY
CARDINALITY	OPEN_FULL_TABLE
SUB_PART	OPEN_FRM_ONLY
PACKED	OPEN_FRM_ONLY
NULLABLE	OPEN_FRM_ONLY
INDEX_TYPE	OPEN_FULL_TABLE
COMMENT	OPEN_FRM_ONLY

- TABLES:

Column	Optimization type
TABLE_CATALOG	SKIP_OPEN_TABLE
TABLE_SCHEMA	SKIP_OPEN_TABLE
TABLE_NAME	SKIP_OPEN_TABLE
TABLE_TYPE	OPEN_FRM_ONLY
ENGINE	OPEN_FRM_ONLY
VERSION	OPEN_FRM_ONLY
ROW_FORMAT	OPEN_FULL_TABLE
TABLE_ROWS	OPEN_FULL_TABLE
AVG_ROW_LENGTH	OPEN_FULL_TABLE
DATA_LENGTH	OPEN_FULL_TABLE
MAX_DATA_LENGTH	OPEN_FULL_TABLE
INDEX_LENGTH	OPEN_FULL_TABLE
DATA_FREE	OPEN_FULL_TABLE
AUTO_INCREMENT	OPEN_FULL_TABLE
CREATE_TIME	OPEN_FULL_TABLE
UPDATE_TIME	OPEN_FULL_TABLE
CHECK_TIME	OPEN_FULL_TABLE
TABLE_COLLATION	OPEN_FRM_ONLY
CHECKSUM	OPEN_FULL_TABLE
CREATE_OPTIONS	OPEN_FRM_ONLY
TABLE_COMMENT	OPEN_FRM_ONLY

- TABLE_CONSTRAINTS: OPEN_FULL_TABLE applies to all columns
- TRIGGERS: OPEN_TRIGGER_ONLY applies to all columns
- VIEWS:

Column	Optimization type
TABLE_CATALOG	OPEN_FRM_ONLY
TABLE_SCHEMA	OPEN_FRM_ONLY
TABLE_NAME	OPEN_FRM_ONLY
VIEW_DEFINITION	OPEN_FRM_ONLY
CHECK_OPTION	OPEN_FRM_ONLY
IS_UPDATABLE	OPEN_FULL_TABLE
DEFINER	OPEN_FRM_ONLY
SECURITY_TYPE	OPEN_FRM_ONLY
CHARACTER_SET_CLIENT	OPEN_FRM_ONLY
COLLATION_CONNECTION	OPEN_FRM_ONLY

3) Use EXPLAIN to determine whether the server can use INFORMATION_SCHEMA optimizations for a query

This applies particularly for INFORMATION_SCHEMA queries that search for information from more than one database, which might take a long time and impact performance. The Extra value in EXPLAIN

output indicates which, if any, of the optimizations described earlier the server can use to evaluate `INFORMATION_SCHEMA` queries. The following examples demonstrate the kinds of information you can expect to see in the `Extra` value.

```
mysql> EXPLAIN SELECT TABLE_NAME FROM INFORMATION_SCHEMA.VIEWS WHERE
       TABLE_SCHEMA = 'test' AND TABLE_NAME = 'v1'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: VIEWS
         type: ALL
possible_keys: NULL
          key: TABLE_SCHEMA,TABLE_NAME
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Using where; Open_frm_only; Scanned 0 databases
```

Use of constant database and table lookup values enables the server to avoid directory scans. For references to `VIEWS.TABLE_NAME`, only the `.frm` file need be opened.

```
mysql> EXPLAIN SELECT TABLE_NAME, ROW_FORMAT FROM INFORMATION_SCHEMA.TABLES\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: TABLES
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Open_full_table; Scanned all databases
```

No lookup values are provided (there is no `WHERE` clause), so the server must scan the data directory and each database directory. For each table thus identified, the table name and row format are selected. `TABLE_NAME` requires no further table files to be opened (the `SKIP_OPEN_TABLE` optimization applies). `ROW_FORMAT` requires all table files to be opened (`OPEN_FULL_TABLE` applies). `EXPLAIN` reports `OPEN_FULL_TABLE` because it is more expensive than `SKIP_OPEN_TABLE`.

```
mysql> EXPLAIN SELECT TABLE_NAME, TABLE_TYPE FROM INFORMATION_SCHEMA.TABLES
       WHERE TABLE_SCHEMA = 'test'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: TABLES
         type: ALL
possible_keys: NULL
          key: TABLE_SCHEMA
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Using where; Open_frm_only; Scanned 1 database
```

No table name lookup value is provided, so the server must scan the `test` database directory. For the `TABLE_NAME` and `TABLE_TYPE` columns, the `SKIP_OPEN_TABLE` and `OPEN_FRM_ONLY` optimizations apply, respectively. `EXPLAIN` reports `OPEN_FRM_ONLY` because it is more expensive.

```
mysql> EXPLAIN SELECT B.TABLE_NAME
       FROM INFORMATION_SCHEMA.TABLES AS A, INFORMATION_SCHEMA.COLUMNS AS B
       WHERE A.TABLE_SCHEMA = 'test'
       AND A.TABLE_NAME = 't1'
       AND B.TABLE_NAME = A.TABLE_NAME\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: A
         type: ALL
possible_keys: NULL
          key: TABLE_SCHEMA,TABLE_NAME
```

```
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Using where; Skip_open_table; Scanned 0 databases
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: B
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra: Using where; Open_frm_only; Scanned all databases;
               Using join buffer
```

For the first `EXPLAIN` output row: Constant database and table lookup values enable the server to avoid directory scans for `TABLES` values. References to `TABLES.TABLE_NAME` require no further table files.

For the second `EXPLAIN` output row: All `COLUMNS` table values are `OPEN_FRM_ONLY` lookups, so `COLUMNS.TABLE_NAME` requires the `.frm` file to be opened.

```
mysql> EXPLAIN SELECT * FROM INFORMATION_SCHEMA.COLLATIONS\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: COLLATIONS
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: NULL
        Extra:
```

In this case, no optimizations apply because `COLLATIONS` is not one of the `INFORMATION_SCHEMA` tables for which optimizations are available.

8.2.4 Optimizing Data Change Statements

This section explains how to speed up data change statements: `INSERT`, `UPDATE`, and `DELETE`. Traditional OLTP applications and modern web applications typically do many small data change operations, where concurrency is vital. Data analysis and reporting applications typically run data change operations that affect many rows at once, where the main considerations is the I/O to write large amounts of data and keep indexes up-to-date. For inserting and updating large volumes of data (known in the industry as ETL, for “extract-transform-load”), sometimes you use other SQL statements or external commands, that mimic the effects of `INSERT`, `UPDATE`, and `DELETE` statements.

8.2.4.1 Optimizing INSERT Statements

To optimize insert speed, combine many small operations into a single large operation. Ideally, you make a single connection, send the data for many new rows at once, and delay all index updates and consistency checking until the very end.

The time required for inserting a row is determined by the following factors, where the numbers indicate approximate proportions:

- Connecting: (3)
- Sending query to server: (2)
- Parsing query: (2)
- Inserting row: (1 × size of row)

- Inserting indexes: (1 × number of indexes)
- Closing: (1)

This does not take into consideration the initial overhead to open tables, which is done once for each concurrently running query.

The size of the table slows down the insertion of indexes by log *N*, assuming B-tree indexes.

You can use the following methods to speed up inserts:

- If you are inserting many rows from the same client at the same time, use `INSERT` statements with multiple `VALUES` lists to insert several rows at a time. This is considerably faster (many times faster in some cases) than using separate single-row `INSERT` statements. If you are adding data to a nonempty table, you can tune the `bulk_insert_buffer_size` variable to make data insertion even faster. See Section 5.1.5, “Server System Variables”.
- When loading a table from a text file, use `LOAD DATA INFILE`. This is usually 20 times faster than using `INSERT` statements. See Section 13.2.6, “LOAD DATA INFILE Syntax”.
- Take advantage of the fact that columns have default values. Insert values explicitly only when the value to be inserted differs from the default. This reduces the parsing that MySQL must do and improves the insert speed.
- See Section 8.5.4, “Bulk Data Loading for InnoDB Tables” for tips specific to `InnoDB` tables.
- See Section 8.6.2, “Bulk Data Loading for MyISAM Tables” for tips specific to `MyISAM` tables.

8.2.4.2 Optimizing UPDATE Statements

An update statement is optimized like a `SELECT` query with the additional overhead of a write. The speed of the write depends on the amount of data being updated and the number of indexes that are updated. Indexes that are not changed do not get updated.

Another way to get fast updates is to delay updates and then do many updates in a row later. Performing multiple updates together is much quicker than doing one at a time if you lock the table.

For a `MyISAM` table that uses dynamic row format, updating a row to a longer total length may split the row. If you do this often, it is very important to use `OPTIMIZE TABLE` occasionally. See Section 13.7.2.4, “OPTIMIZE TABLE Syntax”.

8.2.4.3 Optimizing DELETE Statements

The time required to delete individual rows in a `MyISAM` table is exactly proportional to the number of indexes. To delete rows more quickly, you can increase the size of the key cache by increasing the `key_buffer_size` system variable. See Section 5.1.1, “Configuring the Server”.

To delete all rows from a `MyISAM` table, `TRUNCATE TABLE` *`tbl_name`* is faster than `DELETE FROM` *`tbl_name`*. Truncate operations are not transaction-safe; an error occurs when attempting one in the course of an active transaction or active table lock. See Section 13.1.33, “TRUNCATE TABLE Syntax”.

8.2.5 Optimizing Database Privileges

The more complex your privilege setup, the more overhead applies to all SQL statements. Simplifying the privileges established by `GRANT` statements enables MySQL to reduce permission-checking overhead when clients execute statements. For example, if you do not grant any table-level or column-level privileges, the server need not ever check the contents of the `tables_priv` and `columns_priv` tables. Similarly, if you place no resource limits on any accounts, the server does not have to perform resource counting. If you have a very high statement-processing load, consider using a simplified grant structure to reduce permission-checking overhead.

8.2.6 Other Optimization Tips

This section lists a number of miscellaneous tips for improving query processing speed:

- If your application makes several database requests to perform related updates, combining the statements into a stored routine can help performance. Similarly, if your application computes a single result based on several column values or large volumes of data, combining the computation into a UDF (user-defined function) can help performance. The resulting fast database operations are then available to be reused by other queries, applications, and even code written in different programming languages. See Section 20.2, “Using Stored Routines (Procedures and Functions)” and Section 24.4, “Adding New Functions to MySQL” for more information.
- To fix any compression issues that occur with `ARCHIVE` tables, use `OPTIMIZE TABLE`. See Section 15.6, “The ARCHIVE Storage Engine”.
- If possible, classify reports as “live” or as “statistical”, where data needed for statistical reports is created only from summary tables that are generated periodically from the live data.
- If you have data that does not conform well to a rows-and-columns table structure, you can pack and store data into a `BLOB` column. In this case, you must provide code in your application to pack and unpack information, but this might save I/O operations to read and write the sets of related values.
- With Web servers, store images and other binary assets as files, with the path name stored in the database rather than the file itself. Most Web servers are better at caching files than database contents, so using files is generally faster. (Although you must handle backups and storage issues yourself in this case.)
- If you need really high speed, look at the low-level MySQL interfaces. For example, by accessing the MySQL `InnoDB` or `MyISAM` storage engine directly, you could get a substantial speed increase compared to using the SQL interface.
- Replication can provide a performance benefit for some operations. You can distribute client retrievals among replication servers to split up the load. To avoid slowing down the master while making backups, you can make backups using a slave server. See Chapter 17, *Replication*.

8.3 Optimization and Indexes

The best way to improve the performance of `SELECT` operations is to create indexes on one or more of the columns that are tested in the query. The index entries act like pointers to the table rows, allowing the query to quickly determine which rows match a condition in the `WHERE` clause, and retrieve the other column values for those rows. All MySQL data types can be indexed.

Although it can be tempting to create an indexes for every possible column used in a query, unnecessary indexes waste space and waste time for MySQL to determine which indexes to use. Indexes also add to the cost of inserts, updates, and deletes because each index must be updated. You must find the right balance to achieve fast queries using the optimal set of indexes.

8.3.1 How MySQL Uses Indexes

Indexes are used to find rows with specific column values quickly. Without an index, MySQL must begin with the first row and then read through the entire table to find the relevant rows. The larger the table, the more this costs. If the table has an index for the columns in question, MySQL can quickly determine the position to seek to in the middle of the data file without having to look at all the data. This is much faster than reading every row sequentially.

Most MySQL indexes (`PRIMARY KEY`, `UNIQUE`, `INDEX`, and `FULLTEXT`) are stored in B-trees. Exceptions are that indexes on spatial data types use R-trees, and that `MEMORY` tables also support hash indexes.

In general, indexes are used as described in the following discussion. Characteristics specific to hash indexes (as used in `MEMORY` tables) are described in Section 8.3.8, “Comparison of B-Tree and Hash Indexes”.

MySQL uses indexes for these operations:

- To find the rows matching a `WHERE` clause quickly.
- To eliminate rows from consideration. If there is a choice between multiple indexes, MySQL normally uses the index that finds the smallest number of rows (the most selective index).
- If the table has a multiple-column index, any leftmost prefix of the index can be used by the optimizer to look up rows. For example, if you have a three-column index on `(col1, col2, col3)`, you have indexed search capabilities on `(col1)`, `(col1, col2)`, and `(col1, col2, col3)`. For more information, see Section 8.3.5, “Multiple-Column Indexes”.
- To retrieve rows from other tables when performing joins. MySQL can use indexes on columns more efficiently if they are declared as the same type and size. In this context, `VARCHAR` and `CHAR` are considered the same if they are declared as the same size. For example, `VARCHAR(10)` and `CHAR(10)` are the same size, but `VARCHAR(10)` and `CHAR(15)` are not.

  For comparisons between nonbinary string columns, both columns should use the same character set. For example, comparing a `utf8` column with a `latin1` column precludes use of an index.

  Comparison of dissimilar columns (comparing a string column to a temporal or numeric column, for example) may prevent use of indexes if values cannot be compared directly without conversion. For a given value such as `1` in the numeric column, it might compare equal to any number of values in the string column such as `'1'`, `' 1'`, `'00001'`, or `'01.e1'`. This rules out use of any indexes for the string column.
- To find the `MIN()` or `MAX()` value for a specific indexed column *`key_col`*. This is optimized by a preprocessor that checks whether you are using `WHERE key_part_N = constant` on all key parts that occur before *`key_col`* in the index. In this case, MySQL does a single key lookup for each `MIN()` or `MAX()` expression and replaces it with a constant. If all expressions are replaced with constants, the query returns at once. For example:

```
SELECT MIN(key_part2),MAX(key_part2)
  FROM tbl_name WHERE key_part1=10;
```

- To sort or group a table if the sorting or grouping is done on a leftmost prefix of a usable index (for example, `ORDER BY key_part1, key_part2`). If all key parts are followed by `DESC`, the key is read in reverse order. See Section 8.2.1.10, “ORDER BY Optimization”, and Section 8.2.1.11, “GROUP BY Optimization”.
- In some cases, a query can be optimized to retrieve values without consulting the data rows. (An index that provides all the necessary results for a query is called a covering index.) If a query uses from a table only columns that are included in some index, the selected values can be retrieved from the index tree for greater speed:

```
SELECT key_part3 FROM tbl_name
  WHERE key_part1=1
```

Indexes are less important for queries on small tables, or big tables where report queries process most or all of the rows. When a query needs to access most of the rows, reading sequentially is faster than working through an index. Sequential reads minimize disk seeks, even if not all the rows are needed for the query. See Section 8.2.1.16, “Avoiding Full Table Scans” for details.

8.3.2 Primary Key Optimization

The primary key for a table represents the column or set of columns that you use in your most vital queries. It has an associated index, for fast query performance. Query performance benefits from the `NOT NULL` optimization, because it cannot include any `NULL` values. With the `InnoDB` storage engine, the table data is physically organized to do ultra-fast lookups and sorts based on the primary key column or columns.

If your table is big and important, but does not have an obvious column or set of columns to use as a primary key, you might create a separate column with auto-increment values to use as the primary key. These unique IDs can serve as pointers to corresponding rows in other tables when you join tables using foreign keys.

8.3.3 Foreign Key Optimization

If a table has many columns, and you query many different combinations of columns, it might be efficient to split the less-frequently used data into separate tables with a few columns each, and relate them back to the main table by duplicating the numeric ID column from the main table. That way, each small table can have a primary key for fast lookups of its data, and you can query just the set of columns that you need using a join operation. Depending on how the data is distributed, the queries might perform less I/O and take up less cache memory because the relevant columns are packed together on disk. (To maximize performance, queries try to read as few data blocks as possible from disk; tables with only a few columns can fit more rows in each data block.)

8.3.4 Column Indexes

The most common type of index involves a single column, storing copies of the values from that column in a data structure, allowing fast lookups for the rows with the corresponding column values. The B-tree data structure lets the index quickly find a specific value, a set of values, or a range of values, corresponding to operators such as `=`, `>`, `≤`, `BETWEEN`, `IN`, and so on, in a `WHERE` clause.

The maximum number of indexes per table and the maximum index length is defined per storage engine. See Chapter 14, *The InnoDB Storage Engine*, and Chapter 15, *Alternative Storage Engines*. All storage engines support at least 16 indexes per table and a total index length of at least 256 bytes. Most storage engines have higher limits.

For additional information about column indexes, see Section 13.1.13, “CREATE INDEX Syntax”.

- Index Prefixes
- FULLTEXT Indexes
- Spatial Indexes
- Indexes in the MEMORY Storage Engine

Index Prefixes

With *`col_name(N)`* syntax in an index specification for a string column, you can create an index that uses only the first *`N`* characters of the column. Indexing only a prefix of column values in this way can make the index file much smaller. When you index a `BLOB` or `TEXT` column, you *must* specify a prefix length for the index. For example:

```
CREATE TABLE test (blob_col BLOB, INDEX(blob_col(10)));
```

Prefixes can be up to 1000 bytes long (767 bytes for `InnoDB` tables, unless you have `innodb_large_prefix` set).

Note

Prefix limits are measured in bytes, whereas the prefix length in `CREATE TABLE`, `ALTER TABLE`, and `CREATE INDEX` statements is interpreted as number of characters for nonbinary string types (`CHAR`, `VARCHAR`, `TEXT`) and number of bytes for binary string types (`BINARY`, `VARBINARY`, `BLOB`). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

For additional information about index prefixes, see Section 13.1.13, “CREATE INDEX Syntax”.

FULLTEXT Indexes

`FULLTEXT` indexes are used for full-text searches. Only the `MyISAM` storage engine supports `FULLTEXT` indexes and only for `CHAR`, `VARCHAR`, and `TEXT` columns. Indexing always takes place over the entire column and column prefix indexing is not supported. For details, see Section 12.9, “Full-Text Search Functions”.

For queries that contain full-text expressions, MySQL evaluates those expressions during the optimization phase of query execution. The optimizer does not just look at full-text expressions and make estimates, it actually evaluates them in the process of developing an execution plan.

An implication of this behavior is that `EXPLAIN` for full-text queries is typically slower than for non-full-text queries for which no expression evaluation occurs during the optimization phase.

`EXPLAIN` for full-text queries may show `Select tables optimized away` in the `Extra` column due to matching occurring during optimization; in this case, no table access need occur during later execution.

Spatial Indexes

You can create indexes on spatial data types. Only `MyISAM` supports R-tree indexes on spatial types. Other storage engines use B-trees for indexing spatial types (except for `ARCHIVE`, which does not support spatial type indexing).

Indexes in the MEMORY Storage Engine

The `MEMORY` storage engine uses `HASH` indexes by default, but also supports `BTREE` indexes.

8.3.5 Multiple-Column Indexes

MySQL can create composite indexes (that is, indexes on multiple columns). An index may consist of up to 16 columns. For certain data types, you can index a prefix of the column (see Section 8.3.4, “Column Indexes”).

MySQL can use multiple-column indexes for queries that test all the columns in the index, or queries that test just the first column, the first two columns, the first three columns, and so on. If you specify the columns in the right order in the index definition, a single composite index can speed up several kinds of queries on the same table.

A multiple-column index can be considered a sorted array, the rows of which contain values that are created by concatenating the values of the indexed columns.

Note

As an alternative to a composite index, you can introduce a column that is “hashed” based on information from other columns. If this column is short, reasonably unique, and indexed, it might be faster than a “wide” index on many columns. In MySQL, it is very easy to use this extra column:

```
SELECT * FROM tbl_name
  WHERE hash_col=MD5(CONCAT(val1,val2))
  AND col1=val1 AND col2=val2;
```

Suppose that a table has the following specification:

```
CREATE TABLE test (
    id         INT NOT NULL,
    last_name  CHAR(30) NOT NULL,
    first_name CHAR(30) NOT NULL,
```

```
    PRIMARY KEY (id),
    INDEX name (last_name,first_name)
);
```

The `name` index is an index over the `last_name` and `first_name` columns. The index can be used for lookups in queries that specify values in a known range for combinations of `last_name` and `first_name` values. It can also be used for queries that specify just a `last_name` value because that column is a leftmost prefix of the index (as described later in this section). Therefore, the `name` index is used for lookups in the following queries:

```
SELECT * FROM test WHERE last_name='Widenius';

SELECT * FROM test
  WHERE last_name='Widenius' AND first_name='Michael';

SELECT * FROM test
  WHERE last_name='Widenius'
  AND (first_name='Michael' OR first_name='Monty');

SELECT * FROM test
  WHERE last_name='Widenius'
  AND first_name >='M' AND first_name < 'N';
```

However, the `name` index is *not* used for lookups in the following queries:

```
SELECT * FROM test WHERE first_name='Michael';

SELECT * FROM test
  WHERE last_name='Widenius' OR first_name='Michael';
```

Suppose that you issue the following `SELECT` statement:

```
SELECT * FROM tbl_name
  WHERE col1=val1 AND col2=val2;
```

If a multiple-column index exists on `col1` and `col2`, the appropriate rows can be fetched directly. If separate single-column indexes exist on `col1` and `col2`, the optimizer attempts to use the Index Merge optimization (see Section 8.2.1.3, “Index Merge Optimization”), or attempts to find the most restrictive index by deciding which index excludes more rows and using that index to fetch the rows.

If the table has a multiple-column index, any leftmost prefix of the index can be used by the optimizer to look up rows. For example, if you have a three-column index on `(col1, col2, col3)`, you have indexed search capabilities on `(col1)`, `(col1, col2)`, and `(col1, col2, col3)`.

MySQL cannot use the index to perform lookups if the columns do not form a leftmost prefix of the index. Suppose that you have the `SELECT` statements shown here:

```
SELECT * FROM tbl_name WHERE col1=val1;
SELECT * FROM tbl_name WHERE col1=val1 AND col2=val2;

SELECT * FROM tbl_name WHERE col2=val2;
SELECT * FROM tbl_name WHERE col2=val2 AND col3=val3;
```

If an index exists on `(col1, col2, col3)`, only the first two queries use the index. The third and fourth queries do involve indexed columns, but do not use an index to perform lookups because `(col2)` and `(col2, col3)` are not leftmost prefixes of `(col1, col2, col3)`.

8.3.6 Verifying Index Usage

Always check whether all your queries really use the indexes that you have created in the tables. Use the `EXPLAIN` statement, as described in Section 8.8.1, “Optimizing Queries with EXPLAIN”.

8.3.7 InnoDB and MyISAM Index Statistics Collection

Storage engines collect statistics about tables for use by the optimizer. Table statistics are based on value groups, where a value group is a set of rows with the same key prefix value. For optimizer purposes, an important statistic is the average value group size.

MySQL uses the average value group size in the following ways:

- To estimate how may rows must be read for each `ref` access
- To estimate how many row a partial join will produce; that is, the number of rows that an operation of this form will produce:

```
(...) JOIN tbl_name ON tbl_name.key = expr
```

As the average value group size for an index increases, the index is less useful for those two purposes because the average number of rows per lookup increases: For the index to be good for optimization purposes, it is best that each index value target a small number of rows in the table. When a given index value yields a large number of rows, the index is less useful and MySQL is less likely to use it.

The average value group size is related to table cardinality, which is the number of value groups. The `SHOW INDEX` statement displays a cardinality value based on *`N/S`*, where *`N`* is the number of rows in the table and *`S`* is the average value group size. That ratio yields an approximate number of value groups in the table.

For a join based on the `<=>` comparison operator, `NULL` is not treated differently from any other value: `NULL <=> NULL`, just as *`N <=> N`* for any other *`N`*.

However, for a join based on the `=` operator, `NULL` is different from non-`NULL` values: *`expr1 = expr2`* is not true when *`expr1`* or *`expr2`* (or both) are `NULL`. This affects `ref` accesses for comparisons of the form *`tbl_name.key = expr`*: MySQL will not access the table if the current value of *`expr`* is `NULL`, because the comparison cannot be true.

For `=` comparisons, it does not matter how many `NULL` values are in the table. For optimization purposes, the relevant value is the average size of the non-`NULL` value groups. However, MySQL does not currently enable that average size to be collected or used.

For `InnoDB` and `MyISAM` tables, you have some control over collection of table statistics by means of the `innodb_stats_method` and `myisam_stats_method` system variables, respectively. These variables have three possible values, which differ as follows:

- When the variable is set to `nulls_equal`, all `NULL` values are treated as identical (that is, they all form a single value group).

  If the `NULL` value group size is much higher than the average non-`NULL` value group size, this method skews the average value group size upward. This makes index appear to the optimizer to be less useful than it really is for joins that look for non-`NULL` values. Consequently, the `nulls_equal` method may cause the optimizer not to use the index for `ref` accesses when it should.

- When the variable is set to `nulls_unequal`, `NULL` values are not considered the same. Instead, each `NULL` value forms a separate value group of size 1.

  If you have many `NULL` values, this method skews the average value group size downward. If the average non-`NULL` value group size is large, counting `NULL` values each as a group of size 1 causes the optimizer to overestimate the value of the index for joins that look for non-`NULL` values. Consequently, the `nulls_unequal` method may cause the optimizer to use this index for `ref` lookups when other methods may be better.

- When the variable is set to `nulls_ignored`, `NULL` values are ignored.

If you tend to use many joins that use `<=>` rather than `=`, `NULL` values are not special in comparisons and one `NULL` is equal to another. In this case, `nulls_equal` is the appropriate statistics method.

The `innodb_stats_method` system variable has a global value; the `myisam_stats_method` system variable has both global and session values. Setting the global value affects statistics collection for tables from the corresponding storage engine. Setting the session value affects statistics collection only for the current client connection. This means that you can force a table's statistics to be regenerated with a given method without affecting other clients by setting the session value of `myisam_stats_method`.

To regenerate `MyISAM` table statistics, you can use any of the following methods:

- Execute `myisamchk --stats_method=method_name --analyze`
- Change the table to cause its statistics to go out of date (for example, insert a row and then delete it), and then set `myisam_stats_method` and issue an `ANALYZE TABLE` statement

Some caveats regarding the use of `innodb_stats_method` and `myisam_stats_method`:

- You can force table statistics to be collected explicitly, as just described. However, MySQL may also collect statistics automatically. For example, if during the course of executing statements for a table, some of those statements modify the table, MySQL may collect statistics. (This may occur for bulk inserts or deletes, or some `ALTER TABLE` statements, for example.) If this happens, the statistics are collected using whatever value `innodb_stats_method` or `myisam_stats_method` has at the time. Thus, if you collect statistics using one method, but the system variable is set to the other method when a table's statistics are collected automatically later, the other method will be used.
- There is no way to tell which method was used to generate statistics for a given table.
- These variables apply only to `InnoDB` and `MyISAM` tables. Other storage engines have only one method for collecting table statistics. Usually it is closer to the `nulls_equal` method.

8.3.8 Comparison of B-Tree and Hash Indexes

Understanding the B-tree and hash data structures can help predict how different queries perform on different storage engines that use these data structures in their indexes, particularly for the `MEMORY` storage engine that lets you choose B-tree or hash indexes.

- B-Tree Index Characteristics
- Hash Index Characteristics

B-Tree Index Characteristics

A B-tree index can be used for column comparisons in expressions that use the `=`, `>`, `>=`, `<`, `<=`, or `BETWEEN` operators. The index also can be used for `LIKE` comparisons if the argument to `LIKE` is a constant string that does not start with a wildcard character. For example, the following `SELECT` statements use indexes:

```
SELECT * FROM tbl_name WHERE key_col LIKE 'Patrick%';
SELECT * FROM tbl_name WHERE key_col LIKE 'Pat%_ck%';
```

In the first statement, only rows with `'Patrick' <= key_col < 'Patricl'` are considered. In the second statement, only rows with `'Pat' <= key_col < 'Pau'` are considered.

The following `SELECT` statements do not use indexes:

```
SELECT * FROM tbl_name WHERE key_col LIKE '%Patrick%';
SELECT * FROM tbl_name WHERE key_col LIKE other_col;
```

In the first statement, the `LIKE` value begins with a wildcard character. In the second statement, the `LIKE` value is not a constant.

If you use `... LIKE '%string%'` and *`string`* is longer than three characters, MySQL uses the *Turbo Boyer-Moore algorithm* to initialize the pattern for the string and then uses this pattern to perform the search more quickly.

A search using *`col_name`* `IS NULL` employs indexes if *`col_name`* is indexed.

Any index that does not span all `AND` levels in the `WHERE` clause is not used to optimize the query. In other words, to be able to use an index, a prefix of the index must be used in every `AND` group.

The following `WHERE` clauses use indexes:

```
... WHERE index_part1=1 AND index_part2=2 AND other_column=3

    /* index = 1 OR index = 2 */
... WHERE index=1 OR A=10 AND index=2

    /* optimized like "index_part1='hello'" */
... WHERE index_part1='hello' AND index_part3=5

    /* Can use index on index1 but not on index2 or index3 */
... WHERE index1=1 AND index2=2 OR index1=3 AND index3=3;
```

These `WHERE` clauses do *not* use indexes:

```
    /* index_part1 is not used */
... WHERE index_part2=1 AND index_part3=2

    /*  Index is not used in both parts of the WHERE clause  */
... WHERE index=1 OR A=10

    /* No index spans all rows  */
... WHERE index_part1=1 OR index_part2=10
```

Sometimes MySQL does not use an index, even if one is available. One circumstance under which this occurs is when the optimizer estimates that using the index would require MySQL to access a very large percentage of the rows in the table. (In this case, a table scan is likely to be much faster because it requires fewer seeks.) However, if such a query uses `LIMIT` to retrieve only some of the rows, MySQL uses an index anyway, because it can much more quickly find the few rows to return in the result.

Hash Index Characteristics

Hash indexes have somewhat different characteristics from those just discussed:

- They are used only for equality comparisons that use the `=` or `<=>` operators (but are *very* fast). They are not used for comparison operators such as `<` that find a range of values. Systems that rely on this type of single-value lookup are known as “key-value stores”; to use MySQL for such applications, use hash indexes wherever possible.
- The optimizer cannot use a hash index to speed up `ORDER BY` operations. (This type of index cannot be used to search for the next entry in order.)
- MySQL cannot determine approximately how many rows there are between two values (this is used by the range optimizer to decide which index to use). This may affect some queries if you change a `MyISAM` or `InnoDB` table to a hash-indexed `MEMORY` table.
- Only whole keys can be used to search for a row. (With a B-tree index, any leftmost prefix of the key can be used to find rows.)

8.4 Optimizing Database Structure

In your role as a database designer, look for the most efficient way to organize your schemas, tables, and columns. As when tuning application code, you minimize I/O, keep related items together, and plan

ahead so that performance stays high as the data volume increases. Starting with an efficient database design makes it easier for team members to write high-performing application code, and makes the database likely to endure as applications evolve and are rewritten.

8.4.1 Optimizing Data Size

Design your tables to minimize their space on the disk. This can result in huge improvements by reducing the amount of data written to and read from disk. Smaller tables normally require less main memory while their contents are being actively processed during query execution. Any space reduction for table data also results in smaller indexes that can be processed faster.

MySQL supports many different storage engines (table types) and row formats. For each table, you can decide which storage and indexing method to use. Choosing the proper table format for your application can give you a big performance gain. See Chapter 14, *The InnoDB Storage Engine*, and Chapter 15, *Alternative Storage Engines*.

You can get better performance for a table and minimize storage space by using the techniques listed here:

- Table Columns
- Row Format
- Indexes
- Joins
- Normalization

Table Columns

- Use the most efficient (smallest) data types possible. MySQL has many specialized types that save disk space and memory. For example, use the smaller integer types if possible to get smaller tables. `MEDIUMINT` is often a better choice than `INT` because a `MEDIUMINT` column uses 25% less space.
- Declare columns to be `NOT NULL` if possible. It makes SQL operations faster, by enabling better use of indexes and eliminating overhead for testing whether each value is `NULL`. You also save some storage space, one bit per column. If you really need `NULL` values in your tables, use them. Just avoid the default setting that allows `NULL` values in every column.

Row Format

- In MySQL 5.5, `InnoDB` tables use the `COMPACT` row storage format (`ROW_FORMAT=COMPACT`) by default. Older versions of MySQL use the `REDUNDANT` row format (`ROW_FORMAT=REDUNDANT`).

  The compact family of row formats, which includes `COMPACT`, `DYNAMIC`, and `COMPRESSED`, decreases row storage space at the cost of increasing CPU use for some operations. If your workload is a typical one that is limited by cache hit rates and disk speed it is likely to be faster. If it is a rare case that is limited by CPU speed, it might be slower.

  The compact family of row formats also optimizes `CHAR` column storage when using a variable-length character set such as `utf8mb3` or `utf8mb4`. With `ROW_FORMAT=REDUNDANT`, `CHAR(N)` occupies *`N`* × the maximum byte length of the character set. Many languages can be written primarily using single-byte `utf8` characters, so a fixed storage length often wastes space. With the compact family of rows formats, `InnoDB` allocates a variable amount of storage in the range of *`N`* to *`N`* × the maximum byte length of the character set for these columns by stripping trailing spaces. The minimum storage length is *`N`* bytes to facilitate in-place updates in typical cases. For more information, see Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table”.

- To minimize space even further by storing table data in compressed form, specify `ROW_FORMAT=COMPRESSED` when creating `InnoDB` tables, or run the `myisampack` command on

an existing `MyISAM` table. (`InnoDB` compressed tables are readable and writable, while `MyISAM` compressed tables are read-only.)

- For `MyISAM` tables, if you do not have any variable-length columns (`VARCHAR`, `TEXT`, or `BLOB` columns), a fixed-size row format is used. This is faster but may waste some space. See Section 15.3.3, “MyISAM Table Storage Formats”. You can hint that you want to have fixed length rows even if you have `VARCHAR` columns with the `CREATE TABLE` option `ROW_FORMAT=FIXED`.

Indexes

- The primary index of a table should be as short as possible. This makes identification of each row easy and efficient. For `InnoDB` tables, the primary key columns are duplicated in each secondary index entry, so a short primary key saves considerable space if you have many secondary indexes.
- Create only the indexes that you need to improve query performance. Indexes are good for retrieval, but slow down insert and update operations. If you access a table mostly by searching on a combination of columns, create a single composite index on them rather than a separate index for each column. The first part of the index should be the column most used. If you *always* use many columns when selecting from the table, the first column in the index should be the one with the most duplicates, to obtain better compression of the index.
- If it is very likely that a long string column has a unique prefix on the first number of characters, it is better to index only this prefix, using MySQL's support for creating an index on the leftmost part of the column (see Section 13.1.13, “CREATE INDEX Syntax”). Shorter indexes are faster, not only because they require less disk space, but because they also give you more hits in the index cache, and thus fewer disk seeks. See Section 5.1.1, “Configuring the Server”.

Joins

- In some circumstances, it can be beneficial to split into two a table that is scanned very often. This is especially true if it is a dynamic-format table and it is possible to use a smaller static format table that can be used to find the relevant rows when scanning the table.
- Declare columns with identical information in different tables with identical data types, to speed up joins based on the corresponding columns.
- Keep column names simple, so that you can use the same name across different tables and simplify join queries. For example, in a table named `customer`, use a column name of `name` instead of `customer_name`. To make your names portable to other SQL servers, consider keeping them shorter than 18 characters.

Normalization

- Normally, try to keep all data nonredundant (observing what is referred to in database theory as *third normal form*). Instead of repeating lengthy values such as names and addresses, assign them unique IDs, repeat these IDs as needed across multiple smaller tables, and join the tables in queries by referencing the IDs in the join clause.
- If speed is more important than disk space and the maintenance costs of keeping multiple copies of data, for example in a business intelligence scenario where you analyze all the data from large tables, you can relax the normalization rules, duplicating information or creating summary tables to gain more speed.

8.4.2 Optimizing MySQL Data Types

8.4.2.1 Optimizing for Numeric Data

- For unique IDs or other values that can be represented as either strings or numbers, prefer numeric columns to string columns. Since large numeric values can be stored in fewer bytes than the corresponding strings, it is faster and takes less memory to transfer and compare them.

- If you are using numeric data, it is faster in many cases to access information from a database (using a live connection) than to access a text file. Information in the database is likely to be stored in a more compact format than in the text file, so accessing it involves fewer disk accesses. You also save code in your application because you can avoid parsing the text file to find line and column boundaries.

8.4.2.2 Optimizing for Character and String Types

For character and string columns, follow these guidelines:

- Use binary collation order for fast comparison and sort operations, when you do not need language-specific collation features. You can use the `BINARY` operator to use binary collation within a particular query.
- When comparing values from different columns, declare those columns with the same character set and collation wherever possible, to avoid string conversions while running the query.
- For column values less than 8KB in size, use binary `VARCHAR` instead of `BLOB`. The `GROUP BY` and `ORDER BY` clauses can generate temporary tables, and these temporary tables can use the `MEMORY` storage engine if the original table does not contain any `BLOB` columns.
- If a table contains string columns such as name and address, but many queries do not retrieve those columns, consider splitting the string columns into a separate table and using join queries with a foreign key when necessary. When MySQL retrieves any value from a row, it reads a data block containing all the columns of that row (and possibly other adjacent rows). Keeping each row small, with only the most frequently used columns, allows more rows to fit in each data block. Such compact tables reduce disk I/O and memory usage for common queries.
- When you use a randomly generated value as a primary key in an `InnoDB` table, prefix it with an ascending value such as the current date and time if possible. When consecutive primary values are physically stored near each other, `InnoDB` can insert and retrieve them faster.
- See Section 8.4.2.1, “Optimizing for Numeric Data” for reasons why a numeric column is usually preferable to an equivalent string column.

8.4.2.3 Optimizing for BLOB Types

- When storing a large blob containing textual data, consider compressing it first. Do not use this technique when the entire table is compressed by `InnoDB` or `MyISAM`.
- For a table with several columns, to reduce memory requirements for queries that do not use the BLOB column, consider splitting the BLOB column into a separate table and referencing it with a join query when needed.
- Since the performance requirements to retrieve and display a BLOB value might be very different from other data types, you could put the BLOB-specific table on a different storage device or even a separate database instance. For example, to retrieve a BLOB might require a large sequential disk read that is better suited to a traditional hard drive than to an SSD device.
- See Section 8.4.2.2, “Optimizing for Character and String Types” for reasons why a binary `VARCHAR` column is sometimes preferable to an equivalent BLOB column.
- Rather than testing for equality against a very long text string, you can store a hash of the column value in a separate column, index that column, and test the hashed value in queries. (Use the `MD5()` or `CRC32()` function to produce the hash value.) Since hash functions can produce duplicate results for different inputs, you still include a clause `AND blob_column = long_string_value` in the query to guard against false matches; the performance benefit comes from the smaller, easily scanned index for the hashed values.

8.4.2.4 Using PROCEDURE ANALYSE

```
ANALYSE([max_elements[,max_memory]])
```

`ANALYSE()` examines the result from a query and returns an analysis of the results that suggests optimal data types for each column that may help reduce table sizes. To obtain this analysis, append `PROCEDURE ANALYSE` to the end of a `SELECT` statement:

```
SELECT ... FROM ... WHERE ... PROCEDURE ANALYSE([max_elements,[max_memory]])
```

For example:

```
SELECT col1, col2 FROM table1 PROCEDURE ANALYSE(10, 2000);
```

The results show some statistics for the values returned by the query, and propose an optimal data type for the columns. This can be helpful for checking your existing tables, or after importing new data. You may need to try different settings for the arguments so that `PROCEDURE ANALYSE()` does not suggest the `ENUM` data type when it is not appropriate.

The arguments are optional and are used as follows:

- *`max_elements`* (default 256) is the maximum number of distinct values that `ANALYSE()` notices per column. This is used by `ANALYSE()` to check whether the optimal data type should be of type `ENUM`; if there are more than *`max_elements`* distinct values, then `ENUM` is not a suggested type.
- *`max_memory`* (default 8192) is the maximum amount of memory that `ANALYSE()` should allocate per column while trying to find all distinct values.

A `PROCEDURE` clause is not permitted in a `UNION` statement.

8.4.3 Optimizing for Many Tables

Some techniques for keeping individual queries fast involve splitting data across many tables. When the number of tables runs into the thousands or even millions, the overhead of dealing with all these tables becomes a new performance consideration.

8.4.3.1 How MySQL Opens and Closes Tables

When you execute a `mysqladmin status` command, you should see something like this:

```
Uptime: 426 Running threads: 1 Questions: 11082
Reloads: 1 Open tables: 12
```

The `Open tables` value of 12 can be somewhat puzzling if you have only six tables.

MySQL is multi-threaded, so there may be many clients issuing queries for a given table simultaneously. To minimize the problem with multiple client sessions having different states on the same table, the table is opened independently by each concurrent session. This uses additional memory but normally increases performance. With `MyISAM` tables, one extra file descriptor is required for the data file for each client that has the table open. (By contrast, the index file descriptor is shared between all sessions.)

The `table_open_cache` and `max_connections` system variables affect the maximum number of files the server keeps open. If you increase one or both of these values, you may run up against a limit imposed by your operating system on the per-process number of open file descriptors. Many operating systems permit you to increase the open-files limit, although the method varies widely from system to system. Consult your operating system documentation to determine whether it is possible to increase the limit and how to do so.

`table_open_cache` is related to `max_connections`. For example, for 200 concurrent running connections, specify a table cache size of at least `200 * N`, where *`N`* is the maximum number of tables

per join in any of the queries which you execute. You must also reserve some extra file descriptors for temporary tables and files.

Make sure that your operating system can handle the number of open file descriptors implied by the `table_open_cache` setting. If `table_open_cache` is set too high, MySQL may run out of file descriptors and refuse connections, fail to perform queries, and be very unreliable.

You should also take into account the fact that the `MyISAM` storage engine needs two file descriptors for each unique open table. For a partitioned `MyISAM` table, two file descriptors are required for each partition of the opened table. (Note further that when `MyISAM` opens a partitioned table, it opens every partition of this table, whether or not a given partition is actually used. See MyISAM and partition file descriptor usage.) You can increase the number of file descriptors available to MySQL using the `--open-files-limit` startup option to `mysqld`. See Section B.5.2.18, “File Not Found and Similar Errors”.

The cache of open tables is kept at a level of `table_open_cache` entries. The default value is 400; this can be changed with the `--table_open_cache` option to `mysqld`. Note that MySQL may temporarily open more tables than this to execute queries.

MySQL closes an unused table and removes it from the table cache under the following circumstances:

- When the cache is full and a thread tries to open a table that is not in the cache.
- When the cache contains more than `table_open_cache` entries and a table in the cache is no longer being used by any threads.
- When a table flushing operation occurs. This happens when someone issues a `FLUSH TABLES` statement or executes a `mysqladmin flush-tables` or `mysqladmin refresh` command.

When the table cache fills up, the server uses the following procedure to locate a cache entry to use:

- Tables that are not currently in use are released, beginning with the table least recently used.
- If a new table needs to be opened, but the cache is full and no tables can be released, the cache is temporarily extended as necessary. When the cache is in a temporarily extended state and a table goes from a used to unused state, the table is closed and released from the cache.

A `MyISAM` table is opened for each concurrent access. This means the table needs to be opened twice if two threads access the same table or if a thread accesses the table twice in the same query (for example, by joining the table to itself). Each concurrent open requires an entry in the table cache. The first open of any `MyISAM` table takes two file descriptors: one for the data file and one for the index file. Each additional use of the table takes only one file descriptor for the data file. The index file descriptor is shared among all threads.

If you are opening a table with the `HANDLER tbl_name OPEN` statement, a dedicated table object is allocated for the thread. This table object is not shared by other threads and is not closed until the thread calls `HANDLER tbl_name CLOSE` or the thread terminates. When this happens, the table is put back in the table cache (if the cache is not full). See Section 13.2.4, “HANDLER Syntax”.

You can determine whether your table cache is too small by checking the `mysqld` status variable `Opened_tables`, which indicates the number of table-opening operations since the server started:

```
mysql> SHOW GLOBAL STATUS LIKE 'Opened_tables';
+---------------+-------+
| Variable_name | Value |
+---------------+-------+
| Opened_tables | 2741  |
+---------------+-------+
```

If the value is very large or increases rapidly, even when you have not issued many `FLUSH TABLES` statements, increase the table cache size. See Section 5.1.5, “Server System Variables”, and Section 5.1.7, “Server Status Variables”.

8.4.3.2 Disadvantages of Creating Many Tables in the Same Database

If you have many `MyISAM` tables in the same database directory, open, close, and create operations are slow. If you execute `SELECT` statements on many different tables, there is a little overhead when the table cache is full, because for every table that has to be opened, another must be closed. You can reduce this overhead by increasing the number of entries permitted in the table cache.

8.4.4 Internal Temporary Table Use in MySQL

In some cases, the server creates internal temporary tables while processing statements. Users have no direct control over when this occurs.

The server creates temporary tables under conditions such as these:

- Evaluation of `UNION` statements.
- Evaluation of some views, such those that use the `TEMPTABLE` algorithm, `UNION`, or aggregation.
- Evaluation of statements that contain an `ORDER BY` clause and a different `GROUP BY` clause, or for which the `ORDER BY` or `GROUP BY` contains columns from tables other than the first table in the join queue.
- Evaluation of `DISTINCT` combined with `ORDER BY` may require a temporary table.
- For queries that use the `SQL_SMALL_RESULT` modifier, MySQL uses an in-memory temporary table, unless the query also contains elements (described later) that require on-disk storage.
- To evaluate `INSERT ... SELECT` statements that select from and insert into the same table, MySQL creates an internal temporary table to hold the rows from the `SELECT`, then inserts those rows into the target table. See Section 13.2.5.1, “INSERT ... SELECT Syntax”.
- Evaluation of multiple-table `UPDATE` statements.
- Evaluation of `GROUP_CONCAT()` or `COUNT(DISTINCT)` expressions.

To determine whether a statement requires a temporary table, use `EXPLAIN` and check the `Extra` column to see whether it says `Using temporary` (see Section 8.8.1, “Optimizing Queries with EXPLAIN”).

When the server creates an internal temporary table (either in memory or on disk), it increments the `Created_tmp_tables` status variable. If the server creates the table on disk (either initially or by converting an in-memory table) it increments the `Created_tmp_disk_tables` status variable.

Some query conditions prevent the use of an in-memory temporary table, in which case the server uses an on-disk table instead:

- Presence of a `BLOB` or `TEXT` column in the table. This includes user-defined variables having a string value because they are treated as `BLOB` or `TEXT` columns, depending on whether their value is a binary or nonbinary string, respectively.
- Presence of any string column in a `GROUP BY` or `DISTINCT` clause larger than 512 bytes.
- Presence of any string column with a maximum length larger than 512 (bytes for binary strings, characters for nonbinary strings) in the `SELECT` list, if `UNION` or `UNION ALL` is used.
- The `SHOW COLUMNS` and `DESCRIBE` statements use `BLOB` as the type for some columns, thus the temporary table used for the results is an on-disk table.
- Internal Temporary Table Storage Engine
- Internal Temporary Table Storage Format

Internal Temporary Table Storage Engine

An internal temporary table can be held in memory and processed by the `MEMORY` storage engine, or stored on disk and processed by the `MyISAM` storage engine.

If an internal temporary table is created as an in-memory table but becomes too large, MySQL automatically converts it to an on-disk table. The maximum size for in-memory temporary tables is determined from whichever of the values of `tmp_table_size` and `max_heap_table_size` is smaller. This differs from `MEMORY` tables explicitly created with `CREATE TABLE`: For such tables, only the `max_heap_table_size` system variable determines how large the table is permitted to grow and there is no conversion to on-disk format.

Internal Temporary Table Storage Format

In-memory temporary tables are managed by the `MEMORY` storage engine, which uses fixed-length row format. `VARCHAR` and `VARBINARY` column values are padded to the maximum column length, in effect storing them as `CHAR` and `BINARY` columns.

On-disk temporary tables are managed by the `MyISAM` storage engine using dynamic-width row format. Columns take only as much storage as needed, which reduces disk I/O and space requirements, and processing time compared to on-disk tables that use fixed-length rows. The exception to dynamic-length row format is that on-disk temporary tables for derived tables are stored using fixed-length rows.

Prior to MySQL 5.5.47, on-disk temporary table storage uses fixed-length rows.

For statements that initially create an internal temporary table in memory, then convert it to an on-disk table, better performance might be achieved by skipping the conversion step and creating the table on disk to begin with. The `big_tables` system variable can be used to force disk storage of internal temporary tables.

8.5 Optimizing for InnoDB Tables

`InnoDB` is the storage engine that MySQL customers typically use in production databases where reliability and concurrency are important. Because `InnoDB` is the default storage engine in MySQL 5.5 and higher, you can expect to see `InnoDB` tables more often than before. This section explains how to optimize database operations for `InnoDB` tables.

8.5.1 Optimizing Storage Layout for InnoDB Tables

- Once your data reaches a stable size, or a growing table has increased by tens or some hundreds of megabytes, consider using the `OPTIMIZE TABLE` statement to reorganize the table and compact any wasted space. The reorganized tables require less disk I/O to perform full table scans. This is a straightforward technique that can improve performance when other techniques such as improving index usage or tuning application code are not practical.

  `OPTIMIZE TABLE` copies the data part of the table and rebuilds the indexes. The benefits come from improved packing of data within indexes, and reduced fragmentation within the tablespaces and on disk. The benefits vary depending on the data in each table. You may find that there are significant gains for some and not for others, or that the gains decrease over time until you next optimize the table. This operation can be slow if the table is large or if the indexes being rebuilt do not fit into the buffer pool. The first run after adding a lot of data to a table is often much slower than later runs.

- In `InnoDB`, having a long `PRIMARY KEY` (either a single column with a lengthy value, or several columns that form a long composite value) wastes a lot of disk space. The primary key value for a row is duplicated in all the secondary index records that point to the same row. (See Section 14.11.2.1, “Clustered and Secondary Indexes”.) Create an `AUTO_INCREMENT` column as

the primary key if your primary key is long, or index a prefix of a long VARCHAR column instead of the entire column.

- Use the VARCHAR data type instead of CHAR to store variable-length strings or for columns with many NULL values. A CHAR(*N*) column always takes *N* characters to store data, even if the string is shorter or its value is NULL. Smaller tables fit better in the buffer pool and reduce disk I/O.

  When using COMPACT row format (the default InnoDB format) and variable-length character sets, such as utf8 or sjis, CHAR(*N*) columns occupy a variable amount of space, but still at least *N* bytes.

- For tables that are big, or contain lots of repetitive text or numeric data, consider using COMPRESSED row format. Less disk I/O is required to bring data into the buffer pool, or to perform full table scans. Before making a permanent decision, measure the amount of compression you can achieve by using COMPRESSED versus COMPACT row format.

8.5.2 Optimizing InnoDB Transaction Management

To optimize InnoDB transaction processing, find the ideal balance between the performance overhead of transactional features and the workload of your server. For example, an application might encounter performance issues if it commits thousands of times per second, and different performance issues if it commits only every 2-3 hours.

- The default MySQL setting AUTOCOMMIT=1 can impose performance limitations on a busy database server. Where practical, wrap several related data change operations into a single transaction, by issuing SET AUTOCOMMIT=0 or a START TRANSACTION statement, followed by a COMMIT statement after making all the changes.

  InnoDB must flush the log to disk at each transaction commit if that transaction made modifications to the database. When each change is followed by a commit (as with the default autocommit setting), the I/O throughput of the storage device puts a cap on the number of potential operations per second.

- Avoid performing rollbacks after inserting, updating, or deleting huge numbers of rows. If a big transaction is slowing down server performance, rolling it back can make the problem worse, potentially taking several times as long to perform as the original data change operations. Killing the database process does not help, because the rollback starts again on server startup.

  To minimize the chance of this issue occurring:

  - Increase the size of the buffer pool so that all the data change changes can be cached rather than immediately written to disk.
  - Set innodb_change_buffering=all so that update and delete operations are buffered in addition to inserts.
  - Consider issuing COMMIT statements periodically during the big data change operation, possibly breaking a single delete or update into multiple statements that operate on smaller numbers of rows.

  To get rid of a runaway rollback once it occurs, increase the buffer pool so that the rollback becomes CPU-bound and runs fast, or kill the server and restart with innodb_force_recovery=3, as explained in Section 14.21.2, “InnoDB Recovery”.

  This issue is expected to be infrequent with the default setting innodb_change_buffering=all, which allows update and delete operations to be cached in memory, making them faster to perform in the first place, and also faster to roll back if needed. Make sure to use this parameter setting on servers that process long-running transactions with many inserts, updates, or deletes.

- If you can afford the loss of some of the latest committed transactions if a crash occurs, you can set the innodb_flush_log_at_trx_commit parameter to 0. InnoDB tries to flush the log once per

second anyway, although the flush is not guaranteed. Also, set the value of `innodb_support_xa` to 0, which will reduce the number of disk flushes due to synchronizing on disk data and the binary log.

- When rows are modified or deleted, the rows and associated undo logs are not physically removed immediately, or even immediately after the transaction commits. The old data is preserved until transactions that started earlier or concurrently are finished, so that those transactions can access the previous state of modified or deleted rows. Thus, a long-running transaction can prevent `InnoDB` from purging data that was changed by a different transaction.

- When rows are modified or deleted within a long-running transaction, other transactions using the `READ COMMITTED` and `REPEATABLE READ` isolation levels have to do more work to reconstruct the older data if they read those same rows.

- When a long-running transaction modifies a table, queries against that table from other transactions do not make use of the covering index technique. Queries that normally could retrieve all the result columns from a secondary index, instead look up the appropriate values from the table data.

  If secondary index pages are found to have a `PAGE_MAX_TRX_ID` that is too new, or if records in the secondary index are delete-marked, `InnoDB` may need to look up records using a clustered index.

8.5.3 Optimizing InnoDB Redo Logging

Consider the following guidelines for optimizing redo logging:

- Make your redo log files big, even as big as the buffer pool. When `InnoDB` has written the redo log files full, it must write the modified contents of the buffer pool to disk in a checkpoint. Small redo log files cause many unnecessary disk writes. Although historically big redo log files caused lengthy recovery times, recovery is now much faster and you can confidently use large redo log files.

  The size and number of redo log files are configured using the `innodb_log_file_size` and `innodb_log_files_in_group` configuration options. For information about modifying an existing redo log file configuration, see Section 14.10.2, “Changing the Number or Size of InnoDB Redo Log Files”.

- Consider increasing the size of the log buffer. A large log buffer enables large transactions to run without a need to write the log to disk before the transactions commit. Thus, if you have transactions that update, insert, or delete many rows, making the log buffer larger saves disk I/O. Log buffer size is configured using the `innodb_log_buffer_size` configuration option.

8.5.4 Bulk Data Loading for InnoDB Tables

These performance tips supplement the general guidelines for fast inserts in Section 8.2.4.1, “Optimizing INSERT Statements”.

- When importing data into `InnoDB`, turn off autocommit mode, because it performs a log flush to disk for every insert. To disable autocommit during your import operation, surround it with `SET autocommit` and `COMMIT` statements:

```
SET autocommit=0;
... SQL import statements ...
COMMIT;
```

  The `mysqldump` option `--opt` creates dump files that are fast to import into an `InnoDB` table, even without wrapping them with the `SET autocommit` and `COMMIT` statements.

- If you have `UNIQUE` constraints on secondary keys, you can speed up table imports by temporarily turning off the uniqueness checks during the import session:

```
SET unique_checks=0;
... SQL import statements ...
SET unique_checks=1;
```

For big tables, this saves a lot of disk I/O because `InnoDB` can use its change buffer to write secondary index records in a batch. Be certain that the data contains no duplicate keys.

- If you have `FOREIGN KEY` constraints in your tables, you can speed up table imports by turning off the foreign key checks for the duration of the import session:

```
SET foreign_key_checks=0;
... SQL import statements ...
SET foreign_key_checks=1;
```

For big tables, this can save a lot of disk I/O.

- Use the multiple-row `INSERT` syntax to reduce communication overhead between the client and the server if you need to insert many rows:

```
INSERT INTO yourtable VALUES (1,2), (5,5), ...;
```

This tip is valid for inserts into any table, not just `InnoDB` tables.

- When doing bulk inserts into tables with auto-increment columns, set `innodb_autoinc_lock_mode` to 2 instead of the default value 1. See Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB” for details.

- When performing bulk inserts, it is faster to insert rows in `PRIMARY KEY` order. `InnoDB` tables use a clustered index, which makes it relatively fast to use data in the order of the `PRIMARY KEY`. Performing bulk inserts in `PRIMARY KEY` order is particularly important for tables that do not fit entirely within the buffer pool.

8.5.5 Optimizing InnoDB Queries

To tune queries for `InnoDB` tables, create an appropriate set of indexes on each table. See Section 8.3.1, “How MySQL Uses Indexes” for details. Follow these guidelines for `InnoDB` indexes:

- Because each `InnoDB` table has a primary key (whether you request one or not), specify a set of primary key columns for each table, columns that are used in the most important and time-critical queries.

- Do not specify too many or too long columns in the primary key, because these column values are duplicated in each secondary index. When an index contains unnecessary data, the I/O to read this data and memory to cache it reduce the performance and scalability of the server.

- Do not create a separate secondary index for each column, because each query can only make use of one index. Indexes on rarely tested columns or columns with only a few different values might not be helpful for any queries. If you have many queries for the same table, testing different combinations of columns, try to create a small number of concatenated indexes rather than a large number of single-column indexes. If an index contains all the columns needed for the result set (known as a covering index), the query might be able to avoid reading the table data at all.

- If an indexed column cannot contain any `NULL` values, declare it as `NOT NULL` when you create the table. The optimizer can better determine which index is most effective to use for a query, when it knows whether each column contains `NULL` values.

8.5.6 Optimizing InnoDB DDL Operations

- For DDL operations on tables and indexes (`CREATE`, `ALTER`, and `DROP` statements), the most significant aspect for `InnoDB` tables is that creating and dropping secondary indexes is much faster

in MySQL 5.5 and higher, than in earlier versions. See Section 14.16, “InnoDB Fast Index Creation” for details.

- “Fast index creation” makes it faster in some cases to drop an index before loading data into a table, then re-create the index after loading the data.
- Use `TRUNCATE TABLE` to empty a table, not `DELETE FROM tbl_name`. Foreign key constraints can make a `TRUNCATE` statement work like a regular `DELETE` statement, in which case a sequence of commands like `DROP TABLE` and `CREATE TABLE` might be fastest.
- Because the primary key is integral to the storage layout of each `InnoDB` table, and changing the definition of the primary key involves reorganizing the whole table, always set up the primary key as part of the `CREATE TABLE` statement, and plan ahead so that you do not need to `ALTER` or `DROP` the primary key afterward.

8.5.7 Optimizing InnoDB Disk I/O

If you follow best practices for database design and tuning techniques for SQL operations, but your database is still slow due to heavy disk I/O activity, consider these disk I/O optimizations. If the Unix `top` tool or the Windows Task Manager shows that the CPU usage percentage with your workload is less than 70%, your workload is probably disk-bound.

- Increase buffer pool size

  When table data is cached in the `InnoDB` buffer pool, it can be accessed repeatedly by queries without requiring any disk I/O. Specify the size of the buffer pool with the `innodb_buffer_pool_size` option. This memory area is important enough that it is typically recommended that `innodb_buffer_pool_size` is configured to 50 to 75 percent of system memory. For more information see, Section 8.12.4.1, “How MySQL Uses Memory”.

- Adjust the flush method

  In some versions of GNU/Linux and Unix, flushing files to disk with the Unix `fsync()` call (which `InnoDB` uses by default) and similar methods is surprisingly slow. If database write performance is an issue, conduct benchmarks with the `innodb_flush_method` parameter set to `O_DSYNC`.

- Use a noop or deadline I/O scheduler with native AIO on Linux

  `InnoDB` uses the asynchronous I/O subsystem (native AIO) on Linux to perform read-ahead and write requests for data file pages. This behavior is controlled by the `innodb_use_native_aio` configuration option, which is enabled by default. With native AIO, the type of I/O scheduler has greater influence on I/O performance. Generally, noop and deadline I/O schedulers are recommended. Conduct benchmarks to determine which I/O scheduler provides the best results for your workload and environment. For more information, see Section 14.9.7, “Using Asynchronous I/O on Linux”.

- Use direct I/O on Solaris 10 for x86_64 architecture

  When using the `InnoDB` storage engine on Solaris 10 for x86_64 architecture (AMD Opteron), use direct I/O for `InnoDB`-related files to avoid degradation of `InnoDB` performance. To use direct I/O for an entire UFS file system used for storing `InnoDB`-related files, mount it with the `forcedirectio` option; see `mount_ufs(1M)`. (The default on Solaris 10/x86_64 is *not* to use this option.) To apply direct I/O only to `InnoDB` file operations rather than the whole file system, set `innodb_flush_method = O_DIRECT`. With this setting, `InnoDB` calls `directio()` instead of `fcntl()` for I/O to data files (not for I/O to log files).

- Use raw storage for data and log files with Solaris 2.6 or later

  When using the `InnoDB` storage engine with a large `innodb_buffer_pool_size` value on any release of Solaris 2.6 and up and any platform (sparc/x86/x64/amd64), conduct benchmarks with

`InnoDB` data files and log files on raw devices or on a separate direct I/O UFS file system, using the `forcedirectio` mount option as described earlier. (It is necessary to use the mount option rather than setting `innodb_flush_method` if you want direct I/O for the log files.) Users of the Veritas file system VxFS should use the `convosync=direct` mount option.

Do not place other MySQL data files, such as those for `MyISAM` tables, on a direct I/O file system. Executables or libraries *must not* be placed on a direct I/O file system.

- Use additional storage devices

  Additional storage devices could be used to set up a RAID configuration. For related information, see Section 8.12.2, “Optimizing Disk I/O”.

  Alternatively, `InnoDB` tablespace data files and log files can be placed on different physical disks. For more information, refer to the following sections:

  - Section 14.9.1, “InnoDB Startup Configuration”
  - Section 14.11.1.3, “Moving or Copying InnoDB Tables”

- Non-rotational storage generally provides better performance for random I/O operations; and rotational storage for sequential I/O operations. When distributing data and log files across rotational and non-rotational storage devices, consider the type of I/O operations that are predominantly performed on each file.

  Random I/O-oriented files are typically file-per-table data files. Sequential I/O-oriented files include `InnoDB` system tablespace files (due to doublewrite buffering and change buffering) and log files such as binary log files and redo log files.

  Review settings for the following configuration options when using non-rotational storage:

  - `innodb_io_capacity`

    The default setting of 200 is generally sufficient for a lower-end non-rotational storage device. For higher-end, bus-attached devices, consider a higher setting such as 1000.

  - `innodb_log_file_size`

    If redo logs are on non-rotational storage, configure this option to maximize caching and write combining.

  Early-generation SSD devices often have a 4k sector size, but some newer devices have a 16k sector size. The default `InnoDB` page size is 16k. Keeping the page size close to the storage device block size minimizes the amount of unchanged data that is rewritten to disk.

  Ensure that TRIM support is enabled for your operating system. It is typically enabled by default.

- Increase I/O capacity to avoid backlogs

  If throughput drops periodically because of `InnoDB` checkpoint operations, consider increasing the value of the `innodb_io_capacity` configuration option. Higher values cause more frequent flushing, avoiding the backlog of work that can cause dips in throughput.

- Lower I/O capacity if flushing does not fall behind

  If the system is not falling behind with `InnoDB` flushing operations, consider lowering the value of the `innodb_io_capacity` configuration option. Typically, you keep this option value as low as practical, but not so low that it causes periodic drops in throughput as mentioned in the preceding bullet. In a typical scenario where you could lower the option value, you might see a combination like this in the output from `SHOW ENGINE INNODB STATUS`:

  - History list length low, below a few thousand.

- Insert buffer merges close to rows inserted.
- Modified pages in buffer pool consistently well below `innodb_max_dirty_pages_pct` of the buffer pool. (Measure at a time when the server is not doing bulk inserts; it is normal during bulk inserts for the modified pages percentage to rise significantly.)
- `Log sequence number - Last checkpoint` is at less than 7/8 or ideally less than 6/8 of the total size of the `InnoDB` log files.

8.5.8 Optimizing InnoDB Configuration Variables

Different settings work best for servers with light, predictable loads, versus servers that are running near full capacity all the time, or that experience spikes of high activity.

Because the `InnoDB` storage engine performs many of its optimizations automatically, many performance-tuning tasks involve monitoring to ensure that the database is performing well, and changing configuration options when performance drops. See Section 14.19, “InnoDB Integration with MySQL Performance Schema” for information about detailed `InnoDB` performance monitoring.

For a list of the most important and most recent `InnoDB` performance features, see Section 1.4, “What Is New in MySQL 5.5”. Even if you have used `InnoDB` tables in prior versions, these features might be new to you, because they are from the “InnoDB Plugin”. The Plugin co-existed alongside the built-in `InnoDB` in MySQL 5.1, and becomes the default storage engine in MySQL 5.5 and higher.

The main configuration steps you can perform include:

- Enabling `InnoDB` to use high-performance memory allocators on systems that include them. See Section 14.9.3, “Configuring the Memory Allocator for InnoDB”.
- Controlling the types of data change operations for which `InnoDB` buffers the changed data, to avoid frequent small disk writes. See Section 14.9.4, “Configuring InnoDB Change Buffering”. Because the default is to buffer all types of data change operations, only change this setting if you need to reduce the amount of buffering.
- Turning the adaptive hash indexing feature on and off using the `innodb_adaptive_hash_index` option. See Section 14.7.3, “Adaptive Hash Index” for more information. You might change this setting during periods of unusual activity, then restore it to its original setting.
- Setting a limit on the number of concurrent threads that `InnoDB` processes, if context switching is a bottleneck. See Section 14.9.5, “Configuring Thread Concurrency for InnoDB”.
- Controlling the amount of prefetching that `InnoDB` does with its read-ahead operations. When the system has unused I/O capacity, more read-ahead can improve the performance of queries. Too much read-ahead can cause periodic drops in performance on a heavily loaded system. See Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”.
- Increasing the number of background threads for read or write operations, if you have a high-end I/O subsystem that is not fully utilized by the default values. See Section 14.9.6, “Configuring the Number of Background InnoDB I/O Threads”.
- Controlling how much I/O `InnoDB` performs in the background. See Section 14.9.8, “Configuring the InnoDB Master Thread I/O Rate”. You might scale back this setting if you observe periodic drops in performance.
- Controlling the algorithm that determines when `InnoDB` performs certain types of background writes. See Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing”. The algorithm works for some types of workloads but not others, so might turn off this setting if you observe periodic drops in performance.
- Taking advantage of multicore processors and their cache memory configuration, to minimize delays in context switching. See Section 14.9.9, “Configuring Spin Lock Polling”.

- Preventing one-time operations such as table scans from interfering with the frequently accessed data stored in the `InnoDB` buffer cache. See Section 14.9.2.3, “Making the Buffer Pool Scan Resistant”.
- Adjusting log files to a size that makes sense for reliability and crash recovery. `InnoDB` log files have often been kept small to avoid long startup times after a crash. Optimizations introduced in MySQL 5.5 speed up certain steps of the crash recovery process. In particular, scanning the redo log and applying the redo log are faster due to improved algorithms for memory management. If you have kept your log files artificially small to avoid long startup times, you can now consider increasing log file size to reduce the I/O that occurs due recycling of redo log records.
- Configuring the size and number of instances for the `InnoDB` buffer pool, especially important for systems with multi-gigabyte buffer pools. See Section 14.9.2.2, “Configuring Multiple Buffer Pool Instances”.
- Increasing the maximum number of concurrent transactions, which dramatically improves scalability for the busiest databases. See Section 14.7.8, “Undo Logs”. Although this feature does not require any action during day-to-day operation, you must perform a slow shutdown during or after upgrading the database to MySQL 5.5 to enable the higher limit.
- Moving purge operations (a type of garbage collection) into a background thread. See Section 14.9.10, “Configuring InnoDB Purge Scheduling”. To effectively measure the results of this setting, tune the other I/O-related and thread-related configuration settings first.
- Reducing the amount of switching that `InnoDB` does between concurrent threads, so that SQL operations on a busy server do not queue up and form a “traffic jam”. Set a value for the `innodb_thread_concurrency` option, up to approximately 32 for a high-powered modern system. Increase the value for the `innodb_concurrency_tickets` option, typically to 5000 or so. This combination of options sets a cap on the number of threads that `InnoDB` processes at any one time, and allows each thread to do substantial work before being swapped out, so that the number of waiting threads stays low and operations can complete without excessive context switching.

8.5.9 Optimizing InnoDB for Systems with Many Tables

- `InnoDB` computes index cardinality values for a table the first time that table is accessed after startup, instead of storing such values in the table. This step can take significant time on systems that partition the data into many tables. Since this overhead only applies to the initial table open operation, to “warm up” a table for later use, access it immediately after startup by issuing a statement such as `SELECT 1 FROM tbl_name LIMIT 1`.

8.6 Optimizing for MyISAM Tables

The `MyISAM` storage engine performs best with read-mostly data or with low-concurrency operations, because table locks limit the ability to perform simultaneous updates. In MySQL 5.5, `InnoDB` is the default storage engine rather than `MyISAM`.

8.6.1 Optimizing MyISAM Queries

Some general tips for speeding up queries on `MyISAM` tables:

- To help MySQL better optimize queries, use `ANALYZE TABLE` or run `myisamchk --analyze` on a table after it has been loaded with data. This updates a value for each index part that indicates the average number of rows that have the same value. (For unique indexes, this is always 1.) MySQL uses this to decide which index to choose when you join two tables based on a nonconstant expression. You can check the result from the table analysis by using `SHOW INDEX FROM tbl_name` and examining the `Cardinality` value. `myisamchk --description --verbose` shows index distribution information.
- To sort an index and data according to an index, use `myisamchk --sort-index --sort-records=1` (assuming that you want to sort on index 1). This is a good way to make queries faster

if you have a unique index from which you want to read all rows in order according to the index. The first time you sort a large table this way, it may take a long time.

- Try to avoid complex `SELECT` queries on `MyISAM` tables that are updated frequently, to avoid problems with table locking that occur due to contention between readers and writers.

- `MyISAM` supports concurrent inserts: If a table has no free blocks in the middle of the data file, you can `INSERT` new rows into it at the same time that other threads are reading from the table. If it is important to be able to do this, consider using the table in ways that avoid deleting rows. Another possibility is to run `OPTIMIZE TABLE` to defragment the table after you have deleted a lot of rows from it. This behavior is altered by setting the `concurrent_insert` variable. You can force new rows to be appended (and therefore permit concurrent inserts), even in tables that have deleted rows. See Section 8.11.3, “Concurrent Inserts”.

- For `MyISAM` tables that change frequently, try to avoid all variable-length columns (`VARCHAR`, `BLOB`, and `TEXT`). The table uses dynamic row format if it includes even a single variable-length column. See Chapter 15, *Alternative Storage Engines*.

- It is normally not useful to split a table into different tables just because the rows become large. In accessing a row, the biggest performance hit is the disk seek needed to find the first byte of the row. After finding the data, most modern disks can read the entire row fast enough for most applications. The only cases where splitting up a table makes an appreciable difference is if it is a `MyISAM` table using dynamic row format that you can change to a fixed row size, or if you very often need to scan the table but do not need most of the columns. See Chapter 15, *Alternative Storage Engines*.

- Use `ALTER TABLE ... ORDER BY` *`expr1, expr2, ...`* if you usually retrieve rows in *`expr1, expr2, ...`* order. By using this option after extensive changes to the table, you may be able to get higher performance.

- If you often need to calculate results such as counts based on information from a lot of rows, it may be preferable to introduce a new table and update the counter in real time. An update of the following form is very fast:

  ```
  UPDATE tbl_name SET count_col=count_col+1 WHERE key_col=constant;
  ```

  This is very important when you use a MySQL storage engine such as `MyISAM` that has only table-level locking (multiple readers with single writers). This also gives better performance with most database systems, because the row locking manager in this case has less to do.

- Use `INSERT DELAYED` when you do not need to know when your data is written. This reduces the overall insertion impact because many rows can be written with a single disk write.

- Use `INSERT LOW_PRIORITY` when you want to give `SELECT` statements higher priority than your inserts.

  Use `SELECT HIGH_PRIORITY` to get retrievals that jump the queue. That is, the `SELECT` is executed even if there is another client waiting to do a write.

  `LOW_PRIORITY` and `HIGH_PRIORITY` have an effect only for storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

- Use `OPTIMIZE TABLE` periodically to avoid fragmentation with dynamic-format `MyISAM` tables. See Section 15.3.3, “MyISAM Table Storage Formats”.

- Declaring a `MyISAM` table with the `DELAY_KEY_WRITE=1` table option makes index updates faster because they are not flushed to disk until the table is closed. The downside is that if something kills the server while such a table is open, you must ensure that the table is okay by running the server with the `--myisam-recover-options` option, or by running `myisamchk` before restarting the server. (However, even in this case, you should not lose anything by using `DELAY_KEY_WRITE`, because the key information can always be generated from the data rows.)

- Strings are automatically prefix- and end-space compressed in `MyISAM` indexes. See Section 13.1.13, “CREATE INDEX Syntax”.
- You can increase performance by caching queries or answers in your application and then executing many inserts or updates together. Locking the table during this operation ensures that the index cache is only flushed once after all updates. You can also take advantage of MySQL's query cache to achieve similar results; see Section 8.10.3, “The MySQL Query Cache”.

8.6.2 Bulk Data Loading for MyISAM Tables

These performance tips supplement the general guidelines for fast inserts in Section 8.2.4.1, “Optimizing INSERT Statements”.

- To improve performance when multiple clients insert a lot of rows, use the `INSERT DELAYED` statement. See Section 13.2.5.3, “INSERT DELAYED Syntax”. This technique works for `MyISAM` and some other storage engines, but not `InnoDB`.
- For a `MyISAM` table, you can use concurrent inserts to add rows at the same time that `SELECT` statements are running, if there are no deleted rows in middle of the data file. See Section 8.11.3, “Concurrent Inserts”.
- With some extra work, it is possible to make `LOAD DATA INFILE` run even faster for a `MyISAM` table when the table has many indexes. Use the following procedure:

  1. Execute a `FLUSH TABLES` statement or a `mysqladmin flush-tables` command.
  2. Use `myisamchk --keys-used=0 -rq /path/to/db/tbl_name` to remove all use of indexes for the table.
  3. Insert data into the table with `LOAD DATA INFILE`. This does not update any indexes and therefore is very fast.
  4. If you intend only to read from the table in the future, use `myisampack` to compress it. See Section 15.3.3.3, “Compressed Table Characteristics”.
  5. Re-create the indexes with `myisamchk -rq /path/to/db/tbl_name`. This creates the index tree in memory before writing it to disk, which is much faster than updating the index during `LOAD DATA INFILE` because it avoids lots of disk seeks. The resulting index tree is also perfectly balanced.
  6. Execute a `FLUSH TABLES` statement or a `mysqladmin flush-tables` command.

  `LOAD DATA INFILE` performs the preceding optimization automatically if the `MyISAM` table into which you insert data is empty. The main difference between automatic optimization and using the procedure explicitly is that you can let `myisamchk` allocate much more temporary memory for the index creation than you might want the server to allocate for index re-creation when it executes the `LOAD DATA INFILE` statement.

  You can also disable or enable the nonunique indexes for a `MyISAM` table by using the following statements rather than `myisamchk`. If you use these statements, you can skip the `FLUSH TABLES` operations:

```
ALTER TABLE tbl_name DISABLE KEYS;
ALTER TABLE tbl_name ENABLE KEYS;
```

- To speed up `INSERT` operations that are performed with multiple statements for nontransactional tables, lock your tables:

```
LOCK TABLES a WRITE;
INSERT INTO a VALUES (1,23),(2,34),(4,33);
```

```
INSERT INTO a VALUES (8,26),(6,29);
...
UNLOCK TABLES;
```

This benefits performance because the index buffer is flushed to disk only once, after all `INSERT` statements have completed. Normally, there would be as many index buffer flushes as there are `INSERT` statements. Explicit locking statements are not needed if you can insert all rows with a single `INSERT`.

Locking also lowers the total time for multiple-connection tests, although the maximum wait time for individual connections might go up because they wait for locks. Suppose that five clients attempt to perform inserts simultaneously as follows:

- Connection 1 does 1000 inserts
- Connections 2, 3, and 4 do 1 insert
- Connection 5 does 1000 inserts

If you do not use locking, connections 2, 3, and 4 finish before 1 and 5. If you use locking, connections 2, 3, and 4 probably do not finish before 1 or 5, but the total time should be about 40% faster.

`INSERT`, `UPDATE`, and `DELETE` operations are very fast in MySQL, but you can obtain better overall performance by adding locks around everything that does more than about five successive inserts or updates. If you do very many successive inserts, you could do a `LOCK TABLES` followed by an `UNLOCK TABLES` once in a while (each 1,000 rows or so) to permit other threads to access table. This would still result in a nice performance gain.

`INSERT` is still much slower for loading data than `LOAD DATA INFILE`, even when using the strategies just outlined.

- To increase performance for `MyISAM` tables, for both `LOAD DATA INFILE` and `INSERT`, enlarge the key cache by increasing the `key_buffer_size` system variable. See Section 5.1.1, “Configuring the Server”.

8.6.3 Optimizing REPAIR TABLE Statements

`REPAIR TABLE` for `MyISAM` tables is similar to using `myisamchk` for repair operations, and some of the same performance optimizations apply:

- `myisamchk` has variables that control memory allocation. You may be able to its improve performance by setting these variables, as described in Section 4.6.3.6, “myisamchk Memory Usage”.
- For `REPAIR TABLE`, the same principle applies, but because the repair is done by the server, you set server system variables instead of `myisamchk` variables. Also, in addition to setting memory-allocation variables, increasing the `myisam_max_sort_file_size` system variable increases the likelihood that the repair will use the faster filesort method and avoid the slower repair by key cache method. Set the variable to the maximum file size for your system, after checking to be sure that there is enough free space to hold a copy of the table files. The free space must be available in the file system containing the original table files.

Suppose that a `myisamchk` table-repair operation is done using the following options to set its memory-allocation variables:

```
--key_buffer_size=128M --myisam_sort_buffer_size=256M
--read_buffer_size=64M --write_buffer_size=64M
```

Some of those `myisamchk` variables correspond to server system variables:

myisamchk Variable	System Variable
key_buffer_size	key_buffer_size
myisam_sort_buffer_size	myisam_sort_buffer_size
read_buffer_size	read_buffer_size
write_buffer_size	none

Each of the server system variables can be set at runtime, and some of them (myisam_sort_buffer_size, read_buffer_size) have a session value in addition to a global value. Setting a session value limits the effect of the change to your current session and does not affect other users. Changing a global-only variable (key_buffer_size, myisam_max_sort_file_size) affects other users as well. For key_buffer_size, you must take into account that the buffer is shared with those users. For example, if you set the myisamchk key_buffer_size variable to 128MB, you could set the corresponding key_buffer_size system variable larger than that (if it is not already set larger), to permit key buffer use by activity in other sessions. However, changing the global key buffer size invalidates the buffer, causing increased disk I/O and slowdown for other sessions. An alternative that avoids this problem is to use a separate key cache, assign to it the indexes from the table to be repaired, and deallocate it when the repair is complete. See Section 8.10.2.2, “Multiple Key Caches”.

Based on the preceding remarks, a REPAIR TABLE operation can be done as follows to use settings similar to the myisamchk command. Here a separate 128MB key buffer is allocated and the file system is assumed to permit a file size of at least 100GB.

```
SET SESSION myisam_sort_buffer_size = 256*1024*1024;
SET SESSION read_buffer_size = 64*1024*1024;
SET GLOBAL myisam_max_sort_file_size = 100*1024*1024*1024;
SET GLOBAL repair_cache.key_buffer_size = 128*1024*1024;
CACHE INDEX tbl_name IN repair_cache;
LOAD INDEX INTO CACHE tbl_name;
REPAIR TABLE tbl_name ;
SET GLOBAL repair_cache.key_buffer_size = 0;
```

If you intend to change a global variable but want to do so only for the duration of a REPAIR TABLE operation to minimally affect other users, save its value in a user variable and restore it afterward. For example:

```
SET @old_myisam_sort_buffer_size = @@global.myisam_max_sort_file_size;
SET GLOBAL myisam_max_sort_file_size = 100*1024*1024*1024;
REPAIR TABLE tbl_name ;
SET GLOBAL myisam_max_sort_file_size = @old_myisam_max_sort_file_size;
```

The system variables that affect REPAIR TABLE can be set globally at server startup if you want the values to be in effect by default. For example, add these lines to the server my.cnf file:

```
[mysqld]
myisam_sort_buffer_size=256M
key_buffer_size=1G
myisam_max_sort_file_size=100G
```

These settings do not include read_buffer_size. Setting read_buffer_size globally to a large value does so for all sessions and can cause performance to suffer due to excessive memory allocation for a server with many simultaneous sessions.

8.7 Optimizing for MEMORY Tables

Consider using MEMORY tables for noncritical data that is accessed often, and is read-only or rarely updated. Benchmark your application against equivalent InnoDB or MyISAM tables under a realistic

workload, to confirm that any additional performance is worth the risk of losing data, or the overhead of copying data from a disk-based table at application start.

For best performance with `MEMORY` tables, examine the kinds of queries against each table, and specify the type to use for each associated index, either a B-tree index or a hash index. On the `CREATE INDEX` statement, use the clause `USING BTREE` or `USING HASH`. B-tree indexes are fast for queries that do greater-than or less-than comparisons through operators such as `>` or `BETWEEN`. Hash indexes are only fast for queries that look up single values through the `=` operator, or a restricted set of values through the `IN` operator. For why `USING BTREE` is often a better choice than the default `USING HASH`, see Section 8.2.1.16, “Avoiding Full Table Scans”. For implementation details of the different types of `MEMORY` indexes, see Section 8.3.8, “Comparison of B-Tree and Hash Indexes”.

8.8 Understanding the Query Execution Plan

Depending on the details of your tables, columns, indexes, and the conditions in your `WHERE` clause, the MySQL optimizer considers many techniques to efficiently perform the lookups involved in an SQL query. A query on a huge table can be performed without reading all the rows; a join involving several tables can be performed without comparing every combination of rows. The set of operations that the optimizer chooses to perform the most efficient query is called the “query execution plan”, also known as the `EXPLAIN` plan. Your goals are to recognize the aspects of the `EXPLAIN` plan that indicate a query is optimized well, and to learn the SQL syntax and indexing techniques to improve the plan if you see some inefficient operations.

8.8.1 Optimizing Queries with EXPLAIN

The `EXPLAIN` statement provides information about how MySQL executes statements:

- When you precede a `SELECT` statement with the keyword `EXPLAIN`, MySQL displays information from the optimizer about the statement execution plan. That is, MySQL explains how it would process the statement, including information about how tables are joined and in which order. For information about using `EXPLAIN` to obtain execution plan information, see Section 8.8.2, “EXPLAIN Output Format”.
- `EXPLAIN EXTENDED` produces additional execution plan information. See Section 8.8.3, “Extended EXPLAIN Output Format”.
- `EXPLAIN PARTITIONS` is useful for examining queries involving partitioned tables. See Section 19.3.4, “Obtaining Information About Partitions”.

With the help of `EXPLAIN`, you can see where you should add indexes to tables so that the statement executes faster by using indexes to find rows. You can also use `EXPLAIN` to check whether the optimizer joins the tables in an optimal order. To give a hint to the optimizer to use a join order corresponding to the order in which the tables are named in a `SELECT` statement, begin the statement with `SELECT STRAIGHT_JOIN` rather than just `SELECT`. (See Section 13.2.9, “SELECT Syntax”.)

If you have a problem with indexes not being used when you believe that they should be, run `ANALYZE TABLE` to update table statistics, such as cardinality of keys, that can affect the choices the optimizer makes. See Section 13.7.2.1, “ANALYZE TABLE Syntax”.

Note

`EXPLAIN` can also be used to obtain information about the columns in a table. `EXPLAIN *tbl_name*` is synonymous with `DESCRIBE *tbl_name*` and `SHOW COLUMNS FROM *tbl_name*`. For more information, see Section 13.8.1, “DESCRIBE Syntax”, and Section 13.7.5.6, “SHOW COLUMNS Syntax”.

8.8.2 EXPLAIN Output Format

The `EXPLAIN` statement provides information about the execution plan for a `SELECT` statement.

`EXPLAIN` returns a row of information for each table used in the `SELECT` statement. It lists the tables in the output in the order that MySQL would read them while processing the statement. MySQL resolves all joins using a nested-loop join method. This means that MySQL reads a row from the first table, and then finds a matching row in the second table, the third table, and so on. When all tables are processed, MySQL outputs the selected columns and backtracks through the table list until a table is found for which there are more matching rows. The next row is read from this table and the process continues with the next table.

When the `EXTENDED` keyword is used, `EXPLAIN` produces extra information that can be viewed by issuing a `SHOW WARNINGS` statement following the `EXPLAIN` statement. `EXPLAIN EXTENDED` also displays the `filtered` column. See Section 8.8.3, “Extended EXPLAIN Output Format”.

Note

You cannot use the `EXTENDED` and `PARTITIONS` keywords together in the same `EXPLAIN` statement.

Note

MySQL Workbench has a Visual Explain capability that provides a visual representation of `EXPLAIN` output. See Tutorial: Using Visual Explain to Improve Query Performance.

- EXPLAIN Output Columns
- EXPLAIN Join Types
- EXPLAIN Extra Information
- EXPLAIN Output Interpretation

EXPLAIN Output Columns

This section describes the output columns produced by `EXPLAIN`. Later sections provide additional information about the `type` and `Extra` columns.

Each output row from `EXPLAIN` provides information about one table. Each row contains the values summarized in Table 8.1, “EXPLAIN Output Columns”, and described in more detail following the table.

Table 8.1 EXPLAIN Output Columns

Column	Meaning
`id`	The `SELECT` identifier
`select_type`	The `SELECT` type
`table`	The table for the output row
`partitions`	The matching partitions
`type`	The join type
`possible_keys`	The possible indexes to choose
`key`	The index actually chosen
`key_len`	The length of the chosen key
`ref`	The columns compared to the index
`rows`	Estimate of rows to be examined
`filtered`	Percentage of rows filtered by table condition
`Extra`	Additional information

- `id`

  The `SELECT` identifier. This is the sequential number of the `SELECT` within the query. The value can be `NULL` if the row refers to the union result of other rows. In this case, the `table` column shows a value like `<unionM,N>` to indicate that the row refers to the union of the rows with `id` values of *`M`* and *`N`*.

- `select_type`

  The type of `SELECT`, which can be any of those shown in the following table.

`select_type` Value	**Meaning**
`SIMPLE`	Simple `SELECT` (not using `UNION` or subqueries)
`PRIMARY`	Outermost `SELECT`
`UNION`	Second or later `SELECT` statement in a `UNION`
`DEPENDENT UNION`	Second or later `SELECT` statement in a `UNION`, dependent on outer query
`UNION RESULT`	Result of a `UNION`.
`SUBQUERY`	First `SELECT` in subquery
`DEPENDENT SUBQUERY`	First `SELECT` in subquery, dependent on outer query
`DERIVED`	Derived table `SELECT` (subquery in `FROM` clause)
`UNCACHEABLE SUBQUERY`	A subquery for which the result cannot be cached and must be re-evaluated for each row of the outer query
`UNCACHEABLE UNION`	The second or later select in a `UNION` that belongs to an uncacheable subquery (see `UNCACHEABLE SUBQUERY`)

  `DEPENDENT` typically signifies the use of a correlated subquery. See Section 13.2.10.7, “Correlated Subqueries”.

  `DEPENDENT SUBQUERY` evaluation differs from `UNCACHEABLE SUBQUERY` evaluation. For `DEPENDENT SUBQUERY`, the subquery is re-evaluated only once for each set of different values of the variables from its outer context. For `UNCACHEABLE SUBQUERY`, the subquery is re-evaluated for each row of the outer context.

  Cacheability of subqueries differs from caching of query results in the query cache (which is described in Section 8.10.3.1, “How the Query Cache Operates”). Subquery caching occurs during query execution, whereas the query cache is used to store results only after query execution finishes.

- `table`

  The name of the table to which the row of output refers. This can also be one of the following values:

  - `<unionM,N>`: The row refers to the union of the rows with `id` values of *`M`* and *`N`*.
  - `<derivedN>`: The row refers to the derived table result for the row with an `id` value of *`N`*. A derived table may result, for example, from a subquery in the `FROM` clause.

- `partitions`

  The partitions from which records would be matched by the query. This column is displayed only if the `PARTITIONS` keyword is used. The value is `NULL` for nonpartitioned tables. See Section 19.3.4, “Obtaining Information About Partitions”.

- `type`

  The join type. For descriptions of the different types, see `EXPLAIN` Join Types.

- `possible_keys`

  The `possible_keys` column indicates the indexes from which MySQL can choose to find the rows in this table. Note that this column is totally independent of the order of the tables as displayed in the output from `EXPLAIN`. That means that some of the keys in `possible_keys` might not be usable in practice with the generated table order.

  If this column is `NULL`, there are no relevant indexes. In this case, you may be able to improve the performance of your query by examining the `WHERE` clause to check whether it refers to some column or columns that would be suitable for indexing. If so, create an appropriate index and check the query with `EXPLAIN` again. See Section 13.1.7, “ALTER TABLE Syntax”.

  To see what indexes a table has, use `SHOW INDEX FROM *tbl_name*`.

- `key`

  The `key` column indicates the key (index) that MySQL actually decided to use. If MySQL decides to use one of the `possible_keys` indexes to look up rows, that index is listed as the key value.

  It is possible that `key` will name an index that is not present in the `possible_keys` value. This can happen if none of the `possible_keys` indexes are suitable for looking up rows, but all the columns selected by the query are columns of some other index. That is, the named index covers the selected columns, so although it is not used to determine which rows to retrieve, an index scan is more efficient than a data row scan.

  For `InnoDB`, a secondary index might cover the selected columns even if the query also selects the primary key because `InnoDB` stores the primary key value with each secondary index. If `key` is `NULL`, MySQL found no index to use for executing the query more efficiently.

  To force MySQL to use or ignore an index listed in the `possible_keys` column, use `FORCE INDEX`, `USE INDEX`, or `IGNORE INDEX` in your query. See Section 8.9.3, “Index Hints”.

  For `MyISAM` and `NDB` tables, running `ANALYZE TABLE` helps the optimizer choose better indexes. For `NDB` tables, this also improves performance of distributed pushed-down joins. For `MyISAM` tables, `myisamchk --analyze` does the same as `ANALYZE TABLE`. See Section 7.6, “MyISAM Table Maintenance and Crash Recovery”.

- `key_len`

  The `key_len` column indicates the length of the key that MySQL decided to use. The value of `key_len` enables you to determine how many parts of a multiple-part key MySQL actually uses. If the `key` column says `NULL`, the `len_len` column also says `NULL`.

  Due to the key storage format, the key length is one greater for a column that can be `NULL` than for a `NOT NULL` column.

- `ref`

  The `ref` column shows which columns or constants are compared to the index named in the `key` column to select rows from the table.

- `rows`

  The `rows` column indicates the number of rows MySQL believes it must examine to execute the query.

  For `InnoDB` tables, this number is an estimate, and may not always be exact.

- `filtered`

  The `filtered` column indicates an estimated percentage of table rows that will be filtered by the table condition. That is, `rows` shows the estimated number of rows examined and `rows` × `filtered`

/ `100` shows the number of rows that will be joined with previous tables. This column is displayed if you use `EXPLAIN EXTENDED`.

- `Extra`

  This column contains additional information about how MySQL resolves the query. For descriptions of the different values, see `EXPLAIN` Extra Information.

EXPLAIN Join Types

The `type` column of `EXPLAIN` output describes how tables are joined. The following list describes the join types, ordered from the best type to the worst:

- `system`

  The table has only one row (= system table). This is a special case of the `const` join type.

- `const`

  The table has at most one matching row, which is read at the start of the query. Because there is only one row, values from the column in this row can be regarded as constants by the rest of the optimizer. `const` tables are very fast because they are read only once.

  `const` is used when you compare all parts of a `PRIMARY KEY` or `UNIQUE` index to constant values. In the following queries, *`tbl_name`* can be used as a `const` table:

```
SELECT * FROM tbl_name WHERE primary_key=1;

SELECT * FROM tbl_name
  WHERE primary_key_part1=1 AND primary_key_part2=2;
```

- `eq_ref`

  One row is read from this table for each combination of rows from the previous tables. Other than the `system` and `const` types, this is the best possible join type. It is used when all parts of an index are used by the join and the index is a `PRIMARY KEY` or `UNIQUE NOT NULL` index.

  `eq_ref` can be used for indexed columns that are compared using the `=` operator. The comparison value can be a constant or an expression that uses columns from tables that are read before this table. In the following examples, MySQL can use an `eq_ref` join to process *`ref_table`*:

```
SELECT * FROM ref_table,other_table
  WHERE ref_table.key_column=other_table.column;

SELECT * FROM ref_table,other_table
  WHERE ref_table.key_column_part1=other_table.column
  AND ref_table.key_column_part2=1;
```

- `ref`

  All rows with matching index values are read from this table for each combination of rows from the previous tables. `ref` is used if the join uses only a leftmost prefix of the key or if the key is not a `PRIMARY KEY` or `UNIQUE` index (in other words, if the join cannot select a single row based on the key value). If the key that is used matches only a few rows, this is a good join type.

  `ref` can be used for indexed columns that are compared using the `=` or `<=>` operator. In the following examples, MySQL can use a `ref` join to process *`ref_table`*:

```
SELECT * FROM ref_table WHERE key_column=expr;

SELECT * FROM ref_table,other_table
```

```
  WHERE ref_table.key_column=other_table.column;

SELECT * FROM ref_table,other_table
  WHERE ref_table.key_column_part1=other_table.column
  AND ref_table.key_column_part2=1;
```

- `fulltext`

  The join is performed using a `FULLTEXT` index.

- `ref_or_null`

  This join type is like `ref`, but with the addition that MySQL does an extra search for rows that contain `NULL` values. This join type optimization is used most often in resolving subqueries. In the following examples, MySQL can use a `ref_or_null` join to process *`ref_table`*:

  ```
  SELECT * FROM ref_table
    WHERE key_column=expr OR key_column IS NULL;
  ```

  See Section 8.2.1.9, “IS NULL Optimization”.

- `index_merge`

  This join type indicates that the Index Merge optimization is used. In this case, the `key` column in the output row contains a list of indexes used, and `key_len` contains a list of the longest key parts for the indexes used. For more information, see Section 8.2.1.3, “Index Merge Optimization”.

- `unique_subquery`

  This type replaces `eq_ref` for some `IN` subqueries of the following form:

  ```
  value IN (SELECT primary_key FROM single_table WHERE some_expr)
  ```

  `unique_subquery` is just an index lookup function that replaces the subquery completely for better efficiency.

- `index_subquery`

  This join type is similar to `unique_subquery`. It replaces `IN` subqueries, but it works for nonunique indexes in subqueries of the following form:

  ```
  value IN (SELECT key_column FROM single_table WHERE some_expr)
  ```

- `range`

  Only rows that are in a given range are retrieved, using an index to select the rows. The `key` column in the output row indicates which index is used. The `key_len` contains the longest key part that was used. The `ref` column is `NULL` for this type.

  `range` can be used when a key column is compared to a constant using any of the `=`, `<>`, `>`, `>=`, `<`, `<=`, `IS NULL`, `<=>`, `BETWEEN`, or `IN()` operators:

  ```
  SELECT * FROM tbl_name
    WHERE key_column = 10;

  SELECT * FROM tbl_name
    WHERE key_column BETWEEN 10 and 20;

  SELECT * FROM tbl_name
    WHERE key_column IN (10,20,30);

  SELECT * FROM tbl_name
  ```

```
WHERE key_part1 = 10 AND key_part2 IN (10,20,30);
```

- `index`

  The `index` join type is the same as `ALL`, except that the index tree is scanned. This occurs two ways:

  - If the index is a covering index for the queries and can be used to satisfy all data required from the table, only the index tree is scanned. In this case, the `Extra` column says `Using index`. An index-only scan usually is faster than `ALL` because the size of the index usually is smaller than the table data.
  - A full table scan is performed using reads from the index to look up data rows in index order. `Uses index` does not appear in the `Extra` column.

  MySQL can use this join type when the query uses only columns that are part of a single index.

- `ALL`

  A full table scan is done for each combination of rows from the previous tables. This is normally not good if the table is the first table not marked `const`, and usually *very* bad in all other cases. Normally, you can avoid `ALL` by adding indexes that enable row retrieval from the table based on constant values or column values from earlier tables.

EXPLAIN Extra Information

The `Extra` column of `EXPLAIN` output contains additional information about how MySQL resolves the query. The following list explains the values that can appear in this column. If you want to make your queries as fast as possible, look out for `Extra` values of `Using filesort` and `Using temporary`.

- `Child of 'table' pushed join@1`

  This table is referenced as the child of *`table`* in a join that can be pushed down to the NDB kernel. Applies only in MySQL NDB Cluster 7.2 and later, when pushed-down joins are enabled. See the description of the `ndb_join_pushdown` server system variable for more information and examples.

- `const row not found`

  For a query such as `SELECT ... FROM tbl_name`, the table was empty.

- `Distinct`

  MySQL is looking for distinct values, so it stops searching for more rows for the current row combination after it has found the first matching row.

- `Full scan on NULL key`

  This occurs for subquery optimization as a fallback strategy when the optimizer cannot use an index-lookup access method.

- `Impossible HAVING`

  The `HAVING` clause is always false and cannot select any rows.

- `Impossible WHERE`

  The `WHERE` clause is always false and cannot select any rows.

- `Impossible WHERE noticed after reading const tables`

  MySQL has read all `const` (and `system`) tables and notice that the `WHERE` clause is always false.

- `No matching min/max row`

No row satisfies the condition for a query such as `SELECT MIN(...) FROM ... WHERE condition`.

- `no matching row in const table`

  For a query with a join, there was an empty table or a table with no rows satisfying a unique index condition.

- `No tables used`

  The query has no `FROM` clause, or has a `FROM DUAL` clause.

- `Not exists`

  MySQL was able to do a `LEFT JOIN` optimization on the query and does not examine more rows in this table for the previous row combination after it finds one row that matches the `LEFT JOIN` criteria. Here is an example of the type of query that can be optimized this way:

  ```
  SELECT * FROM t1 LEFT JOIN t2 ON t1.id=t2.id
    WHERE t2.id IS NULL;
  ```

  Assume that `t2.id` is defined as `NOT NULL`. In this case, MySQL scans `t1` and looks up the rows in `t2` using the values of `t1.id`. If MySQL finds a matching row in `t2`, it knows that `t2.id` can never be `NULL`, and does not scan through the rest of the rows in `t2` that have the same `id` value. In other words, for each row in `t1`, MySQL needs to do only a single lookup in `t2`, regardless of how many rows actually match in `t2`.

- `Range checked for each record (index map: N)`

  MySQL found no good index to use, but found that some of indexes might be used after column values from preceding tables are known. For each row combination in the preceding tables, MySQL checks whether it is possible to use a `range` or `index_merge` access method to retrieve rows. This is not very fast, but is faster than performing a join with no index at all. The applicability criteria are as described in Section 8.2.1.2, “Range Optimization”, and Section 8.2.1.3, “Index Merge Optimization”, with the exception that all column values for the preceding table are known and considered to be constants.

  Indexes are numbered beginning with 1, in the same order as shown by `SHOW INDEX` for the table. The index map value *`N`* is a bitmask value that indicates which indexes are candidates. For example, a value of `0x19` (binary 11001) means that indexes 1, 4, and 5 will be considered.

- `Scanned N databases`

  This indicates how many directory scans the server performs when processing a query for `INFORMATION_SCHEMA` tables, as described in Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”. The value of *`N`* can be 0, 1, or `all`.

- `Select tables optimized away`

  The optimizer determined 1) that at most one row should be returned, and 2) that to produce this row, a deterministic set of rows must be read. When the rows to be read can be read during the optimization phase (for example, by reading index rows), there is no need to read any tables during query execution.

  The first condition is fulfilled when the query is implicitly grouped (contains an aggregate function but no `GROUP BY` clause). The second condition is fulfilled when one row lookup is performed per index used. The number of indexes read determines the number of rows to read.

  Consider the following implicitly grouped query:

  ```
  ```

```
SELECT MIN(c1), MIN(c2) FROM t1;
```

Suppose that `MIN(c1)` can be retrieved by reading one index row and `MIN(c2)` can be retrieved by reading one row from a different index. That is, for each column `c1` and `c2`, there exists an index where the column is the first column of the index. In this case, one row is returned, produced by reading two deterministic rows.

This `Extra` value does not occur if the rows to read are not deterministic. Consider this query:

```
SELECT MIN(c2) FROM t1 WHERE c1 <= 10;
```

Suppose that `(c1, c2)` is a covering index. Using this index, all rows with `c1 <= 10` must be scanned to find the minimum `c2` value. By contrast, consider this query:

```
SELECT MIN(c2) FROM t1 WHERE c1 = 10;
```

In this case, the first index row with `c1 = 10` contains the minimum `c2` value. Only one row must be read to produce the returned row.

For storage engines that maintain an exact row count per table (such as `MyISAM`, but not `InnoDB`), this `Extra` value can occur for `COUNT(*)` queries for which the `WHERE` clause is missing or always true and there is no `GROUP BY` clause. (This is an instance of an implicitly grouped query where the storage engine influences whether a deterministic number of rows can be read.)

- `Skip_open_table`, `Open_frm_only`, `Open_full_table`

  These values indicate file-opening optimizations that apply to queries for `INFORMATION_SCHEMA` tables, as described in Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”.

  - `Skip_open_table`: Table files do not need to be opened. The information has already become available within the query by scanning the database directory.
  - `Open_frm_only`: Only the table's `.frm` file need be opened.
  - `Open_full_table`: The unoptimized information lookup. The `.frm`, `.MYD`, and `.MYI` files must be opened.

- `unique row not found`

  For a query such as `SELECT ... FROM tbl_name`, no rows satisfy the condition for a `UNIQUE` index or `PRIMARY KEY` on the table.

- `Using filesort`

  MySQL must do an extra pass to find out how to retrieve the rows in sorted order. The sort is done by going through all rows according to the join type and storing the sort key and pointer to the row for all rows that match the `WHERE` clause. The keys then are sorted and the rows are retrieved in sorted order. See Section 8.2.1.10, “ORDER BY Optimization”.

- `Using index`

  The column information is retrieved from the table using only information in the index tree without having to do an additional seek to read the actual row. This strategy can be used when the query uses only columns that are part of a single index.

  For `InnoDB` tables that have a user-defined clustered index, that index can be used even when `Using index` is absent from the `Extra` column. This is the case if `type` is `index` and `key` is `PRIMARY`.

- `Using index for group-by`

Similar to the `Using index` table access method, `Using index for group-by` indicates that MySQL found an index that can be used to retrieve all columns of a `GROUP BY` or `DISTINCT` query without any extra disk access to the actual table. Additionally, the index is used in the most efficient way so that for each group, only a few index entries are read. For details, see Section 8.2.1.11, "GROUP BY Optimization".

- `Using join buffer`

  Tables from earlier joins are read in portions into the join buffer, and then their rows are used from the buffer to perform the join with the current table.

- `Using sort_union(...)`, `Using union(...)`, `Using intersect(...)`

  These indicate the particular algorithm showing how index scans are merged for the `index_merge` join type. See Section 8.2.1.3, "Index Merge Optimization".

- `Using temporary`

  To resolve the query, MySQL needs to create a temporary table to hold the result. This typically happens if the query contains `GROUP BY` and `ORDER BY` clauses that list columns differently.

- `Using where`

  A `WHERE` clause is used to restrict which rows to match against the next table or send to the client. Unless you specifically intend to fetch or examine all rows from the table, you may have something wrong in your query if the `Extra` value is not `Using where` and the table join type is `ALL` or `index`. Even if you are using an index for all parts of a `WHERE` clause, you may see `Using where` if the column can be `NULL`.

- `Using where with pushed condition`

  This item applies to `NDB` tables *only*. It means that NDB Cluster is using the Condition Pushdown optimization to improve the efficiency of a direct comparison between a nonindexed column and a constant. In such cases, the condition is "pushed down" to the cluster's data nodes and is evaluated on all data nodes simultaneously. This eliminates the need to send nonmatching rows over the network, and can speed up such queries by a factor of 5 to 10 times over cases where Condition Pushdown could be but is not used. For more information, see Section 8.2.1.4, "Engine Condition Pushdown Optimization".

EXPLAIN Output Interpretation

You can get a good indication of how good a join is by taking the product of the values in the `rows` column of the `EXPLAIN` output. This should tell you roughly how many rows MySQL must examine to execute the query. If you restrict queries with the `max_join_size` system variable, this row product also is used to determine which multiple-table `SELECT` statements to execute and which to abort. See Section 5.1.1, "Configuring the Server".

The following example shows how a multiple-table join can be optimized progressively based on the information provided by `EXPLAIN`.

Suppose that you have the `SELECT` statement shown here and that you plan to examine it using `EXPLAIN`:

```
EXPLAIN SELECT tt.TicketNumber, tt.TimeIn,
               tt.ProjectReference, tt.EstimatedShipDate,
               tt.ActualShipDate, tt.ClientID,
               tt.ServiceCodes, tt.RepetitiveID,
               tt.CurrentProcess, tt.CurrentDPPerson,
               tt.RecordVolume, tt.DPPrinted, et.COUNTRY,
               et_1.COUNTRY, do.CUSTNAME
        FROM tt, et, et AS et_1, do
```

```
       WHERE tt.SubmitTime IS NULL
         AND tt.ActualPC = et.EMPLOYID
         AND tt.AssignedPC = et_1.EMPLOYID
         AND tt.ClientID = do.CUSTNMBR;
```

For this example, make the following assumptions:

- The columns being compared have been declared as follows.

Table	Column	Data Type
tt	ActualPC	CHAR(10)
tt	AssignedPC	CHAR(10)
tt	ClientID	CHAR(10)
et	EMPLOYID	CHAR(15)
do	CUSTNMBR	CHAR(15)

- The tables have the following indexes.

Table	Index
tt	ActualPC
tt	AssignedPC
tt	ClientID
et	EMPLOYID (primary key)
do	CUSTNMBR (primary key)

- The tt.ActualPC values are not evenly distributed.

Initially, before any optimizations have been performed, the EXPLAIN statement produces the following information:

```
table type possible_keys key  key_len ref  rows  Extra
et    ALL  PRIMARY       NULL NULL    NULL 74
do    ALL  PRIMARY       NULL NULL    NULL 2135
et_1  ALL  PRIMARY       NULL NULL    NULL 74
tt    ALL  AssignedPC,   NULL NULL    NULL 3872
           ClientID,
           ActualPC
      Range checked for each record (index map: 0x23)
```

Because type is ALL for each table, this output indicates that MySQL is generating a Cartesian product of all the tables; that is, every combination of rows. This takes quite a long time, because the product of the number of rows in each table must be examined. For the case at hand, this product is 74 × 2135 × 74 × 3872 = 45,268,558,720 rows. If the tables were bigger, you can only imagine how long it would take.

One problem here is that MySQL can use indexes on columns more efficiently if they are declared as the same type and size. In this context, VARCHAR and CHAR are considered the same if they are declared as the same size. tt.ActualPC is declared as CHAR(10) and et.EMPLOYID is CHAR(15), so there is a length mismatch.

To fix this disparity between column lengths, use ALTER TABLE to lengthen ActualPC from 10 characters to 15 characters:

```
mysql> ALTER TABLE tt MODIFY ActualPC VARCHAR(15);
```

Now tt.ActualPC and et.EMPLOYID are both VARCHAR(15). Executing the EXPLAIN statement again produces this result:

```
table type   possible_keys key     key_len ref         rows    Extra
tt    ALL    AssignedPC,   NULL    NULL    NULL        3872    Using
             ClientID,                                         where
             ActualPC
do    ALL    PRIMARY       NULL    NULL    NULL        2135
      Range checked for each record (index map: 0x1)
et_1  ALL    PRIMARY       NULL    NULL    NULL        74
      Range checked for each record (index map: 0x1)
et    eq_ref PRIMARY       PRIMARY 15      tt.ActualPC 1
```

This is not perfect, but is much better: The product of the `rows` values is less by a factor of 74. This version executes in a couple of seconds.

A second alteration can be made to eliminate the column length mismatches for the `tt.AssignedPC = et_1.EMPLOYID` and `tt.ClientID = do.CUSTNMBR` comparisons:

```
mysql> ALTER TABLE tt MODIFY AssignedPC VARCHAR(15),
                      MODIFY ClientID   VARCHAR(15);
```

After that modification, `EXPLAIN` produces the output shown here:

```
table type   possible_keys key      key_len ref           rows Extra
et    ALL    PRIMARY       NULL     NULL    NULL          74
tt    ref    AssignedPC,   ActualPC 15      et.EMPLOYID   52   Using
             ClientID,                                         where
             ActualPC
et_1  eq_ref PRIMARY       PRIMARY  15      tt.AssignedPC 1
do    eq_ref PRIMARY       PRIMARY  15      tt.ClientID   1
```

At this point, the query is optimized almost as well as possible. The remaining problem is that, by default, MySQL assumes that values in the `tt.ActualPC` column are evenly distributed, and that is not the case for the `tt` table. Fortunately, it is easy to tell MySQL to analyze the key distribution:

```
mysql> ANALYZE TABLE tt;
```

With the additional index information, the join is perfect and `EXPLAIN` produces this result:

```
table type   possible_keys key     key_len ref           rows Extra
tt    ALL    AssignedPC    NULL    NULL    NULL          3872 Using
             ClientID,                                       where
             ActualPC
et    eq_ref PRIMARY       PRIMARY 15      tt.ActualPC   1
et_1  eq_ref PRIMARY       PRIMARY 15      tt.AssignedPC 1
do    eq_ref PRIMARY       PRIMARY 15      tt.ClientID   1
```

The `rows` column in the output from `EXPLAIN` is an educated guess from the MySQL join optimizer. Check whether the numbers are even close to the truth by comparing the `rows` product with the actual number of rows that the query returns. If the numbers are quite different, you might get better performance by using `STRAIGHT_JOIN` in your `SELECT` statement and trying to list the tables in a different order in the `FROM` clause.

It is possible in some cases to execute statements that modify data when `EXPLAIN SELECT` is used with a subquery; for more information, see Section 13.2.10.8, “Derived Tables (Subqueries in the FROM Clause)”.

8.8.3 Extended EXPLAIN Output Format

When `EXPLAIN` is used with the `EXTENDED` keyword, the output includes a `filtered` column not otherwise displayed. This column indicates the estimated percentage of table rows that will be filtered by the table condition.

In addition, the statement produces extra (“extended”) information that is not part of `EXPLAIN` output but can be viewed by issuing a `SHOW WARNINGS` statement following `EXPLAIN`. The `Message` value in `SHOW WARNINGS` output displays how the optimizer qualifies table and column names in the `SELECT` statement, what the `SELECT` looks like after the application of rewriting and optimization rules, and possibly other notes about the optimization process.

Here is an example of extended `EXPLAIN` output:

```
mysql> EXPLAIN EXTENDED
       SELECT t1.a, t1.a IN (SELECT t2.a FROM t2) FROM t1\G
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: t1
         type: index
possible_keys: NULL
          key: PRIMARY
      key_len: 4
          ref: NULL
         rows: 4
     filtered: 100.00
        Extra: Using index
*************************** 2. row ***************************
           id: 2
  select_type: DEPENDENT SUBQUERY
        table: t2
         type: index_subquery
possible_keys: a
          key: a
      key_len: 5
          ref: func
         rows: 2
     filtered: 100.00
        Extra: Using index
2 rows in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Note
   Code: 1003
Message: select `test`.`t1`.`a` AS `a`,
         <in_optimizer>(`test`.`t1`.`a`,
         <exists>(<index_lookup>(<cache>(`test`.`t1`.`a`)
         in t2 on a checking NULL having
         <is_not_null_test>(`test`.`t2`.`a`)))) AS `t1.a
         IN (SELECT t2.a FROM t2)` from `test`.`t1`
1 row in set (0.00 sec)
```

Because the statement displayed by `SHOW WARNINGS` may contain special markers to provide information about query rewriting or optimizer actions, the statement is not necessarily valid SQL and is not intended to be executed. The output may also include rows with `Message` values that provide additional non-SQL explanatory notes about actions taken by the optimizer.

The following list describes special markers that can appear in the extended output displayed by `SHOW WARNINGS`:

- `<cache>(`*`expr`*`)`

  The expression (such as a scalar subquery) is executed once and the resulting value is saved in memory for later use.

- `<exists>(`*`query fragment`*`)`

  The subquery predicate is converted to an `EXISTS` predicate and the subquery is transformed so that it can be used together with the `EXISTS` predicate.

- `<in_optimizer>(`*`query fragment`*`)`

This is an internal optimizer object with no user significance.

- `<index_lookup>(query fragment)`

  The query fragment is processed using an index lookup to find qualifying rows.

- `<is_not_null_test>(expr)`

  A test to verify that the expression does not evaluate to `NULL`.

- `<primary_index_lookup>(query fragment)`

  The query fragment is processed using a primary key lookup to find qualifying rows.

- `<ref_null_helper>(expr)`

  This is an internal optimizer object with no user significance.

When some tables are of `const` or `system` type, expressions involving columns from these tables are evaluated early by the optimizer and are not part of the displayed statement. However, with `FORMAT=JSON`, some `const` table accesses are displayed as a `ref` access that uses a const value.

8.8.4 Estimating Query Performance

In most cases, you can estimate query performance by counting disk seeks. For small tables, you can usually find a row in one disk seek (because the index is probably cached). For bigger tables, you can estimate that, using B-tree indexes, you need this many seeks to find a row: `log(row_count) / log(index_block_length / 3 * 2 / (index_length + data_pointer_length)) + 1`.

In MySQL, an index block is usually 1,024 bytes and the data pointer is usually four bytes. For a 500,000-row table with a key value length of three bytes (the size of `MEDIUMINT`), the formula indicates `log(500,000)/log(1024/3*2/(3+4)) + 1` = `4` seeks.

This index would require storage of about 500,000 * 7 * 3/2 = 5.2MB (assuming a typical index buffer fill ratio of 2/3), so you probably have much of the index in memory and so need only one or two calls to read data to find the row.

For writes, however, you need four seek requests to find where to place a new index value and normally two seeks to update the index and write the row.

The preceding discussion does not mean that your application performance slowly degenerates by log *N*. As long as everything is cached by the OS or the MySQL server, things become only marginally slower as the table gets bigger. After the data gets too big to be cached, things start to go much slower until your applications are bound only by disk seeks (which increase by log *N*). To avoid this, increase the key cache size as the data grows. For `MyISAM` tables, the key cache size is controlled by the `key_buffer_size` system variable. See Section 5.1.1, “Configuring the Server”.

8.9 Controlling the Query Optimizer

MySQL provides optimizer control through system variables that affect how query plans are evaluated, switchable optimizations, and index hints.

8.9.1 Controlling Query Plan Evaluation

The task of the query optimizer is to find an optimal plan for executing an SQL query. Because the difference in performance between “good” and “bad” plans can be orders of magnitude (that is, seconds versus hours or even days), most query optimizers, including that of MySQL, perform a more or less exhaustive search for an optimal plan among all possible query evaluation plans. For join queries, the number of possible plans investigated by the MySQL optimizer grows exponentially with

the number of tables referenced in a query. For small numbers of tables (typically less than 7 to 10) this is not a problem. However, when larger queries are submitted, the time spent in query optimization may easily become the major bottleneck in the server's performance.

A more flexible method for query optimization enables the user to control how exhaustive the optimizer is in its search for an optimal query evaluation plan. The general idea is that the fewer plans that are investigated by the optimizer, the less time it spends in compiling a query. On the other hand, because the optimizer skips some plans, it may miss finding an optimal plan.

The behavior of the optimizer with respect to the number of plans it evaluates can be controlled using two system variables:

- The `optimizer_prune_level` variable tells the optimizer to skip certain plans based on estimates of the number of rows accessed for each table. Our experience shows that this kind of "educated guess" rarely misses optimal plans, and may dramatically reduce query compilation times. That is why this option is on (`optimizer_prune_level=1`) by default. However, if you believe that the optimizer missed a better query plan, this option can be switched off (`optimizer_prune_level=0`) with the risk that query compilation may take much longer. Note that, even with the use of this heuristic, the optimizer still explores a roughly exponential number of plans.

- The `optimizer_search_depth` variable tells how far into the "future" of each incomplete plan the optimizer should look to evaluate whether it should be expanded further. Smaller values of `optimizer_search_depth` may result in orders of magnitude smaller query compilation times. For example, queries with 12, 13, or more tables may easily require hours and even days to compile if `optimizer_search_depth` is close to the number of tables in the query. At the same time, if compiled with `optimizer_search_depth` equal to 3 or 4, the optimizer may compile in less than a minute for the same query. If you are unsure of what a reasonable value is for `optimizer_search_depth`, this variable can be set to 0 to tell the optimizer to determine the value automatically.

8.9.2 Switchable Optimizations

The `optimizer_switch` system variable enables control over optimizer behavior. Its value is a set of flags, each of which has a value of `on` or `off` to indicate whether the corresponding optimizer behavior is enabled or disabled. This variable has global and session values and can be changed at runtime. The global default can be set at server startup.

To see the current set of optimizer flags, select the variable value:

```
mysql> SELECT @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=on,
                    index_merge_sort_union=on,
                    index_merge_intersection=on,
                    engine_condition_pushdown=on
```

To change the value of `optimizer_switch`, assign a value consisting of a comma-separated list of one or more commands:

```
SET [GLOBAL|SESSION] optimizer_switch='command[,command]...';
```

Each *`command`* value should have one of the forms shown in the following table.

Command Syntax	Meaning
`default`	Reset every optimization to its default value
`opt_name``=default`	Set the named optimization to its default value
`opt_name``=off`	Disable the named optimization

Command Syntax	Meaning
opt_name=on	Enable the named optimization

The order of the commands in the value does not matter, although the `default` command is executed first if present. Setting an *opt_name* flag to `default` sets it to whichever of `on` or `off` is its default value. Specifying any given *opt_name* more than once in the value is not permitted and causes an error. Any errors in the value cause the assignment to fail with an error, leaving the value of `optimizer_switch` unchanged.

The following table lists the permissible *opt_name* flag names, grouped by optimization strategy.

Optimization	Flag Name	Meaning	Default
Engine Condition Pushdown	`engine_condition_pushdown`	Controls engine condition pushdown	`ON`
Index Merge	`index_merge`	Controls all Index Merge optimizations	`ON`
	`index_merge_intersection`	Controls the Index Merge Intersection Access optimization	`ON`
	`index_merge_sort_union`	Controls the Index Merge Sort-Union Access optimization	`ON`
	`index_merge_union`	Controls the Index Merge Union Access optimization	`ON`

For more information about individual optimization strategies, see the following sections:

- Section 8.2.1.3, “Index Merge Optimization”
- Section 8.2.1.4, “Engine Condition Pushdown Optimization”

When you assign a value to `optimizer_switch`, flags that are not mentioned keep their current values. This makes it possible to enable or disable specific optimizer behaviors in a single statement without affecting other behaviors. The statement does not depend on what other optimizer flags exist and what their values are. Suppose that all Index Merge optimizations are enabled:

```
mysql> SELECT @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=on,
                    index_merge_sort_union=on,
                    index_merge_intersection=on,
                    engine_condition_pushdown=on
```

If the server is using the Index Merge Union or Index Merge Sort-Union access methods for certain queries and you want to check whether the optimizer will perform better without them, set the variable value like this:

```
mysql> SET optimizer_switch='index_merge_union=off,index_merge_sort_union=off';

mysql> SELECT @@optimizer_switch\G
*************************** 1. row ***************************
@@optimizer_switch: index_merge=on,index_merge_union=off,
                    index_merge_sort_union=off,
                    index_merge_intersection=on,
                    engine_condition_pushdown=on
```

8.9.3 Index Hints

Index hints give the optimizer information about how to choose indexes during query processing. Index hints are specified following a table name. (For the general syntax for specifying tables in a

SELECT statement, see Section 13.2.9.2, “JOIN Syntax”.) The syntax for referring to an individual table, including index hints, looks like this:

```
tbl_name [[AS] alias] [index_hint_list]

index_hint_list:
    index_hint [index_hint] ...

index_hint:
    USE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] ([index_list])
  | IGNORE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] (index_list)
  | FORCE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] (index_list)

index_list:
    index_name [, index_name] ...
```

The `USE INDEX (index_list)` hint tells MySQL to use only one of the named indexes to find rows in the table. The alternative syntax `IGNORE INDEX (index_list)` tells MySQL to not use some particular index or indexes. These hints are useful if `EXPLAIN` shows that MySQL is using the wrong index from the list of possible indexes.

The `FORCE INDEX` hint acts like `USE INDEX (index_list)`, with the addition that a table scan is assumed to be *very* expensive. In other words, a table scan is used only if there is no way to use one of the named indexes to find rows in the table.

Each hint requires index names, not column names. To refer to a primary key, use the name `PRIMARY`. To see the index names for a table, use the `SHOW INDEX` statement or the `INFORMATION_SCHEMA.STATISTICS` table.

An *index_name* value need not be a full index name. It can be an unambiguous prefix of an index name. If a prefix is ambiguous, an error occurs.

Examples:

```
SELECT * FROM table1 USE INDEX (col1_index,col2_index)
  WHERE col1=1 AND col2=2 AND col3=3;

SELECT * FROM table1 IGNORE INDEX (col3_index)
  WHERE col1=1 AND col2=2 AND col3=3;
```

The syntax for index hints has the following characteristics:

- It is syntactically valid to omit *index_list* for `USE INDEX`, which means “use no indexes.” Omitting *index_list* for `FORCE INDEX` or `IGNORE INDEX` is a syntax error.
- You can specify the scope of an index hint by adding a `FOR` clause to the hint. This provides more fine-grained control over optimizer selection of an execution plan for various phases of query processing. To affect only the indexes used when MySQL decides how to find rows in the table and how to process joins, use `FOR JOIN`. To influence index usage for sorting or grouping rows, use `FOR ORDER BY` or `FOR GROUP BY`.
- You can specify multiple index hints:

  ```
  SELECT * FROM t1 USE INDEX (i1) IGNORE INDEX FOR ORDER BY (i2) ORDER BY a;
  ```

  It is not an error to name the same index in several hints (even within the same hint):

  ```
  SELECT * FROM t1 USE INDEX (i1) USE INDEX (i1,i1);
  ```

However, it is an error to mix `USE INDEX` and `FORCE INDEX` for the same table:

```
SELECT * FROM t1 USE INDEX FOR JOIN (i1) FORCE INDEX FOR JOIN (i2);
```

If an index hint includes no `FOR` clause, the scope of the hint is to apply to all parts of the statement. For example, this hint:

```
IGNORE INDEX (i1)
```

is equivalent to this combination of hints:

```
IGNORE INDEX FOR JOIN (i1)
IGNORE INDEX FOR ORDER BY (i1)
IGNORE INDEX FOR GROUP BY (i1)
```

In MySQL 5.0, hint scope with no `FOR` clause was to apply only to row retrieval. To cause the server to use this older behavior when no `FOR` clause is present, enable the `old` system variable at server startup. Take care about enabling this variable in a replication setup. With statement-based binary logging, having different modes for the master and slaves might lead to replication errors.

When index hints are processed, they are collected in a single list by type (`USE`, `FORCE`, `IGNORE`) and by scope (`FOR JOIN`, `FOR ORDER BY`, `FOR GROUP BY`). For example:

```
SELECT * FROM t1
  USE INDEX () IGNORE INDEX (i2) USE INDEX (i1) USE INDEX (i2);
```

is equivalent to:

```
SELECT * FROM t1
   USE INDEX (i1,i2) IGNORE INDEX (i2);
```

The index hints then are applied for each scope in the following order:

1. `{USE|FORCE} INDEX` is applied if present. (If not, the optimizer-determined set of indexes is used.)
2. `IGNORE INDEX` is applied over the result of the previous step. For example, the following two queries are equivalent:

   ```
   SELECT * FROM t1 USE INDEX (i1) IGNORE INDEX (i2) USE INDEX (i2);

   SELECT * FROM t1 USE INDEX (i1);
   ```

For `FULLTEXT` searches, index hints work as follows:

- For natural language mode searches, index hints are silently ignored. For example, `IGNORE INDEX(i1)` is ignored with no warning and the index is still used.
- For boolean mode searches, index hints with `FOR ORDER BY` or `FOR GROUP BY` are silently ignored. Index hints with `FOR JOIN` or no `FOR` modifier are honored. In contrast to how hints apply for non-`FULLTEXT` searches, the hint is used for all phases of query execution (finding rows and retrieval, grouping, and ordering). This is true even if the hint is given for a non-`FULLTEXT` index.

  For example, the following two queries are equivalent:

  ```
  SELECT * FROM t
    USE INDEX (index1)
    IGNORE INDEX (index1) FOR ORDER BY
  ```

```
  IGNORE INDEX (index1) FOR GROUP BY
  WHERE ... IN BOOLEAN MODE ... ;

SELECT * FROM t
  USE INDEX (index1)
  WHERE ... IN BOOLEAN MODE ... ;
```

8.10 Buffering and Caching

MySQL uses several strategies that cache information in memory buffers to increase performance. Depending on your database architecture, you balance the size and layout of these areas, to provide the most performance benefit without wasting memory or exceeding available memory. When you set up or resize these memory areas, test the resulting performance using the techniques from Section 8.13, “Measuring Performance (Benchmarking)”.

8.10.1 InnoDB Buffer Pool Optimization

`InnoDB` maintains a storage area called the buffer pool for caching data and indexes in memory. Knowing how the `InnoDB` buffer pool works, and taking advantage of it to keep frequently accessed data in memory, is an important aspect of MySQL tuning.

For an explanation of the inner workings of the `InnoDB` buffer pool, an overview of its LRU replacement algorithm, and general configuration information, see Section 14.9.2.1, “The InnoDB Buffer Pool”.

For additional `InnoDB` buffer pool configuration and tuning information, see these sections:

- Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”
- Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing”
- Section 14.9.2.3, “Making the Buffer Pool Scan Resistant”
- Section 14.9.2.2, “Configuring Multiple Buffer Pool Instances”

8.10.2 The MyISAM Key Cache

To minimize disk I/O, the `MyISAM` storage engine exploits a strategy that is used by many database management systems. It employs a cache mechanism to keep the most frequently accessed table pages in memory:

- For index blocks, a special structure called the *key cache* (or *key buffer*) is maintained. The structure contains a number of block buffers where the most-used index blocks are placed.
- For data blocks, MySQL uses no special cache. Instead it relies on the native operating system file system cache.

This section first describes the basic operation of the `MyISAM` key cache. Then it discusses features that improve key cache performance and that enable you to better control cache operation:

- Multiple sessions can access the cache concurrently.
- You can set up multiple key caches and assign table indexes to specific caches.

To control the size of the key cache, use the `key_buffer_size` system variable. If this variable is set equal to zero, no key cache is used. The key cache also is not used if the `key_buffer_size` value is too small to allocate the minimal number of block buffers (8).

When the key cache is not operational, index files are accessed using only the native file system buffering provided by the operating system. (In other words, table index blocks are accessed using the same strategy as that employed for table data blocks.)

An index block is a contiguous unit of access to the MyISAM index files. Usually the size of an index block is equal to the size of nodes of the index B-tree. (Indexes are represented on disk using a B-tree data structure. Nodes at the bottom of the tree are leaf nodes. Nodes above the leaf nodes are nonleaf nodes.)

All block buffers in a key cache structure are the same size. This size can be equal to, greater than, or less than the size of a table index block. Usually one these two values is a multiple of the other.

When data from any table index block must be accessed, the server first checks whether it is available in some block buffer of the key cache. If it is, the server accesses data in the key cache rather than on disk. That is, it reads from the cache or writes into it rather than reading from or writing to disk. Otherwise, the server chooses a cache block buffer containing a different table index block (or blocks) and replaces the data there by a copy of required table index block. As soon as the new index block is in the cache, the index data can be accessed.

If it happens that a block selected for replacement has been modified, the block is considered “dirty.” In this case, prior to being replaced, its contents are flushed to the table index from which it came.

Usually the server follows an *LRU (Least Recently Used)* strategy: When choosing a block for replacement, it selects the least recently used index block. To make this choice easier, the key cache module maintains all used blocks in a special list (*LRU chain*) ordered by time of use. When a block is accessed, it is the most recently used and is placed at the end of the list. When blocks need to be replaced, blocks at the beginning of the list are the least recently used and become the first candidates for eviction.

The InnoDB storage engine also uses an LRU algorithm, to manage its buffer pool. See Section 14.9.2.1, “The InnoDB Buffer Pool”.

8.10.2.1 Shared Key Cache Access

Threads can access key cache buffers simultaneously, subject to the following conditions:

- A buffer that is not being updated can be accessed by multiple sessions.
- A buffer that is being updated causes sessions that need to use it to wait until the update is complete.
- Multiple sessions can initiate requests that result in cache block replacements, as long as they do not interfere with each other (that is, as long as they need different index blocks, and thus cause different cache blocks to be replaced).

Shared access to the key cache enables the server to improve throughput significantly.

8.10.2.2 Multiple Key Caches

Shared access to the key cache improves performance but does not eliminate contention among sessions entirely. They still compete for control structures that manage access to the key cache buffers. To reduce key cache access contention further, MySQL also provides multiple key caches. This feature enables you to assign different table indexes to different key caches.

Where there are multiple key caches, the server must know which cache to use when processing queries for a given MyISAM table. By default, all MyISAM table indexes are cached in the default key cache. To assign table indexes to a specific key cache, use the CACHE INDEX statement (see Section 13.7.6.2, “CACHE INDEX Syntax”). For example, the following statement assigns indexes from the tables t1, t2, and t3 to the key cache named hot_cache:

```
mysql> CACHE INDEX t1, t2, t3 IN hot_cache;
+---------+--------------------+----------+----------+
| Table   | Op                 | Msg_type | Msg_text |
+---------+--------------------+----------+----------+
```

```
| test.t1 | assign_to_keycache | status   | OK       |
| test.t2 | assign_to_keycache | status   | OK       |
| test.t3 | assign_to_keycache | status   | OK       |
+---------+--------------------+----------+----------+
```

The key cache referred to in a `CACHE INDEX` statement can be created by setting its size with a `SET GLOBAL` parameter setting statement or by using server startup options. For example:

```
mysql> SET GLOBAL keycache1.key_buffer_size=128*1024;
```

To destroy a key cache, set its size to zero:

```
mysql> SET GLOBAL keycache1.key_buffer_size=0;
```

You cannot destroy the default key cache. Any attempt to do this is ignored:

```
mysql> SET GLOBAL key_buffer_size = 0;

mysql> SHOW VARIABLES LIKE 'key_buffer_size';
+-----------------+---------+
| Variable_name   | Value   |
+-----------------+---------+
| key_buffer_size | 8384512 |
+-----------------+---------+
```

Key cache variables are structured system variables that have a name and components. For `keycache1.key_buffer_size`, `keycache1` is the cache variable name and `key_buffer_size` is the cache component. See Section 5.1.6.1, “Structured System Variables”, for a description of the syntax used for referring to structured key cache system variables.

By default, table indexes are assigned to the main (default) key cache created at the server startup. When a key cache is destroyed, all indexes assigned to it are reassigned to the default key cache.

For a busy server, you can use a strategy that involves three key caches:

- A “hot” key cache that takes up 20% of the space allocated for all key caches. Use this for tables that are heavily used for searches but that are not updated.
- A “cold” key cache that takes up 20% of the space allocated for all key caches. Use this cache for medium-sized, intensively modified tables, such as temporary tables.
- A “warm” key cache that takes up 60% of the key cache space. Employ this as the default key cache, to be used by default for all other tables.

One reason the use of three key caches is beneficial is that access to one key cache structure does not block access to the others. Statements that access tables assigned to one cache do not compete with statements that access tables assigned to another cache. Performance gains occur for other reasons as well:

- The hot cache is used only for retrieval queries, so its contents are never modified. Consequently, whenever an index block needs to be pulled in from disk, the contents of the cache block chosen for replacement need not be flushed first.
- For an index assigned to the hot cache, if there are no queries requiring an index scan, there is a high probability that the index blocks corresponding to nonleaf nodes of the index B-tree remain in the cache.
- An update operation most frequently executed for temporary tables is performed much faster when the updated node is in the cache and need not be read in from disk first. If the size of the indexes of the temporary tables are comparable with the size of cold key cache, the probability is very high that the updated node is in the cache.

The `CACHE INDEX` statement sets up an association between a table and a key cache, but the association is lost each time the server restarts. If you want the association to take effect each time the server starts, one way to accomplish this is to use an option file: Include variable settings that configure your key caches, and an `init-file` option that names a file containing `CACHE INDEX` statements to be executed. For example:

```
key_buffer_size = 4G
hot_cache.key_buffer_size = 2G
cold_cache.key_buffer_size = 2G
init_file=/path/to/data-directory/mysqld_init.sql
```

The statements in `mysqld_init.sql` are executed each time the server starts. The file should contain one SQL statement per line. The following example assigns several tables each to `hot_cache` and `cold_cache`:

```
CACHE INDEX db1.t1, db1.t2, db2.t3 IN hot_cache
CACHE INDEX db1.t4, db2.t5, db2.t6 IN cold_cache
```

8.10.2.3 Midpoint Insertion Strategy

By default, the key cache management system uses a simple LRU strategy for choosing key cache blocks to be evicted, but it also supports a more sophisticated method called the *midpoint insertion strategy.*

When using the midpoint insertion strategy, the LRU chain is divided into two parts: a hot sublist and a warm sublist. The division point between two parts is not fixed, but the key cache management system takes care that the warm part is not “too short,” always containing at least `key_cache_division_limit` percent of the key cache blocks. `key_cache_division_limit` is a component of structured key cache variables, so its value is a parameter that can be set per cache.

When an index block is read from a table into the key cache, it is placed at the end of the warm sublist. After a certain number of hits (accesses of the block), it is promoted to the hot sublist. At present, the number of hits required to promote a block (3) is the same for all index blocks.

A block promoted into the hot sublist is placed at the end of the list. The block then circulates within this sublist. If the block stays at the beginning of the sublist for a long enough time, it is demoted to the warm sublist. This time is determined by the value of the `key_cache_age_threshold` component of the key cache.

The threshold value prescribes that, for a key cache containing *`N`* blocks, the block at the beginning of the hot sublist not accessed within the last *`N`* `* key_cache_age_threshold / 100` hits is to be moved to the beginning of the warm sublist. It then becomes the first candidate for eviction, because blocks for replacement always are taken from the beginning of the warm sublist.

The midpoint insertion strategy enables you to keep more-valued blocks always in the cache. If you prefer to use the plain LRU strategy, leave the `key_cache_division_limit` value set to its default of 100.

The midpoint insertion strategy helps to improve performance when execution of a query that requires an index scan effectively pushes out of the cache all the index blocks corresponding to valuable high-level B-tree nodes. To avoid this, you must use a midpoint insertion strategy with the `key_cache_division_limit` set to much less than 100. Then valuable frequently hit nodes are preserved in the hot sublist during an index scan operation as well.

8.10.2.4 Index Preloading

If there are enough blocks in a key cache to hold blocks of an entire index, or at least the blocks corresponding to its nonleaf nodes, it makes sense to preload the key cache with index blocks before starting to use it. Preloading enables you to put the table index blocks into a key cache buffer in the most efficient way: by reading the index blocks from disk sequentially.

Without preloading, the blocks are still placed into the key cache as needed by queries. Although the blocks will stay in the cache, because there are enough buffers for all of them, they are fetched from disk in random order, and not sequentially.

To preload an index into a cache, use the `LOAD INDEX INTO CACHE` statement. For example, the following statement preloads nodes (index blocks) of indexes of the tables `t1` and `t2`:

```
mysql> LOAD INDEX INTO CACHE t1, t2 IGNORE LEAVES;
+---------+--------------+----------+----------+
| Table   | Op           | Msg_type | Msg_text |
+---------+--------------+----------+----------+
| test.t1 | preload_keys | status   | OK       |
| test.t2 | preload_keys | status   | OK       |
+---------+--------------+----------+----------+
```

The `IGNORE LEAVES` modifier causes only blocks for the nonleaf nodes of the index to be preloaded. Thus, the statement shown preloads all index blocks from `t1`, but only blocks for the nonleaf nodes from `t2`.

If an index has been assigned to a key cache using a `CACHE INDEX` statement, preloading places index blocks into that cache. Otherwise, the index is loaded into the default key cache.

8.10.2.5 Key Cache Block Size

It is possible to specify the size of the block buffers for an individual key cache using the `key_cache_block_size` variable. This permits tuning of the performance of I/O operations for index files.

The best performance for I/O operations is achieved when the size of read buffers is equal to the size of the native operating system I/O buffers. But setting the size of key nodes equal to the size of the I/O buffer does not always ensure the best overall performance. When reading the big leaf nodes, the server pulls in a lot of unnecessary data, effectively preventing reading other leaf nodes.

To control the size of blocks in the `.MYI` index file of `MyISAM` tables, use the `--myisam-block-size` option at server startup.

8.10.2.6 Restructuring a Key Cache

A key cache can be restructured at any time by updating its parameter values. For example:

```
mysql> SET GLOBAL cold_cache.key_buffer_size=4*1024*1024;
```

If you assign to either the `key_buffer_size` or `key_cache_block_size` key cache component a value that differs from the component's current value, the server destroys the cache's old structure and creates a new one based on the new values. If the cache contains any dirty blocks, the server saves them to disk before destroying and re-creating the cache. Restructuring does not occur if you change other key cache parameters.

When restructuring a key cache, the server first flushes the contents of any dirty buffers to disk. After that, the cache contents become unavailable. However, restructuring does not block queries that need to use indexes assigned to the cache. Instead, the server directly accesses the table indexes using native file system caching. File system caching is not as efficient as using a key cache, so although queries execute, a slowdown can be anticipated. After the cache has been restructured, it becomes available again for caching indexes assigned to it, and the use of file system caching for the indexes ceases.

8.10.3 The MySQL Query Cache

The query cache stores the text of a `SELECT` statement together with the corresponding result that was sent to the client. If an identical statement is received later, the server retrieves the results from the query cache rather than parsing and executing the statement again. The query cache is shared among

sessions, so a result set generated by one client can be sent in response to the same query issued by another client.

The query cache can be useful in an environment where you have tables that do not change very often and for which the server receives many identical queries. This is a typical situation for many Web servers that generate many dynamic pages based on database content. For example, when an order form queries a table to display the lists of all US states or all countries in the world, those values can be retrieved from the query cache. Although the values would probably be retrieved from memory in any case (from the `InnoDB` buffer pool or `MyISAM` key cache), using the query cache avoids the overhead of processing the query, deciding whether to use a table scan, and locating the data block for each row.

The query cache always contains current and reliable data. Any insert, update, delete, or other modification to a table causes any relevant entries in the query cache to be flushed.

Note

The query cache does not work in an environment where you have multiple `mysqld` servers updating the same `MyISAM` tables.

The query cache is used for prepared statements under the conditions described in Section 8.10.3.1, “How the Query Cache Operates”.

Note

As of MySQL 5.5.23, the query cache is not supported for partitioned tables, and is automatically disabled for queries involving partitioned tables. The query cache cannot be enabled for such queries. (Bug #53775)

Some performance data for the query cache follows. These results were generated by running the MySQL benchmark suite on a Linux Alpha 2×500MHz system with 2GB RAM and a 64MB query cache.

- If all the queries you are performing are simple (such as selecting a row from a table with one row), but still differ so that the queries cannot be cached, the overhead for having the query cache active is 13%. This could be regarded as the worst case scenario. In real life, queries tend to be much more complicated, so the overhead normally is significantly lower.
- Searches for a single row in a single-row table are 238% faster with the query cache than without it. This can be regarded as close to the minimum speedup to be expected for a query that is cached.

To disable the query cache at server startup, set the `query_cache_size` system variable to 0. By disabling the query cache code, there is no noticeable overhead.

The query cache offers the potential for substantial performance improvement, but do not assume that it will do so under all circumstances. With some query cache configurations or server workloads, you might actually see a performance decrease:

- Be cautious about sizing the query cache excessively large, which increases the overhead required to maintain the cache, possibly beyond the benefit of enabling it. Sizes in tens of megabytes are usually beneficial. Sizes in the hundreds of megabytes might not be.
- Server workload has a significant effect on query cache efficiency. A query mix consisting almost entirely of a fixed set of `SELECT` statements is much more likely to benefit from enabling the cache than a mix in which frequent `INSERT` statements cause continual invalidation of results in the cache. In some cases, a workaround is to use the `SQL_NO_CACHE` option to prevent results from even entering the cache for `SELECT` statements that use frequently modified tables. (See Section 8.10.3.2, “Query Cache SELECT Options”.)

To verify that enabling the query cache is beneficial, test the operation of your MySQL server with the cache enabled and disabled. Then retest periodically because query cache efficiency may change as server workload changes.

8.10.3.1 How the Query Cache Operates

This section describes how the query cache works when it is operational. Section 8.10.3.3, “Query Cache Configuration”, describes how to control whether it is operational.

Incoming queries are compared to those in the query cache before parsing, so the following two queries are regarded as different by the query cache:

```
SELECT * FROM tbl_name
Select * from tbl_name
```

Queries must be *exactly* the same (byte for byte) to be seen as identical. In addition, query strings that are identical may be treated as different for other reasons. Queries that use different databases, different protocol versions, or different default character sets are considered different queries and are cached separately.

The cache is not used for queries of the following types:

- Queries that are a subquery of an outer query
- Queries executed within the body of a stored function, trigger, or event

Before a query result is fetched from the query cache, MySQL checks whether the user has `SELECT` privilege for all databases and tables involved. If this is not the case, the cached result is not used.

If a query result is returned from query cache, the server increments the `Qcache_hits` status variable, not `Com_select`. See Section 8.10.3.4, “Query Cache Status and Maintenance”.

If a table changes, all cached queries that use the table become invalid and are removed from the cache. This includes queries that use `MERGE` tables that map to the changed table. A table can be changed by many types of statements, such as `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE TABLE`, `ALTER TABLE`, `DROP TABLE`, or `DROP DATABASE`.

The query cache also works within transactions when using `InnoDB` tables.

The result from a `SELECT` query on a view is cached.

The query cache works for `SELECT SQL_CALC_FOUND_ROWS ...` queries and stores a value that is returned by a following `SELECT FOUND_ROWS()` query. `FOUND_ROWS()` returns the correct value even if the preceding query was fetched from the cache because the number of found rows is also stored in the cache. The `SELECT FOUND_ROWS()` query itself cannot be cached.

Prepared statements that are issued using the binary protocol using `mysql_stmt_prepare()` and `mysql_stmt_execute()` (see Section 23.8.8, “C API Prepared Statements”), are subject to limitations on caching. Comparison with statements in the query cache is based on the text of the statement after expansion of `?` parameter markers. The statement is compared only with other cached statements that were executed using the binary protocol. That is, for query cache purposes, prepared statements issued using the binary protocol are distinct from prepared statements issued using the text protocol (see Section 13.5, “Prepared SQL Statement Syntax”).

A query cannot be cached if it contains any of the functions shown in the following table.

`BENCHMARK()`	`CONNECTION_ID()`	`CONVERT_TZ()`
`CURDATE()`	`CURRENT_DATE()`	`CURRENT_TIME()`
`CURRENT_TIMESTAMP()`	`CURRENT_USER()`	`CURTIME()`
`DATABASE()`	`ENCRYPT()` with one parameter	`FOUND_ROWS()`
`GET_LOCK()`	`IS_FREE_LOCK()`	`IS_USED_LOCK()`

LAST_INSERT_ID()	LOAD_FILE()	MASTER_POS_WAIT()
NOW()	RAND()	RELEASE_ALL_LOCKS()
RELEASE_LOCK()	SLEEP()	SYSDATE()
UNIX_TIMESTAMP() with no parameters	USER()	UUID()
UUID_SHORT()		

A query also is not cached under these conditions:

- It refers to user-defined functions (UDFs) or stored functions.
- It refers to user variables or local stored program variables.
- It refers to tables in the `mysql`, `INFORMATION_SCHEMA`, or `performance_schema` database.
- (*MySQL 5.5.23 and later*:) It refers to any partitioned tables.
- It is of any of the following forms:

```
SELECT ... LOCK IN SHARE MODE
SELECT ... FOR UPDATE
SELECT ... INTO OUTFILE ...
SELECT ... INTO DUMPFILE ...
SELECT * FROM ... WHERE autoincrement_col IS NULL
```

  The last form is not cached because it is used as the ODBC workaround for obtaining the last insert ID value. See the Connector/ODBC section of Chapter 23, *Connectors and APIs*.

  Statements within transactions that use `SERIALIZABLE` isolation level also cannot be cached because they use `LOCK IN SHARE MODE` locking.

- It uses `TEMPORARY` tables.
- It does not use any tables.
- It generates warnings.
- The user has a column-level privilege for any of the involved tables.

8.10.3.2 Query Cache SELECT Options

Two query cache-related options may be specified in `SELECT` statements:

- `SQL_CACHE`

  The query result is cached if it is cacheable and the value of the `query_cache_type` system variable is `ON` or `DEMAND`.

- `SQL_NO_CACHE`

  The server does not use the query cache. It neither checks the query cache to see whether the result is already cached, nor does it cache the query result. (Due to a limitation in the parser, a space character must precede and follow the `SQL_NO_CACHE` keyword; a nonspace such as a newline causes the server to check the query cache to see whether the result is already cached.)

Examples:

```
SELECT SQL_CACHE id, name FROM customer;
SELECT SQL_NO_CACHE id, name FROM customer;
```

8.10.3.3 Query Cache Configuration

The `have_query_cache` server system variable indicates whether the query cache is available:

```
mysql> SHOW VARIABLES LIKE 'have_query_cache';
+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| have_query_cache | YES   |
+------------------+-------+
```

When using a standard MySQL binary, this value is always `YES`, even if query caching is disabled.

Several other system variables control query cache operation. These can be set in an option file or on the command line when starting `mysqld`. The query cache system variables all have names that begin with `query_cache_`. They are described briefly in Section 5.1.5, “Server System Variables”, with additional configuration information given here.

To set the size of the query cache, set the `query_cache_size` system variable. Setting it to 0 disables the query cache. The default size is 0, so the query cache is disabled by default.

To reduce overhead significantly, start the server with `query_cache_type=0` if you will not be using the query cache.

Note

When using the Windows Configuration Wizard to install or configure MySQL, the default value for `query_cache_size` will be configured automatically for you based on the different configuration types available. When using the Windows Configuration Wizard, the query cache may be enabled (that is, set to a nonzero value) due to the selected configuration. The query cache is also controlled by the setting of the `query_cache_type` variable. Check the values of these variables as set in your `my.ini` file after configuration has taken place.

When you set `query_cache_size` to a nonzero value, keep in mind that the query cache needs a minimum size of about 40KB to allocate its structures. (The exact size depends on system architecture.) If you set the value too small, you'll get a warning, as in this example:

```
mysql> SET GLOBAL query_cache_size = 40000;
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1282
Message: Query cache failed to set size 39936;
         new query cache size is 0

mysql> SET GLOBAL query_cache_size = 41984;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'query_cache_size';
+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| query_cache_size | 41984 |
+------------------+-------+
```

For the query cache to actually be able to hold any query results, its size must be set larger:

```
mysql> SET GLOBAL query_cache_size = 1000000;
Query OK, 0 rows affected (0.04 sec)

mysql> SHOW VARIABLES LIKE 'query_cache_size';
```

```
+------------------+--------+
| Variable_name    | Value  |
+------------------+--------+
| query_cache_size | 999424 |
+------------------+--------+
1 row in set (0.00 sec)
```

The `query_cache_size` value is aligned to the nearest 1024 byte block. The value reported may therefore be different from the value that you assign.

If the query cache size is greater than 0, the `query_cache_type` variable influences how it works. This variable can be set to the following values:

- A value of `0` or `OFF` prevents caching or retrieval of cached results.
- A value of `1` or `ON` enables caching except of those statements that begin with `SELECT SQL_NO_CACHE`.
- A value of `2` or `DEMAND` causes caching of only those statements that begin with `SELECT SQL_CACHE`.

If `query_cache_size` is 0, you should also set `query_cache_type` variable to 0. In this case, the server does not acquire the query cache mutex at all, which means that the query cache cannot be enabled at runtime and there is reduced overhead in query execution.

Setting the `GLOBAL query_cache_type` value determines query cache behavior for all clients that connect after the change is made. Individual clients can control cache behavior for their own connection by setting the `SESSION query_cache_type` value. For example, a client can disable use of the query cache for its own queries like this:

```
mysql> SET SESSION query_cache_type = OFF;
```

If you set `query_cache_type` at server startup (rather than at runtime with a `SET` statement), only the numeric values are permitted.

To control the maximum size of individual query results that can be cached, set the `query_cache_limit` system variable. The default value is 1MB.

Be careful not to set the size of the cache too large. Due to the need for threads to lock the cache during updates, you may see lock contention issues with a very large cache.

Note

You can set the maximum size that can be specified for the query cache at runtime with the `SET` statement by using the `--maximum-query_cache_size=32M` option on the command line or in the configuration file.

When a query is to be cached, its result (the data sent to the client) is stored in the query cache during result retrieval. Therefore the data usually is not handled in one big chunk. The query cache allocates blocks for storing this data on demand, so when one block is filled, a new block is allocated. Because memory allocation operation is costly (timewise), the query cache allocates blocks with a minimum size given by the `query_cache_min_res_unit` system variable. When a query is executed, the last result block is trimmed to the actual data size so that unused memory is freed. Depending on the types of queries your server executes, you might find it helpful to tune the value of `query_cache_min_res_unit`:

- The default value of `query_cache_min_res_unit` is 4KB. This should be adequate for most cases.
- If you have a lot of queries with small results, the default block size may lead to memory fragmentation, as indicated by a large number of free blocks. Fragmentation can force the query

cache to prune (delete) queries from the cache due to lack of memory. In this case, decrease the value of `query_cache_min_res_unit`. The number of free blocks and queries removed due to pruning are given by the values of the `Qcache_free_blocks` and `Qcache_lowmem_prunes` status variables.

- If most of your queries have large results (check the `Qcache_total_blocks` and `Qcache_queries_in_cache` status variables), you can increase performance by increasing `query_cache_min_res_unit`. However, be careful to not make it too large (see the previous item).

8.10.3.4 Query Cache Status and Maintenance

To check whether the query cache is present in your MySQL server, use the following statement:

```
mysql> SHOW VARIABLES LIKE 'have_query_cache';
+------------------+-------+
| Variable_name    | Value |
+------------------+-------+
| have_query_cache | YES   |
+------------------+-------+
```

You can defragment the query cache to better utilize its memory with the `FLUSH QUERY CACHE` statement. The statement does not remove any queries from the cache.

The `RESET QUERY CACHE` statement removes all query results from the query cache. The `FLUSH TABLES` statement also does this.

To monitor query cache performance, use `SHOW STATUS` to view the cache status variables:

```
mysql> SHOW STATUS LIKE 'Qcache%';
+-------------------------+--------+
| Variable_name           | Value  |
+-------------------------+--------+
| Qcache_free_blocks      | 36     |
| Qcache_free_memory      | 138488 |
| Qcache_hits             | 79570  |
| Qcache_inserts          | 27087  |
| Qcache_lowmem_prunes    | 3114   |
| Qcache_not_cached       | 22989  |
| Qcache_queries_in_cache | 415    |
| Qcache_total_blocks     | 912    |
+-------------------------+--------+
```

Descriptions of each of these variables are given in Section 5.1.7, “Server Status Variables”. Some uses for them are described here.

The total number of `SELECT` queries is given by this formula:

```
  Com_select
+ Qcache_hits
+ queries with errors found by parser
```

The `Com_select` value is given by this formula:

```
  Qcache_inserts
+ Qcache_not_cached
+ queries with errors found during the column-privileges check
```

The query cache uses variable-length blocks, so `Qcache_total_blocks` and `Qcache_free_blocks` may indicate query cache memory fragmentation. After `FLUSH QUERY CACHE`, only a single free block remains.

Every cached query requires a minimum of two blocks (one for the query text and one or more for the query results). Also, every table that is used by a query requires one block. However, if two or more queries use the same table, only one table block needs to be allocated.

The information provided by the `Qcache_lowmem_prunes` status variable can help you tune the query cache size. It counts the number of queries that have been removed from the cache to free up memory for caching new queries. The query cache uses a least recently used (LRU) strategy to decide which queries to remove from the cache. Tuning information is given in Section 8.10.3.3, “Query Cache Configuration”.

8.11 Optimizing Locking Operations

When your database is busy with multiple sessions reading and writing data, the mechanism that controls access to data files and memory areas can become a consideration for performance tuning. Otherwise, sessions can spend time waiting for access to resources when they could be running concurrently.

MySQL manages contention for table contents using locking:

- Internal locking is performed within the MySQL server itself to manage contention for table contents by multiple threads. This type of locking is internal because it is performed entirely by the server and involves no other programs. See Section 8.11.1, “Internal Locking Methods”.
- External locking occurs when the server and other programs lock `MyISAM` table files to coordinate among themselves which program can access the tables at which time. See Section 8.11.5, “External Locking”.

8.11.1 Internal Locking Methods

This section discusses internal locking; that is, locking performed within the MySQL server itself to manage contention for table contents by multiple sessions. This type of locking is internal because it is performed entirely by the server and involves no other programs. For locking performed on MySQL files by other programs, see Section 8.11.5, “External Locking”.

- Row-Level Locking
- Table-Level Locking
- Choosing the Type of Locking

Row-Level Locking

MySQL uses row-level locking for `InnoDB` tables to support simultaneous write access by multiple sessions, making them suitable for multi-user, highly concurrent, and OLTP applications.

To avoid deadlocks when performing multiple concurrent write operations on a single `InnoDB` table, acquire necessary locks at the start of the transaction by issuing a `SELECT ... FOR UPDATE` statement for each group of rows expected to be modified, even if the data change statements come later in the transaction. If transactions modify or lock more than one table, issue the applicable statements in the same order within each transaction. Deadlocks affect performance rather than representing a serious error, because `InnoDB` automatically detects deadlock conditions and rolls back one of the affected transactions.

Advantages of row-level locking:

- Fewer lock conflicts when different sessions access different rows.
- Fewer changes for rollbacks.
- Possible to lock a single row for a long time.

Table-Level Locking

MySQL uses table-level locking for `MyISAM`, `MEMORY`, and `MERGE` tables, permitting only one session to update those tables at a time. This locking level makes these storage engines more suitable for read-only, read-mostly, or single-user applications.

These storage engines avoid deadlocks by always requesting all needed locks at once at the beginning of a query and always locking the tables in the same order. The tradeoff is that this strategy reduces concurrency; other sessions that want to modify the table must wait until the current data change statement finishes.

Advantages of table-level locking:

- Relatively little memory required (row locking requires memory per row or group of rows locked)
- Fast when used on a large part of the table because only a single lock is involved.
- Fast if you often do `GROUP BY` operations on a large part of the data or must scan the entire table frequently.

MySQL grants table write locks as follows:

1. If there are no locks on the table, put a write lock on it.
2. Otherwise, put the lock request in the write lock queue.

MySQL grants table read locks as follows:

1. If there are no write locks on the table, put a read lock on it.
2. Otherwise, put the lock request in the read lock queue.

Table updates are given higher priority than table retrievals. Therefore, when a lock is released, the lock is made available to the requests in the write lock queue and then to the requests in the read lock queue. This ensures that updates to a table are not “starved” even when there is heavy `SELECT` activity for the table. However, if there are many updates for a table, `SELECT` statements wait until there are no more updates.

For information on altering the priority of reads and writes, see Section 8.11.2, “Table Locking Issues”.

You can analyze the table lock contention on your system by checking the `Table_locks_immediate` and `Table_locks_waited` status variables, which indicate the number of times that requests for table locks could be granted immediately and the number that had to wait, respectively:

```
mysql> SHOW STATUS LIKE 'Table%';
+-----------------------+---------+
| Variable_name         | Value   |
+-----------------------+---------+
| Table_locks_immediate | 1151552 |
| Table_locks_waited    | 15324   |
+-----------------------+---------+
```

The `MyISAM` storage engine supports concurrent inserts to reduce contention between readers and writers for a given table: If a `MyISAM` table has no free blocks in the middle of the data file, rows are always inserted at the end of the data file. In this case, you can freely mix concurrent `INSERT` and `SELECT` statements for a `MyISAM` table without locks. That is, you can insert rows into a `MyISAM` table at the same time other clients are reading from it. Holes can result from rows having been deleted from or updated in the middle of the table. If there are holes, concurrent inserts are disabled but are enabled again automatically when all holes have been filled with new data. To control this behavior, use the `concurrent_insert` system variable. See Section 8.11.3, “Concurrent Inserts”.

If you acquire a table lock explicitly with `LOCK TABLES`, you can request a `READ LOCAL` lock rather than a `READ` lock to enable other sessions to perform concurrent inserts while you have the table locked.

To perform many `INSERT` and `SELECT` operations on a table `t1` when concurrent inserts are not possible, you can insert rows into a temporary table `temp_t1` and update the real table with the rows from the temporary table:

```
mysql> LOCK TABLES t1 WRITE, temp_t1 WRITE;
mysql> INSERT INTO t1 SELECT * FROM temp_t1;
mysql> DELETE FROM temp_t1;
mysql> UNLOCK TABLES;
```

Choosing the Type of Locking

Generally, table locks are superior to row-level locks in the following cases:

- Most statements for the table are reads.
- Statements for the table are a mix of reads and writes, where writes are updates or deletes for a single row that can be fetched with one key read:

  ```
  UPDATE tbl_name SET column=value WHERE unique_key_col=key_value;
  DELETE FROM tbl_name WHERE unique_key_col=key_value;
  ```

- `SELECT` combined with concurrent `INSERT` statements, and very few `UPDATE` or `DELETE` statements.
- Many scans or `GROUP BY` operations on the entire table without any writers.

With higher-level locks, you can more easily tune applications by supporting locks of different types, because the lock overhead is less than for row-level locks.

Options other than row-level locking:

- Versioning (such as that used in MySQL for concurrent inserts) where it is possible to have one writer at the same time as many readers. This means that the database or table supports different views for the data depending on when access begins. Other common terms for this are “time travel,” “copy on write,” or “copy on demand.”
- Copy on demand is in many cases superior to row-level locking. However, in the worst case, it can use much more memory than using normal locks.
- Instead of using row-level locks, you can employ application-level locks, such as those provided by `GET_LOCK()` and `RELEASE_LOCK()` in MySQL. These are advisory locks, so they work only with applications that cooperate with each other. See Section 12.17, “Miscellaneous Functions”.

8.11.2 Table Locking Issues

`InnoDB` tables use row-level locking so that multiple sessions and applications can read from and write to the same table simultaneously, without making each other wait or producing inconsistent results. For this storage engine, avoid using the `LOCK TABLES` statement, because it does not offer any extra protection, but instead reduces concurrency. The automatic row-level locking makes these tables suitable for your busiest databases with your most important data, while also simplifying application logic since you do not need to lock and unlock tables. Consequently, the `InnoDB` storage engine is the default in MySQL 5.5 and higher.

MySQL uses table locking (instead of page, row, or column locking) for all storage engines except `InnoDB` and `NDB`. The locking operations themselves do not have much overhead. But because only one session can write to a table at any one time, for best performance with these other storage engines, use them primarily for tables that are queried often and rarely inserted into or updated.

- Performance Considerations Favoring InnoDB
- Workarounds for Locking Performance Issues

Performance Considerations Favoring InnoDB

When choosing whether to create a table using `InnoDB` or a different storage engine, keep in mind the following disadvantages of table locking:

- Table locking enables many sessions to read from a table at the same time, but if a session wants to write to a table, it must first get exclusive access, meaning it might have to wait for other sessions to finish with the table first. During the update, all other sessions that want to access this particular table must wait until the update is done.
- Table locking causes problems when a session is waiting because the disk is full and free space needs to become available before the session can proceed. In this case, all sessions that want to access the problem table are also put in a waiting state until more disk space is made available.
- A `SELECT` statement that takes a long time to run prevents other sessions from updating the table in the meantime, making the other sessions appear slow or unresponsive. While a session is waiting to get exclusive access to the table for updates, other sessions that issue `SELECT` statements will queue up behind it, reducing concurrency even for read-only sessions.

Workarounds for Locking Performance Issues

The following items describe some ways to avoid or reduce contention caused by table locking:

- Consider switching the table to the `InnoDB` storage engine, either using `CREATE TABLE ... ENGINE=INNODB` during setup, or using `ALTER TABLE ... ENGINE=INNODB` for an existing table. See Chapter 14, *The InnoDB Storage Engine* for more details about this storage engine.
- Optimize `SELECT` statements to run faster so that they lock tables for a shorter time. You might have to create some summary tables to do this.
- Start `mysqld` with `--low-priority-updates`. For storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`), this gives all statements that update (modify) a table lower priority than `SELECT` statements. In this case, the second `SELECT` statement in the preceding scenario would execute before the `UPDATE` statement, and would not wait for the first `SELECT` to finish.
- To specify that all updates issued in a specific connection should be done with low priority, set the `low_priority_updates` server system variable equal to 1.
- To give a specific `INSERT`, `UPDATE`, or `DELETE` statement lower priority, use the `LOW_PRIORITY` attribute.
- To give a specific `SELECT` statement higher priority, use the `HIGH_PRIORITY` attribute. See Section 13.2.9, “SELECT Syntax”.
- Start `mysqld` with a low value for the `max_write_lock_count` system variable to force MySQL to temporarily elevate the priority of all `SELECT` statements that are waiting for a table after a specific number of inserts to the table occur. This permits `READ` locks after a certain number of `WRITE` locks.
- If you have problems with `INSERT` combined with `SELECT`, consider switching to `MyISAM` tables, which support concurrent `SELECT` and `INSERT` statements. (See Section 8.11.3, “Concurrent Inserts”.)
- If you mix inserts and deletes on the same table, `INSERT DELAYED` may be of great help. See Section 13.2.5.3, “INSERT DELAYED Syntax”.
- If you have problems with mixed `SELECT` and `DELETE` statements, the `LIMIT` option to `DELETE` may help. See Section 13.2.2, “DELETE Syntax”.

- Using `SQL_BUFFER_RESULT` with `SELECT` statements can help to make the duration of table locks shorter. See Section 13.2.9, “SELECT Syntax”.
- Splitting table contents into separate tables may help, by allowing queries to run against columns in one table, while updates are confined to columns in a different table.
- You could change the locking code in `mysys/thr_lock.c` to use a single queue. In this case, write locks and read locks would have the same priority, which might help some applications.

8.11.3 Concurrent Inserts

The `MyISAM` storage engine supports concurrent inserts to reduce contention between readers and writers for a given table: If a `MyISAM` table has no holes in the data file (deleted rows in the middle), an `INSERT` statement can be executed to add rows to the end of the table at the same time that `SELECT` statements are reading rows from the table. If there are multiple `INSERT` statements, they are queued and performed in sequence, concurrently with the `SELECT` statements. The results of a concurrent `INSERT` may not be visible immediately.

The `concurrent_insert` system variable can be set to modify the concurrent-insert processing. By default, the variable is set to `AUTO` (or 1) and concurrent inserts are handled as just described. If `concurrent_insert` is set to `NEVER` (or 0), concurrent inserts are disabled. If the variable is set to `ALWAYS` (or 2), concurrent inserts at the end of the table are permitted even for tables that have deleted rows. See also the description of the `concurrent_insert` system variable.

Under circumstances where concurrent inserts can be used, there is seldom any need to use the `DELAYED` modifier for `INSERT` statements. See Section 13.2.5.3, “INSERT DELAYED Syntax”.

If you are using the binary log, concurrent inserts are converted to normal inserts for `CREATE ... SELECT` or `INSERT ... SELECT` statements. This is done to ensure that you can re-create an exact copy of your tables by applying the log during a backup operation. See Section 5.4.4, “The Binary Log”. In addition, for those statements a read lock is placed on the selected-from table such that inserts into that table are blocked. The effect is that concurrent inserts for that table must wait as well.

With `LOAD DATA INFILE`, if you specify `CONCURRENT` with a `MyISAM` table that satisfies the condition for concurrent inserts (that is, it contains no free blocks in the middle), other sessions can retrieve data from the table while `LOAD DATA` is executing. Use of the `CONCURRENT` option affects the performance of `LOAD DATA` a bit, even if no other session is using the table at the same time.

If you specify `HIGH_PRIORITY`, it overrides the effect of the `--low-priority-updates` option if the server was started with that option. It also causes concurrent inserts not to be used.

For `LOCK TABLE`, the difference between `READ LOCAL` and `READ` is that `READ LOCAL` permits nonconflicting `INSERT` statements (concurrent inserts) to execute while the lock is held. However, this cannot be used if you are going to manipulate the database using processes external to the server while you hold the lock.

8.11.4 Metadata Locking

MySQL uses metadata locking to manage concurrent access to database objects and to ensure data consistency. Metadata locking applies not just to tables, but also to schemas and stored programs (procedures, functions, triggers, and scheduled events).

Metadata locking does involve some overhead, which increases as query volume increases. Metadata contention increases the more that multiple queries attempt to access the same objects.

Metadata locking is not a replacement for the table definition cache, and its mutexes and locks differ from the `LOCK_open` mutex. The following discussion provides some information about how metadata locking works.

To ensure transaction serializability, the server must not permit one session to perform a data definition language (DDL) statement on a table that is used in an uncompleted explicitly or implicitly started

transaction in another session. The server achieves this by acquiring metadata locks on tables used within a transaction and deferring release of those locks until the transaction ends. A metadata lock on a table prevents changes to the table's structure. This locking approach has the implication that a table that is being used by a transaction within one session cannot be used in DDL statements by other sessions until the transaction ends.

This principle applies not only to transactional tables, but also to nontransactional tables. Suppose that a session begins a transaction that uses transactional table `t` and nontransactional table `nt` as follows:

```
START TRANSACTION;
SELECT * FROM t;
SELECT * FROM nt;
```

The server holds metadata locks on both `t` and `nt` until the transaction ends. If another session attempts a DDL or write lock operation on either table, it blocks until metadata lock release at transaction end. For example, a second session blocks if it attempts any of these operations:

```
DROP TABLE t;
ALTER TABLE t ...;
DROP TABLE nt;
ALTER TABLE nt ...;
LOCK TABLE t ... WRITE;
```

If the server acquires metadata locks for a statement that is syntactically valid but fails during execution, it does not release the locks early. Lock release is still deferred to the end of the transaction because the failed statement is written to the binary log and the locks protect log consistency.

In autocommit mode, each statement is in effect a complete transaction, so metadata locks acquired for the statement are held only to the end of the statement.

Metadata locks acquired during a `PREPARE` statement are released once the statement has been prepared, even if preparation occurs within a multiple-statement transaction.

8.11.5 External Locking

External locking is the use of file system locking to manage contention for `MyISAM` database tables by multiple processes. External locking is used in situations where a single process such as the MySQL server cannot be assumed to be the only process that requires access to tables. Here are some examples:

- If you run multiple servers that use the same database directory (not recommended), each server must have external locking enabled.
- If you use `myisamchk` to perform table maintenance operations on `MyISAM` tables, you must either ensure that the server is not running, or that the server has external locking enabled so that it locks table files as necessary to coordinate with `myisamchk` for access to the tables. The same is true for use of `myisampack` to pack `MyISAM` tables.

  If the server is run with external locking enabled, you can use `myisamchk` at any time for read operations such a checking tables. In this case, if the server tries to update a table that `myisamchk` is using, the server will wait for `myisamchk` to finish before it continues.

  If you use `myisamchk` for write operations such as repairing or optimizing tables, or if you use `myisampack` to pack tables, you *must* always ensure that the `mysqld` server is not using the table. If you do not stop `mysqld`, at least do a `mysqladmin flush-tables` before you run `myisamchk`. Your tables *may become corrupted* if the server and `myisamchk` access the tables simultaneously.

With external locking in effect, each process that requires access to a table acquires a file system lock for the table files before proceeding to access the table. If all necessary locks cannot be acquired, the process is blocked from accessing the table until the locks can be obtained (after the process that currently holds the locks releases them).

External locking affects server performance because the server must sometimes wait for other processes before it can access tables.

External locking is unnecessary if you run a single server to access a given data directory (which is the usual case) and if no other programs such as `myisamchk` need to modify tables while the server is running. If you only *read* tables with other programs, external locking is not required, although `myisamchk` might report warnings if the server changes tables while `myisamchk` is reading them.

With external locking disabled, to use `myisamchk`, you must either stop the server while `myisamchk` executes or else lock and flush the tables before running `myisamchk`. (See Section 8.12.1, “System Factors”.) To avoid this requirement, use the `CHECK TABLE` and `REPAIR TABLE` statements to check and repair `MyISAM` tables.

For `mysqld`, external locking is controlled by the value of the `skip_external_locking` system variable. When this variable is enabled, external locking is disabled, and vice versa. External locking is disabled by default.

Use of external locking can be controlled at server startup by using the `--external-locking` or `--skip-external-locking` option.

If you do use external locking option to enable updates to `MyISAM` tables from many MySQL processes, you must ensure that the following conditions are satisfied:

- Do not use the query cache for queries that use tables that are updated by another process.
- Do not start the server with the `--delay-key-write=ALL` option or use the `DELAY_KEY_WRITE=1` table option for any shared tables. Otherwise, index corruption can occur.

The easiest way to satisfy these conditions is to always use `--external-locking` together with `--delay-key-write=OFF` and `--query-cache-size=0`. (This is not done by default because in many setups it is useful to have a mixture of the preceding options.)

8.12 Optimizing the MySQL Server

This section discusses optimization techniques for the database server, primarily dealing with system configuration rather than tuning SQL statements. The information in this section is appropriate for DBAs who want to ensure performance and scalability across the servers they manage; for developers constructing installation scripts that include setting up the database; and people running MySQL themselves for development, testing, and so on who want to maximize their own productivity.

8.12.1 System Factors

Some system-level factors can affect performance in a major way:

- If you have enough RAM, you could remove all swap devices. Some operating systems use a swap device in some contexts even if you have free memory.
- Avoid external locking for `MyISAM` tables. The default is for external locking to be disabled. The `--external-locking` and `--skip-external-locking` options explicitly enable and disable external locking.

  Disabling external locking does not affect MySQL's functionality as long as you run only one server. Just remember to take down the server (or lock and flush the relevant tables) before you run `myisamchk`. On some systems it is mandatory to disable external locking because it does not work, anyway.

  The only case in which you cannot disable external locking is when you run multiple MySQL *servers* (not clients) on the same data, or if you run `myisamchk` to check (not repair) a table without telling the server to flush and lock the tables first. Note that using multiple MySQL servers to access the same data concurrently is generally *not* recommended, except when using NDB Cluster.

The `LOCK TABLES` and `UNLOCK TABLES` statements use internal locking, so you can use them even if external locking is disabled.

8.12.2 Optimizing Disk I/O

This section describes ways to configure storage devices when you can devote more and faster storage hardware to the database server. For information about optimizing an `InnoDB` configuration to improve I/O performance, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- Disk seeks are a huge performance bottleneck. This problem becomes more apparent when the amount of data starts to grow so large that effective caching becomes impossible. For large databases where you access data more or less randomly, you can be sure that you need at least one disk seek to read and a couple of disk seeks to write things. To minimize this problem, use disks with low seek times.
- Increase the number of available disk spindles (and thereby reduce the seek overhead) by either symlinking files to different disks or striping the disks:
  - Using symbolic links

    This means that, for `MyISAM` tables, you symlink the index file and data files from their usual location in the data directory to another disk (that may also be striped). This makes both the seek and read times better, assuming that the disk is not used for other purposes as well. See Section 8.12.3, “Using Symbolic Links”.

    Symbolic links are not supported for use with `InnoDB` tables. However, it is possible to place `InnoDB` data and log files on different physical disks. For more information, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

  - Striping

    Striping means that you have many disks and put the first block on the first disk, the second block on the second disk, and the *`N`*-th block on the (*`N MOD number_of_disks`*) disk, and so on. This means if your normal data size is less than the stripe size (or perfectly aligned), you get much better performance. Striping is very dependent on the operating system and the stripe size, so benchmark your application with different stripe sizes. See Section 8.13.3, “Using Your Own Benchmarks”.

    The speed difference for striping is *very* dependent on the parameters. Depending on how you set the striping parameters and number of disks, you may get differences measured in orders of magnitude. You have to choose to optimize for random or sequential access.
- For reliability, you may want to use RAID 0+1 (striping plus mirroring), but in this case, you need 2 × *`N`* drives to hold *`N`* drives of data. This is probably the best option if you have the money for it. However, you may also have to invest in some volume-management software to handle it efficiently.
- A good option is to vary the RAID level according to how critical a type of data is. For example, store semi-important data that can be regenerated on a RAID 0 disk, but store really important data such as host information and logs on a RAID 0+1 or RAID *`N`* disk. RAID *`N`* can be a problem if you have many writes, due to the time required to update the parity bits.
- You can also set the parameters for the file system that the database uses:

  If you do not need to know when files were last accessed (which is not really useful on a database server), you can mount your file systems with the `-o noatime` option. That skips updates to the last access time in inodes on the file system, which avoids some disk seeks.

  On many operating systems, you can set a file system to be updated asynchronously by mounting it with the `-o async` option. If your computer is reasonably stable, this should give you better performance without sacrificing too much reliability. (This flag is on by default on Linux.)

Using NFS with MySQL

Caution is advised when considering using NFS with MySQL. Potential issues, which vary by operating system and NFS version, include:

- MySQL data and log files placed on NFS volumes becoming locked and unavailable for use. Locking issues may occur in cases where multiple instances of MySQL access the same data directory or where MySQL is shut down improperly, due to a power outage, for example. NFS version 4 addresses underlying locking issues with the introduction of advisory and lease-based locking. However, sharing a data directory among MySQL instances is not recommended.
- Data inconsistencies introduced due to messages received out of order or lost network traffic. To avoid this issue, use TCP with `hard` and `intr` mount options.
- Maximum file size limitations. NFS Version 2 clients can only access the lowest 2GB of a file (signed 32 bit offset). NFS Version 3 clients support larger files (up to 64 bit offsets). The maximum supported file size also depends on the local file system of the NFS server.

Using NFS within a professional SAN environment or other storage system tends to offer greater reliability than using NFS outside of such an environment. However, NFS within a SAN environment may be slower than directly attached or bus-attached non-rotational storage.

If you choose to use NFS, NFS Version 4 or later is recommended, as is testing your NFS setup thoroughly before deploying into a production environment.

8.12.3 Using Symbolic Links

You can move databases or tables from the database directory to other locations and replace them with symbolic links to the new locations. You might want to do this, for example, to move a database to a file system with more free space or increase the speed of your system by spreading your tables to different disks.

The recommended way to do this is to symlink entire database directories to a different disk. Symlink `MyISAM` tables only as a last resort.

To determine the location of your data directory, use this statement:

```
SHOW VARIABLES LIKE 'datadir';
```

8.12.3.1 Using Symbolic Links for Databases on Unix

On Unix, the way to symlink a database is first to create a directory on some disk where you have free space and then to create a soft link to it from the MySQL data directory.

```
shell> mkdir /dr1/databases/test
shell> ln -s /dr1/databases/test /path/to/datadir
```

MySQL does not support linking one directory to multiple databases. Replacing a database directory with a symbolic link works as long as you do not make a symbolic link between databases. Suppose that you have a database `db1` under the MySQL data directory, and then make a symlink `db2` that points to `db1`:

```
shell> cd /path/to/datadir
shell> ln -s db1 db2
```

The result is that, for any table `tbl_a` in `db1`, there also appears to be a table `tbl_a` in `db2`. If one client updates `db1.tbl_a` and another client updates `db2.tbl_a`, problems are likely to occur.

8.12.3.2 Using Symbolic Links for MyISAM Tables on Unix

Symlinks are fully supported only for `MyISAM` tables. For files used by tables for other storage engines, you may get strange problems if you try to use symbolic links.

Do not symlink tables on systems that do not have a fully operational `realpath()` call. (Linux and Solaris support `realpath()`). To determine whether your system supports symbolic links, check the value of the `have_symlink` system variable using this statement:

```
SHOW VARIABLES LIKE 'have_symlink';
```

The handling of symbolic links for `MyISAM` tables works as follows:

- In the data directory, you always have the table format (`.frm`) file, the data (`.MYD`) file, and the index (`.MYI`) file. The data file and index file can be moved elsewhere and replaced in the data directory by symlinks. The format file cannot.
- You can symlink the data file and the index file independently to different directories.
- To instruct a running MySQL server to perform the symlinking, use the `DATA DIRECTORY` and `INDEX DIRECTORY` options to `CREATE TABLE`. See Section 13.1.17, “CREATE TABLE Syntax”. Alternatively, if `mysqld` is not running, symlinking can be accomplished manually using `ln -s` from the command line.

  Note

  The path used with either or both of the `DATA DIRECTORY` and `INDEX DIRECTORY` options may not include the MySQL `data` directory. (Bug #32167)

- `myisamchk` does not replace a symlink with the data file or index file. It works directly on the file to which the symlink points. Any temporary files are created in the directory where the data file or index file is located. The same is true for the `ALTER TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` statements.
-

  Note

  When you drop a table that is using symlinks, *both the symlink and the file to which the symlink points are dropped*. This is an extremely good reason *not* to run `mysqld` as the system `root` or permit system users to have write access to MySQL database directories.

- If you rename a table with `ALTER TABLE ... RENAME` or `RENAME TABLE` and you do not move the table to another database, the symlinks in the database directory are renamed to the new names and the data file and index file are renamed accordingly.
- If you use `ALTER TABLE ... RENAME` or `RENAME TABLE` to move a table to another database, the table is moved to the other database directory. If the table name changed, the symlinks in the new database directory are renamed to the new names and the data file and index file are renamed accordingly.
- If you are not using symlinks, start `mysqld` with the `--skip-symbolic-links` option to ensure that no one can use `mysqld` to drop or rename a file outside of the data directory.

These table symlink operations are not supported:

- `ALTER TABLE` ignores the `DATA DIRECTORY` and `INDEX DIRECTORY` table options.
- As indicated previously, only the data and index files can be symbolic links. The `.frm` file must *never* be a symbolic link. Attempting to do this (for example, to make one table name a synonym for another) produces incorrect results. Suppose that you have a database `db1` under the MySQL data directory, a table `tbl1` in this database, and in the `db1` directory you make a symlink `tbl2` that points to `tbl1`:

```
shell> cd /path/to/datadir/db1
shell> ln -s tbl1.frm tbl2.frm
shell> ln -s tbl1.MYD tbl2.MYD
shell> ln -s tbl1.MYI tbl2.MYI
```

Problems result if one thread reads `db1.tbl1` and another thread updates `db1.tbl2`:

- The query cache is “fooled” (it has no way of knowing that `tbl1` has not been updated, so it returns outdated results).
- `ALTER` statements on `tbl2` fail.

8.12.3.3 Using Symbolic Links for Databases on Windows

On Windows, symbolic links can be used for database directories. This enables you to put a database directory at a different location (for example, on a different disk) by setting up a symbolic link to it. Use of database symlinks on Windows is similar to their use on Unix, although the procedure for setting up the link differs.

Suppose that you want to place the database directory for a database named `mydb` at `D:\data\mydb`. To do this, create a symbolic link in the MySQL data directory that points to `D:\data\mydb`. However, before creating the symbolic link, make sure that the `D:\data\mydb` directory exists by creating it if necessary. If you already have a database directory named `mydb` in the data directory, move it to `D:\data`. Otherwise, the symbolic link will be ineffective. To avoid problems, make sure that the server is not running when you move the database directory.

The procedure for creating the database symbolic link depends on your version of Windows.

Windows Vista, Windows Server 2008, or newer have native symbolic link support, so you can create a symlink using the `mklink` command. This command requires administrative privileges.

1. Change location into the data directory:

   ```
   C:\> cd \path\to\datadir
   ```

2. In the data directory, create a symlink named `mydb` that points to the location of the database directory:

   ```
   C:\> mklink /d mydb D:\data\mydb
   ```

After this, all tables created in the database `mydb` are created in `D:\data\mydb`.

Alternatively, on any version of Windows supported by MySQL, you can create a symbolic link to a MySQL database by creating a `.sym` file in the data directory that contains the path to the destination directory. The file should be named *`db_name`*`.sym`, where *`db_name`* is the database name.

Support for database symbolic links on Windows using `.sym` files is enabled by default. If you do not need `.sym` file symbolic links, you can disable support for them by starting `mysqld` with the `--skip-symbolic-links` option. To determine whether your system supports `.sym` file symbolic links, check the value of the `have_symlink` system variable using this statement:

```
SHOW VARIABLES LIKE 'have_symlink';
```

To create a `.sym` file symlink, use this procedure:

1. Change location into the data directory:

   ```
   C:\> cd \path\to\datadir
   ```

2. In the data directory, create a text file named `mydb.sym` that contains this path name: `D:\data\mydb\`

Note

The path name to the new database and tables should be absolute. If you specify a relative path, the location will be relative to the `mydb.sym` file.

After this, all tables created in the database `mydb` are created in `D:\data\mydb`.

The following limitations apply to the use of `.sym` files for database symbolic linking on Windows. These limitations do not apply for symlinks created using `mklink`.

- The symbolic link is not used if a directory with the same name as the database exists in the MySQL data directory.
- The `--innodb_file_per_table` option cannot be used.
- If you run `mysqld` as a service, you cannot use a mapped drive to a remote server as the destination of the symbolic link. As a workaround, you can use the full path (`\\servername\path\`).

8.12.4 Optimizing Memory Use

8.12.4.1 How MySQL Uses Memory

MySQL allocates buffers and caches to improve performance of database operations. You can improve MySQL performance by increasing the values of certain cache and buffer-related system variables. You can also modify these variables to run MySQL on systems with limited memory.

The following list describes some of the ways that MySQL uses memory. Where applicable, relevant system variables are referenced. Some items are storage engine or feature specific.

- The `InnoDB` buffer pool is a memory area that holds cached `InnoDB` data for tables, indexes, and other auxiliary buffers. For efficiency of high-volume read operations, the buffer pool is divided into pages that can potentially hold multiple rows. For efficiency of cache management, the buffer pool is implemented as a linked list of pages; data that is rarely used is aged out of the cache, using a variation of the LRU algorithm. For more information, see Section 14.9.2.1, “The InnoDB Buffer Pool”.

  The size of the buffer pool is important for system performance:

  - `InnoDB` allocates memory for the entire buffer pool at server startup, using `malloc()` operations. The `innodb_buffer_pool_size` system variable defines the buffer pool size. Typically, a recommended `innodb_buffer_pool_size` value is 50 to 75 percent of system memory. For more information, see Configuring InnoDB Buffer Pool Size.
  - On systems with a large amount of memory, you can improve concurrency by dividing the buffer pool into multiple buffer pool instances. The `innodb_buffer_pool_instances` system variable defines the number of buffer pool instances.
  - A buffer pool that is too small may cause excessive churning as pages are flushed from the buffer pool only to be required again a short time later.
  - A buffer pool that is too large may cause swapping due to competition for memory.
- All threads share the `MyISAM` key buffer. The `key_buffer_size` system variable determines its size.

  For each `MyISAM` table the server opens, the index file is opened once; the data file is opened once for each concurrently running thread that accesses the table. For each concurrent thread, a table structure, column structures for each column, and a buffer of size `3 * N` are allocated (where *`N`* is

the maximum row length, not counting `BLOB` columns). A `BLOB` column requires five to eight bytes plus the length of the `BLOB` data. The `MyISAM` storage engine maintains one extra row buffer for internal use.

- The `myisam_use_mmap` system variable can be set to 1 to enable memory-mapping for all `MyISAM` tables.
- If an internal in-memory temporary table becomes too large (as determined using the `tmp_table_size` and `max_heap_table_size` system variables), MySQL automatically converts the table from in-memory to on-disk format. On-disk temporary tables use the `MyISAM` storage engine. You can increase the permissible temporary table size as described in Section 8.4.4, "Internal Temporary Table Use in MySQL".

  For `MEMORY` tables explicitly created with `CREATE TABLE`, only the `max_heap_table_size` system variable determines how large the table is permitted to grow and there is no conversion to on-disk format.
- The MySQL Performance Schema is a feature for monitoring MySQL server execution at a low level. For performance reasons, fixed memory buffers for Performance Schema are allocated at server startup and do not change in size while the server is running.
- Each thread that the server uses to manage client connections requires some thread-specific space. The following list indicates these and which system variables control their size:
  - A stack (`thread_stack`)
  - A connection buffer (`net_buffer_length`)
  - A result buffer (`net_buffer_length`)

  The connection buffer and result buffer each begin with a size equal to `net_buffer_length` bytes, but are dynamically enlarged up to `max_allowed_packet` bytes as needed. The result buffer shrinks to `net_buffer_length` bytes after each SQL statement. While a statement is running, a copy of the current statement string is also allocated.
- All threads share the same base memory.
- When a thread is no longer needed, the memory allocated to it is released and returned to the system unless the thread goes back into the thread cache. In that case, the memory remains allocated.
- Each request that performs a sequential scan of a table allocates a *read buffer*. The `read_buffer_size` system variable determines the buffer size.
- When reading rows in an arbitrary sequence (for example, following a sort), a *random-read buffer* may be allocated to avoid disk seeks. The `read_rnd_buffer_size` system variable determines the buffer size.
- All joins are executed in a single pass, and most joins can be done without even using a temporary table. Most temporary tables are memory-based hash tables. Temporary tables with a large row length (calculated as the sum of all column lengths) or that contain `BLOB` columns are stored on disk.
- Most requests that perform a sort allocate a sort buffer and zero to two temporary files depending on the result set size. See Section B.5.3.5, "Where MySQL Stores Temporary Files".
- Almost all parsing and calculating is done in thread-local and reusable memory pools. No memory overhead is needed for small items, thus avoiding the normal slow memory allocation and freeing. Memory is allocated only for unexpectedly large strings.
- For each table having `BLOB` columns, a buffer is enlarged dynamically to read in larger `BLOB` values. If you scan a table, the buffer grows as large as the largest `BLOB` value.

- MySQL requires memory and descriptors for the table cache. Handler structures for all in-use tables are saved in the table cache and managed as “First In, First Out” (FIFO). The `table_open_cache` system variable defines the initial table cache size; see Section 8.4.3.1, “How MySQL Opens and Closes Tables”.

  MySQL also requires memory for the table definition cache. The `table_definition_cache` system variable defines the number of table definitions (from `.frm` files) that can be stored in the table definition cache. If you use a large number of tables, you can create a large table definition cache to speed up the opening of tables. The table definition cache takes less space and does not use file descriptors, unlike the table cache.

- A `FLUSH TABLES` statement or `mysqladmin flush-tables` command closes all tables that are not in use at once and marks all in-use tables to be closed when the currently executing thread finishes. This effectively frees most in-use memory. `FLUSH TABLES` does not return until all tables have been closed.

- The server caches information in memory as a result of `GRANT`, `CREATE USER`, `CREATE SERVER`, and `INSTALL PLUGIN` statements. This memory is not released by the corresponding `REVOKE`, `DROP USER`, `DROP SERVER`, and `UNINSTALL PLUGIN` statements, so for a server that executes many instances of the statements that cause caching, there will be an increase in memory use. This cached memory can be freed with `FLUSH PRIVILEGES`.

`ps` and other system status programs may report that `mysqld` uses a lot of memory. This may be caused by thread stacks on different memory addresses. For example, the Solaris version of `ps` counts the unused memory between stacks as used memory. To verify this, check available swap with `swap -s`. We test `mysqld` with several memory-leakage detectors (both commercial and Open Source), so there should be no memory leaks.

8.12.4.2 Enabling Large Page Support

Some hardware/operating system architectures support memory pages greater than the default (usually 4KB). The actual implementation of this support depends on the underlying hardware and operating system. Applications that perform a lot of memory accesses may obtain performance improvements by using large pages due to reduced Translation Lookaside Buffer (TLB) misses.

In MySQL, large pages can be used by InnoDB, to allocate memory for its buffer pool and additional memory pool.

Standard use of large pages in MySQL attempts to use the largest size supported, up to 4MB. Under Solaris, a “super large pages” feature enables uses of pages up to 256MB. This feature is available for recent SPARC platforms. It can be enabled or disabled by using the `--super-large-pages` or `--skip-super-large-pages` option.

MySQL also supports the Linux implementation of large page support (which is called HugeTLB in Linux).

Before large pages can be used on Linux, the kernel must be enabled to support them and it is necessary to configure the HugeTLB memory pool. For reference, the HugeTBL API is documented in the `Documentation/vm/hugetlbpage.txt` file of your Linux sources.

The kernel for some recent systems such as Red Hat Enterprise Linux appear to have the large pages feature enabled by default. To check whether this is true for your kernel, use the following command and look for output lines containing “huge”:

```
shell> cat /proc/meminfo | grep -i huge
HugePages_Total:       0
HugePages_Free:        0
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:       4096 kB
```

The nonempty command output indicates that large page support is present, but the zero values indicate that no pages are configured for use.

If your kernel needs to be reconfigured to support large pages, consult the `hugetlbpage.txt` file for instructions.

Assuming that your Linux kernel has large page support enabled, configure it for use by MySQL using the following commands. Normally, you put these in an `rc` file or equivalent startup file that is executed during the system boot sequence, so that the commands execute each time the system starts. The commands should execute early in the boot sequence, before the MySQL server starts. Be sure to change the allocation numbers and the group number as appropriate for your system.

```
# Set the number of pages to be used.
# Each page is normally 2MB, so a value of 20 = 40MB.
# This command actually allocates memory, so this much
# memory must be available.
echo 20 > /proc/sys/vm/nr_hugepages

# Set the group number that is permitted to access this
# memory (102 in this case). The mysql user must be a
# member of this group.
echo 102 > /proc/sys/vm/hugetlb_shm_group

# Increase the amount of shmem permitted per segment
# (12G in this case).
echo 1560281088 > /proc/sys/kernel/shmmax

# Increase total amount of shared memory.  The value
# is the number of pages. At 4KB/page, 4194304 = 16GB.
echo 4194304 > /proc/sys/kernel/shmall
```

For MySQL usage, you normally want the value of `shmmax` to be close to the value of `shmall`.

To verify the large page configuration, check `/proc/meminfo` again as described previously. Now you should see some nonzero values:

```
shell> cat /proc/meminfo | grep -i huge
HugePages_Total:      20
HugePages_Free:       20
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:       4096 kB
```

The final step to make use of the `hugetlb_shm_group` is to give the `mysql` user an “unlimited” value for the memlock limit. This can be done either by editing `/etc/security/limits.conf` or by adding the following command to your `mysqld_safe` script:

```
ulimit -l unlimited
```

Adding the `ulimit` command to `mysqld_safe` causes the `root` user to set the memlock limit to `unlimited` before switching to the `mysql` user. (This assumes that `mysqld_safe` is started by `root`.)

Large page support in MySQL is disabled by default. To enable it, start the server with the `--large-pages` option. For example, you can use the following lines in your server's `my.cnf` file:

```
[mysqld]
large-pages
```

With this option, `InnoDB` uses large pages automatically for its buffer pool and additional memory pool. If `InnoDB` cannot do this, it falls back to use of traditional memory and writes a warning to the error log: `Warning: Using conventional memory pool`

To verify that large pages are being used, check `/proc/meminfo` again:

```
shell> cat /proc/meminfo | grep -i huge
HugePages_Total:      20
HugePages_Free:       20
HugePages_Rsvd:        2
HugePages_Surp:        0
Hugepagesize:       4096 kB
```

8.12.5 Optimizing Network Use

8.12.5.1 How MySQL Uses Threads for Client Connections

Connection manager threads handle client connection requests on the network interfaces that the server listens to. On all platforms, one manager thread handles TCP/IP connection requests. On Unix, this manager thread also handles Unix socket file connection requests. On Windows, a manager thread handles shared-memory connection requests, and another handles named-pipe connection requests. The server does not create threads to handle interfaces that it does not listen to. For example, a Windows server that does not have support for named-pipe connections enabled does not create a thread to handle them.

By default, connection manager threads associate each client connection with a thread dedicated to it that handles authentication and request processing for that connection. Manager threads create a new thread when necessary but try to avoid doing so by consulting the thread cache first to see whether it contains a thread that can be used for the connection. When a connection ends, its thread is returned to the thread cache if the cache is not full.

In the default connection thread model, there are as many threads as there are clients currently connected, which has some disadvantages when server workload must scale to handle large numbers of connections. For example, thread creation and disposal becomes expensive. Also, each thread requires server and kernel resources, such as stack space. To accommodate a large number of simultaneous connections, the stack size per thread must be kept small, leading to a situation where it is either too small or the server consumes large amounts of memory. Exhaustion of other resources can occur as well, and scheduling overhead can become significant.

As of MySQL 5.5.16, MySQL Enterprise Edition includes a thread pool plugin that provides an alternative thread-handling model designed to reduce overhead and improve performance. It implements a thread pool that increases server performance by efficiently managing statement execution threads for large numbers of client connections. See Section 5.5.3, “MySQL Enterprise Thread Pool”.

To control and monitor how the server manages threads that handle client connections, several system and status variables are relevant. (See Section 5.1.5, “Server System Variables”, and Section 5.1.7, “Server Status Variables”.)

The thread cache has a size determined by the `thread_cache_size` system variable. The default value is 0 (no caching), which causes a thread to be set up for each new connection and disposed of when the connection terminates. Set `thread_cache_size` to *`N`* to enable *`N`* inactive connection threads to be cached. `thread_cache_size` can be set at server startup or changed while the server runs. A connection thread becomes inactive when the client connection with which it was associated terminates.

To monitor the number of threads in the cache and how many threads have been created because a thread could not be taken from the cache, monitor the `Threads_cached` and `Threads_created` status variables.

You can set `max_connections` at server startup or at runtime to control the maximum number of clients that can connect simultaneously.

When the thread stack is too small, this limits the complexity of the SQL statements which the server can handle, the recursion depth of stored procedures, and other memory-consuming actions. To set a stack size of *`N`* bytes for each thread, start the server with `--thread_stack=`*`N`*.

8.12.5.2 DNS Lookup Optimization and the Host Cache

The MySQL server maintains a host cache in memory that contains information about clients: IP address, host name, and error information. The server uses this cache for nonlocal TCP connections. It does not use the cache for TCP connections established using a loopback interface address (`127.0.0.1` or `::1`), or for connections established using a Unix socket file, named pipe, or shared memory.

For each new client connection, the server uses the client IP address to check whether the client host name is in the host cache. If not, the server attempts to resolve the host name. First, it resolves the IP address to a host name and resolves that host name back to an IP address. Then it compares the result to the original IP address to ensure that they are the same. The server stores information about the result of this operation in the host cache. If the cache is full, the least recently used entry is discarded.

The server performs host name resolution using the thread-safe `gethostbyaddr_r()` and `gethostbyname_r()` calls if the operating system supports them. Otherwise, the thread performing the lookup locks a mutex and calls `gethostbyaddr()` and `gethostbyname()` instead. In this case, no other thread can resolve host names that are not in the host cache until the thread holding the mutex lock releases it.

The server uses the host cache for several purposes:

- By caching the results of IP-to-host name lookups, the server avoids doing a DNS lookup for each client connection. Instead, for a given host, it needs to perform a lookup only for the first connection from that host.
- The cache contains information about errors that occur during the connection process. Some errors are considered “blocking.” If too many of these occur successively from a given host without a successful connection, the server blocks further connections from that host. The `max_connect_errors` system variable determines the number of permitted errors before blocking occurs. See Section B.5.2.6, “Host 'host_name' is blocked”.

To unblock blocked hosts, flush the host cache by issuing a `FLUSH HOSTS` statement or executing a `mysqladmin flush-hosts` command.

It is possible for a blocked host to become unblocked even without `FLUSH HOSTS` if activity from other hosts has occurred since the last connection attempt from the blocked host. This can occur because the server discards the least recently used cache entry to make room for a new entry if the cache is full when a connection arrives from a client IP not in the cache. If the discarded entry is for a blocked host, that host becomes unblocked.

The host cache is enabled by default. To disable it, start the server with the `--skip-host-cache` option.

To disable DNS host name lookups, start the server with the `--skip-name-resolve` option. In this case, the server uses only IP addresses and not host names to match connecting hosts to rows in the MySQL grant tables. Only accounts specified in those tables using IP addresses can be used. (Be sure that an account exists that specifies an IP address or you may not be able to connect.)

If you have a very slow DNS and many hosts, you might be able to improve performance either by disabling DNS lookups with `--skip-name-resolve` or by increasing the `HOST_CACHE_SIZE` define (default value: 128) and recompiling the server

To disallow TCP/IP connections entirely, start the server with the `--skip-networking` option.

Some connection errors are not associated with TCP connections, occur very early in the connection process (even before an IP address is known), or are not specific to any particular IP address (such as out-of-memory conditions).

8.13 Measuring Performance (Benchmarking)

To measure performance, consider the following factors:

- Whether you are measuring the speed of a single operation on a quiet system, or how a set of operations (a “workload”) works over a period of time. With simple tests, you usually test how changing one aspect (a configuration setting, the set of indexes on a table, the SQL clauses in a query) affects performance. Benchmarks are typically long-running and elaborate performance tests, where the results could dictate high-level choices such as hardware and storage configuration, or how soon to upgrade to a new MySQL version.
- For benchmarking, sometimes you must simulate a heavy database workload to get an accurate picture.
- Performance can vary depending on so many different factors that a difference of a few percentage points might not be a decisive victory. The results might shift the opposite way when you test in a different environment.
- Certain MySQL features help or do not help performance depending on the workload. For completeness, always test performance with those features turned on and turned off. The two most important features to try with each workload are the MySQL query cache, and the adaptive hash index for `InnoDB` tables.

This section progresses from simple and direct measurement techniques that a single developer can do, to more complicated ones that require additional expertise to perform and interpret the results.

8.13.1 Measuring the Speed of Expressions and Functions

To measure the speed of a specific MySQL expression or function, invoke the `BENCHMARK()` function using the `mysql` client program. Its syntax is `BENCHMARK(loop_count,expression)`. The return value is always zero, but `mysql` prints a line displaying approximately how long the statement took to execute. For example:

```
mysql> SELECT BENCHMARK(1000000,1+1);
+------------------------+
| BENCHMARK(1000000,1+1) |
+------------------------+
|                      0 |
+------------------------+
1 row in set (0.32 sec)
```

This result was obtained on a Pentium II 400MHz system. It shows that MySQL can execute 1,000,000 simple addition expressions in 0.32 seconds on that system.

The built-in MySQL functions are typically highly optimized, but there may be some exceptions. `BENCHMARK()` is an excellent tool for finding out if some function is a problem for your queries.

8.13.2 The MySQL Benchmark Suite

This benchmark suite is meant to tell any user what operations a given SQL implementation performs well or poorly. You can get a good idea for how the benchmarks work by looking at the code and results in the `sql-bench` directory in any MySQL source distribution.

To use the benchmark suite, the following requirements must be satisfied:

- The benchmark suite is provided with MySQL source distributions. You can either download a released distribution from http://dev.mysql.com/downloads/, or use the current development source tree. (See Section 2.9.3, “Installing MySQL Using a Development Source Tree”.)
- The benchmark scripts are written in Perl and use the Perl DBI module to access database servers, so DBI must be installed. You also need the server-specific DBD drivers for each of the servers you

want to test. For example, to test MySQL, PostgreSQL, and DB2, you must have the `DBD::mysql`, `DBD::Pg`, and `DBD::DB2` modules installed. See Section 2.12, “Perl Installation Notes”.

After you obtain a MySQL source distribution, you can find the benchmark suite located in its `sql-bench` directory. To run the benchmark tests, build MySQL, and then change location into the `sql-bench` directory and execute the `run-all-tests` script:

```
shell> cd sql-bench
shell> perl run-all-tests --server=server_name
```

`server_name` should be the name of one of the supported servers. To get a list of all options and supported servers, invoke this command:

```
shell> perl run-all-tests --help
```

The `crash-me` script also is located in the `sql-bench` directory. `crash-me` tries to determine what features a database system supports and what its capabilities and limitations are by actually running queries. For example, it determines:

- What data types are supported
- How many indexes are supported
- What functions are supported
- How big a query can be
- How big a `VARCHAR` column can be

For more information about benchmark results, visit http://www.mysql.com/why-mysql/benchmarks/.

8.13.3 Using Your Own Benchmarks

Benchmark your application and database to find out where the bottlenecks are. After fixing one bottleneck (or by replacing it with a “dummy” module), you can proceed to identify the next bottleneck. Even if the overall performance for your application currently is acceptable, you should at least make a plan for each bottleneck and decide how to solve it if someday you really need the extra performance.

For examples of portable benchmark programs, look at those in the MySQL benchmark suite. See Section 8.13.2, “The MySQL Benchmark Suite”. You can take any program from this suite and modify it for your own needs. By doing this, you can try different solutions to your problem and test which really is fastest for you.

Another free benchmark suite is the Open Source Database Benchmark, available at http://osdb.sourceforge.net/.

It is very common for a problem to occur only when the system is very heavily loaded. We have had many customers who contact us when they have a (tested) system in production and have encountered load problems. In most cases, performance problems turn out to be due to issues of basic database design (for example, table scans are not good under high load) or problems with the operating system or libraries. Most of the time, these problems would be much easier to fix if the systems were not already in production.

To avoid problems like this, benchmark your whole application under the worst possible load:

- The `mysqlslap` program can be helpful for simulating a high load produced by multiple clients issuing queries simultaneously. See Section 4.5.7, “`mysqlslap` — Load Emulation Client”.
- You can also try benchmarking packages such as SysBench and DBT2, available at https://launchpad.net/sysbench, and http://osdldbt.sourceforge.net/#dbt2.

These programs or packages can bring a system to its knees, so be sure to use them only on your development systems.

8.13.4 Measuring Performance with performance_schema

You can query the tables in the `performance_schema` database to see real-time information about the performance characteristics of your server and the applications it is running. See Chapter 22, *MySQL Performance Schema* for details.

8.14 Examining Thread Information

As you monitor the performance of your MySQL server, examine the process list, which is the set of threads currently executing within the server. Process list information is available from these sources:

- The `SHOW [FULL] PROCESSLIST` statement: Section 13.7.5.30, “SHOW PROCESSLIST Syntax”
- The `SHOW PROFILE` statement: Section 13.7.5.32, “SHOW PROFILES Syntax”
- The `INFORMATION_SCHEMA PROCESSLIST` table: Section 21.14, “The INFORMATION_SCHEMA PROCESSLIST Table”
- The `mysqladmin processlist` command: Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”

You can always view information about your own threads. To view information about threads being executed for other accounts, you must have the `PROCESS` privilege.

Each process list entry contains several pieces of information:

- `Id` is the connection identifier for the client associated with the thread.
- `User` and `Host` indicate the account associated with the thread.
- `db` is the default database for the thread, or `NULL` if none is selected.
- `Command` and `State` indicate what the thread is doing.

  Most states correspond to very quick operations. If a thread stays in a given state for many seconds, there might be a problem that needs to be investigated.
- `Time` indicates how long the thread has been in its current state. The thread's notion of the current time may be altered in some cases: The thread can change the time with `SET TIMESTAMP = value`. For a thread running on a slave that is processing events from the master, the thread time is set to the time found in the events and thus reflects current time on the master and not the slave.
- `Info` contains the text of the statement being executed by the thread, or `NULL` if it is not executing one. By default, this value contains only the first 100 characters of the statement. To see the complete statements, use `SHOW FULL PROCESSLIST`.

The following sections list the possible `Command` values, and `State` values grouped by category. The meaning for some of these values is self-evident. For others, additional description is provided.

8.14.1 Thread Command Values

A thread can have any of the following `Command` values:

- `Binlog Dump`

  This is a thread on a master server for sending binary log contents to a slave server.
- `Change user`

The thread is executing a change-user operation.

- `Close stmt`

  The thread is closing a prepared statement.

- `Connect`

  A replication slave is connected to its master.

- `Connect Out`

  A replication slave is connecting to its master.

- `Create DB`

  The thread is executing a create-database operation.

- `Daemon`

  This thread is internal to the server, not a thread that services a client connection.

- `Debug`

  The thread is generating debugging information.

- `Delayed insert`

  The thread is a delayed-insert handler.

- `Drop DB`

  The thread is executing a drop-database operation.

- `Error`

- `Execute`

  The thread is executing a prepared statement.

- `Fetch`

  The thread is fetching the results from executing a prepared statement.

- `Field List`

  The thread is retrieving information for table columns.

- `Init DB`

  The thread is selecting a default database.

- `Kill`

  The thread is killing another thread.

- `Long Data`

  The thread is retrieving long data in the result of executing a prepared statement.

- `Ping`

  The thread is handling a server-ping request.

- `Prepare`

  The thread is preparing a prepared statement.

- `Processlist`

  The thread is producing information about server threads.

- `Query`

  The thread is executing a statement.

- `Quit`

  The thread is terminating.

- `Refresh`

  The thread is flushing table, logs, or caches, or resetting status variable or replication server information.

- `Register Slave`

  The thread is registering a slave server.

- `Reset stmt`

  The thread is resetting a prepared statement.

- `Set option`

  The thread is setting or resetting a client statement-execution option.

- `Shutdown`

  The thread is shutting down the server.

- `Sleep`

  The thread is waiting for the client to send a new statement to it.

- `Statistics`

  The thread is producing server-status information.

- `Table Dump`

  The thread is sending table contents to a slave server.

- `Time`

  Unused.

8.14.2 General Thread States

The following list describes thread `State` values that are associated with general query processing and not more specialized activities such as replication. Many of these are useful only for finding bugs in the server.

- `After create`

  This occurs when the thread creates a table (including internal temporary tables), at the end of the function that creates the table. This state is used even if the table could not be created due to some error.

- `Analyzing`

  The thread is calculating a `MyISAM` table key distributions (for example, for `ANALYZE TABLE`).

- `checking permissions`

  The thread is checking whether the server has the required privileges to execute the statement.

- `Checking table`

  The thread is performing a table check operation.

- `cleaning up`

  The thread has processed one command and is preparing to free memory and reset certain state variables.

- `closing tables`

  The thread is flushing the changed table data to disk and closing the used tables. This should be a fast operation. If not, verify that you do not have a full disk and that the disk is not in very heavy use.

- `converting HEAP to MyISAM`

  The thread is converting an internal temporary table from a `MEMORY` table to an on-disk `MyISAM` table.

- `copy to tmp table`

  The thread is processing an `ALTER TABLE` statement. This state occurs after the table with the new structure has been created but before rows are copied into it.

- `Copying to group table`

  If a statement has different `ORDER BY` and `GROUP BY` criteria, the rows are sorted by group and copied to a temporary table.

- `Copying to tmp table`

  The server is copying to a temporary table in memory.

- `Copying to tmp table on disk`

  The server is copying to a temporary table on disk. The temporary result set has become too large (see Section 8.4.4, “Internal Temporary Table Use in MySQL”). Consequently, the thread is changing the temporary table from in-memory to disk-based format to save memory.

- `Creating index`

  The thread is processing `ALTER TABLE ... ENABLE KEYS` for a `MyISAM` table.

- `Creating sort index`

  The thread is processing a `SELECT` that is resolved using an internal temporary table.

- `creating table`

  The thread is creating a table. This includes creation of temporary tables.

- `Creating tmp table`

  The thread is creating a temporary table in memory or on disk. If the table is created in memory but later is converted to an on-disk table, the state during that operation will be `Copying to tmp table on disk`.

- `deleting from main table`

  The server is executing the first part of a multiple-table delete. It is deleting only from the first table, and saving columns and offsets to be used for deleting from the other (reference) tables.

- `deleting from reference tables`

  The server is executing the second part of a multiple-table delete and deleting the matched rows from the other tables.

- `discard_or_import_tablespace`

  The thread is processing an `ALTER TABLE ... DISCARD TABLESPACE` or `ALTER TABLE ... IMPORT TABLESPACE` statement.

- `end`

  This occurs at the end but before the cleanup of `ALTER TABLE`, `CREATE VIEW`, `DELETE`, `INSERT`, `SELECT`, or `UPDATE` statements.

- `executing`

  The thread has begun executing a statement.

- `Execution of init_command`

  The thread is executing statements in the value of the `init_command` system variable.

- `freeing items`

  The thread has executed a command. Some freeing of items done during this state involves the query cache. This state is usually followed by `cleaning up`.

- `FULLTEXT initialization`

  The server is preparing to perform a natural-language full-text search.

- `init`

  This occurs before the initialization of `ALTER TABLE`, `DELETE`, `INSERT`, `SELECT`, or `UPDATE` statements. Actions taken by the server in this state include flushing the binary log, the `InnoDB` log, and some query cache cleanup operations.

  For the `end` state, the following operations could be happening:

  - Removing query cache entries after data in a table is changed
  - Writing an event to the binary log
  - Freeing memory buffers, including for blobs

- `Killed`

  Someone has sent a `KILL` statement to the thread and it should abort next time it checks the kill flag. The flag is checked in each major loop in MySQL, but in some cases it might still take a short time for the thread to die. If the thread is locked by some other thread, the kill takes effect as soon as the other thread releases its lock.

- `logging slow query`

  The thread is writing a statement to the slow-query log.

- `login`

The initial state for a connection thread until the client has been authenticated successfully.

- `manage keys`

  The server is enabling or disabling a table index.

- `NULL`

  This state is used for the `SHOW PROCESSLIST` state.

- `Opening tables`, `Opening table`

  The thread is trying to open a table. This is should be very fast procedure, unless something prevents opening. For example, an `ALTER TABLE` or a `LOCK TABLE` statement can prevent opening a table until the statement is finished. It is also worth checking that your `table_open_cache` value is large enough.

- `optimizing`

  The server is performing initial optimizations for a query.

- `preparing`

  This state occurs during query optimization.

- `Purging old relay logs`

  The thread is removing unneeded relay log files.

- `query end`

  This state occurs after processing a query but before the `freeing items` state.

- `Reading from net`

  The server is reading a packet from the network.

- `Removing duplicates`

  The query was using `SELECT DISTINCT` in such a way that MySQL could not optimize away the distinct operation at an early stage. Because of this, MySQL requires an extra stage to remove all duplicated rows before sending the result to the client.

- `removing tmp table`

  The thread is removing an internal temporary table after processing a `SELECT` statement. This state is not used if no temporary table was created.

- `rename`

  The thread is renaming a table.

- `rename result table`

  The thread is processing an `ALTER TABLE` statement, has created the new table, and is renaming it to replace the original table.

- `Reopen tables`

  The thread got a lock for the table, but noticed after getting the lock that the underlying table structure changed. It has freed the lock, closed the table, and is trying to reopen it.

- `Repair by sorting`

The repair code is using a sort to create indexes.

- `Repair done`

  The thread has completed a multi-threaded repair for a `MyISAM` table.

- `Repair with keycache`

  The repair code is using creating keys one by one through the key cache. This is much slower than `Repair by sorting`.

- `Rolling back`

  The thread is rolling back a transaction.

- `Saving state`

  For `MyISAM` table operations such as repair or analysis, the thread is saving the new table state to the `.MYI` file header. State includes information such as number of rows, the `AUTO_INCREMENT` counter, and key distributions.

- `Searching rows for update`

  The thread is doing a first phase to find all matching rows before updating them. This has to be done if the `UPDATE` is changing the index that is used to find the involved rows.

- `Sending data`

  The thread is reading and processing rows for a `SELECT` statement, and sending data to the client. Because operations occurring during this state tend to perform large amounts of disk access (reads), it is often the longest-running state over the lifetime of a given query.

- `setup`

  The thread is beginning an `ALTER TABLE` operation.

- `Sorting for group`

  The thread is doing a sort to satisfy a `GROUP BY`.

- `Sorting for order`

  The thread is doing a sort to satisfy an `ORDER BY`.

- `Sorting index`

  The thread is sorting index pages for more efficient access during a `MyISAM` table optimization operation.

- `Sorting result`

  For a `SELECT` statement, this is similar to `Creating sort index`, but for nontemporary tables.

- `statistics`

  The server is calculating statistics to develop a query execution plan. If a thread is in this state for a long time, the server is probably disk-bound performing other work.

- `System lock`

  The thread has called `mysql_lock_tables()` and the thread state has not been updated since. This is a very general state that can occur for many reasons.

For example, the thread is going to request or is waiting for an internal or external system lock for the table. This can occur when `InnoDB` waits for a table-level lock during execution of `LOCK TABLES`. If this state is being caused by requests for external locks and you are not using multiple `mysqld` servers that are accessing the same `MyISAM` tables, you can disable external system locks with the `--skip-external-locking` option. However, external locking is disabled by default, so it is likely that this option will have no effect. For `SHOW PROFILE`, this state means the thread is requesting the lock (not waiting for it).

- `update`

  The thread is getting ready to start updating the table.

- `Updating`

  The thread is searching for rows to update and is updating them.

- `updating main table`

  The server is executing the first part of a multiple-table update. It is updating only the first table, and saving columns and offsets to be used for updating the other (reference) tables.

- `updating reference tables`

  The server is executing the second part of a multiple-table update and updating the matched rows from the other tables.

- `User lock`

  The thread is going to request or is waiting for an advisory lock requested with a `GET_LOCK()` call. For `SHOW PROFILE`, this state means the thread is requesting the lock (not waiting for it).

- `User sleep`

  The thread has invoked a `SLEEP()` call.

- `Waiting for commit lock`

  A statement that causes an explicit or implicit commit is waiting for release of a read lock or `FLUSH TABLES WITH READ LOCK` is waiting for a commit lock.

- `Waiting for global read lock`

  `FLUSH TABLES WITH READ LOCK` is waiting for a global read lock or the global `read_only` system variable is being set.

- `Waiting for tables`

  The thread got a notification that the underlying structure for a table has changed and it needs to reopen the table to get the new structure. However, to reopen the table, it must wait until all other threads have closed the table in question.

  This notification takes place if another thread has used `FLUSH TABLES` or one of the following statements on the table in question: `FLUSH TABLES` *`tbl_name`*, `ALTER TABLE`, `RENAME TABLE`, `REPAIR TABLE`, `ANALYZE TABLE`, or `OPTIMIZE TABLE`.

- `Waiting for table flush`

  The thread is executing `FLUSH TABLES` and is waiting for all threads to close their tables, or the thread got a notification that the underlying structure for a table has changed and it needs to reopen the table to get the new structure. However, to reopen the table, it must wait until all other threads have closed the table in question.

This notification takes place if another thread has used `FLUSH TABLES` or one of the following statements on the table in question: `FLUSH TABLES tbl_name`, `ALTER TABLE`, `RENAME TABLE`, `REPAIR TABLE`, `ANALYZE TABLE`, or `OPTIMIZE TABLE`.

- `Waiting for lock_type lock`

  The server is waiting to acquire a `THR_LOCK` lock or a lock from the metadata locking subsystem, where `lock_type` indicates the type of lock.

  This state indicates a wait for a `THR_LOCK`:

  - `Waiting for table level lock`

  These states indicate a wait for a metadata lock:

  - `Waiting for event metadata lock`
  - `Waiting for global metadata lock`
  - `Waiting for global read lock`
  - `Waiting for schema metadata lock`
  - `Waiting for stored function metadata lock`
  - `Waiting for stored procedure metadata lock`
  - `Waiting for table metadata lock`
  - `Waiting for trigger metadata lock`

  For information about table lock indicators, see Section 8.11.1, “Internal Locking Methods”. For information about metadata locking, see Section 8.11.4, “Metadata Locking”.

- `Waiting on cond`

  A generic state in which the thread is waiting for a condition to become true. No specific state information is available.

- `Writing to net`

  The server is writing a packet to the network.

8.14.3 Delayed-Insert Thread States

These thread states are associated with processing for `DELAYED` inserts (see Section 13.2.5.3, “INSERT DELAYED Syntax”). Some states are associated with connection threads that process `INSERT DELAYED` statements from clients. Other states are associated with delayed-insert handler threads that insert the rows. There is a delayed-insert handler thread for each table for which `INSERT DELAYED` statements are issued.

States associated with a connection thread that processes an `INSERT DELAYED` statement from the client:

- `allocating local table`

  The thread is preparing to feed rows to the delayed-insert handler thread.

- `Creating delayed handler`

  The thread is creating a handler for `DELAYED` inserts.

- `got handler lock`

  This occurs before the `allocating local table` state and after the `waiting for handler lock` state, when the connection thread gets access to the delayed-insert handler thread.

- `got old table`

  This occurs after the `waiting for handler open` state. The delayed-insert handler thread has signaled that it has ended its initialization phase, which includes opening the table for delayed inserts.

- `storing row into queue`

  The thread is adding a new row to the list of rows that the delayed-insert handler thread must insert.

- `waiting for delay_list`

  This occurs during the initialization phase when the thread is trying to find the delayed-insert handler thread for the table, and before attempting to gain access to the list of delayed-insert threads.

- `waiting for handler insert`

  An `INSERT DELAYED` handler has processed all pending inserts and is waiting for new ones.

- `waiting for handler lock`

  This occurs before the `allocating local table` state when the connection thread waits for access to the delayed-insert handler thread.

- `waiting for handler open`

  This occurs after the `Creating delayed handler` state and before the `got old table` state. The delayed-insert handler thread has just been started, and the connection thread is waiting for it to initialize.

States associated with a delayed-insert handler thread that inserts the rows:

- `insert`

  The state that occurs just before inserting rows into the table.

- `reschedule`

  After inserting a number of rows, the delayed-insert thread sleeps to let other threads do work.

- `upgrading lock`

  A delayed-insert handler is trying to get a lock for the table to insert rows.

- `Waiting for INSERT`

  A delayed-insert handler is waiting for a connection thread to add rows to the queue (see `storing row into queue`).

8.14.4 Query Cache Thread States

These thread states are associated with the query cache (see Section 8.10.3, “The MySQL Query Cache”).

- `checking privileges on cached query`

  The server is checking whether the user has privileges to access a cached query result.

- `checking query cache for query`

  The server is checking whether the current query is present in the query cache.

- `invalidating query cache entries`

  Query cache entries are being marked invalid because the underlying tables have changed.

- `sending cached result to client`

  The server is taking the result of a query from the query cache and sending it to the client.

- `storing result in query cache`

  The server is storing the result of a query in the query cache.

- `Waiting for query cache lock`

  This state occurs while a session is waiting to take the query cache lock. This can happen for any statement that needs to perform some query cache operation, such as an `INSERT` or `DELETE` that invalidates the query cache, a `SELECT` that looks for a cached entry, `RESET QUERY CACHE`, and so forth.

8.14.5 Replication Master Thread States

The following list shows the most common states you may see in the `State` column for the master's `Binlog Dump` thread. If you see no `Binlog Dump` threads on a master server, this means that replication is not running—that is, that no slaves are currently connected.

- `Finished reading one binlog; switching to next binlog`

  The thread has finished reading a binary log file and is opening the next one to send to the slave.

- `Master has sent all binlog to slave; waiting for binlog to be updated`

  The thread has read all outstanding updates from the binary logs and sent them to the slave. The thread is now idle, waiting for new events to appear in the binary log resulting from new updates occurring on the master.

- `Sending binlog event to slave`

  Binary logs consist of *events*, where an event is usually an update plus some other information. The thread has read an event from the binary log and is now sending it to the slave.

- `Waiting to finalize termination`

  A very brief state that occurs as the thread is stopping.

8.14.6 Replication Slave I/O Thread States

The following list shows the most common states you see in the `State` column for a slave server I/O thread. This state also appears in the `Slave_IO_State` column displayed by `SHOW SLAVE STATUS`, so you can get a good view of what is happening by using that statement.

- `Checking master version`

  A state that occurs very briefly, after the connection to the master is established.

- `Connecting to master`

  The thread is attempting to connect to the master.

- `Queueing master event to the relay log`

The thread has read an event and is copying it to the relay log so that the SQL thread can process it.

- `Reconnecting after a failed binlog dump request`

  The thread is trying to reconnect to the master.

- `Reconnecting after a failed master event read`

  The thread is trying to reconnect to the master. When connection is established again, the state becomes `Waiting for master to send event`.

- `Registering slave on master`

  A state that occurs very briefly after the connection to the master is established.

- `Requesting binlog dump`

  A state that occurs very briefly, after the connection to the master is established. The thread sends to the master a request for the contents of its binary logs, starting from the requested binary log file name and position.

- `Waiting for master to send event`

  The thread has connected to the master and is waiting for binary log events to arrive. This can last for a long time if the master is idle. If the wait lasts for `slave_net_timeout` seconds, a timeout occurs. At that point, the thread considers the connection to be broken and makes an attempt to reconnect.

- `Waiting for master update`

  The initial state before `Connecting to master`.

- `Waiting for slave mutex on exit`

  A state that occurs briefly as the thread is stopping.

- `Waiting for the slave SQL thread to free enough relay log space`

  You are using a nonzero `relay_log_space_limit` value, and the relay logs have grown large enough that their combined size exceeds this value. The I/O thread is waiting until the SQL thread frees enough space by processing relay log contents so that it can delete some relay log files.

- `Waiting to reconnect after a failed binlog dump request`

  If the binary log dump request failed (due to disconnection), the thread goes into this state while it sleeps, then tries to reconnect periodically. The interval between retries can be specified using the `CHANGE MASTER TO` statement.

- `Waiting to reconnect after a failed master event read`

  An error occurred while reading (due to disconnection). The thread is sleeping for the number of seconds set by the `CHANGE MASTER TO` statement (default 60) before attempting to reconnect.

8.14.7 Replication Slave SQL Thread States

The following list shows the most common states you may see in the `State` column for a slave server SQL thread:

- `Waiting for the next event in relay log`

  The initial state before `Reading event from the relay log`.

- `Reading event from the relay log`

  The thread has read an event from the relay log so that the event can be processed.

- `Making temp file`

  The thread is executing a `LOAD DATA INFILE` statement and is creating a temporary file containing the data from which the slave will read rows.

- `Slave has read all relay log; waiting for the slave I/O thread to update it`

  The thread has processed all events in the relay log files, and is now waiting for the I/O thread to write new events to the relay log.

- `Waiting for slave mutex on exit`

  A very brief state that occurs as the thread is stopping.

The `State` column for the I/O thread may also show the text of a statement. This indicates that the thread has read an event from the relay log, extracted the statement from it, and is executing it.

8.14.8 Replication Slave Connection Thread States

These thread states occur on a replication slave but are associated with connection threads, not with the I/O or SQL threads.

- `Changing master`

  The thread is processing a `CHANGE MASTER TO` statement.

- `Killing slave`

  The thread is processing a `STOP SLAVE` statement.

- `Opening master dump table`

  This state occurs after `Creating table from master dump`.

- `Reading master dump table data`

  This state occurs after `Opening master dump table`.

- `Rebuilding the index on master dump table`

  This state occurs after `Reading master dump table data`.

8.14.9 NDB Cluster Thread States

- `Committing events to binlog`
- `Opening mysql.ndb_apply_status`
- `Processing events`

  The thread is processing events for binary logging.

- `Processing events from schema table`

  The thread is doing the work of schema replication.

- `Shutting down`

- `Syncing ndb table schema operation and binlog`

  This is used to have a correct binary log of schema operations for NDB.

- `Waiting for allowed to take ndbcluster global schema lock`

  The thread is waiting for permission to take a global schema lock. Added in MySQL NDB Cluster 7.2.

- `Waiting for event from ndbcluster`

  The server is acting as an SQL node in an NDB Cluster, and is connected to a cluster management node.

- `Waiting for first event from ndbcluster`

- `Waiting for ndbcluster binlog update to reach current position`

- `Waiting for ndbcluster global schema lock`

  The thread is waiting for a global schema lock held by another thread to be released. Added in MySQL NDB Cluster 7.2.

- `Waiting for ndbcluster to start`

- `Waiting for schema epoch`

  The thread is waiting for a schema epoch (that is, a global checkpoint).

8.14.10 Event Scheduler Thread States

These states occur for the Event Scheduler thread, threads that are created to execute scheduled events, or threads that terminate the scheduler.

- `Clearing`

  The scheduler thread or a thread that was executing an event is terminating and is about to end.

- `Initialized`

  The scheduler thread or a thread that will execute an event has been initialized.

- `Waiting for next activation`

  The scheduler has a nonempty event queue but the next activation is in the future.

- `Waiting for scheduler to stop`

  The thread issued `SET GLOBAL event_scheduler=OFF` and is waiting for the scheduler to stop.

- `Waiting on empty queue`

  The scheduler's event queue is empty and it is sleeping.

Chapter 9 Language Structure

Table of Contents

9.1 Literal Values 965
9.1.1 String Literals 965
9.1.2 Numeric Literals 968
9.1.3 Date and Time Literals 968
9.1.4 Hexadecimal Literals 970
9.1.5 Bit-Value Literals 972
9.1.6 Boolean Literals 973
9.1.7 NULL Values 974
9.2 Schema Object Names 974
9.2.1 Identifier Qualifiers 976
9.2.2 Identifier Case Sensitivity 978
9.2.3 Mapping of Identifiers to File Names 980
9.2.4 Function Name Parsing and Resolution 982
9.3 Keywords and Reserved Words 986
9.4 User-Defined Variables 1006
9.5 Expression Syntax 1009
9.6 Comment Syntax 1011

This chapter discusses the rules for writing the following elements of SQL statements when using MySQL:

- Literal values such as strings and numbers
- Identifiers such as database, table, and column names
- Keywords and reserved words
- User-defined and system variables
- Comments

9.1 Literal Values

This section describes how to write literal values in MySQL. These include strings, numbers, hexadecimal and bit values, boolean values, and `NULL`. The section also covers various nuances that you may encounter when dealing with these basic types in MySQL.

9.1.1 String Literals

A string is a sequence of bytes or characters, enclosed within either single quote (`'`) or double quote (`"`) characters. Examples:

```
'a string'
"another string"
```

Quoted strings placed next to each other are concatenated to a single string. The following lines are equivalent:

```
'a string'
'a' ' ' 'string'
```

If the `ANSI_QUOTES` SQL mode is enabled, string literals can be quoted only within single quotation marks because a string quoted within double quotation marks is interpreted as an identifier.

A *binary string* is a string of bytes. Every binary string has a character set and collation named `binary`. A *nonbinary string* is a string of characters. It has a character set other than `binary` and a collation that is compatible with the character set.

For both types of strings, comparisons are based on the numeric values of the string unit. For binary strings, the unit is the byte; comparisons use numeric byte values. For nonbinary strings, the unit is the character and some character sets support multibyte characters; comparisons use numeric character code values. Character code ordering is a function of the string collation. (For more information, see Section 10.1.8.5, “The binary Collation Compared to _bin Collations”.)

A character string literal may have an optional character set introducer and `COLLATE` clause, to designate it as a string that uses a particular character set and collation:

```
[_charset_name]'string' [COLLATE collation_name]
```

Examples:

```
SELECT _latin1'string';
SELECT _binary'string';
SELECT _utf8'string' COLLATE utf8_danish_ci;
```

You can use `N'literal'` (or `n'literal'`) to create a string in the national character set. These statements are equivalent:

```
SELECT N'some text';
SELECT n'some text';
SELECT _utf8'some text';
```

For information about these forms of string syntax, see Section 10.1.3.7, “The National Character Set”, and Section 10.1.3.8, “Character Set Introducers”.

Within a string, certain sequences have special meaning unless the `NO_BACKSLASH_ESCAPES` SQL mode is enabled. Each of these sequences begins with a backslash (`\`), known as the *escape character*. MySQL recognizes the escape sequences shown in Table 9.1, “Special Character Escape Sequences”. For all other escape sequences, backslash is ignored. That is, the escaped character is interpreted as if it was not escaped. For example, `\x` is just `x`. These sequences are case sensitive. For example, `\b` is interpreted as a backspace, but `\B` is interpreted as `B`. Escape processing is done according to the character set indicated by the `character_set_connection` system variable. This is true even for strings that are preceded by an introducer that indicates a different character set, as discussed in Section 10.1.3.6, “Character String Literal Character Set and Collation”.

Table 9.1 Special Character Escape Sequences

Escape Sequence	Character Represented by Sequence
`\0`	An ASCII NUL (`X'00'`) character
`\'`	A single quote (`'`) character
`\"`	A double quote (`"`) character
`\b`	A backspace character
`\n`	A newline (linefeed) character
`\r`	A carriage return character
`\t`	A tab character
`\Z`	ASCII 26 (Control+Z); see note following the table
`\\`	A backslash (`\`) character
`\%`	A `%` character; see note following the table

Escape Sequence	Character Represented by Sequence
`\_`	A _ character; see note following the table

The ASCII 26 character can be encoded as `\Z` to enable you to work around the problem that ASCII 26 stands for END-OF-FILE on Windows. ASCII 26 within a file causes problems if you try to use `mysql db_name < file_name`.

The `\%` and `\_` sequences are used to search for literal instances of `%` and `_` in pattern-matching contexts where they would otherwise be interpreted as wildcard characters. See the description of the `LIKE` operator in Section 12.5.1, “String Comparison Functions”. If you use `\%` or `\_` outside of pattern-matching contexts, they evaluate to the strings `\%` and `\_`, not to `%` and `_`.

There are several ways to include quote characters within a string:

- A `'` inside a string quoted with `'` may be written as `''`.
- A `"` inside a string quoted with `"` may be written as `""`.
- Precede the quote character by an escape character (`\`).
- A `'` inside a string quoted with `"` needs no special treatment and need not be doubled or escaped. In the same way, `"` inside a string quoted with `'` needs no special treatment.

The following `SELECT` statements demonstrate how quoting and escaping work:

```
mysql> SELECT 'hello', '"hello"', '""hello""', 'hel''lo', '\'hello';
+-------+---------+-----------+--------+--------+
| hello | "hello" | ""hello"" | hel'lo | 'hello |
+-------+---------+-----------+--------+--------+

mysql> SELECT "hello", "'hello'", "''hello''", "hel""lo", "\"hello";
+-------+---------+-----------+--------+--------+
| hello | 'hello' | ''hello'' | hel"lo | "hello |
+-------+---------+-----------+--------+--------+

mysql> SELECT 'This\nIs\nFour\nLines';
+--------------------+
| This
Is
Four
Lines |
+--------------------+

mysql> SELECT 'disappearing\ backslash';
+------------------------+
| disappearing backslash |
+------------------------+
```

To insert binary data into a string column (such as a `BLOB` column), you should represent certain characters by escape sequences. Backslash (`\`) and the quote character used to quote the string must be escaped. In certain client environments, it may also be necessary to escape `NUL` or Control+Z. The `mysql` client truncates quoted strings containing `NUL` characters if they are not escaped, and Control+Z may be taken for END-OF-FILE on Windows if not escaped. For the escape sequences that represent each of these characters, see Table 9.1, “Special Character Escape Sequences”.

When writing application programs, any string that might contain any of these special characters must be properly escaped before the string is used as a data value in an SQL statement that is sent to the MySQL server. You can do this in two ways:

- Process the string with a function that escapes the special characters. In a C program, you can use the `mysql_real_escape_string()` C API function to escape characters. See Section 23.8.7.53, “mysql_real_escape_string()”. Within SQL statements that construct other SQL statements, you

can use the `QUOTE()` function. The Perl DBI interface provides a `quote` method to convert special characters to the proper escape sequences. See Section 23.10, “MySQL Perl API”. Other language interfaces may provide a similar capability.

- As an alternative to explicitly escaping special characters, many MySQL APIs provide a placeholder capability that enables you to insert special markers into a statement string, and then bind data values to them when you issue the statement. In this case, the API takes care of escaping special characters in the values for you.

9.1.2 Numeric Literals

Number literals include exact-value (integer and `DECIMAL`) literals and approximate-value (floating-point) literals.

Integers are represented as a sequence of digits. Numbers may include `.` as a decimal separator. Numbers may be preceded by `-` or `+` to indicate a negative or positive value, respectively. Numbers represented in scientific notation with a mantissa and exponent are approximate-value numbers.

Exact-value numeric literals have an integer part or fractional part, or both. They may be signed. Examples: `1`, `.2`, `3.4`, `-5`, `-6.78`, `+9.10`.

Approximate-value numeric literals are represented in scientific notation with a mantissa and exponent. Either or both parts may be signed. Examples: `1.2E3`, `1.2E-3`, `-1.2E3`, `-1.2E-3`.

Two numbers that look similar may be treated differently. For example, `2.34` is an exact-value (fixed-point) number, whereas `2.34E0` is an approximate-value (floating-point) number.

The `DECIMAL` data type is a fixed-point type and calculations are exact. In MySQL, the `DECIMAL` type has several synonyms: `NUMERIC`, `DEC`, `FIXED`. The integer types also are exact-value types. For more information about exact-value calculations, see Section 12.18, “Precision Math”.

The `FLOAT` and `DOUBLE` data types are floating-point types and calculations are approximate. In MySQL, types that are synonymous with `FLOAT` or `DOUBLE` are `DOUBLE PRECISION` and `REAL`.

An integer may be used in a floating-point context; it is interpreted as the equivalent floating-point number.

9.1.3 Date and Time Literals

Date and time values can be represented in several formats, such as quoted strings or as numbers, depending on the exact type of the value and other factors. For example, in contexts where MySQL expects a date, it interprets any of `'2015-07-21'`, `'20150721'`, and `20150721` as a date.

This section describes the acceptable formats for date and time literals. For more information about the temporal data types, such as the range of permitted values, consult these sections:

- Section 11.1.2, “Date and Time Type Overview”
- Section 11.3, “Date and Time Types”

Standard SQL and ODBC Date and Time Literals. Standard SQL permits temporal literals to be specified using a type keyword and a string. The space between the keyword and string is optional.

```
DATE 'str'
TIME 'str'
TIMESTAMP 'str'
```

MySQL recognizes those constructions and also the corresponding ODBC syntax:

```
{ d 'str' }
```

```
{ t 'str' }
{ ts 'str' }
```

However, MySQL ignores the type keyword and each of the preceding constructions produces the string value `'str'`, with a type of `VARCHAR`.

String and Numeric Literals in Date and Time Context. MySQL recognizes `DATE` values in these formats:

- As a string in either `'YYYY-MM-DD'` or `'YY-MM-DD'` format. A "relaxed" syntax is permitted: Any punctuation character may be used as the delimiter between date parts. For example, `'2012-12-31'`, `'2012/12/31'`, `'2012^12^31'`, and `'2012@12@31'` are equivalent.
- As a string with no delimiters in either `'YYYYMMDD'` or `'YYMMDD'` format, provided that the string makes sense as a date. For example, `'20070523'` and `'070523'` are interpreted as `'2007-05-23'`, but `'071332'` is illegal (it has nonsensical month and day parts) and becomes `'0000-00-00'`.
- As a number in either `YYYYMMDD` or `YYMMDD` format, provided that the number makes sense as a date. For example, `19830905` and `830905` are interpreted as `'1983-09-05'`.

MySQL recognizes `DATETIME` and `TIMESTAMP` values in these formats:

- As a string in either `'YYYY-MM-DD HH:MM:SS'` or `'YY-MM-DD HH:MM:SS'` format. A "relaxed" syntax is permitted here, too: Any punctuation character may be used as the delimiter between date parts or time parts. For example, `'2012-12-31 11:30:45'`, `'2012^12^31 11+30+45'`, `'2012/12/31 11*30*45'`, and `'2012@12@31 11^30^45'` are equivalent.

  The date and time parts can be separated by `T` rather than a space. For example, `'2012-12-31 11:30:45'` `'2012-12-31T11:30:45'` are equivalent.
- As a string with no delimiters in either `'YYYYMMDDHHMMSS'` or `'YYMMDDHHMMSS'` format, provided that the string makes sense as a date. For example, `'20070523091528'` and `'070523091528'` are interpreted as `'2007-05-23 09:15:28'`, but `'071122129015'` is illegal (it has a nonsensical minute part) and becomes `'0000-00-00 00:00:00'`.
- As a number in either `YYYYMMDDHHMMSS` or `YYMMDDHHMMSS` format, provided that the number makes sense as a date. For example, `19830905132800` and `830905132800` are interpreted as `'1983-09-05 13:28:00'`.

A `DATETIME` or `TIMESTAMP` value can include a trailing fractional seconds part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into `DATETIME` or `TIMESTAMP` columns. For information about fractional seconds support in MySQL, see Section 11.3.6, "Fractional Seconds in Time Values".

Dates containing two-digit year values are ambiguous because the century is unknown. MySQL interprets two-digit year values using these rules:

- Year values in the range `70-99` are converted to `1970-1999`.
- Year values in the range `00-69` are converted to `2000-2069`.

See also Section 11.3.8, "Two-Digit Years in Dates".

For values specified as strings that include date part delimiters, it is unnecessary to specify two digits for month or day values that are less than `10`. `'2015-6-9'` is the same as `'2015-06-09'`. Similarly, for values specified as strings that include time part delimiters, it is unnecessary to specify two digits for hour, minute, or second values that are less than `10`. `'2015-10-30 1:2:3'` is the same as `'2015-10-30 01:02:03'`.

Values specified as numbers should be 6, 8, 12, or 14 digits long. If a number is 8 or 14 digits long, it is assumed to be in `YYYYMMDD` or `YYYYMMDDHHMMSS` format and that the year is given by the first 4

digits. If the number is 6 or 12 digits long, it is assumed to be in `YYMMDD` or `YYMMDDHHMMSS` format and that the year is given by the first 2 digits. Numbers that are not one of these lengths are interpreted as though padded with leading zeros to the closest length.

Values specified as nondelimited strings are interpreted according their length. For a string 8 or 14 characters long, the year is assumed to be given by the first 4 characters. Otherwise, the year is assumed to be given by the first 2 characters. The string is interpreted from left to right to find year, month, day, hour, minute, and second values, for as many parts as are present in the string. This means you should not use strings that have fewer than 6 characters. For example, if you specify `'9903'`, thinking that represents March, 1999, MySQL converts it to the “zero” date value. This occurs because the year and month values are `99` and `03`, but the day part is completely missing. However, you can explicitly specify a value of zero to represent missing month or day parts. For example, to insert the value `'1999-03-00'`, use `'990300'`.

MySQL recognizes `TIME` values in these formats:

- As a string in `'D HH:MM:SS'` format. You can also use one of the following “relaxed” syntaxes: `'HH:MM:SS'`, `'HH:MM'`, `'D HH:MM'`, `'D HH'`, or `'SS'`. Here `D` represents days and can have a value from 0 to 34.
- As a string with no delimiters in `'HHMMSS'` format, provided that it makes sense as a time. For example, `'101112'` is understood as `'10:11:12'`, but `'109712'` is illegal (it has a nonsensical minute part) and becomes `'00:00:00'`.
- As a number in `HHMMSS` format, provided that it makes sense as a time. For example, `101112` is understood as `'10:11:12'`. The following alternative formats are also understood: `SS`, `MMSS`, or `HHMMSS`.

A trailing fractional seconds part is recognized in the `'D HH:MM:SS.fraction'`, `'HH:MM:SS.fraction'`, `'HHMMSS.fraction'`, and `HHMMSS.fraction` time formats, where `fraction` is the fractional part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into `TIME` columns. For information about fractional seconds support in MySQL, see Section 11.3.6, “Fractional Seconds in Time Values”.

For `TIME` values specified as strings that include a time part delimiter, it is unnecessary to specify two digits for hours, minutes, or seconds values that are less than `10`. `'8:3:2'` is the same as `'08:03:02'`.

9.1.4 Hexadecimal Literals

Hexadecimal literal values are written using `X'val'` or `0xval` notation, where *`val`* contains hexadecimal digits (`0..9`, `A..F`). Lettercase of the digits and of any leading `X` does not matter. A leading `0x` is case sensitive and cannot be written as `0X`.

Legal hexadecimal literals:

```
X'01AF'
X'01af'
x'01AF'
x'01af'
0x01AF
0x01af
```

Illegal hexadecimal literals:

```
X'0G'   (G is not a hexadecimal digit)
0X01AF  (0X must be written as 0x)
```

Values written using `X'val'` notation must contain an even number of digits or a syntax error occurs. To correct the problem, pad the value with a leading zero:

```
mysql> SET @s = X'FFF';
ERROR 1064 (42000): You have an error in your SQL syntax;
check the manual that corresponds to your MySQL server
version for the right syntax to use near 'X'FFF''

mysql> SET @s = X'0FFF';
Query OK, 0 rows affected (0.00 sec)
```

Values written using `0xval` notation that contain an odd number of digits are treated as having an extra leading `0`. For example, `0xaaa` is interpreted as `0x0aaa`.

By default, a hexadecimal literal is a binary string, where each pair of hexadecimal digits represents a character:

```
mysql> SELECT X'4D7953514C', CHARSET(X'4D7953514C');
+---------------+------------------------+
| X'4D7953514C' | CHARSET(X'4D7953514C') |
+---------------+------------------------+
| MySQL         | binary                 |
+---------------+------------------------+
mysql> SELECT 0x5461626c65, CHARSET(0x5461626c65);
+--------------+-----------------------+
| 0x5461626c65 | CHARSET(0x5461626c65) |
+--------------+-----------------------+
| Table        | binary                |
+--------------+-----------------------+
```

A hexadecimal literal may have an optional character set introducer and `COLLATE` clause, to designate it as a string that uses a particular character set and collation:

```
[_charset_name] X'val' [COLLATE collation_name]
```

Examples:

```
SELECT _latin1 X'4D7953514C';
SELECT _utf8 0x4D7953514C COLLATE utf8_danish_ci;
```

The examples use `X'val'` notation, but `0xval` notation permits introducers as well. For information about introducers, see Section 10.1.3.8, “Character Set Introducers”.

In numeric contexts, MySQL treats a hexadecimal literal like a `BIGINT` (64-bit integer). To ensure numeric treatment of a hexadecimal literal, use it in numeric context. Ways to do this include adding 0 or using `CAST(... AS UNSIGNED)`. For example, a hexadecimal literal assigned to a user-defined variable is a binary string by default. To assign the value as a number, use it in numeric context:

```
mysql> SET @v1 = X'41';
mysql> SET @v2 = X'41'+0;
mysql> SET @v3 = CAST(X'41' AS UNSIGNED);
mysql> SELECT @v1, @v2, @v3;
+------+------+------+
| @v1  | @v2  | @v3  |
+------+------+------+
| A    |   65 |   65 |
+------+------+------+
```

An empty hexadecimal value (`X''`) evaluates to a zero-length binary string. Converted to a number, it produces 0:

```
mysql> SELECT CHARSET(X''), LENGTH(X'');
+--------------+-------------+
| CHARSET(X'') | LENGTH(X'') |
+--------------+-------------+
| binary       |           0 |
```

```
+-------------+------------+
mysql> SELECT X''+0;
+-------+
| X''+0 |
+-------+
|     0 |
+-------+
```

The `X'val'` notation is based on standard SQL. The `0x` notation is based on ODBC, for which hexadecimal strings are often used to supply values for `BLOB` columns.

To convert a string or a number to a string in hexadecimal format, use the `HEX()` function:

```
mysql> SELECT HEX('cat');
+------------+
| HEX('cat') |
+------------+
| 636174     |
+------------+
mysql> SELECT X'636174';
+-----------+
| X'636174' |
+-----------+
| cat       |
+-----------+
```

9.1.5 Bit-Value Literals

Bit-value literals are written using `b'val'` or `0bval` notation. *`val`* is a binary value written using zeros and ones. Lettercase of any leading `b` does not matter. A leading `0b` is case sensitive and cannot be written as `0B`.

Legal bit-value literals:

```
b'01'
B'01'
0b01
```

Illegal bit-value literals:

```
b'2'    (2 is not a binary digit)
0B01    (0B must be written as 0b)
```

By default, a bit-value literal is a binary string:

```
mysql> SELECT b'1000001', CHARSET(b'1000001');
+------------+---------------------+
| b'1000001' | CHARSET(b'1000001') |
+------------+---------------------+
| A          | binary              |
+------------+---------------------+
mysql> SELECT 0b1100001, CHARSET(0b1100001);
+-----------+--------------------+
| 0b1100001 | CHARSET(0b1100001) |
+-----------+--------------------+
| a         | binary             |
+-----------+--------------------+
```

A bit-value literal may have an optional character set introducer and `COLLATE` clause, to designate it as a string that uses a particular character set and collation:

```
[_charset_name] b'val' [COLLATE collation_name]
```

Examples:

```
SELECT _latin1 b'1000001';
SELECT _utf8 0b1000001 COLLATE utf8_danish_ci;
```

The examples use `b'val'` notation, but `0bval` notation permits introducers as well. For information about introducers, see Section 10.1.3.8, “Character Set Introducers”.

In numeric contexts, MySQL treats a bit literal like an integer. To ensure numeric treatment of a bit literal, use it in numeric context. Ways to do this include adding 0 or using `CAST(... AS UNSIGNED)`. For example, a bit literal assigned to a user-defined variable is a binary string by default. To assign the value as a number, use it in numeric context:

```
mysql> SET @v1 = b'1100001';
mysql> SET @v2 = b'1100001'+0;
mysql> SET @v3 = CAST(b'1100001' AS UNSIGNED);
mysql> SELECT @v1, @v2, @v3;
+------+------+------+
| @v1  | @v2  | @v3  |
+------+------+------+
| a    |   97 |   97 |
+------+------+------+
```

An empty bit value (`b''`) evaluates to a zero-length binary string. Converted to a number, it produces 0:

```
mysql> SELECT CHARSET(b''), LENGTH(b'');
+--------------+-------------+
| CHARSET(b'') | LENGTH(b'') |
+--------------+-------------+
| binary       |           0 |
+--------------+-------------+
mysql> SELECT b''+0;
+-------+
| b''+0 |
+-------+
|     0 |
+-------+
```

Bit-value notation is convenient for specifying values to be assigned to `BIT` columns:

```
mysql> CREATE TABLE t (b BIT(8));
mysql> INSERT INTO t SET b = b'11111111';
mysql> INSERT INTO t SET b = b'1010';
mysql> INSERT INTO t SET b = b'0101';
```

Bit values in result sets are returned as binary values, which may not display well. To convert a bit value to printable form, use it in numeric context or use a conversion function such as `BIN()` or `HEX()`. High-order 0 digits are not displayed in the converted value.

```
mysql> SELECT b+0, BIN(b), OCT(b), HEX(b) FROM t;
+------+----------+--------+--------+
| b+0  | BIN(b)   | OCT(b) | HEX(b) |
+------+----------+--------+--------+
|  255 | 11111111 | 377    | FF     |
|   10 | 1010     | 12     | A      |
|    5 | 101      | 5      | 5      |
+------+----------+--------+--------+
```

9.1.6 Boolean Literals

The constants `TRUE` and `FALSE` evaluate to `1` and `0`, respectively. The constant names can be written in any lettercase.

```
mysql> SELECT TRUE, true, FALSE, false;
        -> 1, 1, 0, 0
```

9.1.7 NULL Values

The `NULL` value means “no data.” `NULL` can be written in any lettercase. A synonym is `\N` (case sensitive).

Be aware that the `NULL` value is different from values such as `0` for numeric types or the empty string for string types. For more information, see Section B.5.4.3, “Problems with NULL Values”.

For text file import or export operations performed with `LOAD DATA INFILE` or `SELECT ... INTO OUTFILE`, `NULL` is represented by the `\N` sequence. See Section 13.2.6, “LOAD DATA INFILE Syntax”.

9.2 Schema Object Names

Certain objects within MySQL, including database, table, index, column, alias, view, stored procedure, partition, tablespace, and other object names are known as identifiers. This section describes the permissible syntax for identifiers in MySQL. Section 9.2.2, “Identifier Case Sensitivity”, describes which types of identifiers are case sensitive and under what conditions.

An identifier may be quoted or unquoted. If an identifier contains special characters or is a reserved word, you *must* quote it whenever you refer to it. (Exception: A reserved word that follows a period in a qualified name must be an identifier, so it need not be quoted.) Reserved words are listed at Section 9.3, “Keywords and Reserved Words”.

Identifiers are converted to Unicode internally. They may contain these characters:

- Permitted characters in unquoted identifiers:
  - ASCII: [0-9,a-z,A-Z$_] (basic Latin letters, digits 0-9, dollar, underscore)
  - Extended: U+0080 .. U+FFFF
- Permitted characters in quoted identifiers include the full Unicode Basic Multilingual Plane (BMP), except U+0000:
  - ASCII: U+0001 .. U+007F
  - Extended: U+0080 .. U+FFFF
- ASCII NUL (U+0000) and supplementary characters (U+10000 and higher) are not permitted in quoted or unquoted identifiers.
- Identifiers may begin with a digit but unless quoted may not consist solely of digits.
- Database, table, and column names cannot end with space characters.

The identifier quote character is the backtick (`):

```
mysql> SELECT * FROM `select` WHERE `select`.id > 100;
```

If the `ANSI_QUOTES` SQL mode is enabled, it is also permissible to quote identifiers within double quotation marks:

```
mysql> CREATE TABLE "test" (col INT);
ERROR 1064: You have an error in your SQL syntax...
mysql> SET sql_mode='ANSI_QUOTES';
```

```
mysql> CREATE TABLE "test" (col INT);
Query OK, 0 rows affected (0.00 sec)
```

The ANSI_QUOTES mode causes the server to interpret double-quoted strings as identifiers. Consequently, when this mode is enabled, string literals must be enclosed within single quotation marks. They cannot be enclosed within double quotation marks. The server SQL mode is controlled as described in Section 5.1.8, “Server SQL Modes”.

Identifier quote characters can be included within an identifier if you quote the identifier. If the character to be included within the identifier is the same as that used to quote the identifier itself, then you need to double the character. The following statement creates a table named a`b that contains a column named c"d:

```
mysql> CREATE TABLE `a``b` (`c"d` INT);
```

In the select list of a query, a quoted column alias can be specified using identifier or string quoting characters:

```
mysql> SELECT 1 AS `one`, 2 AS 'two';
+-----+-----+
| one | two |
+-----+-----+
|   1 |   2 |
+-----+-----+
```

Elsewhere in the statement, quoted references to the alias must use identifier quoting or the reference is treated as a string literal.

It is recommended that you do not use names that begin with *Me* or *MeN*, where *M* and *N* are integers. For example, avoid using 1e as an identifier, because an expression such as 1e+3 is ambiguous. Depending on context, it might be interpreted as the expression 1e + 3 or as the number 1e+3.

Be careful when using MD5() to produce table names because it can produce names in illegal or ambiguous formats such as those just described.

A user variable cannot be used directly in an SQL statement as an identifier or as part of an identifier. See Section 9.4, “User-Defined Variables”, for more information and examples of workarounds.

Special characters in database and table names are encoded in the corresponding file system names as described in Section 9.2.3, “Mapping of Identifiers to File Names”. If you have databases or tables from an older version of MySQL that contain special characters and for which the underlying directory names or file names have not been updated to use the new encoding, the server displays their names with a prefix of #mysql50#. For information about referring to such names or converting them to the newer encoding, see that section.

The following table describes the maximum length for each type of identifier.

Identifier Type	Maximum Length (characters)
Database	64 (NDB storage engine: 63)
Table	64 (NDB storage engine: 63)
Column	64
Index	64

Identifier Type	Maximum Length (characters)
Constraint	64
Stored Program	64
View	64
Tablespace	64
Server	64
Log File Group	64
Alias	256 (see exception following table)
Compound Statement Label	16

Aliases for column names in `CREATE VIEW` statements are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters).

Identifiers are stored using Unicode (UTF-8). This applies to identifiers in table definitions that are stored in `.frm` files and to identifiers stored in the grant tables in the `mysql` database. The sizes of the identifier string columns in the grant tables are measured in characters. You can use multibyte characters without reducing the number of characters permitted for values stored in these columns. As indicated earlier, the permissible Unicode characters are those in the Basic Multilingual Plane (BMP). Supplementary characters are not permitted.

NDB Cluster imposes a maximum length of 63 characters for names of databases and tables. See Section 18.1.6.5, “Limits Associated with Database Objects in NDB Cluster”.

9.2.1 Identifier Qualifiers

Object names may be unqualified or qualified. An unqualified name is permitted in contexts where interpretation of the name is unambiguous. A qualified name includes at least one qualifier to clarify the interpretive context by overriding a default context or providing missing context.

For example, this statement creates a table using the unqualified name `t1`:

```
CREATE TABLE t1 (i INT);
```

Because `t1` includes no qualifier to specify a database, the statement creates the table in the default database. If there is no default database, an error occurs.

This statement creates a table using the qualified name `db1.t1`:

```
CREATE TABLE db1.t1 (i INT);
```

Because `db1.t1` includes a database qualifier `db1`, the statement creates `t1` in the database named `db1`, regardless of the default database. The qualifier *must* be specified if there is no default database. The qualifier *may* be specified if there is a default database, to specify a database different from the default, or to make the database explicit if the default is the same as the one specified.

Qualifiers have these characteristics:

- An unqualified name consists of a single identifier. A qualified name consists of multiple identifiers.
- The components of a multiple-part name must be separated by period (`.`) characters. The initial parts of a multiple-part name act as qualifiers that affect the context within which to interpret the final identifier.
- The qualifier character is a separate token and need not be contiguous with the associated identifiers. For example, *`tbl_name.col_name`* and *`tbl_name . col_name`* are equivalent.
- If any components of a multiple-part name require quoting, quote them individually rather than quoting the name as a whole. For example, write `` `my-table`.`my-column` ``, not `` `my-table.my-column` ``.
- A reserved word that follows a period in a qualified name must be an identifier, so in that context it need not be quoted.
- The syntax *`.tbl_name`* means the table *`tbl_name`* in the default database. This syntax is accepted for ODBC compatibility because some ODBC programs prefix table names with a `.` character.

The permitted qualifiers for object names depend on the object type:

- A database name is fully qualified and takes no qualifier:

```
CREATE DATABASE db1;
```

- A table, view, or stored program name may be given a database-name qualifier. Examples of unqualified and qualified names in `CREATE` statements:

```
CREATE TABLE mytable ...;
CREATE VIEW myview ...;
CREATE PROCEDURE myproc ...;
CREATE FUNCTION myfunc ...;
CREATE EVENT myevent ...;

CREATE TABLE mydb.mytable ...;
CREATE VIEW mydb.myview ...;
CREATE PROCEDURE mydb.myproc ...;
CREATE FUNCTION mydb.myfunc ...;
CREATE EVENT mydb.myevent ...;
```

- A trigger is associated with a table, so any qualifier applies to the table name:

```
CREATE TRIGGER mytrigger ... ON mytable ...;

CREATE TRIGGER mytrigger ... ON mydb.mytable ...;
```

- A column name may be given multiple qualifiers to indicate context in statements that reference it, as shown in the following table.

Column Reference	Meaning
`col_name`	Column *`col_name`* from whichever table used in the statement contains a column of that name
`tbl_name.col_name`	Column *`col_name`* from table *`tbl_name`* of the default database
`db_name.tbl_name.col_name`	Column *`col_name`* from table *`tbl_name`* of the database *`db_name`*

In other words, a column name may be given a table-name qualifier, which itself may be given a database-name qualifier. Examples of unqualified and qualified column references in `SELECT` statements:

```
SELECT c1 FROM mytable
WHERE c2 > 100;

SELECT mytable.c1 FROM mytable
WHERE mytable.c2 > 100;

SELECT mydb.mytable.c1 FROM mydb.mytable
WHERE mydb.mytable.c2 > 100;
```

You need not specify a qualifier for an object reference in a statement unless the unqualified reference is ambiguous. Suppose that column `c1` occurs only in table `t1`, `c2` only in `t2`, and `c` in both `t1` and `t2`. Any unqualified reference to `c` is ambiguous in a statement that refers to both tables and must be qualified as `t1.c` or `t2.c` to indicate which table you mean:

```
SELECT c1, c2, t1.c FROM t1 INNER JOIN t2
WHERE t2.c > 100;
```

Similarly, to retrieve from a table `t` in database `db1` and from a table `t` in database `db2` in the same statement, you must qualify the table references: For references to columns in those tables, qualifiers are required only for column names that appear in both tables. Suppose that column `c1` occurs only in table `db1.t`, `c2` only in `db2.t`, and `c` in both `db1.t` and `db2.t`. In this case, `c` is ambiguous and must be qualified but `c1` and `c2` need not be:

```
SELECT c1, c2, db1.t.c FROM db1.t INNER JOIN db2.t
WHERE db2.t.c > 100;
```

Table aliases enable qualified column references to be written more simply:

```
SELECT c1, c2, t1.c FROM db1.t AS t1 INNER JOIN db2.t AS t2
WHERE t2.c > 100;
```

9.2.2 Identifier Case Sensitivity

In MySQL, databases correspond to directories within the data directory. Each table within a database corresponds to at least one file within the database directory (and possibly more, depending on the storage engine). Triggers also correspond to files. Consequently, the case sensitivity of the underlying operating system plays a part in the case sensitivity of database, table, and trigger names. This means such names are not case sensitive in Windows, but are case sensitive in most varieties of Unix. One notable exception is OS X, which is Unix-based but uses a default file system type (HFS+) that is not case sensitive. However, OS X also supports UFS volumes, which are case sensitive just as on any Unix. See Section 1.7.1, “MySQL Extensions to Standard SQL”. The `lower_case_table_names` system variable also affects how the server handles identifier case sensitivity, as described later in this section.

Note

Although database, table, and trigger names are not case sensitive on some platforms, you should not refer to one of these using different cases within the same statement. The following statement would not work because it refers to a table both as `my_table` and as `MY_TABLE`:

```
mysql> SELECT * FROM my_table WHERE MY_TABLE.col=1;
```

Column, index, stored routine, and event names are not case sensitive on any platform, nor are column aliases.

However, names of logfile groups are case sensitive. This differs from standard SQL.

By default, table aliases are case sensitive on Unix, but not so on Windows or OS X. The following statement would not work on Unix, because it refers to the alias both as `a` and as `A`:

```
mysql> SELECT col_name FROM tbl_name AS a
    -> WHERE a.col_name = 1 OR A.col_name = 2;
```

However, this same statement is permitted on Windows. To avoid problems caused by such differences, it is best to adopt a consistent convention, such as always creating and referring to databases and tables using lowercase names. This convention is recommended for maximum portability and ease of use.

How table and database names are stored on disk and used in MySQL is affected by the `lower_case_table_names` system variable, which you can set when starting `mysqld`. `lower_case_table_names` can take the values shown in the following table. This variable does *not* affect case sensitivity of trigger identifiers. On Unix, the default value of `lower_case_table_names` is 0. On Windows, the default value is 1. On OS X, the default value is 2.

Value	Meaning
`0`	Table and database names are stored on disk using the lettercase specified in the `CREATE TABLE` or `CREATE DATABASE` statement. Name comparisons are case sensitive. You should *not* set this variable to 0 if you are running MySQL on a system that has case-insensitive file names (such as Windows or OS X). If you force this variable to 0 with `--lower-case-table-names=0` on a case-insensitive file system and access `MyISAM` tablenames using different lettercases, index corruption may result.
`1`	Table names are stored in lowercase on disk and name comparisons are not case sensitive. MySQL converts all table names to lowercase on storage and lookup. This behavior also applies to database names and table aliases.
`2`	Table and database names are stored on disk using the lettercase specified in the `CREATE TABLE` or `CREATE DATABASE` statement, but MySQL converts them to lowercase on lookup. Name comparisons are not case sensitive. This works *only* on file systems that are not case sensitive! `InnoDB` table names are stored in lowercase, as for `lower_case_table_names=1`.

If you are using MySQL on only one platform, you do not normally have to change the `lower_case_table_names` variable from its default value. However, you may encounter difficulties if you want to transfer tables between platforms that differ in file system case sensitivity. For example, on Unix, you can have two different tables named `my_table` and `MY_TABLE`, but on Windows these two names are considered identical. To avoid data transfer problems arising from lettercase of database or table names, you have two options:

- Use `lower_case_table_names=1` on all systems. The main disadvantage with this is that when you use `SHOW TABLES` or `SHOW DATABASES`, you do not see the names in their original lettercase.
- Use `lower_case_table_names=0` on Unix and `lower_case_table_names=2` on Windows. This preserves the lettercase of database and table names. The disadvantage of this is that you must ensure that your statements always refer to your database and table names with the correct lettercase on Windows. If you transfer your statements to Unix, where lettercase is significant, they do not work if the lettercase is incorrect.

  Exception: If you are using `InnoDB` tables and you are trying to avoid these data transfer problems, you should set `lower_case_table_names` to 1 on all platforms to force names to be converted to lowercase.

If you plan to set the `lower_case_table_names` system variable to 1 on Unix, you must first convert your old database and table names to lowercase before stopping `mysqld` and restarting it with the new variable setting. To do this for an individual table, use `RENAME TABLE`:

```
RENAME TABLE T1 TO t1;
```

To convert one or more entire databases, dump them before setting `lower_case_table_names`, then drop the databases, and reload them after setting `lower_case_table_names`:

1. Use `mysqldump` to dump each database:

   ```
   mysqldump --databases db1 > db1.sql
   mysqldump --databases db2 > db2.sql
   ...
   ```

   Do this for each database that must be recreated.

2. Use `DROP DATABASE` to drop each database.

3. Stop the server, set `lower_case_table_names`, and restart the server.

4. Reload the dump file for each database. Because `lower_case_table_names` is set, each database and table name will be converted to lowercase as it is recreated:

   ```
   mysql < db1.sql
   mysql < db2.sql
   ...
   ```

Object names may be considered duplicates if their uppercase forms are equal according to a binary collation. That is true for names of cursors, conditions, procedures, functions, savepoints, stored routine parameters, stored program local variables, and plugins. It is not true for names of columns, constraints, databases, partitions, statements prepared with `PREPARE`, tables, triggers, users, and user-defined variables.

File system case sensitivity can affect searches in string columns of `INFORMATION_SCHEMA` tables. For more information, see Section 10.1.8.7, “Using Collation in INFORMATION_SCHEMA Searches”.

9.2.3 Mapping of Identifiers to File Names

There is a correspondence between database and table identifiers and names in the file system. For the basic structure, MySQL represents each database as a directory in the data directory, and each table by one or more files in the appropriate database directory. For the table format files (`.FRM`), the data is always stored in this structure and location.

For the data and index files, the exact representation on disk is storage engine specific. These files may be stored in the same location as the `FRM` files, or the information may be stored in a separate file. `InnoDB` data is stored in the InnoDB data files. If you are using tablespaces with `InnoDB`, then the specific tablespace files you create are used instead.

Any character is legal in database or table identifiers except ASCII NUL (`X'00'`). MySQL encodes any characters that are problematic in the corresponding file system objects when it creates database directories or table files:

- Basic Latin letters (`a..zA..Z`), digits (`0..9`) and underscore (_) are encoded as is. Consequently, their case sensitivity directly depends on file system features.
- All other national letters from alphabets that have uppercase/lowercase mapping are encoded as shown in the following table. Values in the Code Range column are UCS-2 values.

Code Range	Pattern	Number	Used	Unused	Blocks
00C0..017F	[@][0..4][g..z]	5*20= 100	97	3	Latin-1 Supplement + Latin Extended-A
0370..03FF	[@][5..9][g..z]	5*20= 100	88	12	Greek and Coptic

Code Range	Pattern	Number	Used	Unused	Blocks
0400..052F	[@][g..z][0..6]	20*7= 140	137	3	Cyrillic + Cyrillic Supplement
0530..058F	[@][g..z][7..8]	20*2= 40	38	2	Armenian
2160..217F	[@][g..z][9]	20*1= 20	16	4	Number Forms
0180..02AF	[@][g..z][a..k]	20*11=220	203	17	Latin Extended-B + IPA Extensions
1E00..1EFF	[@][g..z][l..r]	20*7= 140	136	4	Latin Extended Additional
1F00..1FFF	[@][g..z][s..z]	20*8= 160	144	16	Greek Extended
....	[@][a..f][g..z]	6*20= 120	0	120	RESERVED
24B6..24E9	[@][@][a..z]	26	26	0	Enclosed Alphanumerics
FF21..FF5A	[@][a..z][@]	26	26	0	Halfwidth and Fullwidth forms

One of the bytes in the sequence encodes lettercase. For example: `LATIN CAPITAL LETTER A WITH GRAVE` is encoded as `@0G`, whereas `LATIN SMALL LETTER A WITH GRAVE` is encoded as `@0g`. Here the third byte (`G` or `g`) indicates lettercase. (On a case-insensitive file system, both letters will be treated as the same.)

For some blocks, such as Cyrillic, the second byte determines lettercase. For other blocks, such as Latin1 Supplement, the third byte determines lettercase. If two bytes in the sequence are letters (as in Greek Extended), the leftmost letter character stands for lettercase. All other letter bytes must be in lowercase.

- All nonletter characters except underscore (_), as well as letters from alphabets that do not have uppercase/lowercase mapping (such as Hebrew) are encoded using hexadecimal representation using lowercase letters for hexadecimal digits `a..f`:

```
0x003F -> @003f
0xFFFF -> @ffff
```

The hexadecimal values correspond to character values in the `ucs2` double-byte character set.

On Windows, some names such as `nul`, `prn`, and `aux` are encoded by appending `@@@` to the name when the server creates the corresponding file or directory. This occurs on all platforms for portability of the corresponding database object between platforms.

If you have databases or tables from a version of MySQL older than 5.1.6 that contain special characters and for which the underlying directory names or file names have not been updated to use the new encoding, the server displays their names with a prefix of `#mysql50#` in the output from `INFORMATION_SCHEMA` tables or `SHOW` statements. For example, if you have a table named `a@b` and its name encoding has not been updated, `SHOW TABLES` displays it like this:

```
mysql> SHOW TABLES;
+----------------+
| Tables_in_test |
+----------------+
| #mysql50#a@b   |
+----------------+
```

To refer to such a name for which the encoding has not been updated, you must supply the `#mysql50#` prefix:

```
mysql> SHOW COLUMNS FROM `a@b`;
```

```
ERROR 1146 (42S02): Table 'test.a@b' doesn't exist

mysql> SHOW COLUMNS FROM `#mysql50#a@b`;
+-------+---------+------+-----+---------+-------+
| Field | Type    | Null | Key | Default | Extra |
+-------+---------+------+-----+---------+-------+
| i     | int(11) | YES  |     | NULL    |       |
+-------+---------+------+-----+---------+-------+
```

To update old names to eliminate the need to use the special prefix to refer to them, re-encode them with `mysqlcheck`. The following commands update all names to the new encoding:

```
shell> mysqlcheck --check-upgrade --all-databases
shell> mysqlcheck --fix-db-names --fix-table-names --all-databases
```

To check only specific databases or tables, omit `--all-databases` and provide the appropriate database or table arguments. For information about `mysqlcheck` invocation syntax, see Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”.

Note

The `#mysql50#` prefix is intended only to be used internally by the server. You should not create databases or tables with names that use this prefix.

Also, `mysqlcheck` cannot fix names that contain literal instances of the `@` character that is used for encoding special characters. If you have databases or tables that contain this character, use `mysqldump` to dump them before upgrading to MySQL 5.1.6 or later, and then reload the dump file after upgrading.

9.2.4 Function Name Parsing and Resolution

MySQL supports built-in (native) functions, user-defined functions (UDFs), and stored functions. This section describes how the server recognizes whether the name of a built-in function is used as a function call or as an identifier, and how the server determines which function to use in cases when functions of different types exist with a given name.

- Built-In Function Name Parsing
- Function Name Resolution

Built-In Function Name Parsing

The parser uses default rules for parsing names of built-in functions. These rules can be changed by enabling the `IGNORE_SPACE` SQL mode.

When the parser encounters a word that is the name of a built-in function, it must determine whether the name signifies a function call or is instead a nonexpression reference to an identifier such as a table or column name. For example, in the following statements, the first reference to `count` is a function call, whereas the second reference is a table name:

```
SELECT COUNT(*) FROM mytable;
CREATE TABLE count (i INT);
```

The parser should recognize the name of a built-in function as indicating a function call only when parsing what is expected to be an expression. That is, in nonexpression context, function names are permitted as identifiers.

However, some built-in functions have special parsing or implementation considerations, so the parser uses the following rules by default to distinguish whether their names are being used as function calls or as identifiers in nonexpression context:

- To use the name as a function call in an expression, there must be no whitespace between the name and the following `(` parenthesis character.
- Conversely, to use the function name as an identifier, it must not be followed immediately by a parenthesis.

The requirement that function calls be written with no whitespace between the name and the parenthesis applies only to the built-in functions that have special considerations. `COUNT` is one such name. The `sql_functions[]` array in the `sql/lex.h` source file lists the names of these special functions for which following whitespace determines their interpretation. In MySQL 5.5, there are about 30 such function names. You may find it easiest to treat the no-whitespace requirement as applying to all function calls.

The following list names the functions that are affected by the `IGNORE_SPACE` setting and listed as special in the `sql/lex.h` source file.

- `ADDDATE`
- `BIT_AND`
- `BIT_OR`
- `BIT_XOR`
- `CAST`
- `COUNT`
- `CURDATE`
- `CURTIME`
- `DATE_ADD`
- `DATE_SUB`
- `EXTRACT`
- `GROUP_CONCAT`
- `MAX`
- `MID`
- `MIN`
- `NOW`
- `POSITION`
- `SESSION_USER`
- `STD`
- `STDDEV`
- `STDDEV_POP`
- `STDDEV_SAMP`
- `SUBDATE`
- `SUBSTR`

- SUBSTRING
- SUM
- SYSDATE
- SYSTEM_USER
- TRIM
- VARIANCE
- VAR_POP
- VAR_SAMP

For functions not listed as special in sql/lex.h, whitespace does not matter. They are interpreted as function calls only when used in expression context and may be used freely as identifiers otherwise. ASCII is one such name. However, for these nonaffected function names, interpretation may vary in expression context: *func_name* () is interpreted as a built-in function if there is one with the given name; if not, *func_name* () is interpreted as a user-defined function or stored function if one exists with that name.

The IGNORE_SPACE SQL mode can be used to modify how the parser treats function names that are whitespace-sensitive:

- With IGNORE_SPACE disabled, the parser interprets the name as a function call when there is no whitespace between the name and the following parenthesis. This occurs even when the function name is used in nonexpression context:

```
mysql> CREATE TABLE count(i INT);
ERROR 1064 (42000): You have an error in your SQL syntax ...
near 'count(i INT)'
```

  To eliminate the error and cause the name to be treated as an identifier, either use whitespace following the name or write it as a quoted identifier (or both):

```
CREATE TABLE count (i INT);
CREATE TABLE `count`(i INT);
CREATE TABLE `count` (i INT);
```

- With IGNORE_SPACE enabled, the parser loosens the requirement that there be no whitespace between the function name and the following parenthesis. This provides more flexibility in writing function calls. For example, either of the following function calls are legal:

```
SELECT COUNT(*) FROM mytable;
SELECT COUNT (*) FROM mytable;
```

  However, enabling IGNORE_SPACE also has the side effect that the parser treats the affected function names as reserved words (see Section 9.3, “Keywords and Reserved Words”). This means that a space following the name no longer signifies its use as an identifier. The name can be used in function calls with or without following whitespace, but causes a syntax error in nonexpression context unless it is quoted. For example, with IGNORE_SPACE enabled, both of the following statements fail with a syntax error because the parser interprets count as a reserved word:

```
CREATE TABLE count(i INT);
CREATE TABLE count (i INT);
```

  To use the function name in nonexpression context, write it as a quoted identifier:

```
```

```
CREATE TABLE `count`(i INT);
CREATE TABLE `count` (i INT);
```

To enable the `IGNORE_SPACE` SQL mode, use this statement:

```
SET sql_mode = 'IGNORE_SPACE';
```

`IGNORE_SPACE` is also enabled by certain other composite modes such as `ANSI` that include it in their value:

```
SET sql_mode = 'ANSI';
```

Check Section 5.1.8, “Server SQL Modes”, to see which composite modes enable `IGNORE_SPACE`.

To minimize the dependency of SQL code on the `IGNORE_SPACE` setting, use these guidelines:

- Avoid creating UDFs or stored functions that have the same name as a built-in function.
- Avoid using function names in nonexpression context. For example, these statements use `count` (one of the affected function names affected by `IGNORE_SPACE`), so they fail with or without whitespace following the name if `IGNORE_SPACE` is enabled:

  ```
  CREATE TABLE count(i INT);
  CREATE TABLE count (i INT);
  ```

  If you must use a function name in nonexpression context, write it as a quoted identifier:

  ```
  CREATE TABLE `count`(i INT);
  CREATE TABLE `count` (i INT);
  ```

Function Name Resolution

The following rules describe how the server resolves references to function names for function creation and invocation:

- Built-in functions and user-defined functions

  An error occurs if you try to create a UDF with the same name as a built-in function.

- Built-in functions and stored functions

  It is possible to create a stored function with the same name as a built-in function, but to invoke the stored function it is necessary to qualify it with a schema name. For example, if you create a stored function named `PI` in the `test` schema, invoke it as `test.PI()` because the server resolves `PI()` without a qualifier as a reference to the built-in function. The server generates a warning if the stored function name collides with a built-in function name. The warning can be displayed with `SHOW WARNINGS`.

- User-defined functions and stored functions

  User-defined functions and stored functions share the same namespace, so you cannot create a UDF and a stored function with the same name.

The preceding function name resolution rules have implications for upgrading to versions of MySQL that implement new built-in functions:

- If you have already created a user-defined function with a given name and upgrade MySQL to a version that implements a new built-in function with the same name, the UDF becomes inaccessible. To correct this, use `DROP FUNCTION` to drop the UDF and `CREATE FUNCTION` to re-create the UDF with a different nonconflicting name. Then modify any affected code to use the new name.

- If a new version of MySQL implements a built-in function with the same name as an existing stored function, you have two choices: Rename the stored function to use a nonconflicting name, or change calls to the function so that they use a schema qualifier (that is, use *`schema_name.func_name()`* syntax). In either case, modify any affected code accordingly.

9.3 Keywords and Reserved Words

- MySQL 5.5 Keywords and Reserved Words
- MySQL 5.5 New Keywords and Reserved Words
- MySQL 5.5 Removed Keywords and Reserved Words

Keywords are words that have significance in SQL. Certain keywords, such as `SELECT`, `DELETE`, or `BIGINT`, are reserved and require special treatment for use as identifiers such as table and column names. This may also be true for the names of built-in functions.

Nonreserved keywords are permitted as identifiers without quoting. Reserved words are permitted as identifiers if you quote them as described in Section 9.2, “Schema Object Names”:

```
mysql> CREATE TABLE interval (begin INT, end INT);
ERROR 1064 (42000): You have an error in your SQL syntax ...
near 'interval (begin INT, end INT)'
```

`BEGIN` and `END` are keywords but not reserved, so their use as identifiers does not require quoting. `INTERVAL` is a reserved keyword and must be quoted to be used as an identifier:

```
mysql> CREATE TABLE `interval` (begin INT, end INT);
Query OK, 0 rows affected (0.01 sec)
```

Exception: A word that follows a period in a qualified name must be an identifier, so it need not be quoted even if it is reserved:

```
mysql> CREATE TABLE mydb.interval (begin INT, end INT);
Query OK, 0 rows affected (0.01 sec)
```

Names of built-in functions are permitted as identifiers but may require care to be used as such. For example, `COUNT` is acceptable as a column name. However, by default, no whitespace is permitted in function invocations between the function name and the following `(` character. This requirement enables the parser to distinguish whether the name is used in a function call or in nonfunction context. For further details on recognition of function names, see Section 9.2.4, “Function Name Parsing and Resolution”.

MySQL 5.5 Keywords and Reserved Words

The following list shows the keywords and reserved words in MySQL 5.5, along with changes to individual words from version to version. Reserved keywords are marked with (R). In addition, `_FILENAME` is reserved.

At some point, you might upgrade to a higher version, so it is a good idea to have a look at future reserved words, too. You can find these in the manuals that cover higher versions of MySQL. Most of the reserved words in the list are forbidden by standard SQL as column or table names (for example, `GROUP`). A few are reserved because MySQL needs them and uses a `yacc` parser.

A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

A

- `ACCESSIBLE` (R)

- ACTION
- ADD (R)
- AFTER
- AGAINST
- AGGREGATE
- ALGORITHM
- ALL (R)
- ALTER (R)
- ANALYZE (R)
- AND (R)
- ANY
- AS (R)
- ASC (R)
- ASCII
- ASENSITIVE (R)
- AT
- AUTHORS
- AUTOEXTEND_SIZE
- AUTO_INCREMENT
- AVG
- AVG_ROW_LENGTH

B

- BACKUP
- BEFORE (R)
- BEGIN
- BETWEEN (R)
- BIGINT (R)
- BINARY (R)
- BINLOG
- BIT
- BLOB (R)
- BLOCK
- BOOL

- BOOLEAN
- BOTH (R)
- BTREE
- BY (R)
- BYTE

C

- CACHE
- CALL (R)
- CASCADE (R)
- CASCADED
- CASE (R)
- CATALOG_NAME
- CHAIN
- CHANGE (R)
- CHANGED
- CHAR (R)
- CHARACTER (R)
- CHARSET
- CHECK (R)
- CHECKSUM
- CIPHER
- CLASS_ORIGIN
- CLIENT
- CLOSE
- COALESCE
- CODE
- COLLATE (R)
- COLLATION
- COLUMN (R)
- COLUMNS
- COLUMN_NAME
- COMMENT
- COMMIT

- COMMITTED
- COMPACT
- COMPLETION
- COMPRESSED
- CONCURRENT
- CONDITION (R)
- CONNECTION
- CONSISTENT
- CONSTRAINT (R)
- CONSTRAINT_CATALOG
- CONSTRAINT_NAME
- CONSTRAINT_SCHEMA
- CONTAINS
- CONTEXT
- CONTINUE (R)
- CONTRIBUTORS
- CONVERT (R)
- CPU
- CREATE (R)
- CROSS (R)
- CUBE
- CURRENT_DATE (R)
- CURRENT_TIME (R)
- CURRENT_TIMESTAMP (R)
- CURRENT_USER (R)
- CURSOR (R)
- CURSOR_NAME

D

- DATA
- DATABASE (R)
- DATABASES (R)
- DATAFILE
- DATE

- DATETIME
- DAY
- DAY_HOUR (R)
- DAY_MICROSECOND (R)
- DAY_MINUTE (R)
- DAY_SECOND (R)
- DEALLOCATE
- DEC (R)
- DECIMAL (R)
- DECLARE (R)
- DEFAULT (R)
- DEFINER
- DELAYED (R)
- DELAY_KEY_WRITE
- DELETE (R)
- DESC (R)
- DESCRIBE (R)
- DES_KEY_FILE
- DETERMINISTIC (R)
- DIRECTORY
- DISABLE
- DISCARD
- DISK
- DISTINCT (R)
- DISTINCTROW (R)
- DIV (R)
- DO
- DOUBLE (R)
- DROP (R)
- DUAL (R)
- DUMPFILE
- DUPLICATE
- DYNAMIC

E

- EACH (R)
- ELSE (R)
- ELSEIF (R)
- ENABLE
- ENCLOSED (R)
- END
- ENDS
- ENGINE
- ENGINES
- ENUM
- ERROR added in 5.5.3 (nonreserved)
- ERRORS
- ESCAPE
- ESCAPED (R)
- EVENT
- EVENTS
- EVERY
- EXECUTE
- EXISTS (R)
- EXIT (R)
- EXPANSION
- EXPLAIN (R)
- EXTENDED
- EXTENT_SIZE

F

- FALSE (R)
- FAST
- FAULTS
- FETCH (R)
- FIELDS
- FILE
- FIRST

- FIXED
- FLOAT (R)
- FLOAT4 (R)
- FLOAT8 (R)
- FLUSH
- FOR (R)
- FORCE (R)
- FOREIGN (R)
- FOUND
- FRAC_SECOND removed in 5.5.3
- FROM (R)
- FULL
- FULLTEXT (R)
- FUNCTION

G

- GENERAL added in 5.5.3 (reserved); became nonreserved in 5.5.8
- GEOMETRY
- GEOMETRYCOLLECTION
- GET_FORMAT
- GLOBAL
- GRANT (R)
- GRANTS
- GROUP (R)

H

- HANDLER
- HASH
- HAVING (R)
- HELP
- HIGH_PRIORITY (R)
- HOST
- HOSTS
- HOUR
- HOUR_MICROSECOND (R)

- HOUR_MINUTE (R)
- HOUR_SECOND (R)

I

- IDENTIFIED
- IF (R)
- IGNORE (R)
- IGNORE_SERVER_IDS became nonreserved in 5.5.8
- IMPORT
- IN (R)
- INDEX (R)
- INDEXES
- INFILE (R)
- INITIAL_SIZE
- INNER (R)
- INNOBASE removed in 5.5.3
- INNODB removed in 5.5.3
- INOUT (R)
- INSENSITIVE (R)
- INSERT (R)
- INSERT_METHOD
- INSTALL
- INT (R)
- INT1 (R)
- INT2 (R)
- INT3 (R)
- INT4 (R)
- INT8 (R)
- INTEGER (R)
- INTERVAL (R)
- INTO (R)
- INVOKER
- IO
- IO_THREAD

- IPC
- IS (R)
- ISOLATION
- ISSUER
- ITERATE (R)

J

- JOIN (R)

K

- KEY (R)
- KEYS (R)
- KEY_BLOCK_SIZE
- KILL (R)

L

- LANGUAGE
- LAST
- LEADING (R)
- LEAVE (R)
- LEAVES
- LEFT (R)
- LESS
- LEVEL
- LIKE (R)
- LIMIT (R)
- LINEAR (R)
- LINES (R)
- LINESTRING
- LIST
- LOAD (R)
- LOCAL
- LOCALTIME (R)
- LOCALTIMESTAMP (R)
- LOCK (R)
- LOCKS

- LOGFILE
- LOGS
- LONG (R)
- LONGBLOB (R)
- LONGTEXT (R)
- LOOP (R)
- LOW_PRIORITY (R)

M

- MASTER
- MASTER_CONNECT_RETRY
- MASTER_HEARTBEAT_PERIOD became nonreserved in 5.5.8
- MASTER_HOST
- MASTER_LOG_FILE
- MASTER_LOG_POS
- MASTER_PASSWORD
- MASTER_PORT
- MASTER_SERVER_ID
- MASTER_SSL
- MASTER_SSL_CA
- MASTER_SSL_CAPATH
- MASTER_SSL_CERT
- MASTER_SSL_CIPHER
- MASTER_SSL_KEY
- MASTER_SSL_VERIFY_SERVER_CERT (R)
- MASTER_USER
- MATCH (R)
- MAXVALUE (R)
- MAX_CONNECTIONS_PER_HOUR
- MAX_QUERIES_PER_HOUR
- MAX_ROWS
- MAX_SIZE
- MAX_UPDATES_PER_HOUR
- MAX_USER_CONNECTIONS

- MEDIUM
- MEDIUMBLOB (R)
- MEDIUMINT (R)
- MEDIUMTEXT (R)
- MEMORY
- MERGE
- MESSAGE_TEXT
- MICROSECOND
- MIDDLEINT (R)
- MIGRATE
- MINUTE
- MINUTE_MICROSECOND (R)
- MINUTE_SECOND (R)
- MIN_ROWS
- MOD (R)
- MODE
- MODIFIES (R)
- MODIFY
- MONTH
- MULTILINESTRING
- MULTIPOINT
- MULTIPOLYGON
- MUTEX
- MYSQL_ERRNO

N

- NAME
- NAMES
- NATIONAL
- NATURAL (R)
- NCHAR
- NDB
- NDBCLUSTER
- NEW

- NEXT
- NO
- NODEGROUP
- NONE
- NOT (R)
- NO_WAIT
- NO_WRITE_TO_BINLOG (R)
- NULL (R)
- NUMERIC (R)
- NVARCHAR

O

- OFFSET
- OLD_PASSWORD
- ON (R)
- ONE
- ONE_SHOT
- OPEN
- OPTIMIZE (R)
- OPTION (R)
- OPTIONALLY (R)
- OPTIONS
- OR (R)
- ORDER (R)
- OUT (R)
- OUTER (R)
- OUTFILE (R)
- OWNER

P

- PACK_KEYS
- PAGE
- PARSER
- PARTIAL
- PARTITION

- PARTITIONING
- PARTITIONS
- PASSWORD
- PHASE
- PLUGIN
- PLUGINS
- POINT
- POLYGON
- PORT
- PRECISION (R)
- PREPARE
- PRESERVE
- PREV
- PRIMARY (R)
- PRIVILEGES
- PROCEDURE (R)
- PROCESSLIST
- PROFILE
- PROFILES
- PROXY added in 5.5.7 (nonreserved)
- PURGE (R)

Q

- QUARTER
- QUERY
- QUICK

R

- RANGE (R)
- READ (R)
- READS (R)
- READ_ONLY
- READ_WRITE (R)
- REAL (R)
- REBUILD

- RECOVER
- REDOFILE
- REDO_BUFFER_SIZE
- REDUNDANT
- REFERENCES (R)
- REGEXP (R)
- RELAY added in 5.5.3 (nonreserved)
- RELAYLOG
- RELAY_LOG_FILE
- RELAY_LOG_POS
- RELAY_THREAD
- RELEASE (R)
- RELOAD
- REMOVE
- RENAME (R)
- REORGANIZE
- REPAIR
- REPEAT (R)
- REPEATABLE
- REPLACE (R)
- REPLICATION
- REQUIRE (R)
- RESET
- RESIGNAL (R)
- RESTORE
- RESTRICT (R)
- RESUME
- RETURN (R)
- RETURNS
- REVOKE (R)
- RIGHT (R)
- RLIKE (R)
- ROLLBACK

- ROLLUP
- ROUTINE
- ROW
- ROWS
- ROW_FORMAT
- RTREE

S

- SAVEPOINT
- SCHEDULE
- SCHEMA (R)
- SCHEMAS (R)
- SCHEMA_NAME
- SECOND
- SECOND_MICROSECOND (R)
- SECURITY
- SELECT (R)
- SENSITIVE (R)
- SEPARATOR (R)
- SERIAL
- SERIALIZABLE
- SERVER
- SESSION
- SET (R)
- SHARE
- SHOW (R)
- SHUTDOWN
- SIGNAL (R)
- SIGNED
- SIMPLE
- SLAVE
- SLOW added in 5.5.3 (reserved); became nonreserved in 5.5.8
- SMALLINT (R)
- SNAPSHOT

- SOCKET
- SOME
- SONAME
- SOUNDS
- SOURCE
- SPATIAL (R)
- SPECIFIC (R)
- SQL (R)
- SQLEXCEPTION (R)
- SQLSTATE (R)
- SQLWARNING (R)
- SQL_BIG_RESULT (R)
- SQL_BUFFER_RESULT
- SQL_CACHE
- SQL_CALC_FOUND_ROWS (R)
- SQL_NO_CACHE
- SQL_SMALL_RESULT (R)
- SQL_THREAD
- SQL_TSI_DAY
- SQL_TSI_FRAC_SECOND removed in 5.5.3
- SQL_TSI_HOUR
- SQL_TSI_MINUTE
- SQL_TSI_MONTH
- SQL_TSI_QUARTER
- SQL_TSI_SECOND
- SQL_TSI_WEEK
- SQL_TSI_YEAR
- SSL (R)
- START
- STARTING (R)
- STARTS
- STATUS
- STOP

- STORAGE
- STRAIGHT_JOIN (R)
- STRING
- SUBCLASS_ORIGIN
- SUBJECT
- SUBPARTITION
- SUBPARTITIONS
- SUPER
- SUSPEND
- SWAPS
- SWITCHES

T

- TABLE (R)
- TABLES
- TABLESPACE
- TABLE_CHECKSUM
- TABLE_NAME
- TEMPORARY
- TEMPTABLE
- TERMINATED (R)
- TEXT
- THAN
- THEN (R)
- TIME
- TIMESTAMP
- TIMESTAMPADD
- TIMESTAMPDIFF
- TINYBLOB (R)
- TINYINT (R)
- TINYTEXT (R)
- TO (R)
- TRAILING (R)
- TRANSACTION

- TRIGGER (R)
- TRIGGERS
- TRUE (R)
- TRUNCATE
- TYPE
- TYPES

U

- UNCOMMITTED
- UNDEFINED
- UNDO (R)
- UNDOFILE
- UNDO_BUFFER_SIZE
- UNICODE
- UNINSTALL
- UNION (R)
- UNIQUE (R)
- UNKNOWN
- UNLOCK (R)
- UNSIGNED (R)
- UNTIL
- UPDATE (R)
- UPGRADE
- USAGE (R)
- USE (R)
- USER
- USER_RESOURCES
- USE_FRM
- USING (R)
- UTC_DATE (R)
- UTC_TIME (R)
- UTC_TIMESTAMP (R)

V

- VALUE

- VALUES (R)
- VARBINARY (R)
- VARCHAR (R)
- VARCHARACTER (R)
- VARIABLES
- VARYING (R)
- VIEW

W

- WAIT
- WARNINGS
- WEEK
- WHEN (R)
- WHERE (R)
- WHILE (R)
- WITH (R)
- WORK
- WRAPPER
- WRITE (R)

X

- X509
- XA
- XML
- XOR (R)

Y

- YEAR
- YEAR_MONTH (R)

Z

- ZEROFILL (R)

MySQL 5.5 New Keywords and Reserved Words

The following list shows the keywords and reserved words that are added in MySQL 5.5, compared to MySQL 5.1. Reserved keywords are marked with (R).

C | E | G | I | M | P | R | S | T | X

C

- CATALOG_NAME
- CLASS_ORIGIN
- COLUMN_NAME
- CONSTRAINT_CATALOG
- CONSTRAINT_NAME
- CONSTRAINT_SCHEMA
- CURSOR_NAME

E

- ERROR

G

- GENERAL

I

- IGNORE_SERVER_IDS

M

- MASTER_HEARTBEAT_PERIOD
- MESSAGE_TEXT
- MYSQL_ERRNO

P

- PROXY

R

- RELAY
- RELAYLOG
- RESIGNAL (R)

S

- SCHEMA_NAME
- SIGNAL (R)
- SLOW
- SUBCLASS_ORIGIN

T

- TABLE_NAME

X

- XML

MySQL 5.5 Removed Keywords and Reserved Words

The following list shows the keywords and reserved words that are removed in MySQL 5.5, compared to MySQL 5.1. Reserved keywords are marked with (R).

- FRAC_SECOND
- INNOBASE
- INNODB
- SQL_TSI_FRAC_SECOND

9.4 User-Defined Variables

You can store a value in a user-defined variable in one statement and refer to it later in another statement. This enables you to pass values from one statement to another.

User variables are written as *@var_name*, where the variable name *var_name* consists of alphanumeric characters, ., _, and $. A user variable name can contain other characters if you quote it as a string or identifier (for example, @'my-var', @"my-var", or @`my-var`).

User-defined variables are session specific. A user variable defined by one client cannot be seen or used by other clients. All variables for a given client session are automatically freed when that client exits.

User variable names are not case sensitive.

One way to set a user-defined variable is by issuing a SET statement:

```
SET @var_name = expr [, @var_name = expr] ...
```

For SET, either = or := can be used as the assignment operator.

You can also assign a value to a user variable in statements other than SET. In this case, the assignment operator must be := and not = because the latter is treated as the comparison operator = in non-SET statements:

```
mysql> SET @t1=1, @t2=2, @t3:=4;
mysql> SELECT @t1, @t2, @t3, @t4 := @t1+@t2+@t3;
+------+------+------+--------------------+
| @t1  | @t2  | @t3  | @t4 := @t1+@t2+@t3 |
+------+------+------+--------------------+
|    1 |    2 |    4 |                  7 |
+------+------+------+--------------------+
```

User variables can be assigned a value from a limited set of data types: integer, decimal, floating-point, binary or nonbinary string, or NULL value. Assignment of decimal and real values does not preserve the precision or scale of the value. A value of a type other than one of the permissible types is converted to a permissible type. For example, a value having a temporal or spatial data type is converted to a binary string.

If a user variable is assigned a nonbinary (character) string value, it has the same character set and collation as the string. The coercibility of user variables is implicit. (This is the same coercibility as for table column values.)

Hexadcimal or bit values assigned to user variables are treated as binary strings. To assign a hexadecimal or bit value as a number to a user variable, use it in numeric context. For example, add 0 or use CAST(... AS UNSIGNED):

```
mysql> SET @v1 = X'41';
mysql> SET @v2 = X'41'+0;
mysql> SET @v3 = CAST(X'41' AS UNSIGNED);
mysql> SELECT @v1, @v2, @v3;
+------+------+------+
| @v1  | @v2  | @v3  |
+------+------+------+
| A    |   65 |   65 |
+------+------+------+
mysql> SET @v1 = b'1000001';
mysql> SET @v2 = b'1000001'+0;
mysql> SET @v3 = CAST(b'1000001' AS UNSIGNED);
mysql> SELECT @v1, @v2, @v3;
+------+------+------+
| @v1  | @v2  | @v3  |
+------+------+------+
| A    |   65 |   65 |
+------+------+------+
```

If the value of a user variable is selected in a result set, it is returned to the client as a string.

If you refer to a variable that has not been initialized, it has a value of `NULL` and a type of string.

User variables may be used in most contexts where expressions are permitted. This does not currently include contexts that explicitly require a literal value, such as in the `LIMIT` clause of a `SELECT` statement, or the `IGNORE N LINES` clause of a `LOAD DATA` statement.

As a general rule, other than in `SET` statements, you should never assign a value to a user variable and read the value within the same statement. For example, to increment a variable, this is okay:

```
SET @a = @a + 1;
```

For other statements, such as `SELECT`, you might get the results you expect, but this is not guaranteed. In the following statement, you might think that MySQL will evaluate `@a` first and then do an assignment second:

```
SELECT @a, @a:=@a+1, ...;
```

However, the order of evaluation for expressions involving user variables is undefined.

Another issue with assigning a value to a variable and reading the value within the same non-`SET` statement is that the default result type of a variable is based on its type at the start of the statement. The following example illustrates this:

```
mysql> SET @a='test';
mysql> SELECT @a,(@a:=20) FROM tbl_name;
```

For this `SELECT` statement, MySQL reports to the client that column one is a string and converts all accesses of `@a` to strings, even though @a is set to a number for the second row. After the `SELECT` statement executes, `@a` is regarded as a number for the next statement.

To avoid problems with this behavior, either do not assign a value to and read the value of the same variable within a single statement, or else set the variable to `0`, `0.0`, or `''` to define its type before you use it.

In a `SELECT` statement, each select expression is evaluated only when sent to the client. This means that in a `HAVING`, `GROUP BY`, or `ORDER BY` clause, referring to a variable that is assigned a value in the select expression list does *not* work as expected:

```
mysql> SELECT (@aa:=id) AS a, (@aa+3) AS b FROM tbl_name HAVING b=5;
```

The reference to `b` in the `HAVING` clause refers to an alias for an expression in the select list that uses `@aa`. This does not work as expected: `@aa` contains the value of `id` from the previous selected row, not from the current row.

User variables are intended to provide data values. They cannot be used directly in an SQL statement as an identifier or as part of an identifier, such as in contexts where a table or database name is expected, or as a reserved word such as `SELECT`. This is true even if the variable is quoted, as shown in the following example:

```
mysql> SELECT c1 FROM t;
+----+
| c1 |
+----+
|  0 |
+----+
|  1 |
+----+
2 rows in set (0.00 sec)

mysql> SET @col = "c1";
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @col FROM t;
+------+
| @col |
+------+
| c1   |
+------+
1 row in set (0.00 sec)

mysql> SELECT `@col` FROM t;
ERROR 1054 (42S22): Unknown column '@col' in 'field list'

mysql> SET @col = "`c1`";
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @col FROM t;
+------+
| @col |
+------+
| `c1` |
+------+
1 row in set (0.00 sec)
```

An exception to this principle that user variables cannot be used to provide identifiers, is when you are constructing a string for use as a prepared statement to execute later. In this case, user variables can be used to provide any part of the statement. The following example illustrates how this can be done:

```
mysql> SET @c = "c1";
Query OK, 0 rows affected (0.00 sec)

mysql> SET @s = CONCAT("SELECT ", @c, " FROM t");
Query OK, 0 rows affected (0.00 sec)

mysql> PREPARE stmt FROM @s;
Query OK, 0 rows affected (0.04 sec)
Statement prepared

mysql> EXECUTE stmt;
+----+
| c1 |
+----+
|  0 |
+----+
|  1 |
+----+
2 rows in set (0.00 sec)
```

```
mysql> DEALLOCATE PREPARE stmt;
Query OK, 0 rows affected (0.00 sec)
```

See Section 13.5, “Prepared SQL Statement Syntax”, for more information.

A similar technique can be used in application programs to construct SQL statements using program variables, as shown here using PHP 5:

```
<?php
  $mysqli = new mysqli("localhost", "user", "pass", "test");

  if( mysqli_connect_errno() )
    die("Connection failed: %s\n", mysqli_connect_error());

  $col = "c1";

  $query = "SELECT $col FROM t";

  $result = $mysqli->query($query);

  while($row = $result->fetch_assoc())
  {
    echo "<p>" . $row["$col"] . "</p>\n";
  }

  $result->close();

  $mysqli->close();
?>
```

Assembling an SQL statement in this fashion is sometimes known as “Dynamic SQL”.

9.5 Expression Syntax

The following rules define expression syntax in MySQL. The grammar shown here is based on that given in the `sql/sql_yacc.yy` file of MySQL source distributions. See the notes after the grammar for additional information about some of the terms.

```
expr:
    expr OR expr
  | expr || expr
  | expr XOR expr
  | expr AND expr
  | expr && expr
  | NOT expr
  | ! expr
  | boolean_primary IS [NOT] {TRUE | FALSE | UNKNOWN}
  | boolean_primary

boolean_primary:
    boolean_primary IS [NOT] NULL
  | boolean_primary <=> predicate
  | boolean_primary comparison_operator predicate
  | boolean_primary comparison_operator {ALL | ANY} (subquery)
  | predicate

comparison_operator: = | >= | > | <= | < | <> | !=

predicate:
    bit_expr [NOT] IN (subquery)
  | bit_expr [NOT] IN (expr [, expr] ...)
  | bit_expr [NOT] BETWEEN bit_expr AND predicate
  | bit_expr SOUNDS LIKE bit_expr
  | bit_expr [NOT] LIKE simple_expr [ESCAPE simple_expr]
  | bit_expr [NOT] REGEXP bit_expr
  | bit_expr

bit_expr:
```

```
    bit_expr | bit_expr
  | bit_expr & bit_expr
  | bit_expr << bit_expr
  | bit_expr >> bit_expr
  | bit_expr + bit_expr
  | bit_expr - bit_expr
  | bit_expr * bit_expr
  | bit_expr / bit_expr
  | bit_expr DIV bit_expr
  | bit_expr MOD bit_expr
  | bit_expr % bit_expr
  | bit_expr ^ bit_expr
  | bit_expr + interval_expr
  | bit_expr - interval_expr
  | simple_expr

simple_expr:
    literal
  | identifier
  | function_call
  | simple_expr COLLATE collation_name
  | param_marker
  | variable
  | simple_expr || simple_expr
  | + simple_expr
  | - simple_expr
  | ~ simple_expr
  | ! simple_expr
  | BINARY simple_expr
  | (expr [, expr] ...)
  | ROW (expr, expr [, expr] ...)
  | (subquery)
  | EXISTS (subquery)
  | {identifier expr}
  | match_expr
  | case_expr
  | interval_expr
```

Notes:

For operator precedence, see in Section 12.3.1, “Operator Precedence”.

For literal value syntax, see Section 9.1, “Literal Values”.

For identifier syntax, see Section 9.2, “Schema Object Names”.

Variables can be user variables, system variables, or stored program local variables or parameters:

- User variables: Section 9.4, “User-Defined Variables”
- System variables: Section 5.1.6, “Using System Variables”
- Local variables: Section 13.6.4.1, “Local Variable DECLARE Syntax”
- Parameters: Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”

`param_marker` is `?` as used in prepared statements for placeholders. See Section 13.5.1, “PREPARE Syntax”.

`(subquery)` indicates a subquery that returns a single value; that is, a scalar subquery. See Section 13.2.10.1, “The Subquery as Scalar Operand”.

`{identifier expr}` is ODBC escape syntax and is accepted for ODBC compatibility. The value is `expr`. The curly braces in the syntax should be written literally; they are not metasyntax as used elsewhere in syntax descriptions.

`match_expr` indicates a `MATCH` expression. See Section 12.9, “Full-Text Search Functions”.

case_expr indicates a CASE expression. See Section 12.4, “Control Flow Functions”.

interval_expr represents a time interval. The syntax is INTERVAL *expr unit*, where *unit* is a specifier such as HOUR, DAY, or WEEK. For the full list of *unit* specifiers, see the description of the DATE_ADD() function in Section 12.7, “Date and Time Functions”.

The meaning of some operators depends on the SQL mode:

- By default, || is a logical OR operator. With PIPES_AS_CONCAT enabled, || is string concatenation, with a precedence between ^ and the unary operators.
- By default, ! has a higher precedence than NOT. With HIGH_NOT_PRECEDENCE enabled, ! and NOT have the same precedence.

See Section 5.1.8, “Server SQL Modes”.

9.6 Comment Syntax

MySQL Server supports three comment styles:

- From a # character to the end of the line.
- From a -- sequence to the end of the line. In MySQL, the -- (double-dash) comment style requires the second dash to be followed by at least one whitespace or control character (such as a space, tab, newline, and so on). This syntax differs slightly from standard SQL comment syntax, as discussed in Section 1.7.2.4, “'--' as the Start of a Comment”.
- From a /* sequence to the following */ sequence, as in the C programming language. This syntax enables a comment to extend over multiple lines because the beginning and closing sequences need not be on the same line.

The following example demonstrates all three comment styles:

```
mysql> SELECT 1+1;     # This comment continues to the end of line
mysql> SELECT 1+1;     -- This comment continues to the end of line
mysql> SELECT 1 /* this is an in-line comment */ + 1;
mysql> SELECT 1+
/*
this is a
multiple-line comment
*/
1;
```

Nested comments are not supported. (Under some conditions, nested comments might be permitted, but usually are not, and users should avoid them.)

MySQL Server supports some variants of C-style comments. These enable you to write code that includes MySQL extensions, but is still portable, by using comments of the following form:

```
/*! MySQL-specific code */
```

In this case, MySQL Server parses and executes the code within the comment as it would any other SQL statement, but other SQL servers will ignore the extensions. For example, MySQL Server recognizes the STRAIGHT_JOIN keyword in the following statement, but other servers will not:

```
SELECT /*! STRAIGHT_JOIN */ col1 FROM table1,table2 WHERE ...
```

If you add a version number after the ! character, the syntax within the comment is executed only if the MySQL version is greater than or equal to the specified version number. The KEY_BLOCK_SIZE keyword in the following comment is executed only by servers from MySQL 5.1.10 or higher:

```
CREATE TABLE t1(a INT, KEY (a)) /*!50110 KEY_BLOCK_SIZE=1024 */;
```

The comment syntax just described applies to how the `mysqld` server parses SQL statements. The `mysql` client program also performs some parsing of statements before sending them to the server. (It does this to determine statement boundaries within a multiple-statement input line.)

Comments in this format, `/*!12345 ... */`, are not stored on the server. If this format is used to comment stored routines, the comments will not be retained on the server.

The use of short-form `mysql` commands such as `\C` within multiple-line `/* ... */` comments is not supported.

Chapter 10 Globalization

Table of Contents

10.1 Character Set Support 1013
10.1.1 Character Sets and Collations in General 1014
10.1.2 Character Sets and Collations in MySQL 1015
10.1.3 Specifying Character Sets and Collations 1019
10.1.4 Connection Character Sets and Collations 1029
10.1.5 Configuring Application Character Set and Collation 1031
10.1.6 Error Message Character Set 1033
10.1.7 Column Character Set Conversion 1034
10.1.8 Collation Issues 1035
10.1.9 Unicode Support 1043
10.1.10 Supported Character Sets and Collations 1049
10.2 Setting the Error Message Language 1061
10.3 Adding a Character Set 1062
10.3.1 Character Definition Arrays 1064
10.3.2 String Collating Support for Complex Character Sets 1065
10.3.3 Multi-Byte Character Support for Complex Character Sets 1065
10.4 Adding a Collation to a Character Set 1066
10.4.1 Collation Implementation Types 1067
10.4.2 Choosing a Collation ID 1068
10.4.3 Adding a Simple Collation to an 8-Bit Character Set 1069
10.4.4 Adding a UCA Collation to a Unicode Character Set 1070
10.5 Character Set Configuration 1073
10.6 MySQL Server Time Zone Support 1074
10.6.1 Staying Current with Time Zone Changes 1077
10.6.2 Time Zone Leap Second Support 1078
10.7 MySQL Server Locale Support 1079

This chapter covers issues of globalization, which includes internationalization (MySQL's capabilities for adapting to local use) and localization (selecting particular local conventions):

- MySQL support for character sets in SQL statements.
- How to configure the server to support different character sets.
- Selecting the language for error messages.
- How to set the server's time zone and enable per-connection time zone support.
- Selecting the locale for day and month names.

10.1 Character Set Support

MySQL includes character set support that enables you to store data using a variety of character sets and perform comparisons according to a variety of collations. You can specify character sets at the server, database, table, and column level. MySQL supports the use of character sets for the `MyISAM`, `MEMORY`, `NDBCLUSTER`, and `InnoDB` storage engines.

This chapter discusses the following topics:

- What are character sets and collations?

- The multiple-level default system for character set assignment.
- Syntax for specifying character sets and collations.
- Affected functions and operations.
- Unicode support.
- The character sets and collations that are available, with notes.

Character set issues affect not only data storage, but also communication between client programs and the MySQL server. If you want the client program to communicate with the server using a character set different from the default, you'll need to indicate which one. For example, to use the `utf8` Unicode character set, issue this statement after connecting to the server:

```
SET NAMES 'utf8';
```

For more information about configuring character sets for application use and character set-related issues in client/server communication, see Section 10.1.5, “Configuring Application Character Set and Collation”, and Section 10.1.4, “Connection Character Sets and Collations”.

10.1.1 Character Sets and Collations in General

A *character set* is a set of symbols and encodings. A *collation* is a set of rules for comparing characters in a character set. Let's make the distinction clear with an example of an imaginary character set.

Suppose that we have an alphabet with four letters: A, B, a, b. We give each letter a number: A = 0, B = 1, a = 2, b = 3. The letter A is a symbol, the number 0 is the *encoding* for A, and the combination of all four letters and their encodings is a *character set*.

Suppose that we want to compare two string values, A and B. The simplest way to do this is to look at the encodings: 0 for A and 1 for B. Because 0 is less than 1, we say A is less than B. What we've just done is apply a collation to our character set. The collation is a set of rules (only one rule in this case): “compare the encodings.” We call this simplest of all possible collations a *binary* collation.

But what if we want to say that the lowercase and uppercase letters are equivalent? Then we would have at least two rules: (1) treat the lowercase letters a and b as equivalent to A and B; (2) then compare the encodings. We call this a *case-insensitive* collation. It is a little more complex than a binary collation.

In real life, most character sets have many characters: not just A and B but whole alphabets, sometimes multiple alphabets or eastern writing systems with thousands of characters, along with many special symbols and punctuation marks. Also in real life, most collations have many rules, not just for whether to distinguish lettercase, but also for whether to distinguish accents (an “accent” is a mark attached to a character as in German Ö), and for multiple-character mappings (such as the rule that Ö = OE in one of the two German collations).

MySQL can do these things for you:

- Store strings using a variety of character sets.
- Compare strings using a variety of collations.
- Mix strings with different character sets or collations in the same server, the same database, or even the same table.
- Enable specification of character set and collation at any level.

To use these features effectively, you must know what character sets and collations are available, how to change the defaults, and how they affect the behavior of string operators and functions.

10.1.2 Character Sets and Collations in MySQL

MySQL Server supports multiple character sets. To display the available character sets, use the `INFORMATION_SCHEMA CHARACTER_SETS` table or the `SHOW CHARACTER SET` statement. A partial listing follows. For more complete information, see Section 10.1.10, “Supported Character Sets and Collations”.

```
mysql> SHOW CHARACTER SET;
+----------+---------------------------------+---------------------+--------+
| Charset  | Description                     | Default collation   | Maxlen |
+----------+---------------------------------+---------------------+--------+
| big5     | Big5 Traditional Chinese        | big5_chinese_ci     |      2 |
...
| latin1   | cp1252 West European            | latin1_swedish_ci   |      1 |
| latin2   | ISO 8859-2 Central European     | latin2_general_ci   |      1 |
...
| utf8     | UTF-8 Unicode                   | utf8_general_ci     |      3 |
| ucs2     | UCS-2 Unicode                   | ucs2_general_ci     |      2 |
...
| utf8mb4  | UTF-8 Unicode                   | utf8mb4_general_ci  |      4 |
...
| binary   | Binary pseudo charset           | binary              |      1 |
...
```

By default, the `SHOW CHARACTER SET` statement displays all available character sets. It takes an optional `LIKE` or `WHERE` clause that indicates which character set names to match. For example:

```
mysql> SHOW CHARACTER SET LIKE 'latin%';
+---------+----------------------------+-------------------+--------+
| Charset | Description                | Default collation | Maxlen |
+---------+----------------------------+-------------------+--------+
| latin1  | cp1252 West European       | latin1_swedish_ci |      1 |
| latin2  | ISO 8859-2 Central European | latin2_general_ci |      1 |
| latin5  | ISO 8859-9 Turkish         | latin5_turkish_ci |      1 |
| latin7  | ISO 8859-13 Baltic         | latin7_general_ci |      1 |
+---------+----------------------------+-------------------+--------+
```

A given character set always has at least one collation, and most character sets have several. To list the display collations for a character set, use the `INFORMATION_SCHEMA COLLATIONS` table or the `SHOW COLLATION` statement.

By default, the `SHOW COLLATION` statement displays all available collations. It takes an optional `LIKE` or `WHERE` clause that indicates which collation names to display. For example, to see the collations for the `latin1` (cp1252 West European) character set, use this statement:

```
mysql> SHOW COLLATION WHERE Charset = 'latin1';
+-------------------+---------+----+---------+----------+---------+
| Collation         | Charset | Id | Default | Compiled | Sortlen |
+-------------------+---------+----+---------+----------+---------+
| latin1_german1_ci | latin1  |  5 |         | Yes      |       1 |
| latin1_swedish_ci | latin1  |  8 | Yes     | Yes      |       1 |
| latin1_danish_ci  | latin1  | 15 |         | Yes      |       1 |
| latin1_german2_ci | latin1  | 31 |         | Yes      |       2 |
| latin1_bin        | latin1  | 47 |         | Yes      |       1 |
| latin1_general_ci | latin1  | 48 |         | Yes      |       1 |
| latin1_general_cs | latin1  | 49 |         | Yes      |       1 |
| latin1_spanish_ci | latin1  | 94 |         | Yes      |       1 |
+-------------------+---------+----+---------+----------+---------+
```

The `latin1` collations have the following meanings.

Collation	Meaning
`latin1_bin`	Binary according to `latin1` encoding
`latin1_danish_ci`	Danish/Norwegian

Collation	Meaning
latin1_general_ci	Multilingual (Western European)
latin1_general_cs	Multilingual (ISO Western European), case sensitive
latin1_german1_ci	German DIN-1 (dictionary order)
latin1_german2_ci	German DIN-2 (phone book order)
latin1_spanish_ci	Modern Spanish
latin1_swedish_ci	Swedish/Finnish

Collations have these general characteristics:

- Two different character sets cannot have the same collation.
- Each character set has a *default collation*. For example, the default collations for latin1 and utf8 are latin1_swedish_ci and utf8_general_ci, respectively. The INFORMATION_SCHEMA CHARACTER_SETS table and the SHOW CHARACTER SET statement indicate the default collation for each character set. The INFORMATION_SCHEMA COLLATIONS table and the SHOW COLLATION statement have a column that indicates for each collation whether it is the default for its character set (Yes if so, empty if not).
- Collation names start with the name of the character set with which they are associated, generally followed by one or more suffixes indicating other collation characteristics. For additional information about naming conventions, see Section 10.1.3.1, “Collation Naming Conventions”.

When a character set has multiple collations, it might not be clear which collation is most suitable for a given application. To avoid choosing an inappropriate collation, perform some comparisons with representative data values to make sure that a given collation sorts values the way you expect.

10.1.2.1 Character Set Repertoire

The *repertoire* of a character set is the collection of characters in the set.

String expressions have a repertoire attribute, which can have two values:

- ASCII: The expression can contain only characters in the Unicode range U+0000 to U+007F.
- UNICODE: The expression can contain characters in the Unicode range U+0000 to U+10FFFF. This includes characters in the Basic Multilingual Plane (BMP) range (U+0000 to U+FFFF) and supplementary characters outside the BMP range (U+01000 to U+10FFFF).

The ASCII range is a subset of UNICODE range, so a string with ASCII repertoire can be converted safely without loss of information to the character set of any string with UNICODE repertoire or to a character set that is a superset of ASCII. (All MySQL character sets are supersets of ASCII with the exception of swe7, which reuses some punctuation characters for Swedish accented characters.) The use of repertoire enables character set conversion in expressions for many cases where MySQL would otherwise return an “illegal mix of collations” error.

The following discussion provides examples of expressions and their repertoires, and describes how the use of repertoire changes string expression evaluation:

- The repertoire for a string constant depends on string content and may differ from the repertoire of the string character set. Consider these statements:

```
SET NAMES utf8; SELECT 'abc';
SELECT _utf8'def';
SELECT N'MySQL';
```

  Although the character set is utf8 in each of the preceding cases, the strings do not actually contain any characters outside the ASCII range, so their repertoire is ASCII rather than UNICODE.

- A column having the `ascii` character set has `ASCII` repertoire because of its character set. In the following table, `c1` has `ASCII` repertoire:

```
CREATE TABLE t1 (c1 CHAR(1) CHARACTER SET ascii);
```

The following example illustrates how repertoire enables a result to be determined in a case where an error occurs without repertoire:

```
CREATE TABLE t1 (
  c1 CHAR(1) CHARACTER SET latin1,
  c2 CHAR(1) CHARACTER SET ascii
);
INSERT INTO t1 VALUES ('a','b');
SELECT CONCAT(c1,c2) FROM t1;
```

Without repertoire, this error occurs:

```
ERROR 1267 (HY000): Illegal mix of collations (latin1_swedish_ci,IMPLICIT)
and (ascii_general_ci,IMPLICIT) for operation 'concat'
```

Using repertoire, subset to superset (`ascii` to `latin1`) conversion can occur and a result is returned:

```
+---------------+
| CONCAT(c1,c2) |
+---------------+
| ab            |
+---------------+
```

- Functions with one string argument inherit the repertoire of their argument. The result of `UPPER(_utf8'abc')` has `ASCII` repertoire because its argument has `ASCII` repertoire.
- For functions that return a string but do not have string arguments and use `character_set_connection` as the result character set, the result repertoire is `ASCII` if `character_set_connection` is `ascii`, and `UNICODE` otherwise:

```
FORMAT(numeric_column, 4);
```

Use of repertoire changes how MySQL evaluates the following example:

```
SET NAMES ascii;
CREATE TABLE t1 (a INT, b VARCHAR(10) CHARACTER SET latin1);
INSERT INTO t1 VALUES (1,'b');
SELECT CONCAT(FORMAT(a, 4), b) FROM t1;
```

Without repertoire, this error occurs:

```
ERROR 1267 (HY000): Illegal mix of collations (ascii_general_ci,COERCIBLE)
and (latin1_swedish_ci,IMPLICIT) for operation 'concat'
```

With repertoire, a result is returned:

```
+-------------------------+
| CONCAT(FORMAT(a, 4), b) |
+-------------------------+
| 1.0000b                 |
+-------------------------+
```

- Functions with two or more string arguments use the “widest” argument repertoire for the result repertoire (`UNICODE` is wider than `ASCII`). Consider the following `CONCAT()` calls:

```
CONCAT(_ucs2 X'0041', _ucs2 X'0042')
CONCAT(_ucs2 X'0041', _ucs2 X'00C2')
```

For the first call, the repertoire is `ASCII` because both arguments are within the range of the `ascii` character set. For the second call, the repertoire is `UNICODE` because the second argument is outside the `ascii` character set range.

- The repertoire for function return values is determined based only on the repertoire of the arguments that affect the result's character set and collation.

```
IF(column1 < column2, 'smaller', 'greater')
```

The result repertoire is `ASCII` because the two string arguments (the second argument and the third argument) both have `ASCII` repertoire. The first argument does not matter for the result repertoire, even if the expression uses string values.

10.1.2.2 UTF-8 for Metadata

Metadata is “the data about the data.” Anything that *describes* the database—as opposed to being the *contents* of the database—is metadata. Thus column names, database names, user names, version names, and most of the string results from `SHOW` are metadata. This is also true of the contents of tables in `INFORMATION_SCHEMA` because those tables by definition contain information about database objects.

Representation of metadata must satisfy these requirements:

- All metadata must be in the same character set. Otherwise, neither the `SHOW` statements nor `SELECT` statements for tables in `INFORMATION_SCHEMA` would work properly because different rows in the same column of the results of these operations would be in different character sets.
- Metadata must include all characters in all languages. Otherwise, users would not be able to name columns and tables using their own languages.

To satisfy both requirements, MySQL stores metadata in a Unicode character set, namely UTF-8. This does not cause any disruption if you never use accented or non-Latin characters. But if you do, you should be aware that metadata is in UTF-8.

The metadata requirements mean that the return values of the `USER()`, `CURRENT_USER()`, `SESSION_USER()`, `SYSTEM_USER()`, `DATABASE()`, and `VERSION()` functions have the UTF-8 character set by default.

The server sets the `character_set_system` system variable to the name of the metadata character set:

```
mysql> SHOW VARIABLES LIKE 'character_set_system';
+----------------------+-------+
| Variable_name        | Value |
+----------------------+-------+
| character_set_system | utf8  |
+----------------------+-------+
```

Storage of metadata using Unicode does *not* mean that the server returns headers of columns and the results of `DESCRIBE` functions in the `character_set_system` character set by default. When you use `SELECT column1 FROM t`, the name `column1` itself is returned from the server to the client in the character set determined by the value of the `character_set_results` system variable, which has a default value of `latin1`. If you want the server to pass metadata results back in a different character set, use the `SET NAMES` statement to force the server to perform character set conversion. `SET NAMES` sets the `character_set_results` and other related system variables. (See Section 10.1.4, “Connection Character Sets and Collations”.) Alternatively, a client program can

perform the conversion after receiving the result from the server. It is more efficient for the client to perform the conversion, but this option is not always available for all clients.

If `character_set_results` is set to `NULL`, no conversion is performed and the server returns metadata using its original character set (the set indicated by `character_set_system`).

Error messages returned from the server to the client are converted to the client character set automatically, as with metadata.

If you are using (for example) the `USER()` function for comparison or assignment within a single statement, don't worry. MySQL performs some automatic conversion for you.

```
SELECT * FROM t1 WHERE USER() = latin1_column;
```

This works because the contents of `latin1_column` are automatically converted to UTF-8 before the comparison.

```
INSERT INTO t1 (latin1_column) SELECT USER();
```

This works because the contents of `USER()` are automatically converted to `latin1` before the assignment.

Although automatic conversion is not in the SQL standard, the standard does say that every character set is (in terms of supported characters) a “subset” of Unicode. Because it is a well-known principle that “what applies to a superset can apply to a subset,” we believe that a collation for Unicode can apply for comparisons with non-Unicode strings. For more information about coercion of strings, see Section 10.1.8.4, “Collation Coercibility in Expressions”.

10.1.3 Specifying Character Sets and Collations

There are default settings for character sets and collations at four levels: server, database, table, and column. The description in the following sections may appear complex, but it has been found in practice that multiple-level defaulting leads to natural and obvious results.

`CHARACTER SET` is used in clauses that specify a character set. `CHARSET` can be used as a synonym for `CHARACTER SET`.

Character set issues affect not only data storage, but also communication between client programs and the MySQL server. If you want the client program to communicate with the server using a character set different from the default, you'll need to indicate which one. For example, to use the `utf8` Unicode character set, issue this statement after connecting to the server:

```
SET NAMES 'utf8';
```

For more information about character set-related issues in client/server communication, see Section 10.1.4, “Connection Character Sets and Collations”.

10.1.3.1 Collation Naming Conventions

MySQL collation names follow these conventions:

- A collation name starts with the name of the character set with which it is associated, generally followed by one or more suffixes indicating other collation characteristics. For example, `utf8_general_ci` and `latin1_swedish_ci` are collations for the `utf8` and `latin1` character sets, respectively. The `binary` character set has a single collation, also named `binary`, with no suffixes.
- A language-specific collation includes a language name. For example, `utf8_turkish_ci` and `utf8_hungarian_ci` sort characters for the `utf8` character set using the rules of Turkish and Hungarian, respectively.

- Collation suffixes indicate whether a collation is case and accent sensitive, or binary. The following table shows the suffixes used to indicate these characteristics.

  Table 10.1 Collation Case Sensitivity Suffixes

Suffix	Meaning
`_ai`	Accent insensitive
`_as`	Accent sensitive
`_ci`	Case insensitive
`_cs`	Case sensitive
`_bin`	Binary

  For nonbinary collation names that do not specify accent sensitivity, it is determined by case sensitivity. If a collation name does not contain `_ai` or `_as`, `_ci` in the name implies `_ai` and `_cs` in the name implies `_as`. For example, `latin1_general_ci` is explicitly case insensitive and implicitly accent insensitive, and `latin1_general_cs` is explicitly case sensitive and implicitly accent sensitive.

  For the `binary` collation of the `binary` character set, comparisons are based on numeric byte values. For the `_bin` collation of a nonbinary character set, comparisons are based on numeric character code values, which differ from byte values for multibyte characters. For more information, see Section 10.1.8.5, “The binary Collation Compared to _bin Collations”.

- For Unicode character sets, the *`xxx`*`_general_mysql500_ci` collations preserve the pre-5.1.24 ordering of the original *`xxx`*`_general_ci` collations and permit upgrades for tables created before MySQL 5.1.24 (Bug #27877).

10.1.3.2 Server Character Set and Collation

MySQL Server has a server character set and a server collation. These can be set at server startup on the command line or in an option file and changed at runtime.

Initially, the server character set and collation depend on the options that you use when you start `mysqld`. You can use `--character-set-server` for the character set. Along with it, you can add `--collation-server` for the collation. If you don't specify a character set, that is the same as saying `--character-set-server=latin1`. If you specify only a character set (for example, `latin1`) but not a collation, that is the same as saying `--character-set-server=latin1 --collation-server=latin1_swedish_ci` because `latin1_swedish_ci` is the default collation for `latin1`. Therefore, the following three commands all have the same effect:

```
shell> mysqld
shell> mysqld --character-set-server=latin1
shell> mysqld --character-set-server=latin1 \
          --collation-server=latin1_swedish_ci
```

One way to change the settings is by recompiling. To change the default server character set and collation when building from sources, use the `DEFAULT_CHARSET` and `DEFAULT_COLLATION` options for `CMake`. For example:

```
shell> cmake . -DDEFAULT_CHARSET=latin1
```

Or:

```
shell> cmake . -DDEFAULT_CHARSET=latin1 \
          -DDEFAULT_COLLATION=latin1_german1_ci
```

Both `mysqld` and `CMake` verify that the character set/collation combination is valid. If not, each program displays an error message and terminates.

The server character set and collation are used as default values if the database character set and collation are not specified in `CREATE DATABASE` statements. They have no other purpose.

The current server character set and collation can be determined from the values of the `character_set_server` and `collation_server` system variables. These variables can be changed at runtime.

10.1.3.3 Database Character Set and Collation

Every database has a database character set and a database collation. The `CREATE DATABASE` and `ALTER DATABASE` statements have optional clauses for specifying the database character set and collation:

```
CREATE DATABASE db_name
    [[DEFAULT] CHARACTER SET charset_name]
    [[DEFAULT] COLLATE collation_name]

ALTER DATABASE db_name
    [[DEFAULT] CHARACTER SET charset_name]
    [[DEFAULT] COLLATE collation_name]
```

The keyword `SCHEMA` can be used instead of `DATABASE`.

All database options are stored in a text file named `db.opt` that can be found in the database directory.

The `CHARACTER SET` and `COLLATE` clauses make it possible to create databases with different character sets and collations on the same MySQL server.

Example:

```
CREATE DATABASE db_name CHARACTER SET latin1 COLLATE latin1_swedish_ci;
```

MySQL chooses the database character set and database collation in the following manner:

- If both `CHARACTER SET charset_name` and `COLLATE collation_name` are specified, character set `charset_name` and collation `collation_name` are used.
- If `CHARACTER SET charset_name` is specified without `COLLATE`, character set `charset_name` and its default collation are used. To see the default collation for each character set, use the `SHOW CHARACTER SET` statement.
- If `COLLATE collation_name` is specified without `CHARACTER SET`, the character set associated with `collation_name` and collation `collation_name` are used.
- Otherwise (neither `CHARACTER SET` nor `COLLATE` is specified), the server character set and server collation are used.

The character set and collation for the default database can be determined from the values of the `character_set_database` and `collation_database` system variables. The server sets these variables whenever the default database changes. If there is no default database, the variables have the same value as the corresponding server-level system variables, `character_set_server` and `collation_server`.

To see the default character set and collation for a given database, use these statements:

```
USE db_name;
SELECT @@character_set_database, @@collation_database;
```

Alternatively, to display the values without changing the default database:

```
SELECT DEFAULT_CHARACTER_SET_NAME, DEFAULT_COLLATION_NAME
```

```
FROM INFORMATION_SCHEMA.SCHEMATA WHERE SCHEMA_NAME = 'db_name';
```

The database character set and collation affect these aspects of server operation:

- For `CREATE TABLE` statements, the database character set and collation are used as default values for table definitions if the table character set and collation are not specified. To override this, provide explicit `CHARACTER SET` and `COLLATE` table options.
- For `LOAD DATA` statements that include no `CHARACTER SET` clause, the server uses the character set indicated by the `character_set_database` system variable to interpret the information in the file. To override this, provide an explicit `CHARACTER SET` clause.
- For stored routines (procedures and functions), the database character set and collation in effect at routine creation time are used as the character set and collation of character data parameters for which the declaration includes no `CHARACTER SET` or `COLLATE` attribute. To override this, provide explicit `CHARACTER SET` and `COLLATE` attributes.

10.1.3.4 Table Character Set and Collation

Every table has a table character set and a table collation. The `CREATE TABLE` and `ALTER TABLE` statements have optional clauses for specifying the table character set and collation:

```
CREATE TABLE tbl_name (column_list)
    [[DEFAULT] CHARACTER SET charset_name]
    [COLLATE collation_name]]

ALTER TABLE tbl_name
    [[DEFAULT] CHARACTER SET charset_name]
    [COLLATE collation_name]
```

Example:

```
CREATE TABLE t1 ( ... )
CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

MySQL chooses the table character set and collation in the following manner:

- If both `CHARACTER SET charset_name` and `COLLATE collation_name` are specified, character set *`charset_name`* and collation *`collation_name`* are used.
- If `CHARACTER SET charset_name` is specified without `COLLATE`, character set *`charset_name`* and its default collation are used. To see the default collation for each character set, use the `SHOW CHARACTER SET` statement.
- If `COLLATE collation_name` is specified without `CHARACTER SET`, the character set associated with *`collation_name`* and collation *`collation_name`* are used.
- Otherwise (neither `CHARACTER SET` nor `COLLATE` is specified), the database character set and collation are used.

The table character set and collation are used as default values for column definitions if the column character set and collation are not specified in individual column definitions. The table character set and collation are MySQL extensions; there are no such things in standard SQL.

10.1.3.5 Column Character Set and Collation

Every “character” column (that is, a column of type `CHAR`, `VARCHAR`, or `TEXT`) has a column character set and a column collation. Column definition syntax for `CREATE TABLE` and `ALTER TABLE` has optional clauses for specifying the column character set and collation:

```
col_name {CHAR | VARCHAR | TEXT} (col_length)
    [CHARACTER SET charset_name]
```

```
    [COLLATE collation_name]
```

These clauses can also be used for ENUM and SET columns:

```
col_name {ENUM | SET} (val_list)
    [CHARACTER SET charset_name]
    [COLLATE collation_name]
```

Examples:

```
CREATE TABLE t1
(
    col1 VARCHAR(5)
      CHARACTER SET latin1
      COLLATE latin1_german1_ci
);

ALTER TABLE t1 MODIFY
    col1 VARCHAR(5)
      CHARACTER SET latin1
      COLLATE latin1_swedish_ci;
```

MySQL chooses the column character set and collation in the following manner:

- If both CHARACTER SET *charset_name* and COLLATE *collation_name* are specified, character set *charset_name* and collation *collation_name* are used.

  ```
  CREATE TABLE t1
  (
      col1 CHAR(10) CHARACTER SET utf8 COLLATE utf8_unicode_ci
  ) CHARACTER SET latin1 COLLATE latin1_bin;
  ```

  The character set and collation are specified for the column, so they are used. The column has character set utf8 and collation utf8_unicode_ci.

- If CHARACTER SET *charset_name* is specified without COLLATE, character set *charset_name* and its default collation are used.

  ```
  CREATE TABLE t1
  (
      col1 CHAR(10) CHARACTER SET utf8
  ) CHARACTER SET latin1 COLLATE latin1_bin;
  ```

  The character set is specified for the column, but the collation is not. The column has character set utf8 and the default collation for utf8, which is utf8_general_ci. To see the default collation for each character set, use the SHOW CHARACTER SET statement.

- If COLLATE *collation_name* is specified without CHARACTER SET, the character set associated with *collation_name* and collation *collation_name* are used.

  ```
  CREATE TABLE t1
  (
      col1 CHAR(10) COLLATE utf8_polish_ci
  ) CHARACTER SET latin1 COLLATE latin1_bin;
  ```

  The collation is specified for the column, but the character set is not. The column has collation utf8_polish_ci and the character set is the one associated with the collation, which is utf8.

- Otherwise (neither CHARACTER SET nor COLLATE is specified), the table character set and collation are used.

  ```
  CREATE TABLE t1
  ```

```
(
    col1 CHAR(10)
) CHARACTER SET latin1 COLLATE latin1_bin;
```

Neither the character set nor collation is specified for the column, so the table defaults are used. The column has character set `latin1` and collation `latin1_bin`.

The `CHARACTER SET` and `COLLATE` clauses are standard SQL.

If you use `ALTER TABLE` to convert a column from one character set to another, MySQL attempts to map the data values, but if the character sets are incompatible, there may be data loss.

10.1.3.6 Character String Literal Character Set and Collation

Every character string literal has a character set and a collation.

For the simple statement `SELECT 'string'`, the string has the connection default character set and collation defined by the `character_set_connection` and `collation_connection` system variables.

A character string literal may have an optional character set introducer and `COLLATE` clause, to designate it as a string that uses a particular character set and collation:

```
[_charset_name]'string' [COLLATE collation_name]
```

Character set introducers and the `COLLATE` clause are implemented according to standard SQL specifications.

Examples:

```
SELECT 'abc';
SELECT _latin1'abc';
SELECT _binary'abc';
SELECT _utf8'abc' COLLATE utf8_danish_ci;
```

The *`_charset_name`* expression is formally called an *introducer*. It tells the parser, “the string that follows uses character set *`charset_name`*.” An introducer does not change the string to the introducer character set like `CONVERT()` would do. It does not change the string value, although padding may occur. The introducer is just a signal.

MySQL determines the character set and collation of a character string literal in the following manner:

- If both *`_charset_name`* and `COLLATE` *`collation_name`* are specified, character set *`charset_name`* and collation *`collation_name`* are used. *`collation_name`* must be a permitted collation for *`charset_name`*.
- If *`_charset_name`* is specified but `COLLATE` is not specified, character set *`charset_name`* and its default collation are used. To see the default collation for each character set, use the `SHOW CHARACTER SET` statement.
- If *`_charset_name`* is not specified but `COLLATE` *`collation_name`* is specified, the connection default character set given by the `character_set_connection` system variable and collation *`collation_name`* are used. *`collation_name`* must be a permitted collation for the connection default character set.
- Otherwise (neither *`_charset_name`* nor `COLLATE` *`collation_name`* is specified), the connection default character set and collation given by the `character_set_connection` and `collation_connection` system variables are used.

Examples:

- A nonbinary string with `latin1` character set and `latin1_german1_ci` collation:

```
SELECT _latin1'Müller' COLLATE latin1_german1_ci;
```

- A nonbinary string with `utf8` character set and its default collation (that is, `utf8_general_ci`):

```
SELECT _utf8'Müller';
```

- A binary string with `binary` character set and its default collation (that is, `binary`):

```
SELECT _binary'Müller';
```

- A nonbinary string with the connection default character set and `utf8_general_ci` collation (fails if the connection character set is not `utf8`):

```
SELECT 'Müller' COLLATE utf8_general_ci;
```

- A string with the connection default character set and collation:

```
SELECT 'Müller';
```

An introducer indicates the character set for the following string, but does not change how the parser performs escape processing within the string. Escapes are always interpreted by the parser according to the character set given by `character_set_connection`.

The following examples show that escape processing occurs using `character_set_connection` even in the presence of an introducer. The examples use `SET NAMES` (which changes `character_set_connection`, as discussed in Section 10.1.4, “Connection Character Sets and Collations”), and display the resulting strings using the `HEX()` function so that the exact string contents can be seen.

Example 1:

```
mysql> SET NAMES latin1;
mysql> SELECT HEX('à\n'), HEX(_sjis'à\n');
+------------+-----------------+
| HEX('à\n')  | HEX(_sjis'à\n')  |
+------------+-----------------+
| E00A       | E00A            |
+------------+-----------------+
```

Here, `à` (hexadecimal value `E0`) is followed by `\n`, the escape sequence for newline. The escape sequence is interpreted using the `character_set_connection` value of `latin1` to produce a literal newline (hexadecimal value `0A`). This happens even for the second string. That is, the `_sjis` introducer does not affect the parser's escape processing.

Example 2:

```
mysql> SET NAMES sjis;
mysql> SELECT HEX('à\n'), HEX(_latin1'à\n');
+------------+------------------+
| HEX('à\n')  | HEX(_latin1'à\n')  |
+------------+------------------+
| E05C6E     | E05C6E           |
+------------+------------------+
```

Here, `character_set_connection` is `sjis`, a character set in which the sequence of `à` followed by `\` (hexadecimal values `05` and `5C`) is a valid multibyte character. Hence, the first two bytes of the string are interpreted as a single `sjis` character, and the `\` is not interpreted as an escape character. The following `n` (hexadecimal value `6E`) is not interpreted as part of an escape sequence. This is true even for the second string; the `_latin1` introducer does not affect escape processing.

10.1.3.7 The National Character Set

Standard SQL defines `NCHAR` or `NATIONAL CHAR` as a way to indicate that a `CHAR` column should use some predefined character set. MySQL uses `utf8` as this predefined character set. For example, these data type declarations are equivalent:

```
CHAR(10) CHARACTER SET utf8
NATIONAL CHARACTER(10)
NCHAR(10)
```

As are these:

```
VARCHAR(10) CHARACTER SET utf8
NATIONAL VARCHAR(10)
NVARCHAR(10)
NCHAR VARCHAR(10)
NATIONAL CHARACTER VARYING(10)
NATIONAL CHAR VARYING(10)
```

You can use `N'literal'` (or `n'literal'`) to create a string in the national character set. These statements are equivalent:

```
SELECT N'some text';
SELECT n'some text';
SELECT _utf8'some text';
```

10.1.3.8 Character Set Introducers

A character string literal, hexadecimal literal, or bit-value literal may have an optional character set introducer and `COLLATE` clause, to designate it as a string that uses a particular character set and collation:

```
[_charset_name] literal [COLLATE collation_name]
```

Character set introducers and the `COLLATE` clause are implemented according to standard SQL specifications.

Examples:

```
SELECT 'abc';
SELECT _latin1'abc';
SELECT _binary'abc';
SELECT _utf8'abc' COLLATE utf8_danish_ci;

SELECT _latin1 X'4D7953514C';
SELECT _utf8 0x4D7953514C COLLATE utf8_danish_ci;

SELECT _latin1 b'1000001';
SELECT _utf8 0b1000001 COLLATE utf8_danish_ci;
```

The *`_charset_name`* expression is formally called an *introducer*. It tells the parser, “the string that follows uses character set *`charset_name`*.” An introducer does not change the string to the introducer character set like `CONVERT()` would do. It does not change the string value, although padding may occur. The introducer is just a signal.

For character string literals, space between the introducer and the string is permitted but optional.

Character string literals can be designated as binary strings by using the `_binary` introducer. Hexadecimal literals and bit-value literals are binary strings by default, so `_binary` is permitted, but unnecessary.

MySQL determines the character set and collation of a character string literal, hexadecimal literal, or bit-value literal in the following manner:

- If both *`_charset_name`* and `COLLATE` *`collation_name`* are specified, character set *`charset_name`* and collation *`collation_name`* are used. *`collation_name`* must be a permitted collation for *`charset_name`*.
- If *`_charset_name`* is specified but `COLLATE` is not specified, character set *`charset_name`* and its default collation are used. To see the default collation for each character set, use the `SHOW CHARACTER SET` statement.
- If *`_charset_name`* is not specified but `COLLATE` *`collation_name`* is specified:
  - For a character string literal, the connection default character set given by the `character_set_connection` system variable and collation *`collation_name`* are used. *`collation_name`* must be a permitted collation for the connection default character set.
  - For a hexadecimal literal or bit-value literal, the only permitted collation is `binary` because these types of literals are binary strings by default.
- Otherwise (neither *`_charset_name`* nor `COLLATE` *`collation_name`* is specified):
  - For a character string literal, the connection default character set and collation given by the `character_set_connection` and `collation_connection` system variables are used.
  - For a hexadecimal literal or bit-value literal, the character set and collation are `binary`.

Examples:

- Nonbinary strings with `latin1` character set and `latin1_german1_ci` collation:

```
SELECT _latin1'Müller' COLLATE latin1_german1_ci;
SELECT _latin1 X'0A0D' COLLATE latin1_german1_ci;
SELECT _latin1 b'0110' COLLATE latin1_german1_ci;
```

- Nonbinary strings with `utf8` character set and its default collation (that is, `utf8_general_ci`):

```
SELECT _utf8'Müller';
SELECT _utf8 X'0A0D';
SELECT _utf8 b'0110';
```

- Binary strings with `binary` character set and its default collation (that is, `binary`):

```
SELECT _binary'Müller';
SELECT X'0A0D';
SELECT b'0110';
```

  The hexadecimal literal and bit-value literal need no introducer because they are binary strings by default.

- A nonbinary string with the connection default character set and `utf8_general_ci` collation (fails if the connection character set is not `utf8`):

```
SELECT 'Müller' COLLATE utf8_general_ci;
```

  This construction (`COLLATE` only) does not work for hexadecimal literals or bit literals because their character set is `binary` no matter the connection character set, and `binary` is not compatible with the `utf8_general_ci` collation. The only permitted `COLLATE` clause in the absence of an introducer is `COLLATE binary`.

- A string with the connection default character set and collation:

```
SELECT 'Müller';
```

For character set literals, an introducer indicates the character set for the following string, but does not change how the parser performs escape processing within the string. Escapes are always interpreted by the parser according to the character set given by `character_set_connection`. For additional discussion and examples, see Section 10.1.3.6, “Character String Literal Character Set and Collation”.

10.1.3.9 Examples of Character Set and Collation Assignment

The following examples show how MySQL determines default character set and collation values.

Example 1: Table and Column Definition

```
CREATE TABLE t1
(
    c1 CHAR(10) CHARACTER SET latin1 COLLATE latin1_german1_ci
) DEFAULT CHARACTER SET latin2 COLLATE latin2_bin;
```

Here we have a column with a `latin1` character set and a `latin1_german1_ci` collation. The definition is explicit, so that is straightforward. Notice that there is no problem with storing a `latin1` column in a `latin2` table.

Example 2: Table and Column Definition

```
CREATE TABLE t1
(
    c1 CHAR(10) CHARACTER SET latin1
) DEFAULT CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

This time we have a column with a `latin1` character set and a default collation. Although it might seem natural, the default collation is not taken from the table level. Instead, because the default collation for `latin1` is always `latin1_swedish_ci`, column `c1` has a collation of `latin1_swedish_ci` (not `latin1_danish_ci`).

Example 3: Table and Column Definition

```
CREATE TABLE t1
(
    c1 CHAR(10)
) DEFAULT CHARACTER SET latin1 COLLATE latin1_danish_ci;
```

We have a column with a default character set and a default collation. In this circumstance, MySQL checks the table level to determine the column character set and collation. Consequently, the character set for column `c1` is `latin1` and its collation is `latin1_danish_ci`.

Example 4: Database, Table, and Column Definition

```
CREATE DATABASE d1
    DEFAULT CHARACTER SET latin2 COLLATE latin2_czech_ci;
USE d1;
CREATE TABLE t1
(
    c1 CHAR(10)
);
```

We create a column without specifying its character set and collation. We're also not specifying a character set and a collation at the table level. In this circumstance, MySQL checks the database level to determine the table settings, which thereafter become the column settings.) Consequently, the character set for column `c1` is `latin2` and its collation is `latin2_czech_ci`.

10.1.3.10 Compatibility with Other DBMSs

For MaxDB compatibility these two statements are the same:

```
```

```
CREATE TABLE t1 (f1 CHAR(N) UNICODE);
CREATE TABLE t1 (f1 CHAR(N) CHARACTER SET ucs2);
```

10.1.4 Connection Character Sets and Collations

Several character set and collation system variables relate to a client's interaction with the server. Some of these have been mentioned in earlier sections:

- The server character set and collation are the values of the `character_set_server` and `collation_server` system variables.
- The character set and collation of the default database are the values of the `character_set_database` and `collation_database` system variables.

Additional character set and collation system variables are involved in handling traffic for the connection between a client and the server. Every client has connection-related character set and collation system variables.

A “connection” is what you make when you connect to the server. The client sends SQL statements, such as queries, over the connection to the server. The server sends responses, such as result sets or error messages, over the connection back to the client. This leads to several questions about character set and collation handling for client connections, each of which can be answered in terms of system variables:

- What character set is the statement in when it leaves the client?

  The server takes the `character_set_client` system variable to be the character set in which statements are sent by the client.

- What character set should the server translate a statement to after receiving it?

  For this, the server uses the `character_set_connection` and `collation_connection` system variables. It converts statements sent by the client from `character_set_client` to `character_set_connection`, xexcept for string literals that have an introducer (for example, `_utf8mb4` or `_latin2`). `collation_connection` is important for comparisons of literal strings. For comparisons of strings with column values, `collation_connection` does not matter because columns have their own collation, which has a higher collation precedence.

- What character set should the server translate to before shipping result sets or error messages back to the client?

  The `character_set_results` system variable indicates the character set in which the server returns query results to the client. This includes result data such as column values, and result metadata such as column names and error messages.

Clients can fine-tune the settings for these variables, or depend on the defaults (in which case, you can skip the rest of this section). If you do not use the defaults, you must change the character settings *for each connection to the server.*

Two statements affect the connection-related character set variables as a group:

- `SET NAMES 'charset_name' [COLLATE 'collation_name']`

  `SET NAMES` indicates what character set the client will use to send SQL statements to the server. Thus, `SET NAMES 'cp1251'` tells the server, “future incoming messages from this client are in character set `cp1251`.” It also specifies the character set that the server should use for sending results back to the client. (For example, it indicates what character set to use for column values if you use a `SELECT` statement.)

  A `SET NAMES 'charset_name'` statement is equivalent to these three statements:

```
SET character_set_client = charset_name;
SET character_set_results = charset_name;
SET character_set_connection = charset_name;
```

Setting `character_set_connection` to *`charset_name`* also implicitly sets `collation_connection` to the default collation for *`charset_name`*. It is unnecessary to set that collation explicitly. To specify a particular collation, use the optional `COLLATE` clause:

```
SET NAMES 'charset_name' COLLATE 'collation_name'
```

- `SET CHARACTER SET '`*`charset_name`*`'`

  `SET CHARACTER SET` is similar to `SET NAMES` but sets `character_set_connection` and `collation_connection` to `character_set_database` and `collation_database`. A `SET CHARACTER SET` *`charset_name`* statement is equivalent to these three statements:

  ```
  SET character_set_client = charset_name;
  SET character_set_results = charset_name;
  SET collation_connection = @@collation_database;
  ```

  Setting `collation_connection` also implicitly sets `character_set_connection` to the character set associated with the collation (equivalent to executing `SET character_set_connection = @@character_set_database`). It is unnecessary to set `character_set_connection` explicitly.

Note

`ucs2`, `utf16`, and `utf32` cannot be used as a client character set, which means that they do not work for `SET NAMES` or `SET CHARACTER SET`.

The MySQL client programs `mysql`, `mysqladmin`, `mysqlcheck`, `mysqlimport`, and `mysqlshow` determine the default character set to use as follows:

- In the absence of other information, the programs use the compiled-in default character set, usually `latin1`.
- The programs can autodetect which character set to use based on the operating system setting, such as the value of the `LANG` or `LC_ALL` locale environment variable on Unix systems or the code page setting on Windows systems. For systems on which the locale is available from the OS, the client uses it to set the default character set rather than using the compiled-in default. For example, setting `LANG` to `ru_RU.KOI8-R` causes the `koi8r` character set to be used. Thus, users can configure the locale in their environment for use by MySQL clients.

  The OS character set is mapped to the closest MySQL character set if there is no exact match. If the client does not support the matching character set, it uses the compiled-in default. For example, `ucs2` is not supported as a connection character set.

  C applications can use character set autodetection based on the OS setting by invoking `mysql_options()` as follows before connecting to the server:

  ```
  mysql_options(mysql,
                MYSQL_SET_CHARSET_NAME,
                MYSQL_AUTODETECT_CHARSET_NAME);
  ```

- The programs support a `--default-character-set` option, which enables users to specify the character set explicitly to override whatever default the client otherwise determines.

Note

Before MySQL 5.5, in the absence of other information, the MySQL client programs used the compiled-in default character set, usually `latin1`. An

> implication of this difference is that if your environment is configured to use a non-`latin1` locale, MySQL client programs will use a different connection character set than previously, as though you had issued an implicit `SET NAMES` statement. If the previous behavior is required, start the client with the `--default-character-set=latin1` option.

When a client connects to the server, it sends the name of the character set to be used for communication with the server. The server uses the name to set the `character_set_client`, `character_set_results`, and `character_set_connection` system variables. In effect, the server performs a `SET NAMES` operation using the character set name.

With the `mysql` client, to use a character set different from the default, you could explicitly execute `SET NAMES` every time you start up. To accomplish the same result more easily, add the `--default-character-set` option setting to your `mysql` command line or in your option file. For example, the following option file setting changes the three connection-related character set variables set to `koi8r` each time you invoke `mysql`:

```
[mysql]
default-character-set=koi8r
```

If you are using the `mysql` client with auto-reconnect enabled (which is not recommended), it is preferable to use the `charset` command rather than `SET NAMES`. For example:

```
mysql> charset utf8
Charset changed
```

The `charset` command issues a `SET NAMES` statement, and also changes the default character set that `mysql` uses when it reconnects after the connection has dropped.

Example: Suppose that `column1` is defined as `CHAR(5) CHARACTER SET latin2`. If you do not say `SET NAMES` or `SET CHARACTER SET`, then for `SELECT column1 FROM t`, the server sends back all the values for `column1` using the character set that the client specified when it connected. On the other hand, if you say `SET NAMES 'latin1'` or `SET CHARACTER SET latin1` before issuing the `SELECT` statement, the server converts the `latin2` values to `latin1` just before sending results back. Conversion may be lossy if there are characters that are not in both character sets.

If you want the server to perform no conversion of result sets or error messages, set `character_set_results` to `NULL` or `binary`:

```
SET character_set_results = NULL;
SET character_set_results = binary;
```

To see the values of the character set and collation system variables that apply to your connection, use these statements:

```
SHOW VARIABLES LIKE 'character_set%';
SHOW VARIABLES LIKE 'collation%';
```

You must also consider the environment within which your MySQL applications execute. See Section 10.1.5, “Configuring Application Character Set and Collation”.

For more information about character sets and error messages, see Section 10.1.6, “Error Message Character Set”.

10.1.5 Configuring Application Character Set and Collation

For applications that store data using the default MySQL character set and collation (`latin1`, `latin1_swedish_ci`), no special configuration should be needed. If applications require data storage using a different character set or collation, you can configure character set information several ways:

- Specify character settings per database. For example, applications that use one database might require `utf8`, whereas applications that use another database might require `sjis`.
- Specify character settings at server startup. This causes the server to use the given settings for all applications that do not make other arrangements.
- Specify character settings at configuration time, if you build MySQL from source. This causes the server to use the given settings for all applications, without having to specify them at server startup.

When different applications require different character settings, the per-database technique provides a good deal of flexibility. If most or all applications use the same character set, specifying character settings at server startup or configuration time may be most convenient.

For the per-database or server-startup techniques, the settings control the character set for data storage. Applications must also tell the server which character set to use for client/server communications, as described in the following instructions.

The examples shown here assume use of the `utf8` character set and `utf8_general_ci` collation.

Specify character settings per database. To create a database such that its tables will use a given default character set and collation for data storage, use a `CREATE DATABASE` statement like this:

```
CREATE DATABASE mydb
  DEFAULT CHARACTER SET utf8
  DEFAULT COLLATE utf8_general_ci;
```

Tables created in the database will use `utf8` and `utf8_general_ci` by default for any character columns.

Applications that use the database should also configure their connection to the server each time they connect. This can be done by executing a `SET NAMES 'utf8'` statement after connecting. The statement can be used regardless of connection method: The `mysql` client, PHP scripts, and so forth.

In some cases, it may be possible to configure the connection to use the desired character set some other way. For example, for connections made using `mysql`, you can specify the `--default-character-set=utf8` command-line option to achieve the same effect as `SET NAMES 'utf8'`.

For more information about configuring client connections, see Section 10.1.4, “Connection Character Sets and Collations”.

If you change the default character set or collation for a database, stored routines that use the database defaults must be dropped and recreated so that they use the new defaults. (In a stored routine, variables with character data types use the database defaults if the character set or collation are not specified explicitly. See Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”.)

Specify character settings at server startup. To select a character set and collation at server startup, use the `--character-set-server` and `--collation-server` options. For example, to specify the options in an option file, include these lines:

```
[mysqld]
character-set-server=utf8
collation-server=utf8_general_ci
```

These settings apply server-wide and apply as the defaults for databases created by any application, and for tables created in those databases.

It is still necessary for applications to configure their connection using `SET NAMES` or equivalent after they connect, as described previously. You might be tempted to start the server with the `--init_connect="SET NAMES 'utf8'"` option to cause `SET NAMES` to be executed automatically for each client that connects. However, this will yield inconsistent results because the `init_connect` value is not executed for users who have the `SUPER` privilege.

Specify character settings at MySQL configuration time. To select a character set and collation when you configure and build MySQL from source, use the `DEFAULT_CHARSET` and `DEFAULT_COLLATION` options for `CMake`:

```
shell> cmake . -DDEFAULT_CHARSET=utf8 \
          -DDEFAULT_COLLATION=utf8_general_ci
```

The resulting server uses `utf8` and `utf8_general_ci` as the default for databases and tables and for client connections. It is unnecessary to use `--character-set-server` and `--collation-server` to specify those defaults at server startup. It is also unnecessary for applications to configure their connection using `SET NAMES` or equivalent after they connect to the server.

Regardless of how you configure the MySQL character set for application use, you must also consider the environment within which those applications execute. If you will send statements using UTF-8 text taken from a file that you create in an editor, you should edit the file with the locale of your environment set to UTF-8 so that the file encoding is correct and so that the operating system handles it correctly. If you use the `mysql` client from within a terminal window, the window must be configured to use UTF-8 or characters may not display properly. For a script that executes in a Web environment, the script must handle character encoding properly for its interaction with the MySQL server, and it must generate pages that correctly indicate the encoding so that browsers know how to display the content of the pages. For example, you can include this `<meta>` tag within your `<head>` element:

```
<meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
```

10.1.6 Error Message Character Set

This section describes how the MySQL server uses character sets for constructing error messages and returning them to clients. For information about the language of error messages (rather than the character set), see Section 10.2, “Setting the Error Message Language”. For general information about configuring error logging, see Section 5.4.2, “The Error Log”.

As of MySQL 5.5, the server constructs error messages using UTF-8 and returns them to clients in the character set specified by the `character_set_results` system variable.

The server constructs error messages as follows:

- The message template uses UTF-8.
- Parameters in the message template are replaced with values that apply to a specific error occurrence:
  - Identifiers such as table or column names use UTF-8 internally so they are copied as is.
  - Character (nonbinary) string values are converted from their character set to UTF-8.
  - Binary string values are copied as is for bytes in the range `0x20` to `0x7E`, and using `\x` hexadecimal encoding for bytes outside that range. For example, if a duplicate-key error occurs for an attempt to insert `0x41CF9F` into a `VARBINARY` unique column, the resulting error message uses UTF-8 with some bytes hexadecimal encoded:

    ```
    Duplicate entry 'A\xC3\x9F' for key 1
    ```

To return a message to the client after it has been constructed, the server converts it from UTF-8 to the character set specified by the `character_set_results` system variable. If `character_set_results` has a value of `NULL` or `binary`, no conversion occurs. No conversion occurs if the variable value is `utf8`, either, because that matches the original error message character set.

For characters that cannot be represented in `character_set_results`, some encoding may occur during the conversion. The encoding uses Unicode code point values:

- Characters in the Basic Multilingual Plane (BMP) range (`0x0000` to `0xFFFF`) are written using `\nnnn` notation.
- Characters outside the BMP range (`0x01000` to `0x10FFFF`) are written using `\+nnnnnn` notation.

Clients can set `character_set_results` to control the character set in which they receive error messages. The variable can be set directly, or indirectly by means such as `SET NAMES`. For more information about `character_set_results`, see Section 10.1.4, “Connection Character Sets and Collations”.

Prior to MySQL 5.5, the server constructs error messages and returns them to clients as follows:

- The message template has the character set associated with the error message language. For example, English, Korean, and Russian messages use `latin1`, `euckr`, and `koi8r`, respectively.
- Parameters in the message template are replaced with values that apply to a specific error occurrence. These parameters use their own character set. Identifiers such as table or column names use UTF-8. Data values retain their character set. For example, in the following duplicate-key message, `'xxx'` has the character set of the table column associated with key 1:

```
Duplicate entry 'xxx' for key1
```

The preceding method of error-message construction can result in messages that contain a mix of character sets unless all items involved contain only ASCII characters.

For MySQL 5.5 and higher, the encoding that occurs during the conversion to `character_set_results` before returning error messages to clients can result in different message content compared to earlier versions. For example, if an error occurs for an attempt to drop a table named ペ (KATAKANA LETTER PE) and `character_set_results` is a character set such as `latin1` that does not contain that character, the resulting message sent to the client has an encoded table name:

```
ERROR 1051 (42S02): Unknown table '\30DA'
```

Before MySQL 5.5, the name is not encoded:

```
ERROR 1051 (42S02): Unknown table 'ペ'
```

10.1.7 Column Character Set Conversion

To convert a binary or nonbinary string column to use a particular character set, use `ALTER TABLE`. For successful conversion to occur, one of the following conditions must apply:

- If the column has a binary data type (`BINARY`, `VARBINARY`, `BLOB`), all the values that it contains must be encoded using a single character set (the character set you're converting the column to). If you use a binary column to store information in multiple character sets, MySQL has no way to know which values use which character set and cannot convert the data properly.
- If the column has a nonbinary data type (`CHAR`, `VARCHAR`, `TEXT`), its contents should be encoded in the column character set, not some other character set. If the contents are encoded in a different character set, you can convert the column to use a binary data type first, and then to a nonbinary column with the desired character set.

Suppose that a table `t` has a binary column named `col1` defined as `VARBINARY(50)`. Assuming that the information in the column is encoded using a single character set, you can convert it to a nonbinary column that has that character set. For example, if `col1` contains binary data representing characters in the `greek` character set, you can convert it as follows:

```
ALTER TABLE t MODIFY col1 VARCHAR(50) CHARACTER SET greek;
```

If your original column has a type of `BINARY(50)`, you could convert it to `CHAR(50)`, but the resulting values will be padded with `0x00` bytes at the end, which may be undesirable. To remove these bytes, use the `TRIM()` function:

```
UPDATE t SET col1 = TRIM(TRAILING 0x00 FROM col1);
```

Suppose that table `t` has a nonbinary column named `col1` defined as `CHAR(50) CHARACTER SET latin1` but you want to convert it to use `utf8` so that you can store values from many languages. The following statement accomplishes this:

```
ALTER TABLE t MODIFY col1 CHAR(50) CHARACTER SET utf8;
```

Conversion may be lossy if the column contains characters that are not in both character sets.

A special case occurs if you have old tables from before MySQL 4.1 where a nonbinary column contains values that actually are encoded in a character set different from the server's default character set. For example, an application might have stored `sjis` values in a column, even though MySQL's default character set was `latin1`. It is possible to convert the column to use the proper character set but an additional step is required. Suppose that the server's default character set was `latin1` and `col1` is defined as `CHAR(50)` but its contents are `sjis` values. The first step is to convert the column to a binary data type, which removes the existing character set information without performing any character conversion:

```
ALTER TABLE t MODIFY col1 BLOB;
```

The next step is to convert the column to a nonbinary data type with the proper character set:

```
ALTER TABLE t MODIFY col1 CHAR(50) CHARACTER SET sjis;
```

This procedure requires that the table not have been modified already with statements such as `INSERT` or `UPDATE` after an upgrade to MySQL 4.1 or later. In that case, MySQL would store new values in the column using `latin1`, and the column will contain a mix of `sjis` and `latin1` values and cannot be converted properly.

If you specified attributes when creating a column initially, you should also specify them when altering the table with `ALTER TABLE`. For example, if you specified `NOT NULL` and an explicit `DEFAULT` value, you should also provide them in the `ALTER TABLE` statement. Otherwise, the resulting column definition will not include those attributes.

To convert all character columns in a table, the `ALTER TABLE ... CONVERT TO CHARACTER SET` *`charset`* statement may be useful. See Section 13.1.7, “ALTER TABLE Syntax”.

10.1.8 Collation Issues

The following sections discuss various aspects of character set collations.

10.1.8.1 Using COLLATE in SQL Statements

With the `COLLATE` clause, you can override whatever the default collation is for a comparison. `COLLATE` may be used in various parts of SQL statements. Here are some examples:

- With `ORDER BY`:

```
SELECT k
FROM t1
ORDER BY k COLLATE latin1_german2_ci;
```

- With `AS`:

```
SELECT k COLLATE latin1_german2_ci AS k1
FROM t1
ORDER BY k1;
```

- With `GROUP BY`:

```
SELECT k
FROM t1
GROUP BY k COLLATE latin1_german2_ci;
```

- With aggregate functions:

```
SELECT MAX(k COLLATE latin1_german2_ci)
FROM t1;
```

- With `DISTINCT`:

```
SELECT DISTINCT k COLLATE latin1_german2_ci
FROM t1;
```

- With `WHERE`:

```
    SELECT *
    FROM t1
    WHERE _latin1 'Müller' COLLATE latin1_german2_ci = k;
```

```
    SELECT *
    FROM t1
    WHERE k LIKE _latin1 'Müller' COLLATE latin1_german2_ci;
```

- With `HAVING`:

```
SELECT k
FROM t1
GROUP BY k
HAVING k = _latin1 'Müller' COLLATE latin1_german2_ci;
```

10.1.8.2 COLLATE Clause Precedence

The `COLLATE` clause has high precedence (higher than `||`), so the following two expressions are equivalent:

```
x || y COLLATE z
x || (y COLLATE z)
```

10.1.8.3 Character Set and Collation Compatibility

Each character set has one or more collations, but each collation is associated with one and only one character set. Therefore, the following statement causes an error message because the `latin2_bin` collation is not legal with the `latin1` character set:

```
mysql> SELECT _latin1 'x' COLLATE latin2_bin;
ERROR 1253 (42000): COLLATION 'latin2_bin' is not valid
for CHARACTER SET 'latin1'
```

10.1.8.4 Collation Coercibility in Expressions

In the great majority of statements, it is obvious what collation MySQL uses to resolve a comparison operation. For example, in the following cases, it should be clear that the collation is the collation of column `x`:

```
SELECT x FROM T ORDER BY x;
SELECT x FROM T WHERE x = x;
SELECT DISTINCT x FROM T;
```

However, with multiple operands, there can be ambiguity. For example:

```
SELECT x FROM T WHERE x = 'Y';
```

Should the comparison use the collation of the column `x`, or of the string literal `'Y'`? Both `x` and `'Y'` have collations, so which collation takes precedence?

A mix of collations may also occur in contexts other than comparison. For example, a multiple-argument concatenation operation such as `CONCAT(x,'Y')` combines its arguments to produce a single string. What collation should the result have?

To resolve questions like these, MySQL checks whether the collation of one item can be coerced to the collation of the other. MySQL assigns coercibility values as follows:

- An explicit `COLLATE` clause has a coercibility of 0 (not coercible at all).
- The concatenation of two strings with different collations has a coercibility of 1.
- The collation of a column or a stored routine parameter or local variable has a coercibility of 2.
- A “system constant” (the string returned by functions such as `USER()` or `VERSION()`) has a coercibility of 3.
- The collation of a literal has a coercibility of 4.
- The collation of a numeric or temporal value has a coercibility of 5.
- `NULL` or an expression that is derived from `NULL` has a coercibility of 6.

MySQL uses coercibility values with the following rules to resolve ambiguities:

- Use the collation with the lowest coercibility value.
- If both sides have the same coercibility, then:
  - If both sides are Unicode, or both sides are not Unicode, it is an error.
  - If one of the sides has a Unicode character set, and another side has a non-Unicode character set, the side with Unicode character set wins, and automatic character set conversion is applied to the non-Unicode side. For example, the following statement does not return an error:

    ```
    SELECT CONCAT(utf8_column, latin1_column) FROM t1;
    ```

    It returns a result that has a character set of `utf8` and the same collation as `utf8_column`. Values of `latin1_column` are automatically converted to `utf8` before concatenating.
  - For an operation with operands from the same character set but that mix a `_bin` collation and a `_ci` or `_cs` collation, the `_bin` collation is used. This is similar to how operations that mix nonbinary and binary strings evaluate the operands as binary strings, except that it is for collations rather than data types.

Although automatic conversion is not in the SQL standard, the standard does say that every character set is (in terms of supported characters) a “subset” of Unicode. Because it is a well-known principle that “what applies to a superset can apply to a subset,” we believe that a collation for Unicode can apply for comparisons with non-Unicode strings.

The following table illustrates some applications of the preceding rules.

Comparison	Collation Used
`column1 = 'A'`	Use collation of `column1`
`column1 = 'A' COLLATE x`	Use collation of `'A' COLLATE x`
`column1 COLLATE x = 'A' COLLATE y`	Error

To determine the coercibility of a string expression, use the `COERCIBILITY()` function (see Section 12.14, “Information Functions”):

```
mysql> SELECT COERCIBILITY('A' COLLATE latin1_swedish_ci);
        -> 0
mysql> SELECT COERCIBILITY(VERSION());
        -> 3
mysql> SELECT COERCIBILITY('A');
        -> 4
mysql> SELECT COERCIBILITY(1000);
        -> 5
```

For implicit conversion of a numeric or temporal value to a string, such as occurs for the argument `1` in the expression `CONCAT(1, 'abc')`, the result is a character (nonbinary) string that has a character set and collation determined by the `character_set_connection` and `collation_connection` system variables. (Before MySQL 5.5.3, the result is a binary string for which the character set and collation are `binary`). See Section 12.2, “Type Conversion in Expression Evaluation”.

10.1.8.5 The binary Collation Compared to _bin Collations

This section describes how the `binary` collation for binary strings compares to the `_bin` collations for nonbinary strings.

Binary strings (as stored using the `BINARY`, `VARBINARY`, and `BLOB` data types) have a character set and collation named `binary`. Binary strings are sequences of bytes and the numeric values of those bytes determine comparison and sort order.

Nonbinary strings (as stored using the `CHAR`, `VARCHAR`, and `TEXT` data types) have a character set and collation other than `binary`. A given nonbinary character set can have several collations, each of which defines a particular comparison and sort order for the characters in the set. One of these is the binary collation for the character set, indicated by a `_bin` suffix in the collation name. For example, the binary collations for `latin1` and `utf8` are named `latin1_bin` and `utf8_bin`, respectively.

The `binary` collation differs from the `_bin` collations in several respects.

The unit for comparison and sorting. Binary strings are sequences of bytes. For the `binary` collation, comparison and sorting are based on numeric byte values. Nonbinary strings are sequences of characters, which might be multibyte. Collations for nonbinary strings define an ordering of the character values for comparison and sorting. For the `_bin` collation, this ordering is based on numeric character code values, which is similar to ordering for binary strings except that character code values might be multibyte.

Character set conversion. A nonbinary string has a character set and is automatically converted to another character set in many cases, even when the string has a `_bin` collation:

- When assigning column values from another column that has a different character set:

```
UPDATE t1 SET utf8_bin_column=latin1_column;
INSERT INTO t1 (latin1_column) SELECT utf8_bin_column FROM t2;
```

- When assigning column values for `INSERT` or `UPDATE` using a string literal:

```
SET NAMES latin1;
INSERT INTO t1 (utf8_bin_column) VALUES ('string-in-latin1');
```

- When sending results from the server to a client:

```
SET NAMES latin1;
SELECT utf8_bin_column FROM t2;
```

For binary string columns, no conversion occurs. For the preceding cases, the string value is copied byte-wise.

Lettercase conversion. Collations for nonbinary character sets provide information about lettercase of characters, so characters in a nonbinary string can be converted from one lettercase to another, even for `_bin` collations that ignore lettercase for ordering:

```
mysql> SET NAMES latin1 COLLATE latin1_bin;
mysql> SELECT LOWER('aA'), UPPER('zZ');
+-------------+-------------+
| LOWER('aA') | UPPER('zZ') |
+-------------+-------------+
| aa          | ZZ          |
+-------------+-------------+
```

The concept of lettercase does not apply to bytes in a binary string. To perform lettercase conversion, the string must be converted to a nonbinary string:

```
mysql> SET NAMES binary;
mysql> SELECT LOWER('aA'), LOWER(CONVERT('aA' USING latin1));
+-------------+-----------------------------------+
| LOWER('aA') | LOWER(CONVERT('aA' USING latin1)) |
+-------------+-----------------------------------+
| aA          | aa                                |
+-------------+-----------------------------------+
```

Trailing space handling in comparisons.
Nonbinary strings have PAD SPACE behavior for all collations, including `_bin` collations. Trailing spaces are insignificant in comparisons:

```
mysql> SET NAMES utf8 COLLATE utf8_bin;
mysql> SELECT 'a ' = 'a';
+------------+
| 'a ' = 'a' |
+------------+
|          1 |
+------------+
```

For binary strings, all characters are significant in comparisons, including trailing spaces:

```
mysql> SET NAMES binary;
mysql> SELECT 'a ' = 'a';
+------------+
| 'a ' = 'a' |
+------------+
|          0 |
+------------+
```

Trailing space handling for inserts and retrievals. `CHAR(N)` columns store nonbinary strings. Values shorter than *N* characters are extended with spaces on insertion. For retrieval, trailing spaces are removed.

`BINARY(N)` columns store binary strings. Values shorter than *N* bytes are extended with `0x00` bytes on insertion. For retrieval, nothing is removed; a value of the declared length is always returned.

```
mysql> CREATE TABLE t1 (
         a CHAR(10) CHARACTER SET utf8 COLLATE utf8_bin,
         b BINARY(10)
```

```
      );
mysql> INSERT INTO t1 VALUES ('a','a');
mysql> SELECT HEX(a), HEX(b) FROM t1;
+--------+----------------------+
| HEX(a) | HEX(b)               |
+--------+----------------------+
| 61     | 6100000000000000000 |
+--------+----------------------+
```

10.1.8.6 Examples of the Effect of Collation

Example 1: Sorting German Umlauts

Suppose that column `X` in table `T` has these `latin1` column values:

```
Muffler
Müller
MX Systems
MySQL
```

Suppose also that the column values are retrieved using the following statement:

```
SELECT X FROM T ORDER BY X COLLATE collation_name;
```

The following table shows the resulting order of the values if we use `ORDER BY` with different collations.

latin1_swedish_ci	latin1_german1_ci	latin1_german2_ci
Muffler	Muffler	Müller
MX Systems	Müller	Muffler
Müller	MX Systems	MX Systems
MySQL	MySQL	MySQL

The character that causes the different sort orders in this example is the U with two dots over it (ü), which the Germans call “U-umlaut.”

- The first column shows the result of the `SELECT` using the Swedish/Finnish collating rule, which says that U-umlaut sorts with Y.
- The second column shows the result of the `SELECT` using the German DIN-1 rule, which says that U-umlaut sorts with U.
- The third column shows the result of the `SELECT` using the German DIN-2 rule, which says that U-umlaut sorts with UE.

Example 2: Searching for German Umlauts

Suppose that you have three tables that differ only by the character set and collation used:

```
mysql> SET NAMES utf8;
mysql> CREATE TABLE german1 (
         c CHAR(10)
       ) CHARACTER SET latin1 COLLATE latin1_german1_ci;
mysql> CREATE TABLE german2 (
         c CHAR(10)
       ) CHARACTER SET latin1 COLLATE latin1_german2_ci;
mysql> CREATE TABLE germanutf8 (
         c CHAR(10)
       ) CHARACTER SET utf8 COLLATE utf8_unicode_ci;
```

Each table contains two records:

```
mysql> INSERT INTO german1 VALUES ('Bar'), ('Bär');
mysql> INSERT INTO german2 VALUES ('Bar'), ('Bär');
mysql> INSERT INTO germanutf8 VALUES ('Bar'), ('Bär');
```

Two of the above collations have an `A = Ä` equality, and one has no such equality (`latin1_german2_ci`). For that reason, you'll get these results in comparisons:

```
mysql> SELECT * FROM german1 WHERE c = 'Bär';
+------+
| c    |
+------+
| Bar  |
| Bär  |
+------+
mysql> SELECT * FROM german2 WHERE c = 'Bär';
+------+
| c    |
+------+
| Bär  |
+------+
mysql> SELECT * FROM germanutf8 WHERE c = 'Bär';
+------+
| c    |
+------+
| Bar  |
| Bär  |
+------+
```

This is not a bug but rather a consequence of the sorting properties of `latin1_german1_ci` and `utf8_unicode_ci` (the sorting shown is done according to the German DIN 5007 standard).

10.1.8.7 Using Collation in INFORMATION_SCHEMA Searches

String columns in `INFORMATION_SCHEMA` tables have a collation of `utf8_general_ci`, which is case insensitive. However, for values that correspond to objects that are represented in the file system, such as databases and tables, searches in `INFORMATION_SCHEMA` string columns can be case sensitive or insensitive, depending on the characteristics of the underlying file system and the value of the `lower_case_table_names` system variable. For example, searches may be case sensitive if the file system is case sensitive. This section describes this behavior and how to modify it if necessary; see also Bug #34921.

Suppose that a query searches the `SCHEMATA.SCHEMA_NAME` column for the `test` database. On Linux, file systems are case sensitive, so comparisons of `SCHEMATA.SCHEMA_NAME` with `'test'` match, but comparisons with `'TEST'` do not:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
       WHERE SCHEMA_NAME = 'test';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+

mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
       WHERE SCHEMA_NAME = 'TEST';
Empty set (0.00 sec)
```

These results occur with the `lower_case_table_names` system system variable set to 0. Changing the value of `lower_case_table_names` to 1 or 2 causes the second query to return the same (nonempty) result as the first query.

On Windows or OS X, file systems are not case sensitive, so comparisons match both `'test'` and `'TEST'`:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
       WHERE SCHEMA_NAME = 'test';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+

mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
       WHERE SCHEMA_NAME = 'TEST';
+-------------+
| SCHEMA_NAME |
+-------------+
| TEST        |
+-------------+
```

The value of `lower_case_table_names` makes no difference in this context.

The preceding behavior occurs because the `utf8_general_ci` collation is not used for `INFORMATION_SCHEMA` queries when searching for values that correspond to objects represented in the file system. It is a result of file system-scanning optimizations implemented for `INFORMATION_SCHEMA` searches. For information about these optimizations, see Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”.

If the result of a string operation on an `INFORMATION_SCHEMA` column differs from expectations, a workaround is to use an explicit `COLLATE` clause to force a suitable collation (see Section 10.1.8.1, “Using COLLATE in SQL Statements”). For example, to perform a case-insensitive search, use `COLLATE` with the `INFORMATION_SCHEMA` column name:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
       WHERE SCHEMA_NAME COLLATE utf8_general_ci = 'test';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+

mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
       WHERE SCHEMA_NAME COLLATE utf8_general_ci = 'TEST';
+-------------+
| SCHEMA_NAME |
+-------------+
| test        |
+-------------+
```

In the preceding queries, it is important to apply the `COLLATE` clause to the `INFORMATION_SCHEMA` column name. Applying `COLLATE` to the comparison value has no effect.

You can also use the `UPPER()` or `LOWER()` function:

```
WHERE UPPER(SCHEMA_NAME) = 'TEST'
WHERE LOWER(SCHEMA_NAME) = 'test'
```

Although a case-insensitive comparison can be performed even on platforms with case-sensitive file systems, as just shown, it is not necessarily always the right thing to do. On such platforms, it is possible to have multiple objects with names that differ only in lettercase. For example, tables named `city`, `CITY`, and `City` can all exist simultaneously. Consider whether a search should match all such names or just one and write queries accordingly. The first of the following comparisons (with `utf8_bin`) is case sensitive; the others are not:

```
WHERE TABLE_NAME COLLATE utf8_bin = 'City'
WHERE TABLE_NAME COLLATE utf8_general_ci = 'city'
WHERE UPPER(TABLE_NAME) = 'CITY'
WHERE LOWER(TABLE_NAME) = 'city'
```

Searches in `INFORMATION_SCHEMA` string columns for values that refer to `INFORMATION_SCHEMA` itself do use the `utf8_general_ci` collation because `INFORMATION_SCHEMA` is a “virtual” database not represented in the file system. For example, comparisons with `SCHEMATA.SCHEMA_NAME` match `'information_schema'` or `'INFORMATION_SCHEMA'` regardless of platform:

```
mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
       WHERE SCHEMA_NAME = 'information_schema';
+--------------------+
| SCHEMA_NAME        |
+--------------------+
| information_schema |
+--------------------+

mysql> SELECT SCHEMA_NAME FROM INFORMATION_SCHEMA.SCHEMATA
       WHERE SCHEMA_NAME = 'INFORMATION_SCHEMA';
+--------------------+
| SCHEMA_NAME        |
+--------------------+
| information_schema |
+--------------------+
```

10.1.9 Unicode Support

The Unicode Standard includes characters from the Basic Multilingual Plane (BMP) and supplementary characters that lie outside the BMP. This section describes support for Unicode in MySQL. For information about the Unicode Standard itself, visit the Unicode Consortium Web site.

BMP characters have these characteristics:

- Their code point values are between 0 and 65535 (or `U+0000` and `U+FFFF`).
- They can be encoded in a variable-length encoding using 8, 16, or 24 bits (1 to 3 bytes).
- They can be encoded in a fixed-length encoding using 16 bits (2 bytes).
- They are sufficient for almost all characters in major languages.

Supplementary characters lie outside the BMP. Their code point values are between `U+10000` and `U+10FFFF`). Unicode support for supplementary characters requires character sets that have a range outside BMP characters and therefore take more space than BMP characters.

MySQL supports these Unicode character sets:

- `utf8`, a UTF-8 encoding of the Unicode character set using one to three bytes per character.
- `ucs2`, the UCS-2 encoding of the Unicode character set using two bytes per character.
- `utf8mb4`, a UTF-8 encoding of the Unicode character set using one to four bytes per character.
- `utf16`, the UTF-16 encoding for the Unicode character set using two or four bytes per character. Like `ucs2` but with an extension for supplementary characters.
- `utf32`, the UTF-32 encoding for the Unicode character set using four bytes per character.

MySQL 5.5.3 and higher supports all Unicode character sets in the preceding list. Prior to 5.5.3, MySQL supports only `utf8` and `ucs2`.

Table 10.2, “Unicode Character Set General Characteristics”, summarizes the general characteristics of Unicode character sets supported by MySQL.

Table 10.2 Unicode Character Set General Characteristics

Character Set	Supported Characters	Required Storage Per Character
`utf8`	BMP only	1, 2, or 3 bytes

Character Set	Supported Characters	Required Storage Per Character
ucs2	BMP only	2 bytes
utf8mb4	BMP and supplementary	1, 2, 3, or 4 bytes
utf16	BMP and supplementary	2 or 4 bytes
utf32	BMP and supplementary	4 bytes

Characters outside the BMP compare as REPLACEMENT CHARACTER and convert to '?' when converted to a Unicode character set that supports only BMP characters (utf8 or ucs2).

If you use character sets that support supplementary characters and thus are "wider" than the BMP-only utf8 and ucs2 character sets, there are potential incompatibility issues for your applications; see Section 10.1.9.7, "Converting Between 3-Byte and 4-Byte Unicode Character Sets". That section also describes how to convert tables from utf8 to the (4-byte) utf8mb4 character set, and what constraints may apply in doing so.

A similar set of collations is available for each Unicode character set. For example, each has a Danish collation, the names of which are ucs2_danish_ci, utf16_danish_ci, utf32_danish_ci, utf8_danish_ci, and utf8mb4_danish_ci. For information about Unicode collations and their differentiating properties, including collation properties for supplementary characters, see Section 10.1.10.1, "Unicode Character Sets".

Although many of the supplementary characters come from East Asian languages, what MySQL 5.5 adds is support for more Japanese and Chinese characters in Unicode character sets, not support for new Japanese and Chinese character sets.

The MySQL implementation of UCS-2, UTF-16, and UTF-32 stores characters in big-endian byte order and does not use a byte order mark (BOM) at the beginning of values. Other database systems might use little-endian byte order or a BOM. In such cases, conversion of values will need to be performed when transferring data between those systems and MySQL.

MySQL uses no BOM for UTF-8 values.

Client applications that communicate with the server using Unicode should set the client character set accordingly; for example, by issuing a SET NAMES 'utf8' statement. ucs2, utf16, and utf32 cannot be used as a client character set, which means that they do not work for SET NAMES or SET CHARACTER SET. (See Section 10.1.4, "Connection Character Sets and Collations".)

The following sections provide additional detail on the Unicode character sets in MySQL.

10.1.9.1 The utf8 Character Set (3-Byte UTF-8 Unicode Encoding)

UTF-8 (Unicode Transformation Format with 8-bit units) is an alternative way to store Unicode data. It is implemented according to RFC 3629, which describes encoding sequences that take from one to four bytes. (An older standard for UTF-8 encoding, RFC 2279, describes UTF-8 sequences that take from one to six bytes. RFC 3629 renders RFC 2279 obsolete; for this reason, sequences with five and six bytes are no longer used.)

The idea of UTF-8 is that various Unicode characters are encoded using byte sequences of different lengths:

- Basic Latin letters, digits, and punctuation signs use one byte.
- Most European and Middle East script letters fit into a 2-byte sequence: extended Latin letters (with tilde, macron, acute, grave and other accents), Cyrillic, Greek, Armenian, Hebrew, Arabic, Syriac, and others.
- Korean, Chinese, and Japanese ideographs use 3-byte or 4-byte sequences.

The utf8 character set in MySQL has these characteristics:

- No support for supplementary characters (BMP characters only).
- A maximum of three bytes per multibyte character.

Exactly the same set of characters is available in `utf8` and `ucs2`. That is, they have the same repertoire.

Tip

To save space with UTF-8, use `VARCHAR` instead of `CHAR`. Otherwise, MySQL must reserve three bytes for each character in a `CHAR CHARACTER SET utf8` column because that is the maximum possible character length. For example, MySQL must reserve 30 bytes for a `CHAR(10) CHARACTER SET utf8` column.

For additional information about data type storage, see Section 11.7, "Data Type Storage Requirements". For information about `InnoDB` physical row storage, including how `InnoDB` tables that use `COMPACT` row format handle UTF-8 `CHAR(N)` columns internally, see Section 14.11.1.2, "The Physical Row Structure of an InnoDB Table".

10.1.9.2 The utf8mb3 Character Set (Alias for utf8)

The `utf8` character set uses a maximum of three bytes per character. As of MySQL 5.5.3, to make this character limit explicit (much as the limit of four bytes per character is explicit in the `utf8mb4` character set name, use the character set name `utf8mb3`, which is an alias for `utf8`. `utf8mb3` can be used in `CHARACTER SET` clauses, and `utf8mb3_collation_substring` in `COLLATE` clauses, where `collation_substring` is `bin`, `czech_ci`, `danish_ci`, `esperanto_ci`, `estonian_ci`, and so forth. For example:

```
CREATE TABLE t (s1 CHAR(1) CHARACTER SET utf8mb3;
SELECT * FROM t WHERE s1 COLLATE utf8mb3_general_ci = 'x';
DECLARE x VARCHAR(5) CHARACTER SET utf8mb3 COLLATE utf8mb3_danish_ci;
SELECT CAST('a' AS CHAR CHARACTER SET utf8) COLLATE utf8_czech_ci;
```

MySQL immediately converts instances of `utf8mb3` in an alias to `utf8`, so in statements such as `SHOW CREATE TABLE` or `SELECT CHARACTER_SET_NAME FROM INFORMATION_SCHEMA.COLUMNS` or `SELECT COLLATION_NAME FROM INFORMATION_SCHEMA.COLUMNS`, users will see the true name, `utf8` or `utf8_collation_substring`.

The `utf8mb3` alias is also valid in certain places other than `CHARACTER SET` clauses. For example, these are legal:

```
mysqld --character-set-server=utf8mb3
SET NAMES 'utf8mb3'; /* and other SET statements that have similar effect */
SELECT _utf8mb3 'a';
```

10.1.9.3 The utf8mb4 Character Set (4-Byte UTF-8 Unicode Encoding)

The character set named `utf8` uses a maximum of three bytes per character and contains only BMP characters. As of MySQL 5.5.3, the `utf8mb4` character set uses a maximum of four bytes per character and supports supplementary characters:

- For a BMP character, `utf8` and `utf8mb4` have identical storage characteristics: same code values, same encoding, same length.
- For a supplementary character, `utf8` cannot store the character at all, whereas `utf8mb4` requires four bytes to store it. Because `utf8` cannot store the character at all, you have no supplementary characters in `utf8` columns and need not worry about converting characters or losing data when upgrading `utf8` data from older versions of MySQL.

`utf8mb4` is a superset of `utf8`, so for an operation such as the following concatenation, the result has character set `utf8mb4` and the collation of `utf8mb4_col`:

```
SELECT CONCAT(utf8_col, utf8mb4_col);
```

Similarly, the following comparison in the `WHERE` clause works according to the collation of `utf8mb4_col`:

```
SELECT * FROM utf8_tbl, utf8mb4_tbl
WHERE utf8_tbl.utf8_col = utf8mb4_tbl.utf8mb4_col;
```

Tip: To save space with `utf8mb4`, use `VARCHAR` instead of `CHAR`. Otherwise, MySQL must reserve four bytes for each character in a `CHAR CHARACTER SET utf8mb4` column because that is the maximum possible length. For example, MySQL must reserve 40 bytes for a `CHAR(10) CHARACTER SET utf8mb4` column.

10.1.9.4 The ucs2 Character Set (UCS-2 Unicode Encoding)

In UCS-2, every character is represented by a 2-byte Unicode code with the most significant byte first. For example: `LATIN CAPITAL LETTER A` has the code `0x0041` and it is stored as a 2-byte sequence: `0x00 0x41`. `CYRILLIC SMALL LETTER YERU` (Unicode `0x044B`) is stored as a 2-byte sequence: `0x04 0x4B`. For Unicode characters and their codes, please refer to the Unicode Consortium Web site.

In MySQL, the `ucs2` character set is a fixed-length 16-bit encoding for Unicode BMP characters.

10.1.9.5 The utf16 Character Set (UTF-16 Unicode Encoding)

The `utf16` character set is the `ucs2` character set with an extension that enables encoding of supplementary characters:

- For a BMP character, `utf16` and `ucs2` have identical storage characteristics: same code values, same encoding, same length.
- For a supplementary character, `utf16` has a special sequence for representing the character using 32 bits. This is called the “surrogate” mechanism: For a number greater than `0xffff`, take 10 bits and add them to `0xd800` and put them in the first 16-bit word, take 10 more bits and add them to `0xdc00` and put them in the next 16-bit word. Consequently, all supplementary characters require 32 bits, where the first 16 bits are a number between `0xd800` and `0xdbff`, and the last 16 bits are a number between `0xdc00` and `0xdfff`. Examples are in Section 15.5 Surrogates Area of the Unicode 4.0 document.

Because `utf16` supports surrogates and `ucs2` does not, there is a validity check that applies only in `utf16`: You cannot insert a top surrogate without a bottom surrogate, or vice versa. For example:

```
INSERT INTO t (ucs2_column) VALUES (0xd800); /* legal */
INSERT INTO t (utf16_column)VALUES (0xd800); /* illegal */
```

There is no validity check for characters that are technically valid but are not true Unicode (that is, characters that Unicode considers to be “unassigned code points” or “private use” characters or even “illegals” like `0xffff`). For example, since `U+F8FF` is the Apple Logo, this is legal:

```
INSERT INTO t (utf16_column)VALUES (0xf8ff); /* legal */
```

Such characters cannot be expected to mean the same thing to everyone.

Because MySQL must allow for the worst case (that one character requires four bytes) the maximum length of a `utf16` column or index is only half of the maximum length for a `ucs2` column or index. For

example, the maximum length of a MEMORY table index key is 3072 bytes, so these statements create tables with the longest permitted indexes for ucs2 and utf16 columns:

```
CREATE TABLE tf (s1 VARCHAR(1536) CHARACTER SET ucs2) ENGINE=MEMORY;
CREATE INDEX i ON tf (s1);
CREATE TABLE tg (s1 VARCHAR(768) CHARACTER SET utf16) ENGINE=MEMORY;
CREATE INDEX i ON tg (s1);
```

10.1.9.6 The utf32 Character Set (UTF-32 Unicode Encoding)

The utf32 character set is fixed length (like ucs2 and unlike utf16). utf32 uses 32 bits for every character, unlike ucs2 (which uses 16 bits for every character), and unlike utf16 (which uses 16 bits for some characters and 32 bits for others).

utf32 takes twice as much space as ucs2 and more space than utf16, but utf32 has the same advantage as ucs2 that it is predictable for storage: The required number of bytes for utf32 equals the number of characters times 4. Also, unlike utf16, there are no tricks for encoding in utf32, so the stored value equals the code value.

To demonstrate how the latter advantage is useful, here is an example that shows how to determine a utf8mb4 value given the utf32 code value:

```
/* Assume code value = 100cc LINEAR B WHEELED CHARIOT */
CREATE TABLE tmp (utf32_col CHAR(1) CHARACTER SET utf32,
                  utf8mb4_col CHAR(1) CHARACTER SET utf8mb4);
INSERT INTO tmp VALUES (0x000100cc,NULL);
UPDATE tmp SET utf8mb4_col = utf32_col;
SELECT HEX(utf32_col),HEX(utf8mb4_col) FROM tmp;
```

MySQL is very forgiving about additions of unassigned Unicode characters or private-use-area characters. There is in fact only one validity check for utf32: No code value may be greater than 0x10ffff. For example, this is illegal:

```
INSERT INTO t (utf32_column) VALUES (0x110000); /* illegal */
```

10.1.9.7 Converting Between 3-Byte and 4-Byte Unicode Character Sets

This section describes issues that you may face when converting from the utf8 character set to the utf8mb4 character set, or vice versa.

Note

The discussion here focuses primarily on converting between utf8 and utf8mb4, but similar principles apply to converting between the ucs2 character set and character sets such as utf16 or utf32.

The utf8 and utf8mb4 character sets differ as follows:

- utf8 supports only characters in the Basic Multilingual Plane (BMP). utf8mb4 additionally supports supplementary characters that lie outside the BMP.
- utf8 uses a maximum of three bytes per character. utf8mb4 uses a maximum of four bytes per character.

One advantage of converting from ut8 to utf8mb4 is that this enables applications to use supplementary characters. One tradeoff is that this may increase data storage space requirements.

In most respects, converting from utf8 to utf8mb4 should present few problems. These are the primary potential areas of incompatibility:

- For the variable-length character data types (VARCHAR and the TEXT types), the maximum permitted length in characters is less for utf8mb4 columns than for utf8 columns.

- For all character data types (CHAR, VARCHAR, and the TEXT types), the maximum number of characters that can be indexed is less for utf8mb4 columns than for utf8 columns.

Consequently, to convert tables from utf8 to utf8mb4, it may be necessary to change some column or index definitions.

Tables can be converted from utf8 to utf8mb4 by using ALTER TABLE. Suppose that a table was originally defined as follows:

```
CREATE TABLE t1 (
  col1 CHAR(10) CHARACTER SET utf8 COLLATE utf8_unicode_ci NOT NULL,
  col2 CHAR(10) CHARACTER SET utf8 COLLATE utf8_bin NOT NULL
) CHARACTER SET utf8;
```

The following statement converts t1 to use utf8mb4:

```
ALTER TABLE t1
  DEFAULT CHARACTER SET utf8mb4,
  MODIFY col1 CHAR(10)
    CHARACTER SET utf8mb4 COLLATE utf8mb4_unicode_ci NOT NULL,
  MODIFY col2 CHAR(10)
    CHARACTER SET utf8mb4 COLLATE utf8mb4_bin NOT NULL;
```

In terms of table content, conversion from utf8 to utf8mb4 presents no problems:

- For a BMP character, utf8 and utf8mb4 have identical storage characteristics: same code values, same encoding, same length.
- For a supplementary character, utf8 cannot store the character at all, whereas utf8mb4 requires four bytes. Because utf8 cannot store the character at all, utf8 columns have no supplementary characters and you need not worry about converting characters or losing data when converting to utf8mb4.

In terms of table structure, the catch when converting from utf8 to utf8mb4 is that the maximum length of a column or index key is unchanged in terms of *bytes*. Therefore, it is smaller in terms of *characters* because the maximum length of a character is four bytes instead of three. For the CHAR, VARCHAR, and TEXT data types, watch for these issues when converting your MySQL tables:

- Check all definitions of utf8 columns and make sure they will not exceed the maximum length for the storage engine.
- Check all indexes on utf8 columns and make sure they will not exceed the maximum length for the storage engine. Sometimes the maximum can change due to storage engine enhancements.

If the preceding conditions apply, you must either reduce the defined length of columns or indexes, or continue to use utf8 rather than utf8mb4.

Here are some examples where structural changes may be needed:

- A TINYTEXT column can hold up to 255 bytes, so it can hold up to 85 3-byte or 63 4-byte characters. Suppose that you have a TINYTEXT column that uses utf8 but must be able to contain more than 63 characters. You cannot convert it to utf8mb4 unless you also change the data type to a longer type such as TEXT.

  Similarly, a very long VARCHAR column may need to be changed to one of the longer TEXT types if you want to convert it from utf8 to utf8mb4.

- InnoDB has a maximum index length of 767 bytes, so for utf8 or utf8mb4 columns, you can index a maximum of 255 or 191 characters, respectively. If you currently have utf8 columns with indexes longer than 191 characters, you will need to index a smaller number of characters. In an InnoDB table, these column and index definitions are legal:

  ```
  ```

```
col1 VARCHAR(500) CHARACTER SET utf8, INDEX (col1(255))
```

To use `utf8mb4` instead, the index must be smaller:

```
col1 VARCHAR(500) CHARACTER SET utf8mb4, INDEX (col1(191))
```

The preceding types of changes are most likely to be required only if you have very long columns or indexes. Otherwise, you should be able to convert your tables from `utf8` to `utf8mb4` without problems, using `ALTER TABLE` as described previously.

The following items summarize other potential areas of incompatibility:

- Performance of 4-byte UTF-8 (`utf8mb4`) is slower than for 3-byte UTF-8 (`utf8`). To avoid this penalty, continue to use `utf8`.
- `SET NAMES 'utf8mb4'` causes use of the 4-byte character set for connection character sets. As long as no 4-byte characters are sent from the server, there should be no problems. Otherwise, applications that expect to receive a maximum of three bytes per character may have problems. Conversely, applications that expect to send 4-byte characters must ensure that the server understands them. More generally, applications cannot send `utf8mb4`, `utf16`, or `utf32` character data to an older server that does not understand it. `utf8mb4`, `utf16`, and `utf32` are not recognized before MySQL 5.5.3.
- For replication, if character sets that support supplementary characters are to be used on the master, all slaves must understand them as well. If you attempt to replicate from a newer master to an older slave, `utf8` data will be seen as `utf8` by the slave and should replicate correctly. But you cannot send `utf8mb4`, `utf16`, or `utf32` data to an older slave that does not understand it. `utf8mb4`, `utf16`, and `utf32` are not recognized before MySQL 5.5.3.

  Also, keep in mind the general principle that if a table has different definitions on the master and slave, this can lead to unexpected results. For example, the differences in maximum index key length make it risky to use `utf8` on the master and `utf8mb4` on the slave.

If you have converted to `utf8mb4`, `utf16`, or `utf32`, and then decide to convert back to `utf8` or `ucs2` (for example, to downgrade to an older version of MySQL), these considerations apply:

- `utf8` and `ucs2` data should present no problems.
- The server must be recent enough to recognize definitions referring to the character set from which you are converting.
- For object definitions that refer to the `utf8mb4` character set, you can dump them with `mysqldump` prior to downgrading, edit the dump file to change instances of `utf8mb4` to `utf8`, and reload the file in the older server, as long as there are no 4-byte characters in the data. The older server will see `utf8` in the dump file object definitions and create new objects that use the (3-byte) `utf8` character set.

10.1.10 Supported Character Sets and Collations

This section indicates which character sets MySQL supports. There is one subsection for each group of related character sets. For each character set, the permissible collations are listed.

To list the available character sets and their default collations, use the `SHOW CHARACTER SET` statement or query the `INFORMATION_SCHEMA CHARACTER_SETS` table. For example:

```
mysql> SHOW CHARACTER SET;
+----------+-----------------------------+---------------------+--------+
| Charset  | Description                 | Default collation   | Maxlen |
+----------+-----------------------------+---------------------+--------+
| big5     | Big5 Traditional Chinese    | big5_chinese_ci     |      2 |
```

```
| dec8     | DEC West European           | dec8_swedish_ci     |      1 |
| cp850    | DOS West European           | cp850_general_ci    |      1 |
| hp8      | HP West European            | hp8_english_ci      |      1 |
| koi8r    | KOI8-R Relcom Russian       | koi8r_general_ci    |      1 |
| latin1   | cp1252 West European        | latin1_swedish_ci   |      1 |
| latin2   | ISO 8859-2 Central European | latin2_general_ci   |      1 |
| swe7     | 7bit Swedish                | swe7_swedish_ci     |      1 |
| ascii    | US ASCII                    | ascii_general_ci    |      1 |
| ujis     | EUC-JP Japanese             | ujis_japanese_ci    |      3 |
| sjis     | Shift-JIS Japanese          | sjis_japanese_ci    |      2 |
| hebrew   | ISO 8859-8 Hebrew           | hebrew_general_ci   |      1 |
| tis620   | TIS620 Thai                 | tis620_thai_ci      |      1 |
| euckr    | EUC-KR Korean               | euckr_korean_ci     |      2 |
| koi8u    | KOI8-U Ukrainian            | koi8u_general_ci    |      1 |
| gb2312   | GB2312 Simplified Chinese   | gb2312_chinese_ci   |      2 |
| greek    | ISO 8859-7 Greek            | greek_general_ci    |      1 |
| cp1250   | Windows Central European    | cp1250_general_ci   |      1 |
| gbk      | GBK Simplified Chinese      | gbk_chinese_ci      |      2 |
| latin5   | ISO 8859-9 Turkish          | latin5_turkish_ci   |      1 |
| armscii8 | ARMSCII-8 Armenian          | armscii8_general_ci |      1 |
| utf8     | UTF-8 Unicode               | utf8_general_ci     |      3 |
| ucs2     | UCS-2 Unicode               | ucs2_general_ci     |      2 |
| cp866    | DOS Russian                 | cp866_general_ci    |      1 |
| keybcs2  | DOS Kamenicky Czech-Slovak  | keybcs2_general_ci  |      1 |
| macce    | Mac Central European        | macce_general_ci    |      1 |
| macroman | Mac West European           | macroman_general_ci |      1 |
| cp852    | DOS Central European        | cp852_general_ci    |      1 |
| latin7   | ISO 8859-13 Baltic          | latin7_general_ci   |      1 |
| utf8mb4  | UTF-8 Unicode               | utf8mb4_general_ci  |      4 |
| cp1251   | Windows Cyrillic            | cp1251_general_ci   |      1 |
| utf16    | UTF-16 Unicode              | utf16_general_ci    |      4 |
| cp1256   | Windows Arabic              | cp1256_general_ci   |      1 |
| cp1257   | Windows Baltic              | cp1257_general_ci   |      1 |
| utf32    | UTF-32 Unicode              | utf32_general_ci    |      4 |
| binary   | Binary pseudo charset       | binary              |      1 |
| geostd8  | GEOSTD8 Georgian            | geostd8_general_ci  |      1 |
| cp932    | SJIS for Windows Japanese   | cp932_japanese_ci   |      2 |
| eucjpms  | UJIS for Windows Japanese   | eucjpms_japanese_ci |      3 |
+----------+-----------------------------+---------------------+--------+
```

The `utf8mb4`, `utf16`, and `utf32` character sets were added in MySQL 5.5.3.

In cases where a character set has multiple collations, it might not be clear which collation is most suitable for a given application. To avoid choosing the wrong collation, it can be helpful to perform some comparisons with representative data values to make sure that a given collation sorts values the way you expect.

10.1.10.1 Unicode Character Sets

MySQL supports multiple Unicode character sets:

- `utf8`, a UTF-8 encoding of the Unicode character set using one to three bytes per character.
- `ucs2`, the UCS-2 encoding of the Unicode character set using two bytes per character.
- `utf8mb4`, a UTF-8 encoding of the Unicode character set using one to four bytes per character.
- `utf16`, the UTF-16 encoding for the Unicode character set using two or four bytes per character. Like `ucs2` but with an extension for supplementary characters.
- `utf32`, the UTF-32 encoding for the Unicode character set using four bytes per character.

`utf8` and `ucs2` support Basic Multilingual Plane (BMP) characters. `utf8mb4`, `utf16`, and `utf32` support BMP and supplementary characters. The `utf8mb4`, `utf16`, and `utf32` character sets were added in MySQL 5.5.3.

This section describes the collations available for Unicode character sets and their differentiating properties. For general information about Unicode, see Section 10.1.9, “Unicode Support”.

Most Unicode character sets have a general collection (indicated by `_general` in the name or by the absence of a language specifier), a binary collation (indicated by `_bin` in the name), and several language-specific collations (indicated by language specifiers). For example, for `utf8`, `utf8_general_ci` and `utf8_bin` are its general and binary collations, and `utf8_danish_ci` is one of its language-specific collations.

A language name shown in the following table indicates a language-specific collation. Unicode character sets may include collations for one or more of these languages.

Table 10.3 Unicode Collation Language Specifiers

Language	Language Specifier
Classical Latin	`roman`
Czech	`czech`
Danish	`danish`
Esperanto	`esperanto`
Estonian	`estonian`
Hungarian	`hungarian`
Icelandic	`icelandic`
Latvian	`latvian`
Lithuanian	`lithuanian`
Persian	`persian`
Polish	`polish`
Romanian	`romanian`
Sinhala	`sinhala`
Slovak	`slovak`
Slovenian	`slovenian`
Modern Spanish	`spanish`
Traditional Spanish	`spanish2`
Swedish	`swedish`
Turkish	`turkish`

Danish collations may also be used for Norwegian.

For Classical Latin collations, `I` and `J` compare as equal, and `U` and `V` compare as equal.

Spanish collations are available for modern and traditional Spanish. For both, `ñ` (n-tilde) is a separate letter between `n` and `o`. In addition, for traditional Spanish, `ch` is a separate letter between `c` and `d`, and `ll` is a separate letter between `l` and `m`.

Traditional Spanish collations may also be used for Asturian and Galician.

Swedish collations include Swedish rules. For example, in Swedish, the following relationship holds, which is not something expected by a German or French speaker:

```
Ü = Y < Ö
```

For questions about particular language orderings, unicode.org provides Common Locale Data Repository (CLDR) collation charts at http://www.unicode.org/cldr/charts/30/collation/index.html.

The *`xxx`*`_general_mysql500_ci` collations were added in MySQL 5.5.21. They preserve the pre-5.1.24 ordering of the original *`xxx`*`_general_ci` collations and permit upgrades for tables created before MySQL 5.1.24 (Bug #27877).

MySQL implements the *xxx*_unicode_ci collations according to the Unicode Collation Algorithm (UCA) described at http://www.unicode.org/reports/tr10/. The collation uses the version-4.0.0 UCA weight keys: http://www.unicode.org/Public/UCA/4.0.0/allkeys-4.0.0.txt. The *xxx*_unicode_ci collations have only partial support for the Unicode Collation Algorithm. Some characters are not supported, and combining marks are not fully supported. This affects primarily Vietnamese, Yoruba, and some smaller languages such as Navajo. A combined character is considered different from the same character written with a single unicode character in string comparisons, and the two characters are considered to have a different length (for example, as returned by the CHAR_LENGTH() function or in result set metadata).

MySQL implements language-specific Unicode collations if the ordering based only on UCA does not work well for a language. Language-specific collations are UCA-based, with additional language tailoring rules.

For any Unicode character set, operations performed using the *xxx*_general_ci collation are faster than those for the *xxx*_unicode_ci collation. For example, comparisons for the utf8_general_ci collation are faster, but slightly less correct, than comparisons for utf8_unicode_ci. The reason for this is that utf8_unicode_ci supports mappings such as expansions; that is, when one character compares as equal to combinations of other characters. For example, in German and some other languages ß is equal to ss. utf8_unicode_ci also supports contractions and ignorable characters. utf8_general_ci is a legacy collation that does not support expansions, contractions, or ignorable characters. It can make only one-to-one comparisons between characters.

To further illustrate, the following equalities hold in both utf8_general_ci and utf8_unicode_ci (for the effect of this in comparisons or searches, see Section 10.1.8.6, “Examples of the Effect of Collation”):

```
Ä = A
Ö = O
Ü = U
```

A difference between the collations is that this is true for utf8_general_ci:

```
ß = s
```

Whereas this is true for utf8_unicode_ci, which supports the German DIN-1 ordering (also known as dictionary order):

```
ß = ss
```

MySQL implements utf8 language-specific collations if the ordering with utf8_unicode_ci does not work well for a language. For example, utf8_unicode_ci works fine for German dictionary order and French, so there is no need to create special utf8 collations.

utf8_general_ci also is satisfactory for both German and French, except that ß is equal to s, and not to ss. If this is acceptable for your application, you should use utf8_general_ci because it is faster. Otherwise, use utf8_unicode_ci because it is more accurate.

For all Unicode collations except the binary (_bin) collations, MySQL performs a table lookup to find a character's collating weight. If a character is not in the table (for example, because it is a “new” character), collating weight determination becomes more complex:

- For BMP characters in general collations (*xxx*_general_ci), weight = code point.
- For BMP characters in UCA collations (for example, *xxx*_unicode_ci and language-specific collations), the following algorithm applies:

```
if (code >= 0x3400 && code <= 0x4DB5)
  base= 0xFB80; /* CJK Ideograph Extension */
else if (code >= 0x4E00 && code <= 0x9FA5)
  base= 0xFB40; /* CJK Ideograph */
else
  base= 0xFBC0; /* All other characters */
aaaa= base +  (code >> 15);
bbbb= (code & 0x7FFF) | 0x8000;
```

The result is a sequence of two collating elements, `aaaa` followed by `bbbb`.

Thus, `U+04cf CYRILLIC SMALL LETTER PALOCHKA` currently is, with all UCA collations, greater than `U+04c0 CYRILLIC LETTER PALOCHKA`. Eventually, after further collation tuning, all palochkas will sort together.

- For supplementary characters in general collations, the weight is the weight for `0xfffd REPLACEMENT CHARACTER`. For supplementary characters in UCA collations, their collating weight is `0xfffd`. That is, to MySQL, all supplementary characters are equal to each other, and greater than almost all BMP characters.

  An example with Deseret characters and `COUNT(DISTINCT)`:

  ```
  CREATE TABLE t (s1 VARCHAR(5) CHARACTER SET utf32 COLLATE utf32_unicode_ci);
  INSERT INTO t VALUES (0xfffd);   /* REPLACEMENT CHARACTER */
  INSERT INTO t VALUES (0x010412); /* DESERET CAPITAL LETTER BEE */
  INSERT INTO t VALUES (0x010413); /* DESERET CAPITAL LETTER TEE */
  SELECT COUNT(DISTINCT s1) FROM t;
  ```

  The result is 2 because in the MySQL *`xxx`*`_unicode_ci` collations, the replacement character has a weight of `0x0dc6`, whereas Deseret Bee and Deseret Tee both have a weight of `0xfffd`. (Were the `utf32_general_ci` collation used instead, the result is 1 because all three characters have a weight of `0xfffd` in that collation.)

The rule that all supplementary characters are equal to each other is nonoptimal but is not expected to cause trouble. These characters are very rare, so it is very rare that a multi-character string consists entirely of supplementary characters. In Japan, since the supplementary characters are obscure Kanji ideographs, the typical user does not care what order they are in, anyway. If you really want rows sorted by the MySQL rule and secondarily by code point value, it is easy:

```
ORDER BY s1 COLLATE utf32_unicode_ci, s1 COLLATE utf32_bin
```

There is a difference between “ordering by the character's code value” and “ordering by the character's binary representation,” a difference that appears only with `utf16_bin`, because of surrogates.

Suppose that `utf16_bin` (the binary collation for `utf16`) was a binary comparison “byte by byte” rather than “character by character.” If that were so, the order of characters in `utf16_bin` would differ from the order in `utf8_bin`. For example, the following chart shows two rare characters. The first character is in the range `E000`-`FFFF`, so it is greater than a surrogate but less than a supplementary. The second character is a supplementary.

```
Code point  Character                   utf8         utf16
----------  ---------                   ----         -----
0FF9D       HALFWIDTH KATAKANA LETTER N  EF BE 9D     FF 9D
10384       UGARITIC LETTER DELTA        F0 90 8E 84  D8 00 DF 84
```

The two characters in the chart are in order by code point value because `0xff9d` < `0x10384`. And they are in order by `utf8` value because `0xef` < `0xf0`. But they are not in order by `utf16` value, if we use byte-by-byte comparison, because `0xff` > `0xd8`.

So MySQL's `utf16_bin` collation is not “byte by byte.” It is “by code point.” When MySQL sees a supplementary-character encoding in `utf16`, it converts to the character's code-point value, and then

compares. Therefore, `utf8_bin` and `utf16_bin` are the same ordering. This is consistent with the SQL:2008 standard requirement for a UCS_BASIC collation: “UCS_BASIC is a collation in which the ordering is determined entirely by the Unicode scalar values of the characters in the strings being sorted. It is applicable to the UCS character repertoire. Since every character repertoire is a subset of the UCS repertoire, the UCS_BASIC collation is potentially applicable to every character set. NOTE 11: The Unicode scalar value of a character is its code point treated as an unsigned integer.”

If the character set is `ucs2`, comparison is byte-by-byte, but `ucs2` strings should not contain surrogates, anyway.

10.1.10.2 West European Character Sets

Western European character sets cover most West European languages, such as French, Spanish, Catalan, Basque, Portuguese, Italian, Albanian, Dutch, German, Danish, Swedish, Norwegian, Finnish, Faroese, Icelandic, Irish, Scottish, and English.

- `ascii` (US ASCII) collations:
  - `ascii_bin`
  - `ascii_general_ci` (default)
- `cp850` (DOS West European) collations:
  - `cp850_bin`
  - `cp850_general_ci` (default)
- `dec8` (DEC Western European) collations:
  - `dec8_bin`
  - `dec8_swedish_ci` (default)
- `hp8` (HP Western European) collations:
  - `hp8_bin`
  - `hp8_english_ci` (default)
- `latin1` (cp1252 West European) collations:
  - `latin1_bin`
  - `latin1_danish_ci`
  - `latin1_general_ci`
  - `latin1_general_cs`
  - `latin1_german1_ci`
  - `latin1_german2_ci`
  - `latin1_spanish_ci`
  - `latin1_swedish_ci` (default)

  `latin1` is the default character set. MySQL's `latin1` is the same as the Windows `cp1252` character set. This means it is the same as the official `ISO 8859-1` or IANA (Internet Assigned Numbers Authority) `latin1`, except that IANA `latin1` treats the code points between `0x80` and `0x9f` as “undefined,” whereas `cp1252`, and therefore MySQL's `latin1`, assign characters for

those positions. For example, `0x80` is the Euro sign. For the “undefined” entries in `cp1252`, MySQL translates `0x81` to Unicode `0x0081`, `0x8d` to `0x008d`, `0x8f` to `0x008f`, `0x90` to `0x0090`, and `0x9d` to `0x009d`.

The `latin1_swedish_ci` collation is the default that probably is used by the majority of MySQL customers. Although it is frequently said that it is based on the Swedish/Finnish collation rules, there are Swedes and Finns who disagree with this statement.

The `latin1_german1_ci` and `latin1_german2_ci` collations are based on the DIN-1 and DIN-2 standards, where DIN stands for *Deutsches Institut für Normung* (the German equivalent of ANSI). DIN-1 is called the “dictionary collation” and DIN-2 is called the “phone book collation.” For an example of the effect this has in comparisons or when doing searches, see Section 10.1.8.6, “Examples of the Effect of Collation”.

- `latin1_german1_ci` (dictionary) rules:

```
Ä = A
Ö = O
Ü = U
ß = s
```

- `latin1_german2_ci` (phone-book) rules:

```
Ä = AE
Ö = OE
Ü = UE
ß = ss
```

In the `latin1_spanish_ci` collation, `ñ` (n-tilde) is a separate letter between `n` and `o`.

- `macroman` (Mac West European) collations:
  - `macroman_bin`
  - `macroman_general_ci` (default)
- `swe7` (7bit Swedish) collations:
  - `swe7_bin`
  - `swe7_swedish_ci` (default)

10.1.10.3 Central European Character Sets

MySQL provides some support for character sets used in the Czech Republic, Slovakia, Hungary, Romania, Slovenia, Croatia, Poland, and Serbia (Latin).

- `cp1250` (Windows Central European) collations:
  - `cp1250_bin`
  - `cp1250_croatian_ci`
  - `cp1250_czech_cs`
  - `cp1250_general_ci` (default)
  - `cp1250_polish_ci`
- `cp852` (DOS Central European) collations:
  - `cp852_bin`

  - `cp852_general_ci` (default)
- `keybcs2` (DOS Kamenicky Czech-Slovak) collations:
  - `keybcs2_bin`
  - `keybcs2_general_ci` (default)
- `latin2` (ISO 8859-2 Central European) collations:
  - `latin2_bin`
  - `latin2_croatian_ci`
  - `latin2_czech_cs`
  - `latin2_general_ci` (default)
  - `latin2_hungarian_ci`
- `macce` (Mac Central European) collations:
  - `macce_bin`
  - `macce_general_ci` (default)

10.1.10.4 South European and Middle East Character Sets

South European and Middle Eastern character sets supported by MySQL include Armenian, Arabic, Georgian, Greek, Hebrew, and Turkish.

- `armscii8` (ARMSCII-8 Armenian) collations:
  - `armscii8_bin`
  - `armscii8_general_ci` (default)
- `cp1256` (Windows Arabic) collations:
  - `cp1256_bin`
  - `cp1256_general_ci` (default)
- `geostd8` (GEOSTD8 Georgian) collations:
  - `geostd8_bin`
  - `geostd8_general_ci` (default)
- `greek` (ISO 8859-7 Greek) collations:
  - `greek_bin`
  - `greek_general_ci` (default)
- `hebrew` (ISO 8859-8 Hebrew) collations:
  - `hebrew_bin`
  - `hebrew_general_ci` (default)
- `latin5` (ISO 8859-9 Turkish) collations:

- latin5_bin
- latin5_turkish_ci (default)

10.1.10.5 Baltic Character Sets

The Baltic character sets cover Estonian, Latvian, and Lithuanian languages.

- cp1257 (Windows Baltic) collations:
  - cp1257_bin
  - cp1257_general_ci (default)
  - cp1257_lithuanian_ci
- latin7 (ISO 8859-13 Baltic) collations:
  - latin7_bin
  - latin7_estonian_cs
  - latin7_general_ci (default)
  - latin7_general_cs

10.1.10.6 Cyrillic Character Sets

The Cyrillic character sets and collations are for use with Belarusian, Bulgarian, Russian, Ukrainian, and Serbian (Cyrillic) languages.

- cp1251 (Windows Cyrillic) collations:
  - cp1251_bin
  - cp1251_bulgarian_ci
  - cp1251_general_ci (default)
  - cp1251_general_cs
  - cp1251_ukrainian_ci
- cp866 (DOS Russian) collations:
  - cp866_bin
  - cp866_general_ci (default)
- koi8r (KOI8-R Relcom Russian) collations:
  - koi8r_bin
  - koi8r_general_ci (default)
- koi8u (KOI8-U Ukrainian) collations:
  - koi8u_bin
  - koi8u_general_ci (default)

10.1.10.7 Asian Character Sets

The Asian character sets that we support include Chinese, Japanese, Korean, and Thai. These can be complicated. For example, the Chinese sets must allow for thousands of different characters. See The cp932 Character Set, for additional information about the `cp932` and `sjis` character sets.

For answers to some common questions and problems relating support for Asian character sets in MySQL, see Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”.

- `big5` (Big5 Traditional Chinese) collations:
  - `big5_bin`
  - `big5_chinese_ci` (default)
- `cp932` (SJIS for Windows Japanese) collations:
  - `cp932_bin`
  - `cp932_japanese_ci` (default)
- `eucjpms` (UJIS for Windows Japanese) collations:
  - `eucjpms_bin`
  - `eucjpms_japanese_ci` (default)
- `euckr` (EUC-KR Korean) collations:
  - `euckr_bin`
  - `euckr_korean_ci` (default)
- `gb2312` (GB2312 Simplified Chinese) collations:
  - `gb2312_bin`
  - `gb2312_chinese_ci` (default)
- `gbk` (GBK Simplified Chinese) collations:
  - `gbk_bin`
  - `gbk_chinese_ci` (default)
- `sjis` (Shift-JIS Japanese) collations:
  - `sjis_bin`
  - `sjis_japanese_ci` (default)
- `tis620` (TIS620 Thai) collations:
  - `tis620_bin`
  - `tis620_thai_ci` (default)
- `ujis` (EUC-JP Japanese) collations:
  - `ujis_bin`
  - `ujis_japanese_ci` (default)

The `big5_chinese_ci` collation sorts on number of strokes.

The cp932 Character Set

Why is cp932 needed?

In MySQL, the sjis character set corresponds to the Shift_JIS character set defined by IANA, which supports JIS X0201 and JIS X0208 characters. (See http://www.iana.org/assignments/character-sets.)

However, the meaning of “SHIFT JIS” as a descriptive term has become very vague and it often includes the extensions to Shift_JIS that are defined by various vendors.

For example, “SHIFT JIS” used in Japanese Windows environments is a Microsoft extension of Shift_JIS and its exact name is Microsoft Windows Codepage : 932 or cp932. In addition to the characters supported by Shift_JIS, cp932 supports extension characters such as NEC special characters, NEC selected—IBM extended characters, and IBM selected characters.

Many Japanese users have experienced problems using these extension characters. These problems stem from the following factors:

- MySQL automatically converts character sets.
- Character sets are converted using Unicode (ucs2).
- The sjis character set does not support the conversion of these extension characters.
- There are several conversion rules from so-called “SHIFT JIS” to Unicode, and some characters are converted to Unicode differently depending on the conversion rule. MySQL supports only one of these rules (described later).

The MySQL cp932 character set is designed to solve these problems.

Because MySQL supports character set conversion, it is important to separate IANA Shift_JIS and cp932 into two different character sets because they provide different conversion rules.

How does cp932 differ from sjis?

The cp932 character set differs from sjis in the following ways:

- cp932 supports NEC special characters, NEC selected—IBM extended characters, and IBM selected characters.
- Some cp932 characters have two different code points, both of which convert to the same Unicode code point. When converting from Unicode back to cp932, one of the code points must be selected. For this “round trip conversion,” the rule recommended by Microsoft is used. (See http://support.microsoft.com/kb/170559/EN-US/.)

  The conversion rule works like this:

  - If the character is in both JIS X 0208 and NEC special characters, use the code point of JIS X 0208.
  - If the character is in both NEC special characters and IBM selected characters, use the code point of NEC special characters.
  - If the character is in both IBM selected characters and NEC selected—IBM extended characters, use the code point of IBM extended characters.

  The table shown at https://msdn.microsoft.com/en-us/goglobal/cc305152.aspx provides information about the Unicode values of cp932 characters. For cp932 table entries with characters under which a four-digit number appears, the number represents the corresponding Unicode (ucs2) encoding. For table entries with an underlined two-digit value appears, there is a range of cp932 character

values that begin with those two digits. Clicking such a table entry takes you to a page that displays the Unicode value for each of the `cp932` characters that begin with those digits.

The following links are of special interest. They correspond to the encodings for the following sets of characters:

- NEC special characters (lead byte `0x87`):

```
https://msdn.microsoft.com/en-us/goglobal/gg674964
```

- NEC selected—IBM extended characters (lead byte `0xED` and `0xEE`):

```
https://msdn.microsoft.com/en-us/goglobal/gg671837
https://msdn.microsoft.com/en-us/goglobal/gg671838
```

- IBM selected characters (lead byte `0xFA`, `0xFB`, `0xFC`):

```
https://msdn.microsoft.com/en-us/goglobal/gg671839
https://msdn.microsoft.com/en-us/goglobal/gg671840
https://msdn.microsoft.com/en-us/goglobal/gg671841
```

- `cp932` supports conversion of user-defined characters in combination with `eucjpms`, and solves the problems with `sjis`/`ujis` conversion. For details, please refer to http://www.sljfaq.org/afaq/encodings.html.

For some characters, conversion to and from `ucs2` is different for `sjis` and `cp932`. The following tables illustrate these differences.

Conversion to `ucs2`:

`sjis`/`cp932` Value	**`sjis` -> `ucs2` Conversion**	**`cp932` -> `ucs2` Conversion**
5C	005C	005C
7E	007E	007E
815C	2015	2015
815F	005C	FF3C
8160	301C	FF5E
8161	2016	2225
817C	2212	FF0D
8191	00A2	FFE0
8192	00A3	FFE1
81CA	00AC	FFE2

Conversion from `ucs2`:

`ucs2` value	**`ucs2` -> `sjis` Conversion**	**`ucs2` -> `cp932` Conversion**
005C	815F	5C
007E	7E	7E
00A2	8191	3F
00A3	8192	3F
00AC	81CA	3F
2015	815C	815C
2016	8161	3F

ucs2 value	ucs2 -> sjis Conversion	ucs2 -> cp932 Conversion
2212	817C	3F
2225	3F	8161
301C	8160	3F
FF0D	3F	817C
FF3C	3F	815F
FF5E	3F	8160
FFE0	3F	8191
FFE1	3F	8192
FFE2	3F	81CA

Users of any Japanese character sets should be aware that using `--character-set-client-handshake` (or `--skip-character-set-client-handshake`) has an important effect. See Section 5.1.4, “Server Command Options”.

10.1.10.8 The Binary Character Set

The `binary` character set is the chararcter set of binary strings, which are sequences of bytes. The `binary` character set has one collation, also named `binary`. Comparison and sorting are based on numeric byte values. The effect is that lettercase and accent differences are significant in comparisons. That is, the `binary` collation is case sensitive and accent sensitive.

```
mysql> SET NAMES 'binary';
mysql> SELECT CHARSET('abc'), COLLATION('abc');
+----------------+------------------+
| CHARSET('abc') | COLLATION('abc') |
+----------------+------------------+
| binary         | binary           |
+----------------+------------------+
mysql> SELECT 'abc' = 'ABC', 'a' = 'ä';
+---------------+------------+
| 'abc' = 'ABC' | 'a' = 'ä'  |
+---------------+------------+
|             0 |          0 |
+---------------+------------+
```

For information about the differences between the `binary` collation of the `binary` character set and the `_bin` collations of nonbinary character sets, see Section 10.1.8.5, “The binary Collation Compared to _bin Collations”.

To convert a string expression to a binary string, any of these constructs are equivalent:

```
BINARY expr
CAST(expr AS BINARY)
CONVERT(expr USING BINARY)
```

If *`expr`* is a character string literal, the `_binary` introducer may be used to designate it as a binary string. For example:

```
_binary 'a'
```

The `_binary` introducer is permitted for hexadecimal literals and bit-value literals as well, but unnecessary; such literals are binary strings by default.

For more information about introducers, see Section 10.1.3.8, “Character Set Introducers”.

10.2 Setting the Error Message Language

By default, `mysqld` produces error messages in English, but they can be displayed instead in any of several other languages: Czech, Danish, Dutch, Estonian, French, German, Greek, Hungarian, Italian, Japanese, Korean, Norwegian, Norwegian-ny, Polish, Portuguese, Romanian, Russian, Slovak, Spanish, or Swedish. This applies to messages the server writes to the error log and sends to clients.

To select the language in which the server writes error messages, follow the instructions in this section. For information about changing the character set for error messages (rather than the language), see Section 10.1.6, “Error Message Character Set”. For general information about configuring error logging, see Section 5.4.2, “The Error Log”.

As of MySQL 5.5, the server searches for the error message file using these rules:

- It tries to find the file in a directory constructed from two system variable values, `lc_messages_dir` and `lc_messages`, with the latter converted to a language name. Suppose that you start the server using this command:

  ```
  mysqld --lc_messages_dir=/usr/share/mysql --lc_messages=fr_FR
  ```

  In this case, `mysqld` maps the locale `fr_FR` to the language `french` and looks for the error file in the `/usr/share/mysql/french` directory.

  By default, the language files are located in the `share/mysql/LANGUAGE` directory under the MySQL base directory.

- If the message file cannot be found in the directory constructed as just described, the server ignores the `lc_messages` value and uses only the `lc_messages_dir` value as the location in which to look.

The `lc_messages_dir` system variable can be set only at server startup and has only a global read-only value at runtime. `lc_messages` can be set at server startup and has global and session values that can be modified at runtime. Thus, the error message language can be changed while the server is running, and individual clients each can have a different error message language by changing their session `lc_messages` value to a different locale name. For example, if the server is using the `fr_FR` locale for error messages, a client can execute this statement to receive error messages in English:

```
SET lc_messages = 'en_US';
```

Before MySQL 5.5, the `lc_messages_dir` and `lc_messages` system variables were unavailable. To start `mysqld` with a particular language for error messages, the `--language` or `-L` option were used. The option value can be a language name or the full path to the error message file. For example:

```
shell> mysqld --language=french
```

Or:

```
shell> mysqld --language=/usr/local/share/french
```

Specify the language name in lowercase.

MySQL 5.5 treats `--language` as an alias for `lc_messages_dir`.

You can change the content of the error messages produced by the server using the instructions in the MySQL Internals manual, available at MySQL Internals: Error Messages. If you do change error message content, remember to repeat your changes after each upgrade to a newer version of MySQL.

10.3 Adding a Character Set

This section discusses the procedure for adding a character set to MySQL. The proper procedure depends on whether the character set is simple or complex:

- If the character set does not need special string collating routines for sorting and does not need multibyte character support, it is simple.
- If the character set needs either of those features, it is complex.

For example, `greek` and `swe7` are simple character sets, whereas `big5` and `czech` are complex character sets.

To use the following instructions, you must have a MySQL source distribution. In the instructions, *`MYSET`* represents the name of the character set that you want to add.

1. Add a `<charset>` element for *`MYSET`* to the `sql/share/charsets/Index.xml` file. Use the existing contents in the file as a guide to adding new contents. A partial listing for the `latin1` `<charset>` element follows:

   ```
   <charset name="latin1">
     <family>Western</family>
     <description>cp1252 West European</description>
     ...
     <collation name="latin1_swedish_ci" id="8" order="Finnish, Swedish">
       <flag>primary</flag>
       <flag>compiled</flag>
     </collation>
     <collation name="latin1_danish_ci" id="15" order="Danish"/>
     ...
     <collation name="latin1_bin" id="47" order="Binary">
       <flag>binary</flag>
       <flag>compiled</flag>
     </collation>
     ...
   </charset>
   ```

   The `<charset>` element must list all the collations for the character set. These must include at least a binary collation and a default (primary) collation. The default collation is often named using a suffix of `general_ci` (general, case insensitive). It is possible for the binary collation to be the default collation, but usually they are different. The default collation should have a `primary` flag. The binary collation should have a `binary` flag.

   You must assign a unique ID number to each collation. The range of IDs from 1024 to 2047 is reserved for user-defined collations. Before MySQL 5.5, the ID must be chosen from the range 1 to 254. To find the maximum of the currently used collation IDs, use this query:

   ```
   SELECT MAX(ID) FROM INFORMATION_SCHEMA.COLLATIONS;
   ```

2. This step depends on whether you are adding a simple or complex character set. A simple character set requires only a configuration file, whereas a complex character set requires C source file that defines collation functions, multibyte functions, or both.

   For a simple character set, create a configuration file, *`MYSET`*`.xml`, that describes the character set properties. Create this file in the `sql/share/charsets` directory. You can use a copy of `latin1.xml` as the basis for this file. The syntax for the file is very simple:

   - Comments are written as ordinary XML comments (`<!-- text -->`).
   - Words within `<map>` array elements are separated by arbitrary amounts of whitespace.
   - Each word within `<map>` array elements must be a number in hexadecimal format.
   - The `<map>` array element for the `<ctype>` element has 257 words. The other `<map>` array elements after that have 256 words. See Section 10.3.1, “Character Definition Arrays”.

- For each collation listed in the `<charset>` element for the character set in `Index.xml`, `MYSET.xml` must contain a `<collation>` element that defines the character ordering.

For a complex character set, create a C source file that describes the character set properties and defines the support routines necessary to properly perform operations on the character set:

- Create the file `ctype-MYSET.c` in the `strings` directory. Look at one of the existing `ctype-*.c` files (such as `ctype-big5.c`) to see what needs to be defined. The arrays in your file must have names like `ctype_MYSET`, `to_lower_MYSET`, and so on. These correspond to the arrays for a simple character set. See Section 10.3.1, “Character Definition Arrays”.
- For each `<collation>` element listed in the `<charset>` element for the character set in `Index.xml`, the `ctype-MYSET.c` file must provide an implementation of the collation.
- If the character set requires string collating functions, see Section 10.3.2, “String Collating Support for Complex Character Sets”.
- If the character set requires multibyte character support, see Section 10.3.3, “Multi-Byte Character Support for Complex Character Sets”.

3. Modify the configuration information. Use the existing configuration information as a guide to adding information for `MYSYS`. The example here assumes that the character set has default and binary collations, but more lines are needed if `MYSET` has additional collations.

   a. Edit `mysys/charset-def.c`, and “register” the collations for the new character set.

      Add these lines to the “declaration” section:

      ```
      #ifdef HAVE_CHARSET_MYSET
      extern CHARSET_INFO my_charset_MYSET_general_ci;
      extern CHARSET_INFO my_charset_MYSET_bin;
      #endif
      ```

      Add these lines to the “registration” section:

      ```
      #ifdef HAVE_CHARSET_MYSET
        add_compiled_collation(&my_charset_MYSET_general_ci);
        add_compiled_collation(&my_charset_MYSET_bin);
      #endif
      ```

   b. If the character set uses `ctype-MYSET.c`, edit `strings/CMakeLists.txt` and add `ctype-MYSET.c` to the definition of the `STRINGS_SOURCES` variable.

   c. Edit `cmake/character_sets.cmake`:

      i. Add `MYSET` to the value of with `CHARSETS_AVAILABLE` in alphabetic order.

      ii. Add `MYSET` to the value of `CHARSETS_COMPLEX` in alphabetic order. This is needed even for simple character sets, or `CMake` will not recognize `-DDEFAULT_CHARSET=MYSET`.

4. Reconfigure, recompile, and test.

10.3.1 Character Definition Arrays

Each simple character set has a configuration file located in the `sql/share/charsets` directory. For a character set named `MYSYS`, the file is named `MYSET.xml`. It uses `<map>` array elements to list character set properties. `<map>` elements appear within these elements:

- `<ctype>` defines attributes for each character.
- `<lower>` and `<upper>` list the lowercase and uppercase characters.

- <unicode> maps 8-bit character values to Unicode values.
- <collation> elements indicate character ordering for comparison and sorting, one element per collation. Binary collations need no <map> element because the character codes themselves provide the ordering.

For a complex character set as implemented in a ctype-*MYSET*.c file in the strings directory, there are corresponding arrays: ctype_*MYSET*[], to_lower_*MYSET*[], and so forth. Not every complex character set has all of the arrays. See also the existing ctype-*.c files for examples. See the CHARSET_INFO.txt file in the strings directory for additional information.

Most of the arrays are indexed by character value and have 256 elements. The <ctype> array is indexed by character value + 1 and has 257 elements. This is a legacy convention for handling EOF.

<ctype> array elements are bit values. Each element describes the attributes of a single character in the character set. Each attribute is associated with a bitmask, as defined in include/m_ctype.h:

```
#define _MY_U   01      /* Upper case */
#define _MY_L   02      /* Lower case */
#define _MY_NMR 04      /* Numeral (digit) */
#define _MY_SPC 010     /* Spacing character */
#define _MY_PNT 020     /* Punctuation */
#define _MY_CTR 040     /* Control character */
#define _MY_B   0100    /* Blank */
#define _MY_X   0200    /* heXadecimal digit */
```

The <ctype> value for a given character should be the union of the applicable bitmask values that describe the character. For example, 'A' is an uppercase character (_MY_U) as well as a hexadecimal digit (_MY_X), so its ctype value should be defined like this:

```
ctype['A'+1] = _MY_U | _MY_X = 01 | 0200 = 0201
```

The bitmask values in m_ctype.h are octal values, but the elements of the <ctype> array in *MYSET*.xml should be written as hexadecimal values.

The <lower> and <upper> arrays hold the lowercase and uppercase characters corresponding to each member of the character set. For example:

```
lower['A'] should contain 'a'
upper['a'] should contain 'A'
```

Each <collation> array indicates how characters should be ordered for comparison and sorting purposes. MySQL sorts characters based on the values of this information. In some cases, this is the same as the <upper> array, which means that sorting is case-insensitive. For more complicated sorting rules (for complex character sets), see the discussion of string collating in Section 10.3.2, “String Collating Support for Complex Character Sets”.

10.3.2 String Collating Support for Complex Character Sets

For a simple character set named *MYSET*, sorting rules are specified in the *MYSET*.xml configuration file using <map> array elements within <collation> elements. If the sorting rules for your language are too complex to be handled with simple arrays, you must define string collating functions in the ctype-*MYSET*.c source file in the strings directory.

The existing character sets provide the best documentation and examples to show how these functions are implemented. Look at the ctype-*.c files in the strings directory, such as the files for the big5, czech, gbk, sjis, and tis160 character sets. Take a look at the MY_COLLATION_HANDLER structures to see how they are used. See also the CHARSET_INFO.txt file in the strings directory for additional information.

10.3.3 Multi-Byte Character Support for Complex Character Sets

If you want to add support for a new character set named *`MYSET`* that includes multibyte characters, you must use multibyte character functions in the `ctype-MYSET.c` source file in the `strings` directory.

The existing character sets provide the best documentation and examples to show how these functions are implemented. Look at the `ctype-*.c` files in the `strings` directory, such as the files for the `euc_kr`, `gb2312`, `gbk`, `sjis`, and `ujis` character sets. Take a look at the `MY_CHARSET_HANDLER` structures to see how they are used. See also the `CHARSET_INFO.txt` file in the `strings` directory for additional information.

10.4 Adding a Collation to a Character Set

A collation is a set of rules that defines how to compare and sort character strings. Each collation in MySQL belongs to a single character set. Every character set has at least one collation, and most have two or more collations.

A collation orders characters based on weights. Each character in a character set maps to a weight. Characters with equal weights compare as equal, and characters with unequal weights compare according to the relative magnitude of their weights.

MySQL supports several collation implementations, as discussed in Section 10.4.1, “Collation Implementation Types”. Some of these can be added to MySQL without recompiling:

- Simple collations for 8-bit character sets.
- UCA-based collations for Unicode character sets.
- Binary (*`xxx`*`_bin`) collations.

The following sections describe how to add collations of the first two types to existing character sets. All existing character sets already have a binary collation, so there is no need here to describe how to add one.

Summary of the procedure for adding a new collation:

1. Choose a collation ID.
2. Add configuration information that names the collation and describes the character-ordering rules.
3. Restart the server.
4. Verify that the collation is present.

The instructions here cover only collations that can be added without recompiling MySQL. To add a collation that does require recompiling (as implemented by means of functions in a C source file), use the instructions in Section 10.3, “Adding a Character Set”. However, instead of adding all the information required for a complete character set, just modify the appropriate files for an existing character set. That is, based on what is already present for the character set's current collations, add data structures, functions, and configuration information for the new collation.

Note

If you modify an existing collation, that may affect the ordering of rows for indexes on columns that use the collation. In this case, rebuild any such indexes to avoid problems such as incorrect query results. See Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”.

Additional Resources

- The Unicode Collation Algorithm (UCA) specification: http://www.unicode.org/reports/tr10/
- The Locale Data Markup Language (LDML) specification: http://www.unicode.org/reports/tr35/

10.4.1 Collation Implementation Types

MySQL implements several types of collations:

Simple collations for 8-bit character sets

This kind of collation is implemented using an array of 256 weights that defines a one-to-one mapping from character codes to weights. `latin1_swedish_ci` is an example. It is a case-insensitive collation, so the uppercase and lowercase versions of a character have the same weights and they compare as equal.

```
mysql> SET NAMES 'latin1' COLLATE 'latin1_swedish_ci';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT 'a' = 'A';
+-----------+
| 'a' = 'A' |
+-----------+
|         1 |
+-----------+
1 row in set (0.00 sec)
```

For implementation instructions, see Section 10.4.3, “Adding a Simple Collation to an 8-Bit Character Set”.

Complex collations for 8-bit character sets

This kind of collation is implemented using functions in a C source file that define how to order characters, as described in Section 10.3, “Adding a Character Set”.

Collations for non-Unicode multibyte character sets

For this type of collation, 8-bit (single-byte) and multibyte characters are handled differently. For 8-bit characters, character codes map to weights in case-insensitive fashion. (For example, the single-byte characters `'a'` and `'A'` both have a weight of `0x41`.) For multibyte characters, there are two types of relationship between character codes and weights:

- Weights equal character codes. `sjis_japanese_ci` is an example of this kind of collation. The multibyte character `'ぢ'` has a character code of `0x82C0`, and the weight is also `0x82C0`.
- Character codes map one-to-one to weights, but a code is not necessarily equal to the weight. `gbk_chinese_ci` is an example of this kind of collation. The multibyte character `'膰'` has a character code of `0x81B0` but a weight of `0xC286`.

For implementation instructions, see Section 10.3, “Adding a Character Set”.

Collations for Unicode multibyte character sets

Some of these collations are based on the Unicode Collation Algorithm (UCA), others are not.

Non-UCA collations have a one-to-one mapping from character code to weight. In MySQL, such collations are case insensitive and accent insensitive. `utf8_general_ci` is an example: `'a'`, `'A'`, `'À'`, and `'á'` each have different character codes but all have a weight of `0x0041` and compare as equal.

```
mysql> SET NAMES 'utf8' COLLATE 'utf8_general_ci';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT 'a' = 'A', 'a' = 'À', 'a' = 'á';
+-----------+-----------+-----------+
| 'a' = 'A' | 'a' = 'À' | 'a' = 'á' |
+-----------+-----------+-----------+
|         1 |         1 |         1 |
```

```
+-----------+-----------+-----------+
1 row in set (0.06 sec)
```

UCA-based collations in MySQL have these properties:

- If a character has weights, each weight uses 2 bytes (16 bits).
- A character may have zero weights (or an empty weight). In this case, the character is ignorable. Example: "U+0000 NULL" does not have a weight and is ignorable.
- A character may have one weight. Example: `'a'` has a weight of `0x0E33`.
- A character may have many weights. This is an expansion. Example: The German letter `'ß'` (SZ ligature, or SHARP S) has a weight of `0x0FEA0FEA`.
- Many characters may have one weight. This is a contraction. Example: `'ch'` is a single letter in Czech and has a weight of `0x0EE2`.

A many-characters-to-many-weights mapping is also possible (this is contraction with expansion), but is not supported by MySQL.

For implementation instructions, for a non-UCA collation, see Section 10.3, “Adding a Character Set”. For a UCA collation, see Section 10.4.4, “Adding a UCA Collation to a Unicode Character Set”.

Miscellaneous collations

There are also a few collations that do not fall into any of the previous categories.

10.4.2 Choosing a Collation ID

Each collation must have a unique ID. To add a collation, you must choose an ID value that is not currently used. The range of IDs from 1024 to 2047 is reserved for user-defined collations. Before MySQL 5.5, an ID must be chosen from the range 1 to 254. As of MySQL 5.5, the 254 limit is removed for `MyISAM` tables with the introduction of support for two-byte collation IDs. Two-byte collation ID support for `InnoDB` tables is not added until MySQL 5.6.3.

The collation ID that you choose will appear in these contexts:

- The `ID` column of the `INFORMATION_SCHEMA.COLLATIONS` table.
- The `Id` column of `SHOW COLLATION` output.
- The `charsetnr` member of the `MYSQL_FIELD` C API data structure.
- The `number` member of the `MY_CHARSET_INFO` data structure returned by the `mysql_get_character_set_info()` C API function.

To determine the largest currently used ID, issue the following statement:

```
mysql> SELECT MAX(ID) FROM INFORMATION_SCHEMA.COLLATIONS;
+---------+
| MAX(ID) |
+---------+
|     210 |
+---------+
```

To display a list of all currently used IDs, issue this statement:

```
mysql> SELECT ID FROM INFORMATION_SCHEMA.COLLATIONS ORDER BY ID;
+-----+
| ID  |
+-----+
|   1 |
|   2 |
```

```
| ... |
|  52 |
|  53 |
|  57 |
|  58 |
| ... |
|  98 |
|  99 |
| 128 |
| 129 |
| ... |
| 210 |
+-----+
```

Warning

Before MySQL 5.5, which provides for a range of user-defined collation IDs, you must choose an ID in the range from 1 to 254. In this case, if you upgrade MySQL, you may find that the collation ID you choose has been assigned to a collation included in the new MySQL distribution. In this case, you will need to choose a new value for your own collation.

In addition, before upgrading, you should save the configuration files that you change. If you upgrade in place, the process will replace the your modified files.

10.4.3 Adding a Simple Collation to an 8-Bit Character Set

This section describes how to add a simple collation for an 8-bit character set by writing the `<collation>` elements associated with a `<charset>` character set description in the MySQL `Index.xml` file. The procedure described here does not require recompiling MySQL. The example adds a collation named `latin1_test_ci` to the `latin1` character set.

1. Choose a collation ID, as shown in Section 10.4.2, “Choosing a Collation ID”. The following steps use an ID of 1024.

2. Modify the `Index.xml` and `latin1.xml` configuration files. These files are located in the directory named by the `character_sets_dir` system variable. You can check the variable value as follows, although the path name might be different on your system:

```
mysql> SHOW VARIABLES LIKE 'character_sets_dir';
+--------------------+----------------------------------------+
| Variable_name      | Value                                  |
+--------------------+----------------------------------------+
| character_sets_dir | /user/local/mysql/share/mysql/charsets/ |
+--------------------+----------------------------------------+
```

3. Choose a name for the collation and list it in the `Index.xml` file. Find the `<charset>` element for the character set to which the collation is being added, and add a `<collation>` element that indicates the collation name and ID, to associate the name with the ID. For example:

```
<charset name="latin1">
  ...
  <collation name="latin1_test_ci" id="1024"/>
  ...
</charset>
```

4. In the `latin1.xml` configuration file, add a `<collation>` element that names the collation and that contains a `<map>` element that defines a character code-to-weight mapping table for character codes 0 to 255. Each value within the `<map>` element must be a number in hexadecimal format.

```
<collation name="latin1_test_ci">
<map>
 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
```

```
 10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F
 20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F
 30 31 32 33 34 35 36 37 38 39 3A 3B 3C 3D 3E 3F
 40 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
 50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F
 60 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
 50 51 52 53 54 55 56 57 58 59 5A 7B 7C 7D 7E 7F
 80 81 82 83 84 85 86 87 88 89 8A 8B 8C 8D 8E 8F
 90 91 92 93 94 95 96 97 98 99 9A 9B 9C 9D 9E 9F
 A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 AA AB AC AD AE AF
 B0 B1 B2 B3 B4 B5 B6 B7 B8 B9 BA BB BC BD BE BF
 41 41 41 41 5B 5D 5B 43 45 45 45 45 49 49 49 49
 44 4E 4F 4F 4F 4F 5C D7 5C 55 55 55 59 59 DE DF
 41 41 41 41 5B 5D 5B 43 45 45 45 45 49 49 49 49
 44 4E 4F 4F 4F 4F 5C F7 5C 55 55 55 59 59 DE FF
</map>
</collation>
```

5. Restart the server and use this statement to verify that the collation is present:

```
mysql> SHOW COLLATION WHERE Collation = 'latin1_test_ci';
+----------------+---------+------+---------+----------+---------+
| Collation      | Charset | Id   | Default | Compiled | Sortlen |
+----------------+---------+------+---------+----------+---------+
| latin1_test_ci | latin1  | 1024 |         |          |       1 |
+----------------+---------+------+---------+----------+---------+
```

10.4.4 Adding a UCA Collation to a Unicode Character Set

This section describes how to add a UCA collation for a Unicode character set by writing the `<collation>` element within a `<charset>` character set description in the MySQL `Index.xml` file. The procedure described here does not require recompiling MySQL. It uses a subset of the Locale Data Markup Language (LDML) specification, which is available at http://www.unicode.org/reports/tr35/. With this method, you need not define the entire collation. Instead, you begin with an existing “base” collation and describe the new collation in terms of how it differs from the base collation. The following table lists the base collations of the Unicode character sets for which UCA collations can be defined.

Table 10.4 MySQL Character Sets Available for User-Defined UCA Collations

Character Set	Base Collation
`utf8`	`utf8_unicode_ci`
`ucs2`	`ucs2_unicode_ci`
`utf16`	`utf16_unicode_ci`
`utf32`	`utf32_unicode_ci`

The following sections show how to add a collation that is defined using LDML syntax, and provide a summary of LDML rules supported in MySQL.

10.4.4.1 Defining a UCA Collation Using LDML Syntax

To add a UCA collation for a Unicode character set without recompiling MySQL, use the following procedure. If you are unfamiliar with the LDML rules used to describe the collation's sort characteristics, see Section 10.4.4.2, “LDML Syntax Supported in MySQL”.

The example adds a collation named `utf8_phone_ci` to the `utf8` character set. The collation is designed for a scenario involving a Web application for which users post their names and phone numbers. Phone numbers can be given in very different formats:

```
+7-12345-67
+7-12-345-67
+7 12 345 67
+7 (12) 345 67
```

```
+71234567
```

The problem raised by dealing with these kinds of values is that the varying permissible formats make searching for a specific phone number very difficult. The solution is to define a new collation that reorders punctuation characters, making them ignorable.

1. Choose a collation ID, as shown in Section 10.4.2, “Choosing a Collation ID”. The following steps use an ID of 1029.

2. To modify the `Index.xml` configuration file. This file is located in the directory named by the `character_sets_dir` system variable. You can check the variable value as follows, although the path name might be different on your system:

```
mysql> SHOW VARIABLES LIKE 'character_sets_dir';
+--------------------+----------------------------------------+
| Variable_name      | Value                                  |
+--------------------+----------------------------------------+
| character_sets_dir | /user/local/mysql/share/mysql/charsets/ |
+--------------------+----------------------------------------+
```

3. Choose a name for the collation and list it in the `Index.xml` file. In addition, you'll need to provide the collation ordering rules. Find the `<charset>` element for the character set to which the collation is being added, and add a `<collation>` element that indicates the collation name and ID, to associate the name with the ID. Within the `<collation>` element, provide a `<rules>` element containing the ordering rules:

```
<charset name="utf8">
  ...
  <collation name="utf8_phone_ci" id="1029">
    <rules>
      <reset>\u0000</reset>
      <i>\u0020</i> <!-- space -->
      <i>\u0028</i> <!-- left parenthesis -->
      <i>\u0029</i> <!-- right parenthesis -->
      <i>\u002B</i> <!-- plus -->
      <i>\u002D</i> <!-- hyphen -->
    </rules>
  </collation>
  ...
</charset>
```

4. If you want a similar collation for other Unicode character sets, add other `<collation>` elements. For example, to define `ucs2_phone_ci`, add a `<collation>` element to the `<charset name="ucs2">` element. Remember that each collation must have its own unique ID.

5. Restart the server and use this statement to verify that the collation is present:

```
mysql> SHOW COLLATION WHERE Collation = 'utf8_phone_ci';
+---------------+---------+------+---------+----------+---------+
| Collation     | Charset | Id   | Default | Compiled | Sortlen |
+---------------+---------+------+---------+----------+---------+
| utf8_phone_ci | utf8    | 1029 |         |          |       8 |
+---------------+---------+------+---------+----------+---------+
```

Now test the collation to make sure that it has the desired properties.

Create a table containing some sample phone numbers using the new collation:

```
mysql> CREATE TABLE phonebook (
         name VARCHAR(64),
         phone VARCHAR(64) CHARACTER SET utf8 COLLATE utf8_phone_ci
       );
Query OK, 0 rows affected (0.09 sec)
```

```
mysql> INSERT INTO phonebook VALUES ('Svoj','+7 912 800 80 02');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO phonebook VALUES ('Hf','+7 (912) 800 80 04');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO phonebook VALUES ('Bar','+7-912-800-80-01');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO phonebook VALUES ('Ramil','(7912) 800 80 03');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO phonebook VALUES ('Sanja','+380 (912) 8008005');
Query OK, 1 row affected (0.00 sec)
```

Run some queries to see whether the ignored punctuation characters are in fact ignored for comparison and sorting:

```
mysql> SELECT * FROM phonebook ORDER BY phone;
+-------+--------------------+
| name  | phone              |
+-------+--------------------+
| Sanja | +380 (912) 8008005 |
| Bar   | +7-912-800-80-01   |
| Svoj  | +7 912 800 80 02   |
| Ramil | (7912) 800 80 03   |
| Hf    | +7 (912) 800 80 04 |
+-------+--------------------+
5 rows in set (0.00 sec)

mysql> SELECT * FROM phonebook WHERE phone='+7(912)800-80-01';
+------+------------------+
| name | phone            |
+------+------------------+
| Bar  | +7-912-800-80-01 |
+------+------------------+
1 row in set (0.00 sec)

mysql> SELECT * FROM phonebook WHERE phone='79128008001';
+------+------------------+
| name | phone            |
+------+------------------+
| Bar  | +7-912-800-80-01 |
+------+------------------+
1 row in set (0.00 sec)

mysql> SELECT * FROM phonebook WHERE phone='7 9 1 2 8 0 0 8 0 0 1';
+------+------------------+
| name | phone            |
+------+------------------+
| Bar  | +7-912-800-80-01 |
+------+------------------+
1 row in set (0.00 sec)
```

10.4.4.2 LDML Syntax Supported in MySQL

This section describes the LDML syntax that MySQL recognizes. This is a subset of the syntax described in the LDML specification available at http://www.unicode.org/reports/tr35/, which should be consulted for further information. The rules described here are all supported except that character sorting occurs only at the primary level. Rules that specify differences at secondary or higher sort levels are recognized (and thus can be included in collation definitions) but are treated as equality at the primary level.

Character Representation

Characters named in LDML rules can be written in `\u`*nnnn* format, where *nnnn* is the hexadecimal Unicode code point value. Within hexadecimal values, the digits `A` through `F` are not case sensitive; `\u00E1` and `\u00e1` are equivalent. Basic Latin letters `A-Z` and `a-z` can also be written literally (this

is a MySQL limitation; the LDML specification permits literal non-Latin1 characters in the rules). Only characters in the Basic Multilingual Plane can be specified. This notation does not apply to characters outside the BMP range of `0000` to `FFFF`.

The `Index.xml` file itself should be written using ASCII encoding.

Syntax Rules

LDML has reset rules and shift rules to specify character ordering. Orderings are given as a set of rules that begin with a reset rule that establishes an anchor point, followed by shift rules that indicate how characters sort relative to the anchor point.

- A `<reset>` rule does not specify any ordering in and of itself. Instead, it "resets" the ordering for subsequent shift rules to cause them to be taken in relation to a given character. Either of the following rules resets subsequent shift rules to be taken in relation to the letter `'A'`:

```
<reset>A</reset>

<reset>\u0041</reset>
```

- The `<p>`, `<s>`, and `<t>` shift rules define primary, secondary, and tertiary differences of a character from another character:

  - Use primary differences to distinguish separate letters.
  - Use secondary differences to distinguish accent variations.
  - Use tertiary differences to distinguish lettercase variations.

  Either of these rules specifies a primary shift rule for the `'G'` character:

```
<p>G</p>

<p>\u0047</p>
```

- The `<i>` shift rule indicates that one character sorts identically to another. The following rules cause `'b'` to sort the same as `'a'`:

```
<reset>a</reset>
<i>b</i>
```

  The `<i>` shift rules is supported as of MySQL 5.5.3. Prior to 5.5.3, use `<s> ... </s>` instead.

10.5 Character Set Configuration

You can change the default server character set and collation with the `--character-set-server` and `--collation-server` options when you start the server. The collation must be a legal collation for the default character set. (Use the `SHOW COLLATION` statement to determine which collations are available for each character set.) See Section 5.1.4, "Server Command Options".

If you try to use a character set that is not compiled into your binary, you might run into the following problems:

- Your program uses an incorrect path to determine where the character sets are stored (which is typically the `share/mysql/charsets` or `share/charsets` directory under the MySQL installation directory). This can be fixed by using the `--character-sets-dir` option when you run the program in question. For example, to specify a directory to be used by MySQL client programs, list it in the `[client]` group of your option file. The examples given here show what the setting might look like for Unix or Windows, respectively:

```
```

```
[client]
character-sets-dir=/usr/local/mysql/share/mysql/charsets

[client]
character-sets-dir="C:/Program Files/MySQL/MySQL Server 5.5/share/charsets"
```

- The character set is a complex character set that cannot be loaded dynamically. In this case, you must recompile the program with support for the character set.

  For Unicode character sets, you can define collations without recompiling by using LDML notation. See Section 10.4.4, “Adding a UCA Collation to a Unicode Character Set”.

- The character set is a dynamic character set, but you do not have a configuration file for it. In this case, you should install the configuration file for the character set from a new MySQL distribution.

- If your character set index file does not contain the name for the character set, your program displays an error message. The file is named `Index.xml` and the message is:

  ```
  Character set 'charset_name' is not a compiled character set and is not
  specified in the '/usr/share/mysql/charsets/Index.xml' file
  ```

  To solve this problem, you should either get a new index file or manually add the name of any missing character sets to the current file.

You can force client programs to use specific character set as follows:

```
[client]
default-character-set=charset_name
```

This is normally unnecessary. However, when `character_set_system` differs from `character_set_server` or `character_set_client`, and you input characters manually (as database object identifiers, column values, or both), these may be displayed incorrectly in output from the client or the output itself may be formatted incorrectly. In such cases, starting the mysql client with `--default-character-set=system_character_set`—that is, setting the client character set to match the system character set—should fix the problem.

For `MyISAM` tables, you can check the character set name and number for a table with `myisamchk -dvv tbl_name`.

10.6 MySQL Server Time Zone Support

MySQL Server maintains several time zone settings:

- The system time zone. When the server starts, it attempts to determine the time zone of the host machine and uses it to set the `system_time_zone` system variable. The value does not change thereafter.

  You can set the system time zone for MySQL Server at startup with the `--timezone=timezone_name` option to `mysqld_safe`. You can also set it by setting the `TZ` environment variable before you start `mysqld`. The permissible values for `--timezone` or `TZ` are system dependent. Consult your operating system documentation to see what values are acceptable.

- The server's current time zone. The global `time_zone` system variable indicates the time zone the server currently is operating in. The initial value for `time_zone` is `'SYSTEM'`, which indicates that the server time zone is the same as the system time zone.

Note

If set to `SYSTEM`, every MySQL function call that requires a timezone calculation makes a system library call to determine the current system

timezone. This call may be protected by a global mutex, resulting in contention.

The initial global server time zone value can be specified explicitly at startup with the `--default-time-zone=timezone` option on the command line, or you can use the following line in an option file:

```
default-time-zone='timezone'
```

If you have the `SUPER` privilege, you can set the global server time zone value at runtime with this statement:

```
mysql> SET GLOBAL time_zone = timezone;
```

- Per-connection time zones. Each client that connects has its own time zone setting, given by the session `time_zone` variable. Initially, the session variable takes its value from the global `time_zone` variable, but the client can change its own time zone with this statement:

```
mysql> SET time_zone = timezone;
```

The current session time zone setting affects display and storage of time values that are zone-sensitive. This includes the values displayed by functions such as `NOW()` or `CURTIME()`, and values stored in and retrieved from `TIMESTAMP` columns. Values for `TIMESTAMP` columns are converted from the current time zone to UTC for storage, and from UTC to the current time zone for retrieval.

The current time zone setting does not affect values displayed by functions such as `UTC_TIMESTAMP()` or values in `DATE`, `TIME`, or `DATETIME` columns. Nor are values in those data types stored in UTC; the time zone applies for them only when converting from `TIMESTAMP` values. If you want locale-specific arithmetic for `DATE`, `TIME`, or `DATETIME` values, convert them to UTC, perform the arithmetic, and then convert back.

The current values of the global and client-specific time zones can be retrieved like this:

```
mysql> SELECT @@global.time_zone, @@session.time_zone;
```

`timezone` values can be given in several formats, none of which are case sensitive:

- The value `'SYSTEM'` indicates that the time zone should be the same as the system time zone.
- The value can be given as a string indicating an offset from UTC, such as `'+10:00'` or `'-6:00'`.
- The value can be given as a named time zone, such as `'Europe/Helsinki'`, `'US/Eastern'`, or `'MET'`. Named time zones can be used only if the time zone information tables in the `mysql` database have been created and populated.

Populating the Time Zone Tables

Several tables in the `mysql` system database exist to maintain time zone information (see Section 5.3, “The mysql System Database”). The MySQL installation procedure creates the time zone tables, but does not load them. You must do so manually using the following instructions.

Note

Loading the time zone information is not necessarily a one-time operation because the information changes occasionally. When such changes occur, applications that use the old rules become out of date and you may find it necessary to reload the time zone tables to keep the information used by your MySQL server current. See the notes at the end of this section.

If your system has its own *zoneinfo* database (the set of files describing time zones), you should use the `mysql_tzinfo_to_sql` program for filling the time zone tables. Examples of such systems are Linux, FreeBSD, Solaris, and OS X. One likely location for these files is the `/usr/share/zoneinfo` directory. If your system does not have a zoneinfo database, you can use the downloadable package described later in this section.

The `mysql_tzinfo_to_sql` program is used to load the time zone tables. On the command line, pass the zoneinfo directory path name to `mysql_tzinfo_to_sql` and send the output into the `mysql` program. For example:

```
shell> mysql_tzinfo_to_sql /usr/share/zoneinfo | mysql -u root mysql
```

`mysql_tzinfo_to_sql` reads your system's time zone files and generates SQL statements from them. `mysql` processes those statements to load the time zone tables.

`mysql_tzinfo_to_sql` also can be used to load a single time zone file or to generate leap second information:

- To load a single time zone file *`tz_file`* that corresponds to a time zone name *`tz_name`*, invoke `mysql_tzinfo_to_sql` like this:

  ```
  shell> mysql_tzinfo_to_sql tz_file tz_name | mysql -u root mysql
  ```

  With this approach, you must execute a separate command to load the time zone file for each named zone that the server needs to know about.

- If your time zone needs to account for leap seconds, initialize the leap second information like this, where *`tz_file`* is the name of your time zone file:

  ```
  shell> mysql_tzinfo_to_sql --leap tz_file | mysql -u root mysql
  ```

- After running `mysql_tzinfo_to_sql`, it is best to restart the server so that it does not continue to use any previously cached time zone data.

If your system is one that has no zoneinfo database (for example, Windows), you can use a package that is available for download at the MySQL Developer Zone:

```
http://dev.mysql.com/downloads/timezones.html
```

You can use either a package that contains SQL statements to populate your existing time zone tables, or a package that contains pre-built `MyISAM` time zone tables to replace your existing tables:

- To use a time zone package that contains SQL statements, download and unpack it, then load the package file contents into your existing time zone tables:

  ```
  shell> mysql -u root mysql < file_name
  ```

  Then restart the server.

- To use a time zone package that contains `.frm`, `.MYD`, and `.MYI` files for the `MyISAM` time zone tables, download and unpack it. These table files are part of the `mysql` database, so you should place the files in the `mysql` subdirectory of your MySQL server's data directory. Stop the server before doing this and restart it afterward.

Warning

Do not use a downloadable package if your system has a zoneinfo database. Use the `mysql_tzinfo_to_sql` utility instead. Otherwise, you may cause a difference in datetime handling between MySQL and other applications on your system.

For information about time zone settings in replication setup, please see Section 17.4.1, “Replication Features and Issues”.

10.6.1 Staying Current with Time Zone Changes

When time zone rules change, applications that use the old rules become out of date. To stay current, it is necessary to make sure that your system uses current time zone information is used. For MySQL, there are two factors to consider in staying current:

- The operating system time affects the value that the MySQL server uses for times if its time zone is set to `SYSTEM`. Make sure that your operating system is using the latest time zone information. For most operating systems, the latest update or service pack prepares your system for the time changes. Check the Web site for your operating system vendor for an update that addresses the time changes.
- If you replace the system's `/etc/localtime` timezone file with a version that uses rules differing from those in effect at `mysqld` startup, you should restart `mysqld` so that it uses the updated rules. Otherwise, `mysqld` might not notice when the system changes its time.
- If you use named time zones with MySQL, make sure that the time zone tables in the `mysql` database are up to date. If your system has its own zoneinfo database, you should reload the MySQL time zone tables whenever the zoneinfo database is updated. For systems that do not have their own zoneinfo database, check the MySQL Developer Zone for updates. When a new update is available, download it and use it to replace the content of your current time zone tables. For instructions for both methods, see Populating the Time Zone Tables. `mysqld` caches time zone information that it looks up, so after updating the time zone tables, you should restart `mysqld` to make sure that it does not continue to serve outdated time zone data.

If you are uncertain whether named time zones are available, for use either as the server's time zone setting or by clients that set their own time zone, check whether your time zone tables are empty. The following query determines whether the table that contains time zone names has any rows:

```
mysql> SELECT COUNT(*) FROM mysql.time_zone_name;
+----------+
| COUNT(*) |
+----------+
|        0 |
+----------+
```

A count of zero indicates that the table is empty. In this case, no one can be using named time zones, and you don't need to update the tables. A count greater than zero indicates that the table is not empty and that its contents are available to be used for named time zone support. In this case, you should be sure to reload your time zone tables so that anyone who uses named time zones will get correct query results.

To check whether your MySQL installation is updated properly for a change in Daylight Saving Time rules, use a test like the one following. The example uses values that are appropriate for the 2007 DST 1-hour change that occurs in the United States on March 11 at 2 a.m.

The test uses these two queries:

```
SELECT CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central');
SELECT CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central');
```

The two time values indicate the times at which the DST change occurs, and the use of named time zones requires that the time zone tables be used. The desired result is that both queries return the same result (the input time, converted to the equivalent value in the 'US/Central' time zone).

Before updating the time zone tables, you would see an incorrect result like this:

```
mysql> SELECT CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central');
+-----------------------------------------------------------+
| CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central') |
+-----------------------------------------------------------+
| 2007-03-11 01:00:00                                       |
+-----------------------------------------------------------+

mysql> SELECT CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central');
+-----------------------------------------------------------+
| CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central') |
+-----------------------------------------------------------+
| 2007-03-11 02:00:00                                       |
+-----------------------------------------------------------+
```

After updating the tables, you should see the correct result:

```
mysql> SELECT CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central');
+-----------------------------------------------------------+
| CONVERT_TZ('2007-03-11 2:00:00','US/Eastern','US/Central') |
+-----------------------------------------------------------+
| 2007-03-11 01:00:00                                       |
+-----------------------------------------------------------+

mysql> SELECT CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central');
+-----------------------------------------------------------+
| CONVERT_TZ('2007-03-11 3:00:00','US/Eastern','US/Central') |
+-----------------------------------------------------------+
| 2007-03-11 01:00:00                                       |
+-----------------------------------------------------------+
```

10.6.2 Time Zone Leap Second Support

Leap second values are returned with a time part that ends with `:59:59`. This means that a function such as `NOW()` can return the same value for two or three consecutive seconds during the leap second. It remains true that literal temporal values having a time part that ends with `:59:60` or `:59:61` are considered invalid.

If it is necessary to search for `TIMESTAMP` values one second before the leap second, anomalous results may be obtained if you use a comparison with `'YYYY-MM-DD hh:mm:ss'` values. The following example demonstrates this. It changes the local time zone to UTC so there is no difference between internal values (which are in UTC) and displayed values (which have time zone correction applied).

```
mysql> CREATE TABLE t1 (
         a INT,
         ts TIMESTAMP DEFAULT NOW(),
         PRIMARY KEY (ts)
       );
Query OK, 0 rows affected (0.01 sec)

mysql> -- change to UTC
mysql> SET time_zone = '+00:00';
Query OK, 0 rows affected (0.00 sec)

mysql> -- Simulate NOW() = '2008-12-31 23:59:59'
mysql> SET timestamp = 1230767999;
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t1 (a) VALUES (1);
Query OK, 1 row affected (0.00 sec)

mysql> -- Simulate NOW() = '2008-12-31 23:59:60'
mysql> SET timestamp = 1230768000;
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t1 (a) VALUES (2);
Query OK, 1 row affected (0.00 sec)
```

```
mysql> -- values differ internally but display the same
mysql> SELECT a, ts, UNIX_TIMESTAMP(ts) FROM t1;
+------+---------------------+--------------------+
| a    | ts                  | UNIX_TIMESTAMP(ts) |
+------+---------------------+--------------------+
|    1 | 2008-12-31 23:59:59 |         1230767999 |
|    2 | 2008-12-31 23:59:59 |         1230768000 |
+------+---------------------+--------------------+
2 rows in set (0.00 sec)

mysql> -- only the non-leap value matches
mysql> SELECT * FROM t1 WHERE ts = '2008-12-31 23:59:59';
+------+---------------------+
| a    | ts                  |
+------+---------------------+
|    1 | 2008-12-31 23:59:59 |
+------+---------------------+
1 row in set (0.00 sec)

mysql> -- the leap value with seconds=60 is invalid
mysql> SELECT * FROM t1 WHERE ts = '2008-12-31 23:59:60';
Empty set, 2 warnings (0.00 sec)
```

To work around this, you can use a comparison based on the UTC value actually stored in column, which has the leap second correction applied:

```
mysql> -- selecting using UNIX_TIMESTAMP value return leap value
mysql> SELECT * FROM t1 WHERE UNIX_TIMESTAMP(ts) = 1230768000;
+------+---------------------+
| a    | ts                  |
+------+---------------------+
|    2 | 2008-12-31 23:59:59 |
+------+---------------------+
1 row in set (0.00 sec)
```

10.7 MySQL Server Locale Support

The locale indicated by the `lc_time_names` system variable controls the language used to display day and month names and abbreviations. This variable affects the output from the `DATE_FORMAT()`, `DAYNAME()`, and `MONTHNAME()` functions.

`lc_time_names` does not affect the `STR_TO_DATE()` or `GET_FORMAT()` function.

The `lc_time_names` value does not affect the result from `FORMAT()`, but this function takes an optional third parameter that enables a locale to be specified to be used for the result number's decimal point, thousands separator, and grouping between separators. Permissible locale values are the same as the legal values for the `lc_time_names` system variable.

Locale names have language and region subtags listed by IANA (http://www.iana.org/assignments/language-subtag-registry) such as `'ja_JP'` or `'pt_BR'`. The default value is `'en_US'` regardless of your system's locale setting, but you can set the value at server startup or set the `GLOBAL` value if you have the `SUPER` privilege. Any client can examine the value of `lc_time_names` or set its `SESSION` value to affect the locale for its own connection.

```
mysql> SET NAMES 'utf8';
Query OK, 0 rows affected (0.09 sec)

mysql> SELECT @@lc_time_names;
+-----------------+
| @@lc_time_names |
+-----------------+
| en_US           |
+-----------------+
1 row in set (0.00 sec)
```

```
mysql> SELECT DAYNAME('2010-01-01'), MONTHNAME('2010-01-01');
+----------------------+------------------------+
| DAYNAME('2010-01-01') | MONTHNAME('2010-01-01') |
+----------------------+------------------------+
| Friday                | January                |
+----------------------+------------------------+
1 row in set (0.00 sec)

mysql> SELECT DATE_FORMAT('2010-01-01','%W %a %M %b');
+----------------------------------------+
| DATE_FORMAT('2010-01-01','%W %a %M %b') |
+----------------------------------------+
| Friday Fri January Jan                  |
+----------------------------------------+
1 row in set (0.00 sec)

mysql> SET lc_time_names = 'es_MX';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @@lc_time_names;
+-----------------+
| @@lc_time_names |
+-----------------+
| es_MX           |
+-----------------+
1 row in set (0.00 sec)

mysql> SELECT DAYNAME('2010-01-01'), MONTHNAME('2010-01-01');
+----------------------+------------------------+
| DAYNAME('2010-01-01') | MONTHNAME('2010-01-01') |
+----------------------+------------------------+
| viernes               | enero                  |
+----------------------+------------------------+
1 row in set (0.00 sec)

mysql> SELECT DATE_FORMAT('2010-01-01','%W %a %M %b');
+----------------------------------------+
| DATE_FORMAT('2010-01-01','%W %a %M %b') |
+----------------------------------------+
| viernes vie enero ene                   |
+----------------------------------------+
1 row in set (0.00 sec)
```

The day or month name for each of the affected functions is converted from `utf8` to the character set indicated by the `character_set_connection` system variable.

`lc_time_names` may be set to any of the following locale values. The set of locales supported by MySQL may differ from those supported by your operating system.

`ar_AE`: Arabic - United Arab Emirates	`ar_BH`: Arabic - Bahrain
`ar_DZ`: Arabic - Algeria	`ar_EG`: Arabic - Egypt
`ar_IN`: Arabic - India	`ar_IQ`: Arabic - Iraq
`ar_JO`: Arabic - Jordan	`ar_KW`: Arabic - Kuwait
`ar_LB`: Arabic - Lebanon	`ar_LY`: Arabic - Libya
`ar_MA`: Arabic - Morocco	`ar_OM`: Arabic - Oman
`ar_QA`: Arabic - Qatar	`ar_SA`: Arabic - Saudi Arabia
`ar_SD`: Arabic - Sudan	`ar_SY`: Arabic - Syria
`ar_TN`: Arabic - Tunisia	`ar_YE`: Arabic - Yemen
`be_BY`: Belarusian - Belarus	`bg_BG`: Bulgarian - Bulgaria
`ca_ES`: Catalan - Spain	`cs_CZ`: Czech - Czech Republic
`da_DK`: Danish - Denmark	`de_AT`: German - Austria
`de_BE`: German - Belgium	`de_CH`: German - Switzerland

de_DE: German - Germany	de_LU: German - Luxembourg
el_GR: Greek - Greece	en_AU: English - Australia
en_CA: English - Canada	en_GB: English - United Kingdom
en_IN: English - India	en_NZ: English - New Zealand
en_PH: English - Philippines	en_US: English - United States
en_ZA: English - South Africa	en_ZW: English - Zimbabwe
es_AR: Spanish - Argentina	es_BO: Spanish - Bolivia
es_CL: Spanish - Chile	es_CO: Spanish - Columbia
es_CR: Spanish - Costa Rica	es_DO: Spanish - Dominican Republic
es_EC: Spanish - Ecuador	es_ES: Spanish - Spain
es_GT: Spanish - Guatemala	es_HN: Spanish - Honduras
es_MX: Spanish - Mexico	es_NI: Spanish - Nicaragua
es_PA: Spanish - Panama	es_PE: Spanish - Peru
es_PR: Spanish - Puerto Rico	es_PY: Spanish - Paraguay
es_SV: Spanish - El Salvador	es_US: Spanish - United States
es_UY: Spanish - Uruguay	es_VE: Spanish - Venezuela
et_EE: Estonian - Estonia	eu_ES: Basque - Basque
fi_FI: Finnish - Finland	fo_FO: Faroese - Faroe Islands
fr_BE: French - Belgium	fr_CA: French - Canada
fr_CH: French - Switzerland	fr_FR: French - France
fr_LU: French - Luxembourg	gl_ES: Galician - Spain
gu_IN: Gujarati - India	he_IL: Hebrew - Israel
hi_IN: Hindi - India	hr_HR: Croatian - Croatia
hu_HU: Hungarian - Hungary	id_ID: Indonesian - Indonesia
is_IS: Icelandic - Iceland	it_CH: Italian - Switzerland
it_IT: Italian - Italy	ja_JP: Japanese - Japan
ko_KR: Korean - Republic of Korea	lt_LT: Lithuanian - Lithuania
lv_LV: Latvian - Latvia	mk_MK: Macedonian - FYROM
mn_MN: Mongolia - Mongolian	ms_MY: Malay - Malaysia
nb_NO: Norwegian(Bokmål) - Norway	nl_BE: Dutch - Belgium
nl_NL: Dutch - The Netherlands	no_NO: Norwegian - Norway
pl_PL: Polish - Poland	pt_BR: Portugese - Brazil
pt_PT: Portugese - Portugal	ro_RO: Romanian - Romania
ru_RU: Russian - Russia	ru_UA: Russian - Ukraine
sk_SK: Slovak - Slovakia	sl_SI: Slovenian - Slovenia
sq_AL: Albanian - Albania	sr_RS: Serbian - Yugoslavia
sv_FI: Swedish - Finland	sv_SE: Swedish - Sweden
ta_IN: Tamil - India	te_IN: Telugu - India
th_TH: Thai - Thailand	tr_TR: Turkish - Turkey
uk_UA: Ukrainian - Ukraine	ur_PK: Urdu - Pakistan
vi_VN: Vietnamese - Viet Nam	zh_CN: Chinese - China
zh_HK: Chinese - Hong Kong	zh_TW: Chinese - Taiwan Province of China

Chapter 11 Data Types

Table of Contents

11.1 Data Type Overview 1084
11.1.1 Numeric Type Overview 1084
11.1.2 Date and Time Type Overview 1087
11.1.3 String Type Overview 1088
11.2 Numeric Types 1092
11.2.1 Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT 1092
11.2.2 Fixed-Point Types (Exact Value) - DECIMAL, NUMERIC 1092
11.2.3 Floating-Point Types (Approximate Value) - FLOAT, DOUBLE 1093
11.2.4 Bit-Value Type - BIT 1093
11.2.5 Numeric Type Attributes 1094
11.2.6 Out-of-Range and Overflow Handling 1095
11.3 Date and Time Types 1096
11.3.1 The DATE, DATETIME, and TIMESTAMP Types 1097
11.3.2 The TIME Type 1099
11.3.3 The YEAR Type 1099
11.3.4 YEAR(2) Limitations and Migrating to YEAR(4) 1100
11.3.5 Automatic Initialization and Updating for TIMESTAMP 1101
11.3.6 Fractional Seconds in Time Values 1104
11.3.7 Conversion Between Date and Time Types 1105
11.3.8 Two-Digit Years in Dates 1105
11.4 String Types 1106
11.4.1 The CHAR and VARCHAR Types 1106
11.4.2 The BINARY and VARBINARY Types 1108
11.4.3 The BLOB and TEXT Types 1109
11.4.4 The ENUM Type 1110
11.4.5 The SET Type 1113
11.5 Spatial Data Types 1115
11.5.1 Spatial Data Types 1117
11.5.2 The OpenGIS Geometry Model 1118
11.5.3 Supported Spatial Data Formats 1123
11.5.4 Creating Spatial Columns 1126
11.5.5 Populating Spatial Columns 1126
11.5.6 Fetching Spatial Data 1127
11.5.7 Optimizing Spatial Analysis 1128
11.5.8 Creating Spatial Indexes 1128
11.5.9 Using Spatial Indexes 1129
11.6 Data Type Default Values 1131
11.7 Data Type Storage Requirements 1132
11.8 Choosing the Right Type for a Column 1136
11.9 Using Data Types from Other Database Engines 1136

MySQL supports a number of SQL data types in several categories: numeric types, date and time types, string (character and byte) types, and spatial types. This chapter provides an overview of these data types, a more detailed description of the properties of the types in each category, and a summary of the data type storage requirements. The initial overview is intentionally brief. The more detailed descriptions later in the chapter should be consulted for additional information about particular data types, such as the permissible formats in which you can specify values.

Data type descriptions use these conventions:

- *M* indicates the maximum display width for integer types. For floating-point and fixed-point types, *M* is the total number of digits that can be stored (the precision). For string types, *M* is the maximum length. The maximum permissible value of *M* depends on the data type.
- *D* applies to floating-point and fixed-point types and indicates the number of digits following the decimal point (the scale). The maximum possible value is 30, but should be no greater than *M*−2.
- Square brackets ([and]) indicate optional parts of type definitions.

11.1 Data Type Overview

11.1.1 Numeric Type Overview

A summary of the numeric data types follows. For additional information about properties and storage requirements of the numeric types, see Section 11.2, “Numeric Types”, and Section 11.7, “Data Type Storage Requirements”.

M indicates the maximum display width for integer types. The maximum display width is 255. Display width is unrelated to the range of values a type can contain, as described in Section 11.2, “Numeric Types”. For floating-point and fixed-point types, *M* is the total number of digits that can be stored.

If you specify ZEROFILL for a numeric column, MySQL automatically adds the UNSIGNED attribute to the column.

Numeric data types that permit the UNSIGNED attribute also permit SIGNED. However, these data types are signed by default, so the SIGNED attribute has no effect.

SERIAL is an alias for BIGINT UNSIGNED NOT NULL AUTO_INCREMENT UNIQUE.

SERIAL DEFAULT VALUE in the definition of an integer column is an alias for NOT NULL AUTO_INCREMENT UNIQUE.

Warning

When you use subtraction between integer values where one is of type UNSIGNED, the result is unsigned unless the NO_UNSIGNED_SUBTRACTION SQL mode is enabled. See Section 12.10, “Cast Functions and Operators”.

- BIT[(*M*)]

  A bit-value type. *M* indicates the number of bits per value, from 1 to 64. The default is 1 if *M* is omitted.

- TINYINT[(*M*)] [UNSIGNED] [ZEROFILL]

  A very small integer. The signed range is -128 to 127. The unsigned range is 0 to 255.

- BOOL, BOOLEAN

  These types are synonyms for TINYINT(1). A value of zero is considered false. Nonzero values are considered true:

```
mysql> SELECT IF(0, 'true', 'false');
+-----------------------+
| IF(0, 'true', 'false') |
+-----------------------+
| false                 |
+-----------------------+

mysql> SELECT IF(1, 'true', 'false');
+-----------------------+
```

```
| IF(1, 'true', 'false') |
+------------------------+
| true                   |
+------------------------+

mysql> SELECT IF(2, 'true', 'false');
+------------------------+
| IF(2, 'true', 'false') |
+------------------------+
| true                   |
+------------------------+
```

However, the values `TRUE` and `FALSE` are merely aliases for `1` and `0`, respectively, as shown here:

```
mysql> SELECT IF(0 = FALSE, 'true', 'false');
+--------------------------------+
| IF(0 = FALSE, 'true', 'false') |
+--------------------------------+
| true                           |
+--------------------------------+

mysql> SELECT IF(1 = TRUE, 'true', 'false');
+-------------------------------+
| IF(1 = TRUE, 'true', 'false') |
+-------------------------------+
| true                          |
+-------------------------------+

mysql> SELECT IF(2 = TRUE, 'true', 'false');
+-------------------------------+
| IF(2 = TRUE, 'true', 'false') |
+-------------------------------+
| false                         |
+-------------------------------+

mysql> SELECT IF(2 = FALSE, 'true', 'false');
+--------------------------------+
| IF(2 = FALSE, 'true', 'false') |
+--------------------------------+
| false                          |
+--------------------------------+
```

The last two statements display the results shown because `2` is equal to neither `1` nor `0`.

- `SMALLINT[(M)] [UNSIGNED] [ZEROFILL]`

  A small integer. The signed range is `-32768` to `32767`. The unsigned range is `0` to `65535`.

- `MEDIUMINT[(M)] [UNSIGNED] [ZEROFILL]`

  A medium-sized integer. The signed range is `-8388608` to `8388607`. The unsigned range is `0` to `16777215`.

- `INT[(M)] [UNSIGNED] [ZEROFILL]`

  A normal-size integer. The signed range is `-2147483648` to `2147483647`. The unsigned range is `0` to `4294967295`.

- `INTEGER[(M)] [UNSIGNED] [ZEROFILL]`

  This type is a synonym for `INT`.

- `BIGINT[(M)] [UNSIGNED] [ZEROFILL]`

  A large integer. The signed range is `-9223372036854775808` to `9223372036854775807`. The unsigned range is `0` to `18446744073709551615`.

  `SERIAL` is an alias for `BIGINT UNSIGNED NOT NULL AUTO_INCREMENT UNIQUE`.

Some things you should be aware of with respect to `BIGINT` columns:

- All arithmetic is done using signed `BIGINT` or `DOUBLE` values, so you should not use unsigned big integers larger than `9223372036854775807` (63 bits) except with bit functions! If you do that, some of the last digits in the result may be wrong because of rounding errors when converting a `BIGINT` value to a `DOUBLE`.

  MySQL can handle `BIGINT` in the following cases:

  - When using integers to store large unsigned values in a `BIGINT` column.
  - In `MIN(col_name)` or `MAX(col_name)`, where `col_name` refers to a `BIGINT` column.
  - When using operators (`+`, `-`, `*`, and so on) where both operands are integers.

- You can always store an exact integer value in a `BIGINT` column by storing it using a string. In this case, MySQL performs a string-to-number conversion that involves no intermediate double-precision representation.
- The `-`, `+`, and `*` operators use `BIGINT` arithmetic when both operands are integer values. This means that if you multiply two big integers (or results from functions that return integers), you may get unexpected results when the result is larger than `9223372036854775807`.

- `DECIMAL[(M[,D])] [UNSIGNED] [ZEROFILL]`

  A packed “exact” fixed-point number. *`M`* is the total number of digits (the precision) and *`D`* is the number of digits after the decimal point (the scale). The decimal point and (for negative numbers) the `-` sign are not counted in *`M`*. If *`D`* is 0, values have no decimal point or fractional part. The maximum number of digits (*`M`*) for `DECIMAL` is 65. The maximum number of supported decimals (*`D`*) is 30. If *`D`* is omitted, the default is 0. If *`M`* is omitted, the default is 10.

  `UNSIGNED`, if specified, disallows negative values.

  All basic calculations (`+, -, *, /`) with `DECIMAL` columns are done with a precision of 65 digits.

- `DEC[(M[,D])] [UNSIGNED] [ZEROFILL]`, `NUMERIC[(M[,D])] [UNSIGNED] [ZEROFILL]`, `FIXED[(M[,D])] [UNSIGNED] [ZEROFILL]`

  These types are synonyms for `DECIMAL`. The `FIXED` synonym is available for compatibility with other database systems.

- `FLOAT[(M,D)] [UNSIGNED] [ZEROFILL]`

  A small (single-precision) floating-point number. Permissible values are `-3.402823466E+38` to `-1.175494351E-38`, `0`, and `1.175494351E-38` to `3.402823466E+38`. These are the theoretical limits, based on the IEEE standard. The actual range might be slightly smaller depending on your hardware or operating system.

  `M` is the total number of digits and *`D`* is the number of digits following the decimal point. If *`M`* and *`D`* are omitted, values are stored to the limits permitted by the hardware. A single-precision floating-point number is accurate to approximately 7 decimal places.

  `UNSIGNED`, if specified, disallows negative values.

  Using `FLOAT` might give you some unexpected problems because all calculations in MySQL are done with double precision. See Section B.5.4.7, “Solving Problems with No Matching Rows”.

- `DOUBLE[(M,D)] [UNSIGNED] [ZEROFILL]`

  A normal-size (double-precision) floating-point number. Permissible values are `-1.7976931348623157E+308` to `-2.2250738585072014E-308`, `0`, and

2.2250738585072014E-308 to 1.7976931348623157E+308. These are the theoretical limits, based on the IEEE standard. The actual range might be slightly smaller depending on your hardware or operating system.

M is the total number of digits and *D* is the number of digits following the decimal point. If *M* and *D* are omitted, values are stored to the limits permitted by the hardware. A double-precision floating-point number is accurate to approximately 15 decimal places.

UNSIGNED, if specified, disallows negative values.

- DOUBLE PRECISION[(*M*,*D*)] [UNSIGNED] [ZEROFILL], REAL[(*M*,*D*)] [UNSIGNED] [ZEROFILL]

  These types are synonyms for DOUBLE. Exception: If the REAL_AS_FLOAT SQL mode is enabled, REAL is a synonym for FLOAT rather than DOUBLE.

- FLOAT(*p*) [UNSIGNED] [ZEROFILL]

  A floating-point number. *p* represents the precision in bits, but MySQL uses this value only to determine whether to use FLOAT or DOUBLE for the resulting data type. If *p* is from 0 to 24, the data type becomes FLOAT with no *M* or *D* values. If *p* is from 25 to 53, the data type becomes DOUBLE with no *M* or *D* values. The range of the resulting column is the same as for the single-precision FLOAT or double-precision DOUBLE data types described earlier in this section.

  FLOAT(*p*) syntax is provided for ODBC compatibility.

11.1.2 Date and Time Type Overview

A summary of the temporal data types follows. For additional information about properties and storage requirements of the temporal types, see Section 11.3, “Date and Time Types”, and Section 11.7, “Data Type Storage Requirements”. For descriptions of functions that operate on temporal values, see Section 12.7, “Date and Time Functions”.

For the DATE and DATETIME range descriptions, “supported” means that although earlier values might work, there is no guarantee.

- DATE

  A date. The supported range is '1000-01-01' to '9999-12-31'. MySQL displays DATE values in 'YYYY-MM-DD' format, but permits assignment of values to DATE columns using either strings or numbers.

- DATETIME

  A date and time combination. The supported range is '1000-01-01 00:00:00' to '9999-12-31 23:59:59'. MySQL displays DATETIME values in 'YYYY-MM-DD HH:MM:SS' format, but permits assignment of values to DATETIME columns using either strings or numbers.

- TIMESTAMP

  A timestamp. The range is '1970-01-01 00:00:01' UTC to '2038-01-19 03:14:07' UTC. TIMESTAMP values are stored as the number of seconds since the epoch ('1970-01-01 00:00:00' UTC). A TIMESTAMP cannot represent the value '1970-01-01 00:00:00' because that is equivalent to 0 seconds from the epoch and the value 0 is reserved for representing '0000-00-00 00:00:00', the “zero” TIMESTAMP value.

  Unless specified otherwise, the first TIMESTAMP column in a table is defined to be automatically set to the date and time of the most recent modification if not explicitly assigned a value. This makes TIMESTAMP useful for recording the timestamp of an INSERT or UPDATE operation. You can also set any TIMESTAMP column to the current date and time by assigning it a NULL value, unless it has been defined with the NULL attribute to permit NULL values. The automatic initialization and

updating to the current date and time can be specified using `DEFAULT CURRENT_TIMESTAMP` and `ON UPDATE CURRENT_TIMESTAMP` clauses, as described in Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”.

- `TIME`

  A time. The range is `'-838:59:59'` to `'838:59:59'`. MySQL displays `TIME` values in `'HH:MM:SS'` format, but permits assignment of values to `TIME` columns using either strings or numbers.

- `YEAR[(2|4)]`

  A year in two-digit or four-digit format. The default is four-digit format. `YEAR(2)` or `YEAR(4)` differ in display format, but have the same range of values. In four-digit format, values display as `1901` to `2155`, and `0000`. In two-digit format, values display as `70` to `69`, representing years from 1970 to 2069. MySQL displays `YEAR` values in `YYYY` or `YY` format, but permits assignment of values to `YEAR` columns using either strings or numbers.

Note

The `YEAR(2)` data type has certain issues that you should consider before choosing to use it. As of MySQL 5.5.27, `YEAR(2)` is deprecated. For more information, see Section 11.3.4, “YEAR(2) Limitations and Migrating to YEAR(4)”.

  For additional information about `YEAR` display format and interpretation of input values, see Section 11.3.3, “The YEAR Type”.

The `SUM()` and `AVG()` aggregate functions do not work with temporal values. (They convert the values to numbers, losing everything after the first nonnumeric character.) To work around this problem, convert to numeric units, perform the aggregate operation, and convert back to a temporal value. Examples:

```
SELECT SEC_TO_TIME(SUM(TIME_TO_SEC(time_col))) FROM tbl_name;
SELECT FROM_DAYS(SUM(TO_DAYS(date_col))) FROM tbl_name;
```

Note

The MySQL server can be run with the `MAXDB` SQL mode enabled. In this case, `TIMESTAMP` is identical with `DATETIME`. If this mode is enabled at the time that a table is created, `TIMESTAMP` columns are created as `DATETIME` columns. As a result, such columns use `DATETIME` display format, have the same range of values, and there is no automatic initialization or updating to the current date and time. See Section 5.1.8, “Server SQL Modes”.

11.1.3 String Type Overview

A summary of the string data types follows. For additional information about properties and storage requirements of the string types, see Section 11.4, “String Types”, and Section 11.7, “Data Type Storage Requirements”.

In some cases, MySQL may change a string column to a type different from that given in a `CREATE TABLE` or `ALTER TABLE` statement. See Section 13.1.17.7, “Silent Column Specification Changes”.

MySQL interprets length specifications in character column definitions in character units. This applies to `CHAR`, `VARCHAR`, and the `TEXT` types.

Column definitions for many string data types can include attributes that specify the character set or collation of the column. These attributes apply to the `CHAR`, `VARCHAR`, the `TEXT` types, `ENUM`, and `SET` data types:

- The `CHARACTER SET` attribute specifies the character set, and the `COLLATE` attribute specifies a collation for the character set. For example:

```
CREATE TABLE t
(
    c1 VARCHAR(20) CHARACTER SET utf8,
    c2 TEXT CHARACTER SET latin1 COLLATE latin1_general_cs
);
```

  This table definition creates a column named `c1` that has a character set of `utf8` with the default collation for that character set, and a column named `c2` that has a character set of `latin1` and a case-sensitive collation.

  The rules for assigning the character set and collation when either or both of the `CHARACTER SET` and `COLLATE` attributes are missing are described in Section 10.1.3.5, “Column Character Set and Collation”.

  `CHARSET` is a synonym for `CHARACTER SET`.

- Specifying the `CHARACTER SET binary` attribute for a character string data type causes the column to be created as the corresponding binary string data type: `CHAR` becomes `BINARY`, `VARCHAR` becomes `VARBINARY`, and `TEXT` becomes `BLOB`. For the `ENUM` and `SET` data types, this does not occur; they are created as declared. Suppose that you specify a table using this definition:

```
CREATE TABLE t
(
  c1 VARCHAR(10) CHARACTER SET binary,
  c2 TEXT CHARACTER SET binary,
  c3 ENUM('a','b','c') CHARACTER SET binary
);
```

  The resulting table has this definition:

```
CREATE TABLE t
(
  c1 VARBINARY(10),
  c2 BLOB,
  c3 ENUM('a','b','c') CHARACTER SET binary
);
```

- The `BINARY` attribute is shorthand for specifying the table default character set and the binary (`_bin`) collation of that character set. In this case, comparison and sorting are based on numeric character code values.

- The `ASCII` attribute is shorthand for `CHARACTER SET latin1`.

- The `UNICODE` attribute is shorthand for `CHARACTER SET ucs2`.

Character column comparison and sorting are based on the collation assigned to the column. For the `CHAR`, `VARCHAR`, `TEXT`, `ENUM`, and `SET` data types, you can declare a column with a binary (`_bin`) collation or the `BINARY` attribute to cause comparison and sorting to use the underlying character code values rather than a lexical ordering.

For additional information about use of character sets in MySQL, see Section 10.1, “Character Set Support”.

- `[NATIONAL] CHAR[(M)] [CHARACTER SET charset_name] [COLLATE collation_name]`

  A fixed-length string that is always right-padded with spaces to the specified length when stored. *`M`* represents the column length in characters. The range of *`M`* is 0 to 255. If *`M`* is omitted, the length is 1.

Note

Trailing spaces are removed when `CHAR` values are retrieved unless the `PAD_CHAR_TO_FULL_LENGTH` SQL mode is enabled.

`CHAR` is shorthand for `CHARACTER`. `NATIONAL CHAR` (or its equivalent short form, `NCHAR`) is the standard SQL way to define that a `CHAR` column should use some predefined character set. MySQL uses `utf8` as this predefined character set. Section 10.1.3.7, “The National Character Set”.

The `CHAR BYTE` data type is an alias for the `BINARY` data type. This is a compatibility feature.

MySQL permits you to create a column of type `CHAR(0)`. This is useful primarily when you have to be compliant with old applications that depend on the existence of a column but that do not actually use its value. `CHAR(0)` is also quite nice when you need a column that can take only two values: A column that is defined as `CHAR(0) NULL` occupies only one bit and can take only the values `NULL` and `''` (the empty string).

- `[NATIONAL] VARCHAR(M) [CHARACTER SET charset_name] [COLLATE collation_name]`

  A variable-length string. *`M`* represents the maximum column length in characters. The range of *`M`* is 0 to 65,535. The effective maximum length of a `VARCHAR` is subject to the maximum row size (65,535 bytes, which is shared among all columns) and the character set used. For example, `utf8` characters can require up to three bytes per character, so a `VARCHAR` column that uses the `utf8` character set can be declared to be a maximum of 21,844 characters. See Section C.10.4, “Limits on Table Column Count and Row Size”.

  MySQL stores `VARCHAR` values as a 1-byte or 2-byte length prefix plus data. The length prefix indicates the number of bytes in the value. A `VARCHAR` column uses one length byte if values require no more than 255 bytes, two length bytes if values may require more than 255 bytes.

  Note

  MySQL follows the standard SQL specification, and does *not* remove trailing spaces from `VARCHAR` values.

  `VARCHAR` is shorthand for `CHARACTER VARYING`. `NATIONAL VARCHAR` is the standard SQL way to define that a `VARCHAR` column should use some predefined character set. MySQL uses `utf8` as this predefined character set. Section 10.1.3.7, “The National Character Set”. `NVARCHAR` is shorthand for `NATIONAL VARCHAR`.

- `BINARY[(M)]`

  The `BINARY` type is similar to the `CHAR` type, but stores binary byte strings rather than nonbinary character strings. An optional length *`M`* represents the column length in bytes. If omitted, *`M`* defaults to 1.

- `VARBINARY(M)`

  The `VARBINARY` type is similar to the `VARCHAR` type, but stores binary byte strings rather than nonbinary character strings. *`M`* represents the maximum column length in bytes.

- `TINYBLOB`

  A `BLOB` column with a maximum length of 255 (2^8 − 1) bytes. Each `TINYBLOB` value is stored using a 1-byte length prefix that indicates the number of bytes in the value.

- `TINYTEXT [CHARACTER SET charset_name] [COLLATE collation_name]`

A `TEXT` column with a maximum length of 255 ($2^8 - 1$) characters. The effective maximum length is less if the value contains multibyte characters. Each `TINYTEXT` value is stored using a 1-byte length prefix that indicates the number of bytes in the value.

- `BLOB[(M)]`

  A `BLOB` column with a maximum length of 65,535 ($2^{16} - 1$) bytes. Each `BLOB` value is stored using a 2-byte length prefix that indicates the number of bytes in the value.

  An optional length *`M`* can be given for this type. If this is done, MySQL creates the column as the smallest `BLOB` type large enough to hold values *`M`* bytes long.

- `TEXT[(M)] [CHARACTER SET charset_name] [COLLATE collation_name]`

  A `TEXT` column with a maximum length of 65,535 ($2^{16} - 1$) characters. The effective maximum length is less if the value contains multibyte characters. Each `TEXT` value is stored using a 2-byte length prefix that indicates the number of bytes in the value.

  An optional length *`M`* can be given for this type. If this is done, MySQL creates the column as the smallest `TEXT` type large enough to hold values *`M`* characters long.

- `MEDIUMBLOB`

  A `BLOB` column with a maximum length of 16,777,215 ($2^{24} - 1$) bytes. Each `MEDIUMBLOB` value is stored using a 3-byte length prefix that indicates the number of bytes in the value.

- `MEDIUMTEXT [CHARACTER SET charset_name] [COLLATE collation_name]`

  A `TEXT` column with a maximum length of 16,777,215 ($2^{24} - 1$) characters. The effective maximum length is less if the value contains multibyte characters. Each `MEDIUMTEXT` value is stored using a 3-byte length prefix that indicates the number of bytes in the value.

- `LONGBLOB`

  A `BLOB` column with a maximum length of 4,294,967,295 or 4GB ($2^{32} - 1$) bytes. The effective maximum length of `LONGBLOB` columns depends on the configured maximum packet size in the client/server protocol and available memory. Each `LONGBLOB` value is stored using a 4-byte length prefix that indicates the number of bytes in the value.

- `LONGTEXT [CHARACTER SET charset_name] [COLLATE collation_name]`

  A `TEXT` column with a maximum length of 4,294,967,295 or 4GB ($2^{32} - 1$) characters. The effective maximum length is less if the value contains multibyte characters. The effective maximum length of `LONGTEXT` columns also depends on the configured maximum packet size in the client/server protocol and available memory. Each `LONGTEXT` value is stored using a 4-byte length prefix that indicates the number of bytes in the value.

- `ENUM('value1','value2',...) [CHARACTER SET charset_name] [COLLATE collation_name]`

  An enumeration. A string object that can have only one value, chosen from the list of values `'value1'`, `'value2'`, `...`, `NULL` or the special `''` error value. `ENUM` values are represented internally as integers.

  An `ENUM` column can have a maximum of 65,535 distinct elements. (The practical limit is less than 3000.) A table can have no more than 255 unique element list definitions among its `ENUM` and `SET` columns considered as a group. For more information on these limits, see Section C.10.5, “Limits Imposed by .frm File Structure”.

- `SET('value1','value2',...) [CHARACTER SET charset_name] [COLLATE collation_name]`

A set. A string object that can have zero or more values, each of which must be chosen from the list of values `'value1'`, `'value2'`, `...` `SET` values are represented internally as integers.

A `SET` column can have a maximum of 64 distinct members. A table can have no more than 255 unique element list definitions among its `ENUM` and `SET` columns considered as a group. For more information on this limit, see Section C.10.5, “Limits Imposed by .frm File Structure”.

11.2 Numeric Types

MySQL supports all standard SQL numeric data types. These types include the exact numeric data types (`INTEGER`, `SMALLINT`, `DECIMAL`, and `NUMERIC`), as well as the approximate numeric data types (`FLOAT`, `REAL`, and `DOUBLE PRECISION`). The keyword `INT` is a synonym for `INTEGER`, and the keywords `DEC` and `FIXED` are synonyms for `DECIMAL`. MySQL treats `DOUBLE` as a synonym for `DOUBLE PRECISION` (a nonstandard extension). MySQL also treats `REAL` as a synonym for `DOUBLE PRECISION` (a nonstandard variation), unless the `REAL_AS_FLOAT` SQL mode is enabled.

The `BIT` data type stores bit values and is supported for `MyISAM`, `MEMORY`, `InnoDB`, and `NDBCLUSTER` tables.

For information about how MySQL handles assignment of out-of-range values to columns and overflow during expression evaluation, see Section 11.2.6, “Out-of-Range and Overflow Handling”.

For information about numeric type storage requirements, see Section 11.7, “Data Type Storage Requirements”.

The data type used for the result of a calculation on numeric operands depends on the types of the operands and the operations performed on them. For more information, see Section 12.6.1, “Arithmetic Operators”.

11.2.1 Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT

MySQL supports the SQL standard integer types `INTEGER` (or `INT`) and `SMALLINT`. As an extension to the standard, MySQL also supports the integer types `TINYINT`, `MEDIUMINT`, and `BIGINT`. The following table shows the required storage and range for each integer type.

Type	Storage	Minimum Value	Maximum Value
	(Bytes)	(Signed/Unsigned)	(Signed/Unsigned)
`TINYINT`	1	`-128`	`127`
		`0`	`255`
`SMALLINT`	2	`-32768`	`32767`
		`0`	`65535`
`MEDIUMINT`	3	`-8388608`	`8388607`
		`0`	`16777215`
`INT`	4	`-2147483648`	`2147483647`
		`0`	`4294967295`
`BIGINT`	8	`-9223372036854775808`	`9223372036854775807`
		`0`	`18446744073709551615`

11.2.2 Fixed-Point Types (Exact Value) - DECIMAL, NUMERIC

The `DECIMAL` and `NUMERIC` types store exact numeric data values. These types are used when it is important to preserve exact precision, for example with monetary data. In MySQL, `NUMERIC` is implemented as `DECIMAL`, so the following remarks about `DECIMAL` apply equally to `NUMERIC`.

MySQL stores `DECIMAL` values in binary format. See Section 12.18, “Precision Math”.

In a `DECIMAL` column declaration, the precision and scale can be (and usually is) specified; for example:

```
salary DECIMAL(5,2)
```

In this example, `5` is the precision and `2` is the scale. The precision represents the number of significant digits that are stored for values, and the scale represents the number of digits that can be stored following the decimal point.

Standard SQL requires that `DECIMAL(5,2)` be able to store any value with five digits and two decimals, so values that can be stored in the `salary` column range from `-999.99` to `999.99`.

In standard SQL, the syntax `DECIMAL(M)` is equivalent to `DECIMAL(M,0)`. Similarly, the syntax `DECIMAL` is equivalent to `DECIMAL(M,0)`, where the implementation is permitted to decide the value of *`M`*. MySQL supports both of these variant forms of `DECIMAL` syntax. The default value of *`M`* is 10.

If the scale is 0, `DECIMAL` values contain no decimal point or fractional part.

The maximum number of digits for `DECIMAL` is 65, but the actual range for a given `DECIMAL` column can be constrained by the precision or scale for a given column. When such a column is assigned a value with more digits following the decimal point than are permitted by the specified scale, the value is converted to that scale. (The precise behavior is operating system-specific, but generally the effect is truncation to the permissible number of digits.)

11.2.3 Floating-Point Types (Approximate Value) - FLOAT, DOUBLE

The `FLOAT` and `DOUBLE` types represent approximate numeric data values. MySQL uses four bytes for single-precision values and eight bytes for double-precision values.

For `FLOAT`, the SQL standard permits an optional specification of the precision (but not the range of the exponent) in bits following the keyword `FLOAT` in parentheses. MySQL also supports this optional precision specification, but the precision value is used only to determine storage size. A precision from 0 to 23 results in a 4-byte single-precision `FLOAT` column. A precision from 24 to 53 results in an 8-byte double-precision `DOUBLE` column.

MySQL permits a nonstandard syntax: `FLOAT(M,D)` or `REAL(M,D)` or `DOUBLE PRECISION(M,D)`. Here, `(M,D)` means than values can be stored with up to *`M`* digits in total, of which *`D`* digits may be after the decimal point. For example, a column defined as `FLOAT(7,4)` will look like `-999.9999` when displayed. MySQL performs rounding when storing values, so if you insert `999.00009` into a `FLOAT(7,4)` column, the approximate result is `999.0001`.

Because floating-point values are approximate and not stored as exact values, attempts to treat them as exact in comparisons may lead to problems. They are also subject to platform or implementation dependencies. For more information, see Section B.5.4.8, “Problems with Floating-Point Values”

For maximum portability, code requiring storage of approximate numeric data values should use `FLOAT` or `DOUBLE PRECISION` with no specification of precision or number of digits.

11.2.4 Bit-Value Type - BIT

The `BIT` data type is used to store bit values. A type of `BIT(M)` enables storage of *`M`*-bit values. *`M`* can range from 1 to 64.

To specify bit values, `b'value'` notation can be used. *`value`* is a binary value written using zeros and ones. For example, `b'111'` and `b'10000000'` represent 7 and 128, respectively. See Section 9.1.5, “Bit-Value Literals”.

If you assign a value to a `BIT(M)` column that is less than *`M`* bits long, the value is padded on the left with zeros. For example, assigning a value of `b'101'` to a `BIT(6)` column is, in effect, the same as assigning `b'000101'`.

NDB Cluster. The maximum combined size of all `BIT` columns used in a given `NDB` table must not exceed 4096 bits.

11.2.5 Numeric Type Attributes

MySQL supports an extension for optionally specifying the display width of integer data types in parentheses following the base keyword for the type. For example, `INT(4)` specifies an `INT` with a display width of four digits. This optional display width may be used by applications to display integer values having a width less than the width specified for the column by left-padding them with spaces. (That is, this width is present in the metadata returned with result sets. Whether it is used or not is up to the application.)

The display width does *not* constrain the range of values that can be stored in the column. Nor does it prevent values wider than the column display width from being displayed correctly. For example, a column specified as `SMALLINT(3)` has the usual `SMALLINT` range of `-32768` to `32767`, and values outside the range permitted by three digits are displayed in full using more than three digits.

When used in conjunction with the optional (nonstandard) attribute `ZEROFILL`, the default padding of spaces is replaced with zeros. For example, for a column declared as `INT(4) ZEROFILL`, a value of `5` is retrieved as `0005`.

Note

The `ZEROFILL` attribute is ignored when a column is involved in expressions or `UNION` queries.

If you store values larger than the display width in an integer column that has the `ZEROFILL` attribute, you may experience problems when MySQL generates temporary tables for some complicated joins. In these cases, MySQL assumes that the data values fit within the column display width.

All integer types can have an optional (nonstandard) attribute `UNSIGNED`. Unsigned type can be used to permit only nonnegative numbers in a column or when you need a larger upper numeric range for the column. For example, if an `INT` column is `UNSIGNED`, the size of the column's range is the same but its endpoints shift from `-2147483648` and `2147483647` up to `0` and `4294967295`.

Floating-point and fixed-point types also can be `UNSIGNED`. As with integer types, this attribute prevents negative values from being stored in the column. Unlike the integer types, the upper range of column values remains the same.

If you specify `ZEROFILL` for a numeric column, MySQL automatically adds the `UNSIGNED` attribute to the column.

Integer or floating-point data types can have the additional attribute `AUTO_INCREMENT`. When you insert a value of `NULL` into an indexed `AUTO_INCREMENT` column, the column is set to the next sequence value. Typically this is *`value`*`+1`, where *`value`* is the largest value for the column currently in the table. (`AUTO_INCREMENT` sequences begin with `1`.)

Storing `0` into an `AUTO_INCREMENT` column has the same effect as storing `NULL`, unless the `NO_AUTO_VALUE_ON_ZERO` SQL mode is enabled.

Inserting `NULL` to generate `AUTO_INCREMENT` values requires that the column be declared `NOT NULL`. If the column is declared `NULL`, inserting `NULL` stores a `NULL`. When you insert any other value into an `AUTO_INCREMENT` column, the column is set to that value and the sequence is reset so that the next automatically generated value follows sequentially from the inserted value.

As of MySQL 5.5.29, negative values for `AUTO_INCREMENT` columns are not supported.

11.2.6 Out-of-Range and Overflow Handling

When MySQL stores a value in a numeric column that is outside the permissible range of the column data type, the result depends on the SQL mode in effect at the time:

- If strict SQL mode is enabled, MySQL rejects the out-of-range value with an error, and the insert fails, in accordance with the SQL standard.
- If no restrictive modes are enabled, MySQL clips the value to the appropriate endpoint of the column data type range and stores the resulting value instead.

  When an out-of-range value is assigned to an integer column, MySQL stores the value representing the corresponding endpoint of the column data type range.

  When a floating-point or fixed-point column is assigned a value that exceeds the range implied by the specified (or default) precision and scale, MySQL stores the value representing the corresponding endpoint of that range.

Suppose that a table `t1` has this definition:

```
CREATE TABLE t1 (i1 TINYINT, i2 TINYINT UNSIGNED);
```

With strict SQL mode enabled, an out of range error occurs:

```
mysql> SET sql_mode = 'TRADITIONAL';
mysql> INSERT INTO t1 (i1, i2) VALUES(256, 256);
ERROR 1264 (22003): Out of range value for column 'i1' at row 1
mysql> SELECT * FROM t1;
Empty set (0.00 sec)
```

With strict SQL mode not enabled, clipping with warnings occurs:

```
mysql> SET sql_mode = '';
mysql> INSERT INTO t1 (i1, i2) VALUES(256, 256);
mysql> SHOW WARNINGS;
+---------+------+-------------------------------------------+
| Level   | Code | Message                                   |
+---------+------+-------------------------------------------+
| Warning | 1264 | Out of range value for column 'i1' at row 1 |
| Warning | 1264 | Out of range value for column 'i2' at row 1 |
+---------+------+-------------------------------------------+
mysql> SELECT * FROM t1;
+------+------+
| i1   | i2   |
+------+------+
|  127 |  255 |
+------+------+
```

When strict SQL mode is not enabled, column-assignment conversions that occur due to clipping are reported as warnings for `ALTER TABLE`, `LOAD DATA INFILE`, `UPDATE`, and multiple-row `INSERT` statements. In strict mode, these statements fail, and some or all the values are not inserted or changed, depending on whether the table is a transactional table and other factors. For details, see Section 5.1.8, “Server SQL Modes”.

Overflow during numeric expression evaluation results in an error. For example, the largest signed `BIGINT` value is 9223372036854775807, so the following expression produces an error:

```
mysql> SELECT 9223372036854775807 + 1;
ERROR 1690 (22003): BIGINT value is out of range in '(9223372036854775807 + 1)'
```

To enable the operation to succeed in this case, convert the value to unsigned;

```
mysql> SELECT CAST(9223372036854775807 AS UNSIGNED) + 1;
+-----------------------------------------+
| CAST(9223372036854775807 AS UNSIGNED) + 1 |
+-----------------------------------------+
|                      9223372036854775808 |
+-----------------------------------------+
```

Whether overflow occurs depends on the range of the operands, so another way to handle the preceding expression is to use exact-value arithmetic because `DECIMAL` values have a larger range than integers:

```
mysql> SELECT 9223372036854775807.0 + 1;
+--------------------------+
| 9223372036854775807.0 + 1 |
+--------------------------+
|     9223372036854775808.0 |
+--------------------------+
```

Subtraction between integer values, where one is of type `UNSIGNED`, produces an unsigned result by default. If the result would otherwise have been negative, an error results:

```
mysql> SET sql_mode = '';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT CAST(0 AS UNSIGNED) - 1;
ERROR 1690 (22003): BIGINT UNSIGNED value is out of range in '(cast(0 as unsigned) - 1)'
```

If the `NO_UNSIGNED_SUBTRACTION` SQL mode is enabled, the result is negative:

```
mysql> SET sql_mode = 'NO_UNSIGNED_SUBTRACTION';
mysql> SELECT CAST(0 AS UNSIGNED) - 1;
+-------------------------+
| CAST(0 AS UNSIGNED) - 1 |
+-------------------------+
|                      -1 |
+-------------------------+
```

If the result of such an operation is used to update an `UNSIGNED` integer column, the result is clipped to the maximum value for the column type, or clipped to 0 if `NO_UNSIGNED_SUBTRACTION` is enabled. If strict SQL mode is enabled, an error occurs and the column remains unchanged.

11.3 Date and Time Types

The date and time types for representing temporal values are `DATE`, `TIME`, `DATETIME`, `TIMESTAMP`, and `YEAR`. Each temporal type has a range of valid values, as well as a “zero” value that may be used when you specify an invalid value that MySQL cannot represent. The `TIMESTAMP` type has special automatic updating behavior, described later. For temporal type storage requirements, see Section 11.7, “Data Type Storage Requirements”.

Keep in mind these general considerations when working with date and time types:

- MySQL retrieves values for a given date or time type in a standard output format, but it attempts to interpret a variety of formats for input values that you supply (for example, when you specify a value to be assigned to or compared to a date or time type). For a description of the permitted formats for date and time types, see Section 9.1.3, “Date and Time Literals”. It is expected that you supply valid values. Unpredictable results may occur if you use values in other formats.
- Although MySQL tries to interpret values in several formats, date parts must always be given in year-month-day order (for example, `'98-09-04'`), rather than in the month-day-year or day-month-year orders commonly used elsewhere (for example, `'09-04-98'`, `'04-09-98'`).

- Dates containing two-digit year values are ambiguous because the century is unknown. MySQL interprets two-digit year values using these rules:
  - Year values in the range `70-99` are converted to `1970-1999`.
  - Year values in the range `00-69` are converted to `2000-2069`.

  See also Section 11.3.8, “Two-Digit Years in Dates”.
- Conversion of values from one temporal type to another occurs according to the rules in Section 11.3.7, “Conversion Between Date and Time Types”.
- MySQL automatically converts a date or time value to a number if the value is used in a numeric context and vice versa.
- By default, when MySQL encounters a value for a date or time type that is out of range or otherwise invalid for the type, it converts the value to the “zero” value for that type. The exception is that out-of-range `TIME` values are clipped to the appropriate endpoint of the `TIME` range.
- By setting the SQL mode to the appropriate value, you can specify more exactly what kind of dates you want MySQL to support. (See Section 5.1.8, “Server SQL Modes”.) You can get MySQL to accept certain dates, such as `'2009-11-31'`, by enabling the `ALLOW_INVALID_DATES` SQL mode. This is useful when you want to store a “possibly wrong” value which the user has specified (for example, in a web form) in the database for future processing. Under this mode, MySQL verifies only that the month is in the range from 1 to 12 and that the day is in the range from 1 to 31.
- MySQL permits you to store dates where the day or month and day are zero in a `DATE` or `DATETIME` column. This is useful for applications that need to store birthdates for which you may not know the exact date. In this case, you simply store the date as `'2009-00-00'` or `'2009-01-00'`. If you store dates such as these, you should not expect to get correct results for functions such as `DATE_SUB()` or `DATE_ADD()` that require complete dates. To disallow zero month or day parts in dates, enable the `NO_ZERO_IN_DATE` SQL mode.
- MySQL permits you to store a “zero” value of `'0000-00-00'` as a “dummy date.” This is in some cases more convenient than using `NULL` values, and uses less data and index space. To disallow `'0000-00-00'`, enable the `NO_ZERO_DATE` SQL mode.
- “Zero” date or time values used through Connector/ODBC are converted automatically to `NULL` because ODBC cannot handle such values.

The following table shows the format of the “zero” value for each type. The “zero” values are special, but you can store or refer to them explicitly using the values shown in the table. You can also do this using the values `'0'` or `0`, which are easier to write. For temporal types that include a date part (`DATE`, `DATETIME`, and `TIMESTAMP`), use of these values produces warnings if the `NO_ZERO_DATE` SQL mode is enabled.

Data Type	“Zero” Value
`DATE`	`'0000-00-00'`
`TIME`	`'00:00:00'`
`DATETIME`	`'0000-00-00 00:00:00'`
`TIMESTAMP`	`'0000-00-00 00:00:00'`
`YEAR`	`0000`

11.3.1 The DATE, DATETIME, and TIMESTAMP Types

The `DATE`, `DATETIME`, and `TIMESTAMP` types are related. This section describes their characteristics, how they are similar, and how they differ. MySQL recognizes `DATE`, `DATETIME`, and `TIMESTAMP` values in several formats, described in Section 9.1.3, “Date and Time Literals”. For the `DATE` and

DATETIME range descriptions, “supported” means that although earlier values might work, there is no guarantee.

The DATE type is used for values with a date part but no time part. MySQL retrieves and displays DATE values in 'YYYY-MM-DD' format. The supported range is '1000-01-01' to '9999-12-31'.

The DATETIME type is used for values that contain both date and time parts. MySQL retrieves and displays DATETIME values in 'YYYY-MM-DD HH:MM:SS' format. The supported range is '1000-01-01 00:00:00' to '9999-12-31 23:59:59'.

The TIMESTAMP data type is used for values that contain both date and time parts. TIMESTAMP has a range of '1970-01-01 00:00:01' UTC to '2038-01-19 03:14:07' UTC.

MySQL converts TIMESTAMP values from the current time zone to UTC for storage, and back from UTC to the current time zone for retrieval. (This does not occur for other types such as DATETIME.) By default, the current time zone for each connection is the server's time. The time zone can be set on a per-connection basis. As long as the time zone setting remains constant, you get back the same value you store. If you store a TIMESTAMP value, and then change the time zone and retrieve the value, the retrieved value is different from the value you stored. This occurs because the same time zone was not used for conversion in both directions. The current time zone is available as the value of the time_zone system variable. For more information, see Section 10.6, “MySQL Server Time Zone Support”.

The TIMESTAMP data type offers automatic initialization and updating to the current date and time. For more information, see Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”.

A DATETIME or TIMESTAMP value can include a trailing fractional seconds part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into DATETIME or TIMESTAMP columns. For information about fractional seconds support in MySQL, see Section 11.3.6, “Fractional Seconds in Time Values”.

Invalid DATE, DATETIME, or TIMESTAMP values are converted to the “zero” value of the appropriate type ('0000-00-00' or '0000-00-00 00:00:00').

Be aware of certain properties of date value interpretation in MySQL:

- MySQL permits a “relaxed” format for values specified as strings, in which any punctuation character may be used as the delimiter between date parts or time parts. In some cases, this syntax can be deceiving. For example, a value such as '10:11:12' might look like a time value because of the :, but is interpreted as the year '2010-11-12' if used in a date context. The value '10:45:15' is converted to '0000-00-00' because '45' is not a valid month.
- The server requires that month and day values be valid, and not merely in the range 1 to 12 and 1 to 31, respectively. With strict mode disabled, invalid dates such as '2004-04-31' are converted to '0000-00-00' and a warning is generated. With strict mode enabled, invalid dates generate an error. To permit such dates, enable ALLOW_INVALID_DATES. See Section 5.1.8, “Server SQL Modes”, for more information.
- MySQL does not accept TIMESTAMP values that include a zero in the day or month column or values that are not a valid date. The sole exception to this rule is the special “zero” value '0000-00-00 00:00:00'.
- CAST() treats a TIMESTAMP value as a string when not selecting from a table. (This is true even if you specify FROM DUAL.) See Section 12.10, “Cast Functions and Operators”.
- Dates containing two-digit year values are ambiguous because the century is unknown. MySQL interprets two-digit year values using these rules:
  - Year values in the range 00-69 are converted to 2000-2069.
  - Year values in the range 70-99 are converted to 1970-1999.

See also Section 11.3.8, “Two-Digit Years in Dates”.

Note

The MySQL server can be run with the `MAXDB` SQL mode enabled. In this case, `TIMESTAMP` is identical with `DATETIME`. If this mode is enabled at the time that a table is created, `TIMESTAMP` columns are created as `DATETIME` columns. As a result, such columns use `DATETIME` display format, have the same range of values, and there is no automatic initialization or updating to the current date and time. See Section 5.1.8, “Server SQL Modes”.

11.3.2 The TIME Type

MySQL retrieves and displays `TIME` values in `'HH:MM:SS'` format (or `'HHH:MM:SS'` format for large hours values). `TIME` values may range from `'-838:59:59'` to `'838:59:59'`. The hours part may be so large because the `TIME` type can be used not only to represent a time of day (which must be less than 24 hours), but also elapsed time or a time interval between two events (which may be much greater than 24 hours, or even negative).

MySQL recognizes `TIME` values in several formats, described in Section 9.1.3, “Date and Time Literals”. Some of these formats can include a trailing fractional seconds part in up to microseconds (6 digits) precision. Although this fractional part is recognized, it is discarded from values stored into `TIME` columns. For information about fractional seconds support in MySQL, see Section 11.3.6, “Fractional Seconds in Time Values”.

Be careful about assigning abbreviated values to a `TIME` column. MySQL interprets abbreviated `TIME` values with colons as time of the day. That is, `'11:12'` means `'11:12:00'`, not `'00:11:12'`. MySQL interprets abbreviated values without colons using the assumption that the two rightmost digits represent seconds (that is, as elapsed time rather than as time of day). For example, you might think of `'1112'` and `1112` as meaning `'11:12:00'` (12 minutes after 11 o'clock), but MySQL interprets them as `'00:11:12'` (11 minutes, 12 seconds). Similarly, `'12'` and `12` are interpreted as `'00:00:12'`.

By default, values that lie outside the `TIME` range but are otherwise valid are clipped to the closest endpoint of the range. For example, `'-850:00:00'` and `'850:00:00'` are converted to `'-838:59:59'` and `'838:59:59'`. Invalid `TIME` values are converted to `'00:00:00'`. Note that because `'00:00:00'` is itself a valid `TIME` value, there is no way to tell, from a value of `'00:00:00'` stored in a table, whether the original value was specified as `'00:00:00'` or whether it was invalid.

For more restrictive treatment of invalid `TIME` values, enable strict SQL mode to cause errors to occur. See Section 5.1.8, “Server SQL Modes”.

11.3.3 The YEAR Type

The `YEAR` type is a 1-byte type used to represent year values. It can be declared as `YEAR(4)` or `YEAR(2)` to specify a display width of four or two characters. The default is four characters if no width is given.

Note

The `YEAR(2)` data type has certain issues that you should consider before choosing to use it. As of MySQL 5.5.27, `YEAR(2)` is deprecated. For more information, see Section 11.3.4, “YEAR(2) Limitations and Migrating to YEAR(4)”.

`YEAR(4)` and `YEAR(2)` differ in display format, but have the same range of values. For 4-digit format, MySQL displays `YEAR` values in `YYYY` format, with a range of `1901` to `2155`, or `0000`. For 2-digit format, MySQL displays only the last two (least significant) digits; for example, `70` (1970 or 2070) or `69` (2069).

You can specify input `YEAR` values in a variety of formats:

- As a 4-digit number in the range `1901` to `2155`.
- As a 4-digit string in the range `'1901'` to `'2155'`.
- As a 1- or 2-digit number in the range `1` to `99`. MySQL converts values in the ranges `1` to `69` and `70` to `99` to `YEAR` values in the ranges `2001` to `2069` and `1970` to `1999`.
- As a 1- or 2-digit string in the range `'0'` to `'99'`. MySQL converts values in the ranges `'0'` to `'69'` and `'70'` to `'99'` to `YEAR` values in the ranges `2000` to `2069` and `1970` to `1999`.
- Inserting a numeric `0` has a different effect for `YEAR(2)` and `YEAR(4)`. For `YEAR(2)`, the result has a display value of `00` and an internal value of `2000`. For `YEAR(4)`, the result has a display value of `0000` and an internal value of `0000`. To specify zero for `YEAR(4)` and have it be interpreted as `2000`, specify it as a string `'0'` or `'00'`.
- As the result of a function that returns a value that is acceptable in a `YEAR` context, such as `NOW()`.

MySQL converts invalid `YEAR` values to `0000`.

See also Section 11.3.8, “Two-Digit Years in Dates”.

11.3.4 YEAR(2) Limitations and Migrating to YEAR(4)

This section describes problems that can occur when using `YEAR(2)` and provides information about converting existing `YEAR(2)` columns to `YEAR(4)`.

Although the internal range of values for `YEAR(4)` and `YEAR(2)` is the same (`1901` to `2155`, and `0000`), the display width for `YEAR(2)` makes that type inherently ambiguous because displayed values indicate only the last two digits of the internal values and omit the century digits. The result can be a loss of information under certain circumstances. For this reason, consider avoiding `YEAR(2)` throughout your applications and using `YEAR(4)` wherever you need a `YEAR` data type. Note that conversion will become necessary at some point because support for `YEAR` data types with display values other than 4, most notably `YEAR(2)`, is reduced as of MySQL 5.6.6 and will be removed entirely in a future release.

YEAR(2) Limitations

Issues with the `YEAR(2)` data type include ambiguity of displayed values, and possible loss of information when values are dumped and reloaded or converted to strings.

- Displayed `YEAR(2)` values can be ambiguous. It is possible for up to three `YEAR(2)` values that have different internal values to have the same displayed value, as the following example demonstrates:

```
mysql> CREATE TABLE t (y2 YEAR(2), y4 YEAR(4));
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO t (y2) VALUES(1912),(2012),(2112);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> UPDATE t SET y4 = y2;
Query OK, 3 rows affected (0.00 sec)
Rows matched: 3  Changed: 3  Warnings: 0

mysql> SELECT * FROM t;
+------+------+
| y2   | y4   |
+------+------+
|   12 | 1912 |
|   12 | 2012 |
|   12 | 2112 |
+------+------+
3 rows in set (0.00 sec)
```

- If you use `mysqldump` to dump the table created in the preceding item, the dump file represents all `y2` values using the same 2-digit representation (`12`). If you reload the table from the dump file, all resulting rows have internal value `2012` and display value `12`, thus losing the distinctions among them.
- Conversion of a `YEAR(2)` or `YEAR(4)` data value to string form uses the display width of the `YEAR` type. Suppose that `YEAR(2)` and `YEAR(4)` columns both contain the value `1970`. Assigning each column to a string results in a value of `'70'` or `'1970'`, respectively. That is, loss of information occurs for conversion from `YEAR(2)` to string.
- Values outside the range from `1970` to `2069` are stored incorrectly when inserted into a `YEAR(2)` column in a `CSV` table. For example, inserting `2111` results in a display value of `11` but an internal value of `2011`.

To avoid these problems, use `YEAR(4)` rather than `YEAR(2)`. Suggestions regarding migration strategies appear later in this section.

Migrating from YEAR(2) to YEAR(4)

To convert `YEAR(2)` columns to `YEAR(4)`, use `ALTER TABLE`. Suppose that a table `t1` has this definition:

```
CREATE TABLE t1 (ycol YEAR(2) NOT NULL DEFAULT '70');
```

Modify the column using `ALTER TABLE` as follows. Remember to include any column attributes such as `NOT NULL` or `DEFAULT`:

```
ALTER TABLE t1 MODIFY ycol YEAR(4) NOT NULL DEFAULT '1970';
```

The `ALTER TABLE` statement converts the table without changing `YEAR(2)` values. If the server is a replication master, the `ALTER TABLE` statement replicates to slaves and makes the corresponding table change on each one.

One migration method should be avoided: Do not dump your data with `mysqldump` and reload the dump file after upgrading. This has the potential to change `YEAR(2)` values, as described previously.

A migration from `YEAR(2)` to `YEAR(4)` should also involve examining application code for the possibility of changed behavior under conditions such as these:

- Code that expects selecting a `YEAR` column to produce exactly two digits.
- Code that does not account for different handling for inserts of numeric `0`: Inserting `0` into `YEAR(2)` or `YEAR(4)` results in an internal value of `2000` or `0000`, respectively.

11.3.5 Automatic Initialization and Updating for TIMESTAMP

Note

In older versions of MySQL (prior to 4.1), the properties of the `TIMESTAMP` data type differed significantly in several ways from what is described in this section (see the *MySQL 3.23, 4.0, 4.1 Reference Manual* for details); these include syntax extensions which are deprecated in MySQL 5.1, and no longer supported in MySQL 5.5. This has implications for performing a dump and restore or replicating between MySQL Server versions. If you are using columns that are defined using the old `TIMESTAMP(N)` syntax, see Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”, prior to upgrading to MySQL 5.5.

The `TIMESTAMP` data type offers automatic initialization and updating to the current date and time (that is, the current timestamp). You can choose whether to use these properties and which column should have them:

- One TIMESTAMP column in a table can have the current timestamp as the default value for initializing the column, as the auto-update value, or both. It is not possible to have the current timestamp be the default value for one column and the auto-update value for another column.
- If the column is auto-initialized, it is set to the current timestamp for inserted rows that specify no value for the column.
- If the column is auto-updated, it is automatically updated to the current timestamp when the value of any other column in the row is changed from its current value. The column remains unchanged if all other columns are set to their current values. To prevent the column from updating when other columns change, explicitly set it to its current value. To update the column even when other columns do not change, explicitly set it to the value it should have (for example, set it to CURRENT_TIMESTAMP).

In addition, you can initialize or update any TIMESTAMP column to the current date and time by assigning it a NULL value, unless it has been defined with the NULL attribute to permit NULL values.

To specify automatic properties, use the DEFAULT CURRENT_TIMESTAMP and ON UPDATE CURRENT_TIMESTAMP clauses. The order of the clauses does not matter. If both are present in a column definition, either can occur first. Any of the synonyms for CURRENT_TIMESTAMP have the same meaning as CURRENT_TIMESTAMP. These are CURRENT_TIMESTAMP(), NOW(), LOCALTIME, LOCALTIME(), LOCALTIMESTAMP, and LOCALTIMESTAMP().

Use of DEFAULT CURRENT_TIMESTAMP and ON UPDATE CURRENT_TIMESTAMP is specific to TIMESTAMP. The DEFAULT clause also can be used to specify a constant (nonautomatic) default value; for example, DEFAULT 0 or DEFAULT '2000-01-01 00:00:00'.

Note

The following examples use DEFAULT 0, a default that can produce warnings or errors depending on whether strict SQL mode or the NO_ZERO_DATE SQL mode is enabled. Be aware that the TRADITIONAL SQL mode includes strict mode and NO_ZERO_DATE. See Section 5.1.8, “Server SQL Modes”.

The following rules describe the possibilities for defining the first TIMESTAMP column in a table with the current timestamp for both the default and auto-update values, for one but not the other, or for neither:

- With both DEFAULT CURRENT_TIMESTAMP and ON UPDATE CURRENT_TIMESTAMP, the column has the current timestamp for its default value and is automatically updated to the current timestamp.

```
CREATE TABLE t1 (
  ts TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP
);
```

- With neither DEFAULT CURRENT_TIMESTAMP nor ON UPDATE CURRENT_TIMESTAMP, it is the same as specifying both DEFAULT CURRENT_TIMESTAMP and ON UPDATE CURRENT_TIMESTAMP.

```
CREATE TABLE t1 (
  ts TIMESTAMP
);
```

- With a DEFAULT clause but no ON UPDATE CURRENT_TIMESTAMP clause, the column has the given default value and is not automatically updated to the current timestamp.

  The default depends on whether the DEFAULT clause specifies CURRENT_TIMESTAMP or a constant value. With CURRENT_TIMESTAMP, the default is the current timestamp.

```
CREATE TABLE t1 (
  ts TIMESTAMP DEFAULT CURRENT_TIMESTAMP
);
```

With a constant, the default is the given value. In this case, the column has no automatic properties at all.

```
CREATE TABLE t1 (
  ts TIMESTAMP DEFAULT 0
);
```

- With an `ON UPDATE CURRENT_TIMESTAMP` clause and a constant `DEFAULT` clause, the column is automatically updated to the current timestamp and has the given constant default value.

```
CREATE TABLE t1 (
  ts TIMESTAMP DEFAULT 0 ON UPDATE CURRENT_TIMESTAMP
);
```

- With an `ON UPDATE CURRENT_TIMESTAMP` clause but no `DEFAULT` clause, the column is automatically updated to the current timestamp. The default is 0 unless the column is defined with the `NULL` attribute, in which case the default is `NULL`.

```
CREATE TABLE t1 (
  ts TIMESTAMP ON UPDATE CURRENT_TIMESTAMP      -- default 0
);
CREATE TABLE t2 (
  ts TIMESTAMP NULL ON UPDATE CURRENT_TIMESTAMP -- default NULL
);
```

It need not be the first `TIMESTAMP` column in a table that is automatically initialized or updated to the current timestamp. However, to specify automatic initialization or updating for a different `TIMESTAMP` column, you must suppress the automatic properties for the first one. Then, for the other `TIMESTAMP` column, the rules for the `DEFAULT` and `ON UPDATE` clauses are the same as for the first `TIMESTAMP` column, except that if you omit both clauses, no automatic initialization or updating occurs.

To suppress automatic properties for the first `TIMESTAMP` column, do either of the following:

- Define the column with a `DEFAULT` clause that specifies a constant default value.
- Specify the `NULL` attribute. This also causes the column to permit `NULL` values, which means that you cannot assign the current timestamp by setting the column to `NULL`. Assigning `NULL` sets the column to `NULL`.

Consider these table definitions:

```
CREATE TABLE t1 (
  ts1 TIMESTAMP DEFAULT 0,
  ts2 TIMESTAMP DEFAULT CURRENT_TIMESTAMP
                ON UPDATE CURRENT_TIMESTAMP);
CREATE TABLE t2 (
  ts1 TIMESTAMP NULL,
  ts2 TIMESTAMP DEFAULT CURRENT_TIMESTAMP
                ON UPDATE CURRENT_TIMESTAMP);
CREATE TABLE t3 (
  ts1 TIMESTAMP NULL DEFAULT 0,
  ts2 TIMESTAMP DEFAULT CURRENT_TIMESTAMP
                ON UPDATE CURRENT_TIMESTAMP);
```

The tables have these properties:

- In each table definition, the first `TIMESTAMP` column has no automatic initialization or updating.
- The tables differ in how the `ts1` column handles `NULL` values. For `t1`, `ts1` is `NOT NULL` and assigning it a value of `NULL` sets it to the current timestamp. For `t2` and `t3`, `ts1` permits `NULL` and assigning it a value of `NULL` sets it to `NULL`.

- `t2` and `t3` differ in the default value for `ts1`. For `t2`, `ts1` is defined to permit `NULL`, so the default is also `NULL` in the absence of an explicit `DEFAULT` clause. For `t3`, `ts1` permits `NULL` but has an explicit default of 0.

TIMESTAMP Initialization and the NULL Attribute

By default, `TIMESTAMP` columns are `NOT NULL`, cannot contain `NULL` values, and assigning `NULL` assigns the current timestamp. To permit a `TIMESTAMP` column to contain `NULL`, explicitly declare it with the `NULL` attribute. In this case, the default value also becomes `NULL` unless overridden with a `DEFAULT` clause that specifies a different default value. `DEFAULT NULL` can be used to explicitly specify `NULL` as the default value. (For a `TIMESTAMP` column not declared with the `NULL` attribute, `DEFAULT NULL` is invalid.) If a `TIMESTAMP` column permits `NULL` values, assigning `NULL` sets it to `NULL`, not to the current timestamp.

The following table contains several `TIMESTAMP` columns that permit `NULL` values:

```
CREATE TABLE t
(
  ts1 TIMESTAMP NULL DEFAULT NULL,
  ts2 TIMESTAMP NULL DEFAULT 0,
  ts3 TIMESTAMP NULL DEFAULT CURRENT_TIMESTAMP
);
```

A `TIMESTAMP` column that permits `NULL` values does *not* take on the current timestamp at insert time except under one of the following conditions:

- Its default value is defined as `CURRENT_TIMESTAMP` and no value is specified for the column
- `CURRENT_TIMESTAMP` or any of its synonyms such as `NOW()` is explicitly inserted into the column

In other words, a `TIMESTAMP` column defined to permit `NULL` values auto-initializes only if its definition includes `DEFAULT CURRENT_TIMESTAMP`:

```
CREATE TABLE t (ts TIMESTAMP NULL DEFAULT CURRENT_TIMESTAMP);
```

If the `TIMESTAMP` column permits `NULL` values but its definition does not include `DEFAULT CURRENT_TIMESTAMP`, you must explicitly insert a value corresponding to the current date and time. Suppose that tables `t1` and `t2` have these definitions:

```
CREATE TABLE t1 (ts TIMESTAMP NULL DEFAULT '0000-00-00 00:00:00');
CREATE TABLE t2 (ts TIMESTAMP NULL DEFAULT NULL);
```

To set the `TIMESTAMP` column in either table to the current timestamp at insert time, explicitly assign it that value. For example:

```
INSERT INTO t2 VALUES (CURRENT_TIMESTAMP);
INSERT INTO t1 VALUES (NOW());
```

11.3.6 Fractional Seconds in Time Values

A trailing fractional seconds part is permissible for temporal values in contexts such as literal values, and in the arguments to or return values from some temporal functions. Example:

```
mysql> SELECT MICROSECOND('2010-12-10 14:12:09.019473');
+-----------------------------------------+
| MICROSECOND('2010-12-10 14:12:09.019473') |
+-----------------------------------------+
|                                   19473 |
+-----------------------------------------+
```

However, when MySQL stores a value into a column of any temporal data type, it discards any fractional part and does not store it.

11.3.7 Conversion Between Date and Time Types

To some extent, you can convert a value from one temporal type to another. However, there may be some alteration of the value or loss of information. In all cases, conversion between temporal types is subject to the range of valid values for the resulting type. For example, although `DATE`, `DATETIME`, and `TIMESTAMP` values all can be specified using the same set of formats, the types do not all have the same range of values. `TIMESTAMP` values cannot be earlier than `1970` UTC or later than `'2038-01-19 03:14:07'` UTC. This means that a date such as `'1968-01-01'`, while valid as a `DATE` or `DATETIME` value, is not valid as a `TIMESTAMP` value and is converted to `0`.

Conversion of `DATE` values:

- Conversion to a `DATETIME` or `TIMESTAMP` value adds a time part of `'00:00:00'` because the `DATE` value contains no time information.
- Conversion to a `TIME` value is not useful; the result is `'00:00:00'`.

Conversion of `DATETIME` and `TIMESTAMP` values:

- Conversion to a `DATE` value discards the time part because the `DATE` type contains no time information.
- Conversion to a `TIME` value discards the date part because the `TIME` type contains no date information.

Conversion of `TIME` values:

MySQL converts a time value to a date or date-and-time value by parsing the string value of the time as a date or date-and-time. This is unlikely to be useful. For example, `'23:12:31'` interpreted as a date becomes `'2023-12-31'`. Time values not valid as dates become `'0000-00-00'` or `NULL`.

Explicit conversion can be used to override implicit conversion. For example, in comparison of `DATE` and `DATETIME` values, the `DATE` value is coerced to the `DATETIME` type by adding a time part of `'00:00:00'`. To perform the comparison by ignoring the time part of the `DATETIME` value instead, use the `CAST()` function in the following way:

```
date_col = CAST(datetime_col AS DATE)
```

Conversion of `TIME` or `DATETIME` values to numeric form (for example, by adding `+0`) results in a double-precision value with a microseconds part of `.000000`:

```
mysql> SELECT CURTIME(), CURTIME()+0;
+-----------+---------------+
| CURTIME() | CURTIME()+0   |
+-----------+---------------+
| 10:41:36  | 104136.000000 |
+-----------+---------------+
mysql> SELECT NOW(), NOW()+0;
+---------------------+-----------------------+
| NOW()               | NOW()+0               |
+---------------------+-----------------------+
| 2007-11-30 10:41:47 | 20071130104147.000000 |
+---------------------+-----------------------+
```

11.3.8 Two-Digit Years in Dates

Date values with two-digit years are ambiguous because the century is unknown. Such values must be interpreted into four-digit form because MySQL stores years internally using four digits.

For DATETIME, DATE, and TIMESTAMP types, MySQL interprets dates specified with ambiguous year values using these rules:

- Year values in the range 00-69 are converted to 2000-2069.
- Year values in the range 70-99 are converted to 1970-1999.

For YEAR, the rules are the same, with this exception: A numeric 00 inserted into YEAR(4) results in 0000 rather than 2000. To specify zero for YEAR(4) and have it be interpreted as 2000, specify it as a string '0' or '00'.

Remember that these rules are only heuristics that provide reasonable guesses as to what your data values mean. If the rules used by MySQL do not produce the values you require, you must provide unambiguous input containing four-digit year values.

ORDER BY properly sorts YEAR values that have two-digit years.

Some functions like MIN() and MAX() convert a YEAR to a number. This means that a value with a two-digit year does not work properly with these functions. The fix in this case is to convert the YEAR to four-digit year format.

11.4 String Types

The string types are CHAR, VARCHAR, BINARY, VARBINARY, BLOB, TEXT, ENUM, and SET. This section describes how these types work and how to use them in your queries. For string type storage requirements, see Section 11.7, “Data Type Storage Requirements”.

11.4.1 The CHAR and VARCHAR Types

The CHAR and VARCHAR types are similar, but differ in the way they are stored and retrieved. They also differ in maximum length and in whether trailing spaces are retained.

The CHAR and VARCHAR types are declared with a length that indicates the maximum number of characters you want to store. For example, CHAR(30) can hold up to 30 characters.

The length of a CHAR column is fixed to the length that you declare when you create the table. The length can be any value from 0 to 255. When CHAR values are stored, they are right-padded with spaces to the specified length. When CHAR values are retrieved, trailing spaces are removed unless the PAD_CHAR_TO_FULL_LENGTH SQL mode is enabled.

Values in VARCHAR columns are variable-length strings. The length can be specified as a value from 0 to 65,535. The effective maximum length of a VARCHAR is subject to the maximum row size (65,535 bytes, which is shared among all columns) and the character set used. See Section C.10.4, “Limits on Table Column Count and Row Size”.

In contrast to CHAR, VARCHAR values are stored as a 1-byte or 2-byte length prefix plus data. The length prefix indicates the number of bytes in the value. A column uses one length byte if values require no more than 255 bytes, two length bytes if values may require more than 255 bytes.

If strict SQL mode is not enabled and you assign a value to a CHAR or VARCHAR column that exceeds the column's maximum length, the value is truncated to fit and a warning is generated. For truncation of nonspace characters, you can cause an error to occur (rather than a warning) and suppress insertion of the value by using strict SQL mode. See Section 5.1.8, “Server SQL Modes”.

For VARCHAR columns, trailing spaces in excess of the column length are truncated prior to insertion and a warning is generated, regardless of the SQL mode in use. For CHAR columns, truncation of excess trailing spaces from inserted values is performed silently regardless of the SQL mode.

VARCHAR values are not padded when they are stored. Trailing spaces are retained when values are stored and retrieved, in conformance with standard SQL.

The following table illustrates the differences between CHAR and VARCHAR by showing the result of storing various string values into CHAR(4) and VARCHAR(4) columns (assuming that the column uses a single-byte character set such as latin1).

Value	CHAR(4)	Storage Required	VARCHAR(4)	Storage Required
''	' '	4 bytes	''	1 byte
'ab'	'ab '	4 bytes	'ab'	3 bytes
'abcd'	'abcd'	4 bytes	'abcd'	5 bytes
'abcdefgh'	'abcd'	4 bytes	'abcd'	5 bytes

The values shown as stored in the last row of the table apply *only when not using strict mode*; if MySQL is running in strict mode, values that exceed the column length are *not stored*, and an error results.

InnoDB encodes fixed-length fields greater than or equal to 768 bytes in length as variable-length fields, which can be stored off-page. For example, a CHAR(255) column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with utf8mb4.

If a given value is stored into the CHAR(4) and VARCHAR(4) columns, the values retrieved from the columns are not always the same because trailing spaces are removed from CHAR columns upon retrieval. The following example illustrates this difference:

```
mysql> CREATE TABLE vc (v VARCHAR(4), c CHAR(4));
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO vc VALUES ('ab  ', 'ab  ');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT CONCAT('(', v, ')'), CONCAT('(', c, ')') FROM vc;
+---------------------+---------------------+
| CONCAT('(', v, ')') | CONCAT('(', c, ')') |
+---------------------+---------------------+
| (ab  )              | (ab)                |
+---------------------+---------------------+
1 row in set (0.06 sec)
```

Values in CHAR and VARCHAR columns are sorted and compared according to the character set collation assigned to the column.

All MySQL collations are of type PAD SPACE. This means that all CHAR, VARCHAR, and TEXT values are compared without regard to any trailing spaces. “Comparison” in this context does not include the LIKE pattern-matching operator, for which trailing spaces are significant. For example:

```
mysql> CREATE TABLE names (myname CHAR(10));
Query OK, 0 rows affected (0.03 sec)

mysql> INSERT INTO names VALUES ('Monty');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT myname = 'Monty', myname = 'Monty  ' FROM names;
+------------------+--------------------+
| myname = 'Monty' | myname = 'Monty  ' |
+------------------+--------------------+
|                1 |                  1 |
+------------------+--------------------+
1 row in set (0.00 sec)

mysql> SELECT myname LIKE 'Monty', myname LIKE 'Monty  ' FROM names;
+--------------------+----------------------+
| myname LIKE 'Monty' | myname LIKE 'Monty  ' |
+--------------------+----------------------+
|                  1 |                    0 |
+--------------------+----------------------+
```

```
1 row in set (0.00 sec)
```

This is true for all MySQL versions, and is not affected by the server SQL mode.

Note

For more information about MySQL character sets and collations, see Section 10.1, “Character Set Support”. For additional information about storage requirements, see Section 11.7, “Data Type Storage Requirements”.

For those cases where trailing pad characters are stripped or comparisons ignore them, if a column has an index that requires unique values, inserting into the column values that differ only in number of trailing pad characters will result in a duplicate-key error. For example, if a table contains `'a'`, an attempt to store `'a '` causes a duplicate-key error.

11.4.2 The BINARY and VARBINARY Types

The `BINARY` and `VARBINARY` types are similar to `CHAR` and `VARCHAR`, except that they contain binary strings rather than nonbinary strings. That is, they contain byte strings rather than character strings. This means they have the `binary` character set and collation, and comparison and sorting are based on the numeric values of the bytes in the values.

The permissible maximum length is the same for `BINARY` and `VARBINARY` as it is for `CHAR` and `VARCHAR`, except that the length for `BINARY` and `VARBINARY` is a length in bytes rather than in characters.

The `BINARY` and `VARBINARY` data types are distinct from the `CHAR BINARY` and `VARCHAR BINARY` data types. For the latter types, the `BINARY` attribute does not cause the column to be treated as a binary string column. Instead, it causes the binary (`_bin`) collation for the column character set to be used, and the column itself contains nonbinary character strings rather than binary byte strings. For example, `CHAR(5) BINARY` is treated as `CHAR(5) CHARACTER SET latin1 COLLATE latin1_bin`, assuming that the default character set is `latin1`. This differs from `BINARY(5)`, which stores 5-bytes binary strings that have the `binary` character set and collation. For information about differences between binary strings and binary collations for nonbinary strings, see Section 10.1.8.5, “The binary Collation Compared to _bin Collations”.

If strict SQL mode is not enabled and you assign a value to a `BINARY` or `VARBINARY` column that exceeds the column's maximum length, the value is truncated to fit and a warning is generated. For cases of truncation, you can cause an error to occur (rather than a warning) and suppress insertion of the value by using strict SQL mode. See Section 5.1.8, “Server SQL Modes”.

When `BINARY` values are stored, they are right-padded with the pad value to the specified length. The pad value is `0x00` (the zero byte). Values are right-padded with `0x00` on insert, and no trailing bytes are removed on select. All bytes are significant in comparisons, including `ORDER BY` and `DISTINCT` operations. `0x00` bytes and spaces are different in comparisons, with `0x00` < space.

Example: For a `BINARY(3)` column, `'a '` becomes `'a \0'` when inserted. `'a\0'` becomes `'a \0\0'` when inserted. Both inserted values remain unchanged when selected.

For `VARBINARY`, there is no padding on insert and no bytes are stripped on select. All bytes are significant in comparisons, including `ORDER BY` and `DISTINCT` operations. `0x00` bytes and spaces are different in comparisons, with `0x00` < space.

For those cases where trailing pad bytes are stripped or comparisons ignore them, if a column has an index that requires unique values, inserting into the column values that differ only in number of trailing pad bytes will result in a duplicate-key error. For example, if a table contains `'a'`, an attempt to store `'a\0'` causes a duplicate-key error.

You should consider the preceding padding and stripping characteristics carefully if you plan to use the `BINARY` data type for storing binary data and you require that the value retrieved be exactly the same

as the value stored. The following example illustrates how `0x00`-padding of `BINARY` values affects column value comparisons:

```
mysql> CREATE TABLE t (c BINARY(3));
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO t SET c = 'a';
Query OK, 1 row affected (0.01 sec)

mysql> SELECT HEX(c), c = 'a', c = 'a\0\0' from t;
+--------+---------+-------------+
| HEX(c) | c = 'a' | c = 'a\0\0' |
+--------+---------+-------------+
| 610000 |       0 |           1 |
+--------+---------+-------------+
1 row in set (0.09 sec)
```

If the value retrieved must be the same as the value specified for storage with no padding, it might be preferable to use `VARBINARY` or one of the `BLOB` data types instead.

11.4.3 The BLOB and TEXT Types

A `BLOB` is a binary large object that can hold a variable amount of data. The four `BLOB` types are `TINYBLOB`, `BLOB`, `MEDIUMBLOB`, and `LONGBLOB`. These differ only in the maximum length of the values they can hold. The four `TEXT` types are `TINYTEXT`, `TEXT`, `MEDIUMTEXT`, and `LONGTEXT`. These correspond to the four `BLOB` types and have the same maximum lengths and storage requirements. See Section 11.7, “Data Type Storage Requirements”.

`BLOB` values are treated as binary strings (byte strings). They have the `binary` character set and collation, and comparison and sorting are based on the numeric values of the bytes in column values. `TEXT` values are treated as nonbinary strings (character strings). They have a character set other than `binary`, and values are sorted and compared based on the collation of the character set.

If strict SQL mode is not enabled and you assign a value to a `BLOB` or `TEXT` column that exceeds the column's maximum length, the value is truncated to fit and a warning is generated. For truncation of nonspace characters, you can cause an error to occur (rather than a warning) and suppress insertion of the value by using strict SQL mode. See Section 5.1.8, “Server SQL Modes”.

Truncation of excess trailing spaces from values to be inserted into `TEXT` columns always generates a warning, regardless of the SQL mode.

For `TEXT` and `BLOB` columns, there is no padding on insert and no bytes are stripped on select.

If a `TEXT` column is indexed, index entry comparisons are space-padded at the end. This means that, if the index requires unique values, duplicate-key errors will occur for values that differ only in the number of trailing spaces. For example, if a table contains `'a'`, an attempt to store `'a '` causes a duplicate-key error. This is not true for `BLOB` columns.

In most respects, you can regard a `BLOB` column as a `VARBINARY` column that can be as large as you like. Similarly, you can regard a `TEXT` column as a `VARCHAR` column. `BLOB` and `TEXT` differ from `VARBINARY` and `VARCHAR` in the following ways:

- For indexes on `BLOB` and `TEXT` columns, you must specify an index prefix length. For `CHAR` and `VARCHAR`, a prefix length is optional. See Section 8.3.4, “Column Indexes”.
- `BLOB` and `TEXT` columns cannot have `DEFAULT` values.

If you use the `BINARY` attribute with a `TEXT` data type, the column is assigned the binary (`_bin`) collation of the column character set.

`LONG` and `LONG VARCHAR` map to the `MEDIUMTEXT` data type. This is a compatibility feature.

MySQL Connector/ODBC defines `BLOB` values as `LONGVARBINARY` and `TEXT` values as `LONGVARCHAR`.

Because `BLOB` and `TEXT` values can be extremely long, you might encounter some constraints in using them:

- Only the first `max_sort_length` bytes of the column are used when sorting. The default value of `max_sort_length` is 1024. You can make more bytes significant in sorting or grouping by increasing the value of `max_sort_length` at server startup or runtime. Any client can change the value of its session `max_sort_length` variable:

```
mysql> SET max_sort_length = 2000;
mysql> SELECT id, comment FROM t
    -> ORDER BY comment;
```

- Instances of `BLOB` or `TEXT` columns in the result of a query that is processed using a temporary table causes the server to use a table on disk rather than in memory because the `MEMORY` storage engine does not support those data types (see Section 8.4.4, “Internal Temporary Table Use in MySQL”). Use of disk incurs a performance penalty, so include `BLOB` or `TEXT` columns in the query result only if they are really needed. For example, avoid using `SELECT *`, which selects all columns.

- The maximum size of a `BLOB` or `TEXT` object is determined by its type, but the largest value you actually can transmit between the client and server is determined by the amount of available memory and the size of the communications buffers. You can change the message buffer size by changing the value of the `max_allowed_packet` variable, but you must do so for both the server and your client program. For example, both `mysql` and `mysqldump` enable you to change the client-side `max_allowed_packet` value. See Section 5.1.1, “Configuring the Server”, Section 4.5.1, “`mysql` — The MySQL Command-Line Tool”, and Section 4.5.4, “`mysqldump` — A Database Backup Program”. You may also want to compare the packet sizes and the size of the data objects you are storing with the storage requirements, see Section 11.7, “Data Type Storage Requirements”

Each `BLOB` or `TEXT` value is represented internally by a separately allocated object. This is in contrast to all other data types, for which storage is allocated once per column when the table is opened.

In some cases, it may be desirable to store binary data such as media files in `BLOB` or `TEXT` columns. You may find MySQL's string handling functions useful for working with such data. See Section 12.5, “String Functions”. For security and other reasons, it is usually preferable to do so using application code rather than giving application users the `FILE` privilege. You can discuss specifics for various languages and platforms in the MySQL Forums (http://forums.mysql.com/).

11.4.4 The ENUM Type

An `ENUM` is a string object with a value chosen from a list of permitted values that are enumerated explicitly in the column specification at table creation time. It has these advantages:

- Compact data storage in situations where a column has a limited set of possible values. The strings you specify as input values are automatically encoded as numbers. See Section 11.7, “Data Type Storage Requirements” for the storage requirements for `ENUM` types.

- Readable queries and output. The numbers are translated back to the corresponding strings in query results.

and these potential issues to consider:

- If you make enumeration values that look like numbers, it is easy to mix up the literal values with their internal index numbers, as explained in Enumeration Limitations.

- Using `ENUM` columns in `ORDER BY` clauses requires extra care, as explained in Enumeration Sorting.

- Creating and Using ENUM Columns

- Index Values for Enumeration Literals
- Handling of Enumeration Literals
- Empty or NULL Enumeration Values
- Enumeration Sorting
- Enumeration Limitations

Creating and Using ENUM Columns

An enumeration value must be a quoted string literal. For example, you can create a table with an `ENUM` column like this:

```
CREATE TABLE shirts (
    name VARCHAR(40),
    size ENUM('x-small', 'small', 'medium', 'large', 'x-large')
);
INSERT INTO shirts (name, size) VALUES ('dress shirt','large'), ('t-shirt','medium'),
  ('polo shirt','small');
SELECT name, size FROM shirts WHERE size = 'medium';
+---------+--------+
| name    | size   |
+---------+--------+
| t-shirt | medium |
+---------+--------+
UPDATE shirts SET size = 'small' WHERE size = 'large';
COMMIT;
```

Inserting 1 million rows into this table with a value of `'medium'` would require 1 million bytes of storage, as opposed to 6 million bytes if you stored the actual string `'medium'` in a `VARCHAR` column.

Index Values for Enumeration Literals

Each enumeration value has an index:

- The elements listed in the column specification are assigned index numbers, beginning with 1.
- The index value of the empty string error value is 0. This means that you can use the following `SELECT` statement to find rows into which invalid `ENUM` values were assigned:

  ```
  mysql> SELECT * FROM tbl_name WHERE enum_col=0;
  ```

- The index of the `NULL` value is `NULL`.
- The term “index” here refers to a position within the list of enumeration values. It has nothing to do with table indexes.

For example, a column specified as `ENUM('Mercury', 'Venus', 'Earth')` can have any of the values shown here. The index of each value is also shown.

Value	Index
`NULL`	`NULL`
`''`	0
`'Mercury'`	1
`'Venus'`	2
`'Earth'`	3

An `ENUM` column can have a maximum of 65,535 distinct elements. (The practical limit is less than 3000.) A table can have no more than 255 unique element list definitions among its `ENUM` and `SET`

columns considered as a group. For more information on these limits, see Section C.10.5, “Limits Imposed by .frm File Structure”.

If you retrieve an ENUM value in a numeric context, the column value's index is returned. For example, you can retrieve numeric values from an ENUM column like this:

```
mysql> SELECT enum_col+0 FROM tbl_name;
```

Functions such as SUM() or AVG() that expect a numeric argument cast the argument to a number if necessary. For ENUM values, the index number is used in the calculation.

Handling of Enumeration Literals

Trailing spaces are automatically deleted from ENUM member values in the table definition when a table is created.

When retrieved, values stored into an ENUM column are displayed using the lettercase that was used in the column definition. Note that ENUM columns can be assigned a character set and collation. For binary or case-sensitive collations, lettercase is taken into account when assigning values to the column.

If you store a number into an ENUM column, the number is treated as the index into the possible values, and the value stored is the enumeration member with that index. (However, this does *not* work with LOAD DATA, which treats all input as strings.) If the numeric value is quoted, it is still interpreted as an index if there is no matching string in the list of enumeration values. For these reasons, it is not advisable to define an ENUM column with enumeration values that look like numbers, because this can easily become confusing. For example, the following column has enumeration members with string values of '0', '1', and '2', but numeric index values of 1, 2, and 3:

```
numbers ENUM('0','1','2')
```

If you store 2, it is interpreted as an index value, and becomes '1' (the value with index 2). If you store '2', it matches an enumeration value, so it is stored as '2'. If you store '3', it does not match any enumeration value, so it is treated as an index and becomes '2' (the value with index 3).

```
mysql> INSERT INTO t (numbers) VALUES(2),('2'),('3');
mysql> SELECT * FROM t;
+---------+
| numbers |
+---------+
| 1       |
| 2       |
| 2       |
+---------+
```

To determine all possible values for an ENUM column, use SHOW COLUMNS FROM *tbl_name* LIKE '*enum_col*' and parse the ENUM definition in the Type column of the output.

In the C API, ENUM values are returned as strings. For information about using result set metadata to distinguish them from other strings, see Section 23.8.5, “C API Data Structures”.

Empty or NULL Enumeration Values

An enumeration value can also be the empty string ('') or NULL under certain circumstances:

- If you insert an invalid value into an ENUM (that is, a string not present in the list of permitted values), the empty string is inserted instead as a special error value. This string can be distinguished from a “normal” empty string by the fact that this string has the numeric value 0. See Index Values for Enumeration Literals for details about the numeric indexes for the enumeration values.

  If strict SQL mode is enabled, attempts to insert invalid ENUM values result in an error.

- If an ENUM column is declared to permit NULL, the NULL value is a valid value for the column, and the default value is NULL. If an ENUM column is declared NOT NULL, its default value is the first element of the list of permitted values.

Enumeration Sorting

ENUM values are sorted based on their index numbers, which depend on the order in which the enumeration members were listed in the column specification. For example, 'b' sorts before 'a' for ENUM('b', 'a'). The empty string sorts before nonempty strings, and NULL values sort before all other enumeration values.

To prevent unexpected results when using the ORDER BY clause on an ENUM column, use one of these techniques:

- Specify the ENUM list in alphabetic order.
- Make sure that the column is sorted lexically rather than by index number by coding ORDER BY CAST(*col* AS CHAR) or ORDER BY CONCAT(*col*).

Enumeration Limitations

An enumeration value cannot be an expression, even one that evaluates to a string value.

For example, this CREATE TABLE statement does *not* work because the CONCAT function cannot be used to construct an enumeration value:

```
CREATE TABLE sizes (
    size ENUM('small', CONCAT('med','ium'), 'large')
);
```

You also cannot employ a user variable as an enumeration value. This pair of statements do *not* work:

```
SET @mysize = 'medium';

CREATE TABLE sizes (
    size ENUM('small', @mysize, 'large')
);
```

We strongly recommend that you do *not* use numbers as enumeration values, because it does not save on storage over the appropriate TINYINT or SMALLINT type, and it is easy to mix up the strings and the underlying number values (which might not be the same) if you quote the ENUM values incorrectly. If you do use a number as an enumeration value, always enclose it in quotation marks. If the quotation marks are omitted, the number is regarded as an index. See Handling of Enumeration Literals to see how even a quoted number could be mistakenly used as a numeric index value.

Duplicate values in the definition cause a warning, or an error if strict SQL mode is enabled.

11.4.5 The SET Type

A SET is a string object that can have zero or more values, each of which must be chosen from a list of permitted values specified when the table is created. SET column values that consist of multiple set members are specified with members separated by commas (,). A consequence of this is that SET member values should not themselves contain commas.

For example, a column specified as SET('one', 'two') NOT NULL can have any of these values:

```
''
'one'
'two'
'one,two'
```

A SET column can have a maximum of 64 distinct members. A table can have no more than 255 unique element list definitions among its ENUM and SET columns considered as a group. For more information on this limit, see Section C.10.5, “Limits Imposed by .frm File Structure”.

Duplicate values in the definition cause a warning, or an error if strict SQL mode is enabled.

Trailing spaces are automatically deleted from SET member values in the table definition when a table is created.

When retrieved, values stored in a SET column are displayed using the lettercase that was used in the column definition. Note that SET columns can be assigned a character set and collation. For binary or case-sensitive collations, lettercase is taken into account when assigning values to the column.

MySQL stores SET values numerically, with the low-order bit of the stored value corresponding to the first set member. If you retrieve a SET value in a numeric context, the value retrieved has bits set corresponding to the set members that make up the column value. For example, you can retrieve numeric values from a SET column like this:

```
mysql> SELECT set_col+0 FROM tbl_name;
```

If a number is stored into a SET column, the bits that are set in the binary representation of the number determine the set members in the column value. For a column specified as SET('a','b','c','d'), the members have the following decimal and binary values.

SET Member	Decimal Value	Binary Value
'a'	1	0001
'b'	2	0010
'c'	4	0100
'd'	8	1000

If you assign a value of 9 to this column, that is 1001 in binary, so the first and fourth SET value members 'a' and 'd' are selected and the resulting value is 'a,d'.

For a value containing more than one SET element, it does not matter what order the elements are listed in when you insert the value. It also does not matter how many times a given element is listed in the value. When the value is retrieved later, each element in the value appears once, with elements listed according to the order in which they were specified at table creation time. For example, suppose that a column is specified as SET('a','b','c','d'):

```
mysql> CREATE TABLE myset (col SET('a', 'b', 'c', 'd'));
```

If you insert the values 'a,d', 'd,a', 'a,d,d', 'a,d,a', and 'd,a,d':

```
mysql> INSERT INTO myset (col) VALUES
-> ('a,d'), ('d,a'), ('a,d,a'), ('a,d,d'), ('d,a,d');
Query OK, 5 rows affected (0.01 sec)
Records: 5  Duplicates: 0  Warnings: 0
```

Then all these values appear as 'a,d' when retrieved:

```
mysql> SELECT col FROM myset;
+------+
| col  |
+------+
| a,d  |
| a,d  |
| a,d  |
| a,d  |
```

```
| a,d  |
+------+
5 rows in set (0.04 sec)
```

If you set a SET column to an unsupported value, the value is ignored and a warning is issued:

```
mysql> INSERT INTO myset (col) VALUES ('a,d,d,s');
Query OK, 1 row affected, 1 warning (0.03 sec)

mysql> SHOW WARNINGS;
+---------+------+-----------------------------------------+
| Level   | Code | Message                                 |
+---------+------+-----------------------------------------+
| Warning | 1265 | Data truncated for column 'col' at row 1 |
+---------+------+-----------------------------------------+
1 row in set (0.04 sec)

mysql> SELECT col FROM myset;
+------+
| col  |
+------+
| a,d  |
| a,d  |
| a,d  |
| a,d  |
| a,d  |
| a,d  |
+------+
6 rows in set (0.01 sec)
```

If strict SQL mode is enabled, attempts to insert invalid SET values result in an error.

SET values are sorted numerically. NULL values sort before non-NULL SET values.

Functions such as SUM() or AVG() that expect a numeric argument cast the argument to a number if necessary. For SET values, the cast operation causes the numeric value to be used.

Normally, you search for SET values using the FIND_IN_SET() function or the LIKE operator:

```
mysql> SELECT * FROM tbl_name WHERE FIND_IN_SET('value',set_col)>0;
mysql> SELECT * FROM tbl_name WHERE set_col LIKE '%value%';
```

The first statement finds rows where *set_col* contains the *value* set member. The second is similar, but not the same: It finds rows where *set_col* contains *value* anywhere, even as a substring of another set member.

The following statements also are permitted:

```
mysql> SELECT * FROM tbl_name WHERE set_col & 1;
mysql> SELECT * FROM tbl_name WHERE set_col = 'val1,val2';
```

The first of these statements looks for values containing the first set member. The second looks for an exact match. Be careful with comparisons of the second type. Comparing set values to *'val1,val2'* returns different results than comparing values to *'val2,val1'*. You should specify the values in the same order they are listed in the column definition.

To determine all possible values for a SET column, use SHOW COLUMNS FROM *tbl_name* LIKE *set_col* and parse the SET definition in the Type column of the output.

In the C API, SET values are returned as strings. For information about using result set metadata to distinguish them from other strings, see Section 23.8.5, “C API Data Structures”.

11.5 Spatial Data Types

The Open Geospatial Consortium (OGC) is an international consortium of more than 250 companies, agencies, and universities participating in the development of publicly available conceptual solutions that can be useful with all kinds of applications that manage spatial data.

The Open Geospatial Consortium publishes the *OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 2: SQL option*, a document that proposes several conceptual ways for extending an SQL RDBMS to support spatial data. This specification is available from the OGC Web site at http://www.opengeospatial.org/standards/sfs.

Following the OGC specification, MySQL implements spatial extensions as a subset of the **SQL with Geometry Types** environment. This term refers to an SQL environment that has been extended with a set of geometry types. A geometry-valued SQL column is implemented as a column that has a geometry type. The specification describes a set of SQL geometry types, as well as functions on those types to create and analyze geometry values.

MySQL spatial extensions enable the generation, storage, and analysis of geographic features:

- Data types for representing spatial values
- Functions for manipulating spatial values
- Spatial indexing for improved access times to spatial columns

The spatial data types and functions are available for `MyISAM`, `InnoDB`, `NDB`, and `ARCHIVE` tables. For indexing spatial columns, `MyISAM` supports both `SPATIAL` and non-`SPATIAL` indexes. The other storage engines support non-`SPATIAL` indexes, as described in Section 13.1.13, “CREATE INDEX Syntax”.

A **geographic feature** is anything in the world that has a location. A feature can be:

- An entity. For example, a mountain, a pond, a city.
- A space. For example, town district, the tropics.
- A definable location. For example, a crossroad, as a particular place where two streets intersect.

Some documents use the term **geospatial feature** to refer to geographic features.

Geometry is another word that denotes a geographic feature. Originally the word **geometry** meant measurement of the earth. Another meaning comes from cartography, referring to the geometric features that cartographers use to map the world.

The discussion here considers these terms synonymous: **geographic feature**, **geospatial feature**, **feature**, or **geometry**. The term most commonly used is **geometry**, defined as *a point or an aggregate of points representing anything in the world that has a location*.

The following material covers these topics:

- The spatial data types implemented in MySQL model
- The basis of the spatial extensions in the OpenGIS geometry model
- Data formats for representing spatial data
- How to use spatial data in MySQL
- Use of indexing for spatial data
- MySQL differences from the OpenGIS specification

For information about functions that operate on spatial data, see Section 12.15, “Spatial Analysis Functions”.

MySQL GIS Conformance and Compatibility

MySQL does not implement the following GIS features:

- Additional Metadata Views

  OpenGIS specifications propose several additional metadata views. For example, a system view named `GEOMETRY_COLUMNS` contains a description of geometry columns, one row for each geometry column in the database.

- The OpenGIS function `Length()` on `LineString` and `MultiLineString` should be called in MySQL as `GLength()`

  The problem is that there is an existing SQL function `Length()` that calculates the length of string values, and sometimes it is not possible to distinguish whether the function is called in a textual or spatial context.

Additional Resources

- The Open Geospatial Consortium publishes the *OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 2: SQL option*, a document that proposes several conceptual ways for extending an SQL RDBMS to support spatial data. The Open Geospatial Consortium (OGC) maintains a Web site at http://www.opengeospatial.org/. The specification is available there at http://www.opengeospatial.org/standards/sfs. It contains additional information relevant to the material here.

- If you have questions or concerns about the use of the spatial extensions to MySQL, you can discuss them in the GIS forum: http://forums.mysql.com/list.php?23.

11.5.1 Spatial Data Types

MySQL has spatial data types that correspond to OpenGIS classes. The basis for these types is described in Section 11.5.2, “The OpenGIS Geometry Model”.

Some spatial data types hold single geometry values:

- `GEOMETRY`
- `POINT`
- `LINESTRING`
- `POLYGON`

`GEOMETRY` can store geometry values of any type. The other single-value types (`POINT`, `LINESTRING`, and `POLYGON`) restrict their values to a particular geometry type.

The other spatial data types hold collections of values:

- `MULTIPOINT`
- `MULTILINESTRING`
- `MULTIPOLYGON`
- `GEOMETRYCOLLECTION`

`GEOMETRYCOLLECTION` can store a collection of objects of any type. The other collection types (`MULTIPOINT`, `MULTILINESTRING`, `MULTIPOLYGON`, and `GEOMETRYCOLLECTION`) restrict collection members to those having a particular geometry type.

Example: To create a table named `geom` that has a column named `g` that can store values of any geometry type, use this statement:

```
CREATE TABLE geom (g GEOMETRY);
```

`SPATIAL` indexes can be created on `NOT NULL` spatial columns, so if you plan to index the column, declare it `NOT NULL`:

```
CREATE TABLE geom (g GEOMETRY NOT NULL);
```

For other examples showing how to use spatial data types in MySQL, see Section 11.5.4, “Creating Spatial Columns”.

11.5.2 The OpenGIS Geometry Model

The set of geometry types proposed by OGC's **SQL with Geometry Types** environment is based on the **OpenGIS Geometry Model**. In this model, each geometric object has the following general properties:

- It is associated with a spatial reference system, which describes the coordinate space in which the object is defined.
- It belongs to some geometry class.

11.5.2.1 The Geometry Class Hierarchy

The geometry classes define a hierarchy as follows:

- `Geometry` (noninstantiable)
  - `Point` (instantiable)
  - `Curve` (noninstantiable)
    - `LineString` (instantiable)
      - `Line`
      - `LinearRing`
  - `Surface` (noninstantiable)
    - `Polygon` (instantiable)
  - `GeometryCollection` (instantiable)
    - `MultiPoint` (instantiable)
    - `MultiCurve` (noninstantiable)
      - `MultiLineString` (instantiable)
    - `MultiSurface` (noninstantiable)
      - `MultiPolygon` (instantiable)

It is not possible to create objects in noninstantiable classes. It is possible to create objects in instantiable classes. All classes have properties, and instantiable classes may also have assertions (rules that define valid class instances).

`Geometry` is the base class. It is an abstract class. The instantiable subclasses of `Geometry` are restricted to zero-, one-, and two-dimensional geometric objects that exist in two-dimensional

coordinate space. All instantiable geometry classes are defined so that valid instances of a geometry class are topologically closed (that is, all defined geometries include their boundary).

The base `Geometry` class has subclasses for `Point`, `Curve`, `Surface`, and `GeometryCollection`:

- `Point` represents zero-dimensional objects.
- `Curve` represents one-dimensional objects, and has subclass `LineString`, with sub-subclasses `Line` and `LinearRing`.
- `Surface` is designed for two-dimensional objects and has subclass `Polygon`.
- `GeometryCollection` has specialized zero-, one-, and two-dimensional collection classes named `MultiPoint`, `MultiLineString`, and `MultiPolygon` for modeling geometries corresponding to collections of `Points`, `LineStrings`, and `Polygons`, respectively. `MultiCurve` and `MultiSurface` are introduced as abstract superclasses that generalize the collection interfaces to handle `Curves` and `Surfaces`.

`Geometry`, `Curve`, `Surface`, `MultiCurve`, and `MultiSurface` are defined as noninstantiable classes. They define a common set of methods for their subclasses and are included for extensibility.

`Point`, `LineString`, `Polygon`, `GeometryCollection`, `MultiPoint`, `MultiLineString`, and `MultiPolygon` are instantiable classes.

11.5.2.2 Geometry Class

`Geometry` is the root class of the hierarchy. It is a noninstantiable class but has a number of properties, described in the following list, that are common to all geometry values created from any of the `Geometry` subclasses. Particular subclasses have their own specific properties, described later.

Geometry Properties

A geometry value has the following properties:

- Its **type**. Each geometry belongs to one of the instantiable classes in the hierarchy.
- Its **SRID**, or spatial reference identifier. This value identifies the geometry's associated spatial reference system that describes the coordinate space in which the geometry object is defined.

  In MySQL, the SRID value is an integer associated with the geometry value. The maximum usable SRID value is $2^{32}-1$. If a larger value is given, only the lower 32 bits are used. All computations are done assuming SRID 0, regardless of the actual SRID value. SRID 0 represents an infinite flat Cartesian plane with no units assigned to its axes.
- Its **coordinates** in its spatial reference system, represented as double-precision (8-byte) numbers. All nonempty geometries include at least one pair of (X,Y) coordinates. Empty geometries contain no coordinates.

  Coordinates are related to the SRID. For example, in different coordinate systems, the distance between two objects may differ even when objects have the same coordinates, because the distance on the **planar** coordinate system and the distance on the **geodetic** system (coordinates on the Earth's surface) are different things.
- Its **interior**, **boundary**, and **exterior**.

  Every geometry occupies some position in space. The exterior of a geometry is all space not occupied by the geometry. The interior is the space occupied by the geometry. The boundary is the interface between the geometry's interior and exterior.
- Its **MBR** (minimum bounding rectangle), or envelope. This is the bounding geometry, formed by the minimum and maximum (X,Y) coordinates:

```
((MINX MINY, MAXX MINY, MAXX MAXY, MINX MAXY, MINX MINY))
```

- Whether the value is **simple** or **nonsimple**. Geometry values of types (`LineString`, `MultiPoint`, `MultiLineString`) are either simple or nonsimple. Each type determines its own assertions for being simple or nonsimple.
- Whether the value is **closed** or **not closed**. Geometry values of types (`LineString`, `MultiString`) are either closed or not closed. Each type determines its own assertions for being closed or not closed.
- Whether the value is **empty** or **nonempty** A geometry is empty if it does not have any points. Exterior, interior, and boundary of an empty geometry are not defined (that is, they are represented by a `NULL` value). An empty geometry is defined to be always simple and has an area of 0.
- Its **dimension**. A geometry can have a dimension of −1, 0, 1, or 2:
  - −1 for an empty geometry.
  - 0 for a geometry with no length and no area.
  - 1 for a geometry with nonzero length and zero area.
  - 2 for a geometry with nonzero area.

  `Point` objects have a dimension of zero. `LineString` objects have a dimension of 1. `Polygon` objects have a dimension of 2. The dimensions of `MultiPoint`, `MultiLineString`, and `MultiPolygon` objects are the same as the dimensions of the elements they consist of.

11.5.2.3 Point Class

A `Point` is a geometry that represents a single location in coordinate space.

`Point` Examples

- Imagine a large-scale map of the world with many cities. A `Point` object could represent each city.
- On a city map, a `Point` object could represent a bus stop.

`Point` Properties

- X-coordinate value.
- Y-coordinate value.
- `Point` is defined as a zero-dimensional geometry.
- The boundary of a `Point` is the empty set.

11.5.2.4 Curve Class

A `Curve` is a one-dimensional geometry, usually represented by a sequence of points. Particular subclasses of `Curve` define the type of interpolation between points. `Curve` is a noninstantiable class.

`Curve` Properties

- A `Curve` has the coordinates of its points.
- A `Curve` is defined as a one-dimensional geometry.
- A `Curve` is simple if it does not pass through the same point twice, with the exception that a curve can still be simple if the start and end points are the same.

- A `Curve` is closed if its start point is equal to its endpoint.
- The boundary of a closed `Curve` is empty.
- The boundary of a nonclosed `Curve` consists of its two endpoints.
- A `Curve` that is simple and closed is a `LinearRing`.

11.5.2.5 LineString Class

A `LineString` is a `Curve` with linear interpolation between points.

`LineString` Examples

- On a world map, `LineString` objects could represent rivers.
- In a city map, `LineString` objects could represent streets.

`LineString` Properties

- A `LineString` has coordinates of segments, defined by each consecutive pair of points.
- A `LineString` is a `Line` if it consists of exactly two points.
- A `LineString` is a `LinearRing` if it is both closed and simple.

11.5.2.6 Surface Class

A `Surface` is a two-dimensional geometry. It is a noninstantiable class. Its only instantiable subclass is `Polygon`.

`Surface` Properties

- A `Surface` is defined as a two-dimensional geometry.
- The OpenGIS specification defines a simple `Surface` as a geometry that consists of a single “patch” that is associated with a single exterior boundary and zero or more interior boundaries.
- The boundary of a simple `Surface` is the set of closed curves corresponding to its exterior and interior boundaries.

11.5.2.7 Polygon Class

A `Polygon` is a planar `Surface` representing a multisided geometry. It is defined by a single exterior boundary and zero or more interior boundaries, where each interior boundary defines a hole in the `Polygon`.

`Polygon` Examples

- On a region map, `Polygon` objects could represent forests, districts, and so on.

`Polygon` Assertions

- The boundary of a `Polygon` consists of a set of `LinearRing` objects (that is, `LineString` objects that are both simple and closed) that make up its exterior and interior boundaries.
- A `Polygon` has no rings that cross. The rings in the boundary of a `Polygon` may intersect at a `Point`, but only as a tangent.
- A `Polygon` has no lines, spikes, or punctures.
- A `Polygon` has an interior that is a connected point set.

- A `Polygon` may have holes. The exterior of a `Polygon` with holes is not connected. Each hole defines a connected component of the exterior.

The preceding assertions make a `Polygon` a simple geometry.

11.5.2.8 GeometryCollection Class

A `GeometryCollection` is a geometry that is a collection of one or more geometries of any class.

All the elements in a `GeometryCollection` must be in the same spatial reference system (that is, in the same coordinate system). There are no other constraints on the elements of a `GeometryCollection`, although the subclasses of `GeometryCollection` described in the following sections may restrict membership. Restrictions may be based on:

- Element type (for example, a `MultiPoint` may contain only `Point` elements)
- Dimension
- Constraints on the degree of spatial overlap between elements

11.5.2.9 MultiPoint Class

A `MultiPoint` is a geometry collection composed of `Point` elements. The points are not connected or ordered in any way.

`MultiPoint` Examples

- On a world map, a `MultiPoint` could represent a chain of small islands.
- On a city map, a `MultiPoint` could represent the outlets for a ticket office.

`MultiPoint` Properties

- A `MultiPoint` is a zero-dimensional geometry.
- A `MultiPoint` is simple if no two of its `Point` values are equal (have identical coordinate values).
- The boundary of a `MultiPoint` is the empty set.

11.5.2.10 MultiCurve Class

A `MultiCurve` is a geometry collection composed of `Curve` elements. `MultiCurve` is a noninstantiable class.

`MultiCurve` Properties

- A `MultiCurve` is a one-dimensional geometry.
- A `MultiCurve` is simple if and only if all of its elements are simple; the only intersections between any two elements occur at points that are on the boundaries of both elements.
- A `MultiCurve` boundary is obtained by applying the “mod 2 union rule” (also known as the “odd-even rule”): A point is in the boundary of a `MultiCurve` if it is in the boundaries of an odd number of `Curve` elements.
- A `MultiCurve` is closed if all of its elements are closed.
- The boundary of a closed `MultiCurve` is always empty.

11.5.2.11 MultiLineString Class

A `MultiLineString` is a `MultiCurve` geometry collection composed of `LineString` elements.

`MultiLineString` Examples

- On a region map, a `MultiLineString` could represent a river system or a highway system.

11.5.2.12 MultiSurface Class

A `MultiSurface` is a geometry collection composed of surface elements. `MultiSurface` is a noninstantiable class. Its only instantiable subclass is `MultiPolygon`.

`MultiSurface` Assertions

- Surfaces within a `MultiSurface` have no interiors that intersect.
- Surfaces within a `MultiSurface` have boundaries that intersect at most at a finite number of points.

11.5.2.13 MultiPolygon Class

A `MultiPolygon` is a `MultiSurface` object composed of `Polygon` elements.

`MultiPolygon` Examples

- On a region map, a `MultiPolygon` could represent a system of lakes.

`MultiPolygon` Assertions

- A `MultiPolygon` has no two `Polygon` elements with interiors that intersect.
- A `MultiPolygon` has no two `Polygon` elements that cross (crossing is also forbidden by the previous assertion), or that touch at an infinite number of points.
- A `MultiPolygon` may not have cut lines, spikes, or punctures. A `MultiPolygon` is a regular, closed point set.
- A `MultiPolygon` that has more than one `Polygon` has an interior that is not connected. The number of connected components of the interior of a `MultiPolygon` is equal to the number of `Polygon` values in the `MultiPolygon`.

`MultiPolygon` Properties

- A `MultiPolygon` is a two-dimensional geometry.
- A `MultiPolygon` boundary is a set of closed curves (`LineString` values) corresponding to the boundaries of its `Polygon` elements.
- Each `Curve` in the boundary of the `MultiPolygon` is in the boundary of exactly one `Polygon` element.
- Every `Curve` in the boundary of an `Polygon` element is in the boundary of the `MultiPolygon`.

11.5.3 Supported Spatial Data Formats

Two standard spatial data formats are used to represent geometry objects in queries:

- Well-Known Text (WKT) format
- Well-Known Binary (WKB) format

Internally, MySQL stores geometry values in a format that is not identical to either WKT or WKB format. (Internal format is like WKB but with an initial 4 bytes to indicate the SRID.)

There are functions available to convert between different data formats; see Section 12.15.6, “Geometry Format Conversion Functions”.

The following sections describe the spatial data formats MySQL uses:

- Well-Known Text (WKT) Format
- Well-Known Binary (WKB) Format
- Internal Geometry Storage Format

Well-Known Text (WKT) Format

The Well-Known Text (WKT) representation of geometry values is designed for exchanging geometry data in ASCII form. The OpenGIS specification provides a Backus-Naur grammar that specifies the formal production rules for writing WKT values (see Section 11.5, “Spatial Data Types”).

Examples of WKT representations of geometry objects:

- A `Point`:

```
POINT(15 20)
```

  The point coordinates are specified with no separating comma. This differs from the syntax for the SQL `Point()` function, which requires a comma between the coordinates. Take care to use the syntax appropriate to the context of a given spatial operation. For example, the following statements both use `X()` to extract the X-coordinate from a `Point` object. The first produces the object directly using the `Point()` function. The second uses a WKT representation converted to a `Point` with `GeomFromText()`.

```
mysql> SELECT X(Point(15, 20));
+------------------+
| X(POINT(15, 20)) |
+------------------+
|               15 |
+------------------+

mysql> SELECT X(GeomFromText('POINT(15 20)'));
+---------------------------------+
| X(GeomFromText('POINT(15 20)')) |
+---------------------------------+
|                              15 |
+---------------------------------+
```

- A `LineString` with four points:

```
LINESTRING(0 0, 10 10, 20 25, 50 60)
```

  The point coordinate pairs are separated by commas.

- A `Polygon` with one exterior ring and one interior ring:

```
POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7, 5 5))
```

- A `MultiPoint` with three `Point` values:

```
MULTIPOINT(0 0, 20 20, 60 60)
```

- A `MultiLineString` with two `LineString` values:

```
MULTILINESTRING((10 10, 20 20), (15 15, 30 15))
```

- A `MultiPolygon` with two `Polygon` values:

```
MULTIPOLYGON(((0 0,10 0,10 10,0 10,0 0)),((5 5,7 5,7 7,5 7, 5 5)))
```

- A `GeometryCollection` consisting of two `Point` values and one `LineString`:

```
GEOMETRYCOLLECTION(POINT(10 10), POINT(30 30), LINESTRING(15 15, 20 20))
```

Well-Known Binary (WKB) Format

The Well-Known Binary (WKB) representation of geometric values is used for exchanging geometry data as binary streams represented by `BLOB` values containing geometric WKB information. This format is defined by the OpenGIS specification (see Section 11.5, “Spatial Data Types”). It is also defined in the ISO *SQL/MM Part 3: Spatial* standard.

WKB uses 1-byte unsigned integers, 4-byte unsigned integers, and 8-byte double-precision numbers (IEEE 754 format). A byte is eight bits.

For example, a WKB value that corresponds to `POINT(1 -1)` consists of this sequence of 21 bytes, each represented by two hexadecimal digits:

```
0101000000000000000000F03F000000000000F0BF
```

The sequence consists of the components shown in the following table.

Table 11.1 WKB Components Example

Component	Size	Value
Byte order	1 byte	`01`
WKB type	4 bytes	`01000000`
X coordinate	8 bytes	`000000000000F03F`
Y coordinate	8 bytes	`000000000000F0BF`

Component representation is as follows:

- The byte order indicator is either 1 or 0 to signify little-endian or big-endian storage. The little-endian and big-endian byte orders are also known as Network Data Representation (NDR) and External Data Representation (XDR), respectively.
- The WKB type is a code that indicates the geometry type. MySQL uses values from 1 through 7 to indicate `Point`, `LineString`, `Polygon`, `MultiPoint`, `MultiLineString`, `MultiPolygon`, and `GeometryCollection`.
- A `Point` value has X and Y coordinates, each represented as a double-precision value.

WKB values for more complex geometry values have more complex data structures, as detailed in the OpenGIS specification.

Internal Geometry Storage Format

MySQL stores geometry values using 4 bytes to indicate the SRID followed by the WKB representation of the value. For a description of WKB format, see Well-Known Binary (WKB) Format.

For the WKB part, these MySQL-specific considerations apply:

- The byte-order indicator byte is 1 because MySQL stores geometries as little-ending values.
- MySQL supports geometry types of `Point`, `LineString`, `Polygon`, `MultiPoint`, `MultiLineString`, `MultiPolygon`, and `GeometryCollection`. Other geometry types are not supported.

The `LENGTH()` function returns the space in bytes required for value storage. Example:

```
mysql> SET @g = GeomFromText('POINT(1 -1)');
mysql> SELECT LENGTH(@g);
+------------+
| LENGTH(@g) |
+------------+
|         25 |
+------------+
mysql> SELECT HEX(@g);
+----------------------------------------------------+
| HEX(@g)                                            |
+----------------------------------------------------+
| 000000000101000000000000000000F03F000000000000F0BF |
+----------------------------------------------------+
```

The value length is 25 bytes, made up of these components (as can be seen from the hexadecimal value):

- 4 bytes for integer SRID (0)
- 1 byte for integer byte order (1 = little-endian)
- 4 bytes for integer type information (1 = `Point`)
- 8 bytes for double-precision X coordinate (1)
- 8 bytes for double-precision Y coordinate (−1)

11.5.4 Creating Spatial Columns

MySQL provides a standard way of creating spatial columns for geometry types, for example, with `CREATE TABLE` or `ALTER TABLE`. Spatial columns are supported for `MyISAM`, `InnoDB`, `NDB`, and `ARCHIVE` tables. See also the notes about spatial indexes under Section 11.5.8, “Creating Spatial Indexes”.

- Use the `CREATE TABLE` statement to create a table with a spatial column:

```
CREATE TABLE geom (g GEOMETRY);
```

- Use the `ALTER TABLE` statement to add or drop a spatial column to or from an existing table:

```
ALTER TABLE geom ADD pt POINT;
ALTER TABLE geom DROP pt;
```

11.5.5 Populating Spatial Columns

After you have created spatial columns, you can populate them with spatial data.

Values should be stored in internal geometry format, but you can convert them to that format from either Well-Known Text (WKT) or Well-Known Binary (WKB) format. The following examples demonstrate how to insert geometry values into a table by converting WKT values to internal geometry format:

- Perform the conversion directly in the `INSERT` statement:

```
INSERT INTO geom VALUES (GeomFromText('POINT(1 1)'));

SET @g = 'POINT(1 1)';
INSERT INTO geom VALUES (GeomFromText(@g));
```

- Perform the conversion prior to the `INSERT`:

```
SET @g = GeomFromText('POINT(1 1)');
INSERT INTO geom VALUES (@g);
```

The following examples insert more complex geometries into the table:

```
SET @g = 'LINESTRING(0 0,1 1,2 2)';
INSERT INTO geom VALUES (GeomFromText(@g));

SET @g = 'POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7, 5 5))';
INSERT INTO geom VALUES (GeomFromText(@g));

SET @g =
'GEOMETRYCOLLECTION(POINT(1 1),LINESTRING(0 0,1 1,2 2,3 3,4 4))';
INSERT INTO geom VALUES (GeomFromText(@g));
```

The preceding examples use `GeomFromText()` to create geometry values. You can also use type-specific functions:

```
SET @g = 'POINT(1 1)';
INSERT INTO geom VALUES (PointFromText(@g));

SET @g = 'LINESTRING(0 0,1 1,2 2)';
INSERT INTO geom VALUES (LineStringFromText(@g));

SET @g = 'POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7, 5 5))';
INSERT INTO geom VALUES (PolygonFromText(@g));

SET @g =
'GEOMETRYCOLLECTION(POINT(1 1),LINESTRING(0 0,1 1,2 2,3 3,4 4))';
INSERT INTO geom VALUES (GeomCollFromText(@g));
```

A client application program that wants to use WKB representations of geometry values is responsible for sending correctly formed WKB in queries to the server. There are several ways to satisfy this requirement. For example:

- Inserting a `POINT(1 1)` value with hex literal syntax:

  ```
  INSERT INTO geom VALUES
  (GeomFromWKB(X'0101000000000000000000F03F000000000000F03F'));
  ```

- An ODBC application can send a WKB representation, binding it to a placeholder using an argument of `BLOB` type:

  ```
  INSERT INTO geom VALUES (GeomFromWKB(?))
  ```

  Other programming interfaces may support a similar placeholder mechanism.

- In a C program, you can escape a binary value using `mysql_real_escape_string()` and include the result in a query string that is sent to the server. See Section 23.8.7.53, “mysql_real_escape_string()”.

11.5.6 Fetching Spatial Data

Geometry values stored in a table can be fetched in internal format. You can also convert them to WKT or WKB format.

- Fetching spatial data in internal format:

  Fetching geometry values using internal format can be useful in table-to-table transfers:

  ```
  ```

```
CREATE TABLE geom2 (g GEOMETRY) SELECT g FROM geom;
```

- Fetching spatial data in WKT format:

  The `AsText()` function converts a geometry from internal format to a WKT string.

```
SELECT AsText(g) FROM geom;
```

- Fetching spatial data in WKB format:

  The `AsBinary()` function converts a geometry from internal format to a `BLOB` containing the WKB value.

```
SELECT AsBinary(g) FROM geom;
```

11.5.7 Optimizing Spatial Analysis

For `MyISAM` tables, search operations in columns containing spatial data can be optimized using `SPATIAL` indexes. The most typical operations are:

- Point queries that search for all objects that contain a given point
- Region queries that search for all objects that overlap a given region

MySQL uses **R-Trees with quadratic splitting** for `SPATIAL` indexes on spatial columns. A `SPATIAL` index is built using the minimum bounding rectangle (MBR) of a geometry. For most geometries, the MBR is a minimum rectangle that surrounds the geometries. For a horizontal or a vertical linestring, the MBR is a rectangle degenerated into the linestring. For a point, the MBR is a rectangle degenerated into the point.

It is also possible to create normal indexes on spatial columns. In a non-`SPATIAL` index, you must declare a prefix for any spatial column except for `POINT` columns.

`MyISAM` supports both `SPATIAL` and non-`SPATIAL` indexes. Other storage engines support non-`SPATIAL` indexes, as described in Section 13.1.13, “CREATE INDEX Syntax”.

11.5.8 Creating Spatial Indexes

For `MyISAM` tables, MySQL can create spatial indexes using syntax similar to that for creating regular indexes, but using the `SPATIAL` keyword. Columns in spatial indexes must be declared `NOT NULL`. The following examples demonstrate how to create spatial indexes:

- With `CREATE TABLE`:

```
CREATE TABLE geom (g GEOMETRY NOT NULL, SPATIAL INDEX(g)) ENGINE=MyISAM;
```

- With `ALTER TABLE`:

```
CREATE TABLE geom (g GEOMETRY NOT NULL) ENGINE=MyISAM;
ALTER TABLE geom ADD SPATIAL INDEX(g);
```

- With `CREATE INDEX`:

```
CREATE TABLE geom (g GEOMETRY NOT NULL) ENGINE=MyISAM;
CREATE SPATIAL INDEX g ON geom (g);
```

`SPATIAL INDEX` creates an R-tree index. For storage engines that support nonspatial indexing of spatial columns, the engine creates a B-tree index. A B-tree index on spatial values is useful for exact-value lookups, but not for range scans.

For more information on indexing spatial columns, see Section 13.1.13, “CREATE INDEX Syntax”.

To drop spatial indexes, use `ALTER TABLE` or `DROP INDEX`:

- With `ALTER TABLE`:

```
ALTER TABLE geom DROP INDEX g;
```

- With `DROP INDEX`:

```
DROP INDEX g ON geom;
```

Example: Suppose that a table `geom` contains more than 32,000 geometries, which are stored in the column `g` of type `GEOMETRY`. The table also has an `AUTO_INCREMENT` column `fid` for storing object ID values.

```
mysql> DESCRIBE geom;
+-------+----------+------+-----+---------+----------------+
| Field | Type     | Null | Key | Default | Extra          |
+-------+----------+------+-----+---------+----------------+
| fid   | int(11)  |      | PRI | NULL    | auto_increment |
| g     | geometry |      |     |         |                |
+-------+----------+------+-----+---------+----------------+
2 rows in set (0.00 sec)

mysql> SELECT COUNT(*) FROM geom;
+----------+
| count(*) |
+----------+
|    32376 |
+----------+
1 row in set (0.00 sec)
```

To add a spatial index on the column `g`, use this statement:

```
mysql> ALTER TABLE geom ADD SPATIAL INDEX(g) ENGINE=MyISAM;
Query OK, 32376 rows affected (4.05 sec)
Records: 32376  Duplicates: 0  Warnings: 0
```

11.5.9 Using Spatial Indexes

The optimizer investigates whether available spatial indexes can be involved in the search for queries that use a function such as `MBRContains()` or `MBRWithin()` in the `WHERE` clause. The following query finds all objects that are in the given rectangle:

```
mysql> SET @poly =
    -> 'Polygon((30000 15000,
                 31000 15000,
                 31000 16000,
                 30000 16000,
                 30000 15000))';
mysql> SELECT fid,AsText(g) FROM geom WHERE
    -> MBRContains(GeomFromText(@poly),g);
+-----+-------------------------------------------------------------+
| fid | AsText(g)                                                   |
+-----+-------------------------------------------------------------+
|  21 | LINESTRING(30350.4 15828.8,30350.6 15845,30333.8 15845,30 ... |
|  22 | LINESTRING(30350.6 15871.4,30350.6 15887.8,30334 15887.8, ... |
|  23 | LINESTRING(30350.6 15914.2,30350.6 15930.4,30334 15930.4, ... |
|  24 | LINESTRING(30290.2 15823,30290.2 15839.4,30273.4 15839.4, ... |
|  25 | LINESTRING(30291.4 15866.2,30291.6 15882.4,30274.8 15882. ... |
|  26 | LINESTRING(30291.6 15918.2,30291.6 15934.4,30275 15934.4, ... |
| 249 | LINESTRING(30337.8 15938.6,30337.8 15946.8,30320.4 15946. ... |
|   1 | LINESTRING(30250.4 15129.2,30248.8 15138.4,30238.2 15136. ... |
```

```
|   2 | LINESTRING(30220.2 15122.8,30217.2 15137.8,30207.6 15136, ... |
|   3 | LINESTRING(30179 15114.4,30176.6 15129.4,30167 15128,3016 ... |
|   4 | LINESTRING(30155.2 15121.4,30140.4 15118.6,30142 15109,30 ... |
|   5 | LINESTRING(30192.4 15085,30177.6 15082.2,30179.2 15072.4, ... |
|   6 | LINESTRING(30244 15087,30229 15086.2,30229.4 15076.4,3024 ... |
|   7 | LINESTRING(30200.6 15059.4,30185.6 15058.6,30186 15048.8, ... |
|  10 | LINESTRING(30179.6 15017.8,30181 15002.8,30190.8 15003.6, ... |
|  11 | LINESTRING(30154.2 15000.4,30168.6 15004.8,30166 15014.2, ... |
|  13 | LINESTRING(30105 15065.8,30108.4 15050.8,30118 15053,3011 ... |
| 154 | LINESTRING(30276.2 15143.8,30261.4 15141,30263 15131.4,30 ... |
| 155 | LINESTRING(30269.8 15084,30269.4 15093.4,30258.6 15093,30 ... |
| 157 | LINESTRING(30128.2 15011,30113.2 15010.2,30113.6 15000.4, ... |
+-----+--------------------------------------------------------------+
20 rows in set (0.00 sec)
```

Use `EXPLAIN` to check the way this query is executed:

```
mysql> SET @poly =
    -> 'Polygon((30000 15000,
                 31000 15000,
                 31000 16000,
                 30000 16000,
                 30000 15000))';
mysql> EXPLAIN SELECT fid,AsText(g) FROM geom WHERE
    -> MBRContains(GeomFromText(@poly),g)\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: geom
         type: range
possible_keys: g
          key: g
      key_len: 32
          ref: NULL
         rows: 50
        Extra: Using where
1 row in set (0.00 sec)
```

Check what would happen without a spatial index:

```
mysql> SET @poly =
    -> 'Polygon((30000 15000,
                 31000 15000,
                 31000 16000,
                 30000 16000,
                 30000 15000))';
mysql> EXPLAIN SELECT fid,AsText(g) FROM g IGNORE INDEX (g) WHERE
    -> MBRContains(GeomFromText(@poly),g)\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: geom
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 32376
        Extra: Using where
1 row in set (0.00 sec)
```

Executing the `SELECT` statement without the spatial index yields the same result but causes the execution time to rise from 0.00 seconds to 0.46 seconds:

```
mysql> SET @poly =
    -> 'Polygon((30000 15000,
                 31000 15000,
                 31000 16000,
```

```
                30000 16000,
                30000 15000))';
mysql> SELECT fid,AsText(g) FROM geom IGNORE INDEX (g) WHERE
    -> MBRContains(GeomFromText(@poly),g);
+-----+-------------------------------------------------------------+
| fid | AsText(g)                                                   |
+-----+-------------------------------------------------------------+
|   1 | LINESTRING(30250.4 15129.2,30248.8 15138.4,30238.2 15136. ... |
|   2 | LINESTRING(30220.2 15122.8,30217.2 15137.8,30207.6 15136, ... |
|   3 | LINESTRING(30179 15114.4,30176.6 15129.4,30167 15128,3016 ... |
|   4 | LINESTRING(30155.2 15121.4,30140.4 15118.6,30142 15109,30 ... |
|   5 | LINESTRING(30192.4 15085,30177.6 15082.2,30179.2 15072.4, ... |
|   6 | LINESTRING(30244 15087,30229 15086.2,30229.4 15076.4,3024 ... |
|   7 | LINESTRING(30200.6 15059.4,30185.6 15058.6,30186 15048.8, ... |
|  10 | LINESTRING(30179.6 15017.8,30181 15002.8,30190.8 15003.6, ... |
|  11 | LINESTRING(30154.2 15000.4,30168.6 15004.8,30166 15014.2, ... |
|  13 | LINESTRING(30105 15065.8,30108.4 15050.8,30118 15053,3011 ... |
|  21 | LINESTRING(30350.4 15828.8,30350.6 15845,30333.8 15845,30 ... |
|  22 | LINESTRING(30350.6 15871.4,30350.6 15887.8,30334 15887.8, ... |
|  23 | LINESTRING(30350.6 15914.2,30350.6 15930.4,30334 15930.4, ... |
|  24 | LINESTRING(30290.2 15823,30290.2 15839.4,30273.4 15839.4, ... |
|  25 | LINESTRING(30291.4 15866.2,30291.6 15882.4,30274.8 15882. ... |
|  26 | LINESTRING(30291.6 15918.2,30291.6 15934.4,30275 15934.4, ... |
| 154 | LINESTRING(30276.2 15143.8,30261.4 15141,30263 15131.4,30 ... |
| 155 | LINESTRING(30269.8 15084,30269.4 15093.4,30258.6 15093,30 ... |
| 157 | LINESTRING(30128.2 15011,30113.2 15010.2,30113.6 15000.4, ... |
| 249 | LINESTRING(30337.8 15938.6,30337.8 15946.8,30320.4 15946. ... |
+-----+-------------------------------------------------------------+
20 rows in set (0.46 sec)
```

11.6 Data Type Default Values

The `DEFAULT value` clause in a data type specification indicates a default value for a column. With one exception, the default value must be a constant; it cannot be a function or an expression. This means, for example, that you cannot set the default for a date column to be the value of a function such as `NOW()` or `CURRENT_DATE`. The exception is that you can specify `CURRENT_TIMESTAMP` as the default for a `TIMESTAMP` column. See Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”.

`BLOB` and `TEXT` columns cannot be assigned a default value.

If a column definition includes no explicit `DEFAULT` value, MySQL determines the default value as follows:

If the column can take `NULL` as a value, the column is defined with an explicit `DEFAULT NULL` clause.

If the column cannot take `NULL` as the value, MySQL defines the column with no explicit `DEFAULT` clause. Exception: If the column is defined as part of a `PRIMARY KEY` but not explicitly as `NOT NULL`, MySQL creates it as a `NOT NULL` column (because `PRIMARY KEY` columns must be `NOT NULL`), but also assigns it a `DEFAULT` clause using the implicit default value. To prevent this, include an explicit `NOT NULL` in the definition of any `PRIMARY KEY` column.

For data entry into a `NOT NULL` column that has no explicit `DEFAULT` clause, if an `INSERT` or `REPLACE` statement includes no value for the column, or an `UPDATE` statement sets the column to `NULL`, MySQL handles the column according to the SQL mode in effect at the time:

- If strict SQL mode is enabled, an error occurs for transactional tables and the statement is rolled back. For nontransactional tables, an error occurs, but if this happens for the second or subsequent row of a multiple-row statement, the preceding rows will have been inserted.
- If strict mode is not enabled, MySQL sets the column to the implicit default value for the column data type.

Suppose that a table `t` is defined as follows:

```
CREATE TABLE t (i INT NOT NULL);
```

In this case, `i` has no explicit default, so in strict mode each of the following statements produce an error and no row is inserted. When not using strict mode, only the third statement produces an error; the implicit default is inserted for the first two statements, but the third fails because `DEFAULT(i)` cannot produce a value:

```
INSERT INTO t VALUES();
INSERT INTO t VALUES(DEFAULT);
INSERT INTO t VALUES(DEFAULT(i));
```

See Section 5.1.8, “Server SQL Modes”.

For a given table, you can use the `SHOW CREATE TABLE` statement to see which columns have an explicit `DEFAULT` clause.

Implicit defaults are defined as follows:

- For numeric types, the default is `0`, with the exception that for integer or floating-point types declared with the `AUTO_INCREMENT` attribute, the default is the next value in the sequence.
- For date and time types other than `TIMESTAMP`, the default is the appropriate “zero” value for the type. For the first `TIMESTAMP` column in a table, the default value is the current date and time. See Section 11.3, “Date and Time Types”.
- For string types other than `ENUM`, the default value is the empty string. For `ENUM`, the default is the first enumeration value.

`SERIAL DEFAULT VALUE` in the definition of an integer column is an alias for `NOT NULL AUTO_INCREMENT UNIQUE`.

11.7 Data Type Storage Requirements

- InnoDB Table Storage Requirements
- NDBCLUSTER Table Storage Requirements
- Numeric Type Storage Requirements
- Date and Time Type Storage Requirements
- String Type Storage Requirements
- Spatial Type Storage Requirements

The storage requirements for data vary, according to the storage engine being used for the table in question. Different storage engines use different methods for recording the raw data and different data types. In addition, some engines may compress the information in a given row, either on a column or entire row basis, making calculation of the storage requirements for a given table or column structure.

However, all storage engines must communicate and exchange information on a given row within a table using the same structure, and this information is consistent, irrespective of the storage engine used to write the information to disk.

This sections includes some guideliness and information for the storage requirements for each data type supported by MySQL, including details for the internal format and the sizes used by storage engines that used a fixed size representation for different types. Information is listed by category or storage engine.

The internal representation of a table has a maximum row size of 65,535 bytes, even if the storage engine is capable of supporting larger rows. This figure excludes `BLOB` or `TEXT` columns, which

contribute only 9 to 12 bytes toward this size. For BLOB and TEXT data, the information is stored internally in a different area of memory than the row buffer. Different storage engines handle the allocation and storage of this data in different ways, according to the method they use for handling the corresponding types. For more information, see Chapter 15, *Alternative Storage Engines*, and Section C.10.4, "Limits on Table Column Count and Row Size".

InnoDB Table Storage Requirements

See Section 14.11.1.2, "The Physical Row Structure of an InnoDB Table" for information about storage requirements for InnoDB tables.

NDBCLUSTER Table Storage Requirements

Important

For tables using the NDBCLUSTER storage engine, there is the factor of *4-byte alignment* to be taken into account when calculating storage requirements. This means that all NDB data storage is done in multiples of 4 bytes. Thus, a column value that would take 15 bytes in a table using a storage engine other than NDB requires 16 bytes in an NDB table. This requirement applies in addition to any other considerations that are discussed in this section. For example, in NDBCLUSTER tables, the TINYINT, SMALLINT, MEDIUMINT, and INTEGER (INT) column types each require 4 bytes storage per record due to the alignment factor.

An exception to this rule is the BIT type, which is *not* 4-byte aligned. In NDB Cluster tables, a BIT(*M*) column takes *M* bits of storage space. However, if a table definition contains 1 or more BIT columns (up to 32 BIT columns), then NDBCLUSTER reserves 4 bytes (32 bits) per row for these. If a table definition contains more than 32 BIT columns (up to 64 such columns), then NDBCLUSTER reserves 8 bytes (that is, 64 bits) per row.

In addition, while a NULL itself does not require any storage space, NDBCLUSTER reserves 4 bytes per row if the table definition contains any columns defined as NULL, up to 32 NULL columns. (If an NDB Cluster table is defined with more than 32 NULL columns up to 64 NULL columns, then 8 bytes per row is reserved.)

When calculating storage requirements for NDB Cluster tables, you must also remember that every table using the NDBCLUSTER storage engine requires a primary key; if no primary key is defined by the user, then a "hidden" primary key will be created by NDB. This hidden primary key consumes 31-35 bytes per table record.

You may find the ndb_size.pl utility to be useful for estimating NDB storage requirements. This Perl script connects to a current MySQL (non-Cluster) database and creates a report on how much space that database would require if it used the NDBCLUSTER storage engine. See Section 18.4.25, "ndb_size.pl — NDBCLUSTER Size Requirement Estimator", for more information.

Numeric Type Storage Requirements

Data Type	Storage Required
TINYINT	1 byte
SMALLINT	2 bytes
MEDIUMINT	3 bytes
INT, INTEGER	4 bytes
BIGINT	8 bytes

Data Type	Storage Required
FLOAT(*p*)	4 bytes if 0 <= *p* <= 24, 8 bytes if 25 <= *p* <= 53
FLOAT	4 bytes
DOUBLE [PRECISION], REAL	8 bytes
DECIMAL(*M*,*D*), NUMERIC(*M*,*D*)	Varies; see following discussion
BIT(*M*)	approximately (*M*+7)/8 bytes

Values for DECIMAL (and NUMERIC) columns are represented using a binary format that packs nine decimal (base 10) digits into four bytes. Storage for the integer and fractional parts of each value are determined separately. Each multiple of nine digits requires four bytes, and the “leftover” digits require some fraction of four bytes. The storage required for excess digits is given by the following table.

Leftover Digits	Number of Bytes
0	0
1	1
2	1
3	2
4	2
5	3
6	3
7	4
8	4

Date and Time Type Storage Requirements

Data Type	Storage Required
DATE	3 bytes
TIME	3 bytes
DATETIME	8 bytes
TIMESTAMP	4 bytes
YEAR	1 byte

For details about internal representation of temporal values, see MySQL Internals: Important Algorithms and Structures.

String Type Storage Requirements

In the following table, *M* represents the declared column length in characters for nonbinary string types and bytes for binary string types. *L* represents the actual length in bytes of a given string value.

Data Type	Storage Required
CHAR(*M*)	*M* × *w* bytes, 0 <= *M* <= 255, where *w* is the number of bytes required for the maximum-length character in the character set. See Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table” for information about CHAR data type storage requirements for InnoDB tables.
BINARY(*M*)	*M* bytes, 0 <= *M* <= 255
VARCHAR(*M*), VARBINARY(*M*)	*L* + 1 bytes if column values require 0 − 255 bytes, *L* + 2 bytes if values may require more than 255 bytes

Data Type	Storage Required
TINYBLOB, TINYTEXT	*L* + 1 bytes, where *L* < 2^8
BLOB, TEXT	*L* + 2 bytes, where *L* < 2^{16}
MEDIUMBLOB, MEDIUMTEXT	*L* + 3 bytes, where *L* < 2^{24}
LONGBLOB, LONGTEXT	*L* + 4 bytes, where *L* < 2^{32}
ENUM('*value1*','*value2*',...)	1 or 2 bytes, depending on the number of enumeration values (65,535 values maximum)
SET('*value1*','*value2*',...)	1, 2, 3, 4, or 8 bytes, depending on the number of set members (64 members maximum)

Variable-length string types are stored using a length prefix plus data. The length prefix requires from one to four bytes depending on the data type, and the value of the prefix is *L* (the byte length of the string). For example, storage for a MEDIUMTEXT value requires *L* bytes to store the value plus three bytes to store the length of the value.

To calculate the number of bytes used to store a particular CHAR, VARCHAR, or TEXT column value, you must take into account the character set used for that column and whether the value contains multibyte characters. In particular, when using a utf8 Unicode character set, you must keep in mind that not all characters use the same number of bytes. utf8mb3 and utf8mb4 character sets can require up to three and four bytes per character, respectively. For a breakdown of the storage used for different categories of utf8mb3 or utf8mb4 characters, see Section 10.1.9, “Unicode Support”.

VARCHAR, VARBINARY, and the BLOB and TEXT types are variable-length types. For each, the storage requirements depend on these factors:

- The actual length of the column value
- The column's maximum possible length
- The character set used for the column, because some character sets contain multibyte characters

For example, a VARCHAR(255) column can hold a string with a maximum length of 255 characters. Assuming that the column uses the latin1 character set (one byte per character), the actual storage required is the length of the string (*L*), plus one byte to record the length of the string. For the string 'abcd', *L* is 4 and the storage requirement is five bytes. If the same column is instead declared to use the ucs2 double-byte character set, the storage requirement is 10 bytes: The length of 'abcd' is eight bytes and the column requires two bytes to store lengths because the maximum length is greater than 255 (up to 510 bytes).

The effective maximum number of *bytes* that can be stored in a VARCHAR or VARBINARY column is subject to the maximum row size of 65,535 bytes, which is shared among all columns. For a VARCHAR column that stores multibyte characters, the effective maximum number of *characters* is less. For example, utf8mb3 characters can require up to three bytes per character, so a VARCHAR column that uses the utf8mb3 character set can be declared to be a maximum of 21,844 characters. See Section C.10.4, “Limits on Table Column Count and Row Size”.

InnoDB encodes fixed-length fields greater than or equal to 768 bytes in length as variable-length fields, which can be stored off-page. For example, a CHAR(255) column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with utf8mb4.

The NDBCLUSTER storage engine supports variable-width columns. This means that a VARCHAR column in an NDB Cluster table requires the same amount of storage as would any other storage engine, with the exception that such values are 4-byte aligned. Thus, the string 'abcd' stored in a VARCHAR(50) column using the latin1 character set requires 8 bytes (rather than 5 bytes for the same column value in a MyISAM table).

TEXT and BLOB columns are implemented differently in the NDB Cluster storage engine, wherein each row in a TEXT column is made up of two separate parts. One of these is of fixed size (256 bytes), and

is actually stored in the original table. The other consists of any data in excess of 256 bytes, which is stored in a hidden table. The rows in this second table are always 2,000 bytes long. This means that the size of a `TEXT` column is 256 if *`size`* <= 256 (where *`size`* represents the size of the row); otherwise, the size is 256 + *`size`* + (2000 − (*`size`* − 256) % 2000).

The size of an `ENUM` object is determined by the number of different enumeration values. One byte is used for enumerations with up to 255 possible values. Two bytes are used for enumerations having between 256 and 65,535 possible values. See Section 11.4.4, “The ENUM Type”.

The size of a `SET` object is determined by the number of different set members. If the set size is *`N`*, the object occupies `(`*`N`*`+7)/8` bytes, rounded up to 1, 2, 3, 4, or 8 bytes. A `SET` can have a maximum of 64 members. See Section 11.4.5, “The SET Type”.

Spatial Type Storage Requirements

MySQL stores geometry values using 4 bytes to indicate the SRID followed by the WKB representation of the value. The `LENGTH()` function returns the space in bytes required for value storage.

For descriptions of WKB and internal storage formats for spatial values, see Section 11.5.3, “Supported Spatial Data Formats”.

11.8 Choosing the Right Type for a Column

For optimum storage, you should try to use the most precise type in all cases. For example, if an integer column is used for values in the range from `1` to `99999`, `MEDIUMINT UNSIGNED` is the best type. Of the types that represent all the required values, this type uses the least amount of storage.

All basic calculations (`+`, `-`, `*`, and `/`) with `DECIMAL` columns are done with precision of 65 decimal (base 10) digits. See Section 11.1.1, “Numeric Type Overview”.

If accuracy is not too important or if speed is the highest priority, the `DOUBLE` type may be good enough. For high precision, you can always convert to a fixed-point type stored in a `BIGINT`. This enables you to do all calculations with 64-bit integers and then convert results back to floating-point values as necessary.

`PROCEDURE ANALYSE` can be used to obtain suggestions for optimal column data types. For more information, see Section 8.4.2.4, “Using PROCEDURE ANALYSE”.

11.9 Using Data Types from Other Database Engines

To facilitate the use of code written for SQL implementations from other vendors, MySQL maps data types as shown in the following table. These mappings make it easier to import table definitions from other database systems into MySQL.

Other Vendor Type	MySQL Type
`BOOL`	`TINYINT`
`BOOLEAN`	`TINYINT`
`CHARACTER VARYING(`*`M`*`)`	`VARCHAR(`*`M`*`)`
`FIXED`	`DECIMAL`
`FLOAT4`	`FLOAT`
`FLOAT8`	`DOUBLE`
`INT1`	`TINYINT`
`INT2`	`SMALLINT`
`INT3`	`MEDIUMINT`
`INT4`	`INT`

Other Vendor Type	MySQL Type
INT8	BIGINT
LONG VARBINARY	MEDIUMBLOB
LONG VARCHAR	MEDIUMTEXT
LONG	MEDIUMTEXT
MIDDLEINT	MEDIUMINT
NUMERIC	DECIMAL

Data type mapping occurs at table creation time, after which the original type specifications are discarded. If you create a table with types used by other vendors and then issue a DESCRIBE *tbl_name* statement, MySQL reports the table structure using the equivalent MySQL types. For example:

```
mysql> CREATE TABLE t (a BOOL, b FLOAT8, c LONG VARCHAR, d NUMERIC);
Query OK, 0 rows affected (0.00 sec)

mysql> DESCRIBE t;
+-------+---------------+------+-----+---------+-------+
| Field | Type          | Null | Key | Default | Extra |
+-------+---------------+------+-----+---------+-------+
| a     | tinyint(1)    | YES  |     | NULL    |       |
| b     | double        | YES  |     | NULL    |       |
| c     | mediumtext    | YES  |     | NULL    |       |
| d     | decimal(10,0) | YES  |     | NULL    |       |
+-------+---------------+------+-----+---------+-------+
4 rows in set (0.01 sec)
```

Chapter 12 Functions and Operators

Table of Contents

12.1 Function and Operator Reference 1140
12.2 Type Conversion in Expression Evaluation 1149
12.3 Operators 1151
12.3.1 Operator Precedence 1152
12.3.2 Comparison Functions and Operators 1153
12.3.3 Logical Operators 1159
12.3.4 Assignment Operators 1160
12.4 Control Flow Functions 1162
12.5 String Functions 1164
12.5.1 String Comparison Functions 1175
12.5.2 Regular Expressions 1179
12.5.3 Character Set and Collation of Function Results 1184
12.6 Numeric Functions and Operators 1185
12.6.1 Arithmetic Operators 1186
12.6.2 Mathematical Functions 1188
12.7 Date and Time Functions 1197
12.8 What Calendar Is Used By MySQL? 1218
12.9 Full-Text Search Functions 1219
12.9.1 Natural Language Full-Text Searches 1220
12.9.2 Boolean Full-Text Searches 1223
12.9.3 Full-Text Searches with Query Expansion 1226
12.9.4 Full-Text Stopwords 1226
12.9.5 Full-Text Restrictions 1229
12.9.6 Fine-Tuning MySQL Full-Text Search 1230
12.9.7 Adding a Collation for Full-Text Indexing 1232
12.10 Cast Functions and Operators 1233
12.11 XML Functions 1239
12.12 Bit Functions and Operators 1250
12.13 Encryption and Compression Functions 1252
12.14 Information Functions 1258
12.15 Spatial Analysis Functions 1267
12.15.1 Spatial Function Reference 1268
12.15.2 Argument Handling by Spatial Functions 1269
12.15.3 Functions That Create Geometry Values from WKT Values 1270
12.15.4 Functions That Create Geometry Values from WKB Values 1270
12.15.5 MySQL-Specific Functions That Create Geometry Values 1271
12.15.6 Geometry Format Conversion Functions 1272
12.15.7 Geometry Property Functions 1272
12.15.8 Spatial Operator Functions 1278
12.15.9 Functions That Test Spatial Relations Between Geometry Objects 1278
12.16 Aggregate (GROUP BY) Functions 1280
12.16.1 Aggregate (GROUP BY) Function Descriptions 1280
12.16.2 GROUP BY Modifiers 1284
12.16.3 MySQL Handling of GROUP BY 1287
12.17 Miscellaneous Functions 1289
12.18 Precision Math 1294
12.18.1 Types of Numeric Values 1295
12.18.2 DECIMAL Data Type Characteristics 1295
12.18.3 Expression Handling 1296
12.18.4 Rounding Behavior 1297
12.18.5 Precision Math Examples 1298

Expressions can be used at several points in SQL statements, such as in the ORDER BY or HAVING clauses of SELECT statements, in the WHERE clause of a SELECT, DELETE, or UPDATE statement, or in SET statements. Expressions can be written using literal values, column values, NULL, built-in functions, stored functions, user-defined functions, and operators. This chapter describes the functions and operators that are permitted for writing expressions in MySQL. Instructions for writing stored functions and user-defined functions are given in Section 20.2, "Using Stored Routines (Procedures and Functions)", and Section 24.4, "Adding New Functions to MySQL". See Section 9.2.4, "Function Name Parsing and Resolution", for the rules describing how the server interprets references to different kinds of functions.

An expression that contains NULL always produces a NULL value unless otherwise indicated in the documentation for a particular function or operator.

Note

By default, there must be no whitespace between a function name and the parenthesis following it. This helps the MySQL parser distinguish between function calls and references to tables or columns that happen to have the same name as a function. However, spaces around function arguments are permitted.

You can tell the MySQL server to accept spaces after function names by starting it with the --sql-mode=IGNORE_SPACE option. (See Section 5.1.8, "Server SQL Modes".) Individual client programs can request this behavior by using the CLIENT_IGNORE_SPACE option for mysql_real_connect(). In either case, all function names become reserved words.

For the sake of brevity, most examples in this chapter display the output from the mysql program in abbreviated form. Rather than showing examples in this format:

```
mysql> SELECT MOD(29,9);
+-----------+
| mod(29,9) |
+-----------+
|         2 |
+-----------+
1 rows in set (0.00 sec)
```

This format is used instead:

```
mysql> SELECT MOD(29,9);
       -> 2
```

12.1 Function and Operator Reference

Table 12.1 Functions and Operators

Name	Description
ABS()	Return the absolute value
ACOS()	Return the arc cosine
ADDDATE()	Add time values (intervals) to a date value
ADDTIME()	Add time
AES_DECRYPT()	Decrypt using AES
AES_ENCRYPT()	Encrypt using AES
AND, &&	Logical AND
Area()	Return Polygon or MultiPolygon area
AsBinary(), AsWKB()	Convert from internal geometry format to WKB
ASCII()	Return numeric value of left-most character
ASIN()	Return the arc sine

Name	Description
=	Assign a value (as part of a SET statement, or as part of the SET clause in an UPDATE statement)
:=	Assign a value
AsText(), AsWKT()	Convert from internal geometry format to WKT
ATAN()	Return the arc tangent
ATAN2(), ATAN()	Return the arc tangent of the two arguments
AVG()	Return the average value of the argument
BENCHMARK()	Repeatedly execute an expression
BETWEEN ... AND ...	Check whether a value is within a range of values
BIN()	Return a string containing binary representation of a number
BINARY	Cast a string to a binary string
BIT_AND()	Return bitwise AND
BIT_COUNT()	Return the number of bits that are set
BIT_LENGTH()	Return length of argument in bits
BIT_OR()	Return bitwise OR
BIT_XOR()	Return bitwise XOR
&	Bitwise AND
~	Bitwise inversion
|	Bitwise OR
^	Bitwise XOR
CASE	Case operator
CAST()	Cast a value as a certain type
CEIL()	Return the smallest integer value not less than the argument
CEILING()	Return the smallest integer value not less than the argument
Centroid()	Return centroid as a point
CHAR()	Return the character for each integer passed
CHAR_LENGTH()	Return number of characters in argument
CHARACTER_LENGTH()	Synonym for CHAR_LENGTH()
CHARSET()	Return the character set of the argument
COALESCE()	Return the first non-NULL argument
COERCIBILITY()	Return the collation coercibility value of the string argument
COLLATION()	Return the collation of the string argument
COMPRESS()	Return result as a binary string
CONCAT()	Return concatenated string
CONCAT_WS()	Return concatenate with separator
CONNECTION_ID()	Return the connection ID (thread ID) for the connection
Contains()	Whether MBR of one geometry contains MBR of another
CONV()	Convert numbers between different number bases
CONVERT()	Cast a value as a certain type
CONVERT_TZ()	Convert from one time zone to another
COS()	Return the cosine

Name	Description
COT()	Return the cotangent
COUNT()	Return a count of the number of rows returned
COUNT(DISTINCT)	Return the count of a number of different values
CRC32()	Compute a cyclic redundancy check value
Crosses()	Whether one geometry crosses another
CURDATE()	Return the current date
CURRENT_DATE(), CURRENT_DATE	Synonyms for CURDATE()
CURRENT_TIME(), CURRENT_TIME	Synonyms for CURTIME()
CURRENT_TIMESTAMP(), CURRENT_TIMESTAMP	Synonyms for NOW()
CURRENT_USER(), CURRENT_USER	The authenticated user name and host name
CURTIME()	Return the current time
DATABASE()	Return the default (current) database name
DATE()	Extract the date part of a date or datetime expression
DATE_ADD()	Add time values (intervals) to a date value
DATE_FORMAT()	Format date as specified
DATE_SUB()	Subtract a time value (interval) from a date
DATEDIFF()	Subtract two dates
DAY()	Synonym for DAYOFMONTH()
DAYNAME()	Return the name of the weekday
DAYOFMONTH()	Return the day of the month (0-31)
DAYOFWEEK()	Return the weekday index of the argument
DAYOFYEAR()	Return the day of the year (1-366)
DECODE()	Decodes a string encrypted using ENCODE()
DEFAULT()	Return the default value for a table column
DEGREES()	Convert radians to degrees
DES_DECRYPT()	Decrypt a string
DES_ENCRYPT()	Encrypt a string
Dimension()	Dimension of geometry
Disjoint()	Whether MBRs of two geometries are disjoint
DIV	Integer division
/	Division operator
ELT()	Return string at index number
ENCODE()	Encode a string
ENCRYPT()	Encrypt a string
EndPoint()	End Point of LineString
Envelope()	Return MBR of geometry
=	Equal operator
<=>	NULL-safe equal to operator
Equals()	Whether MBRs of two geometries are equal
EXP()	Raise to the power of

Name	Description
EXPORT_SET()	Return a string such that for every bit set in the value bits, you get an on string and for every unset bit, you get an off string
ExteriorRing()	Return exterior ring of Polygon
EXTRACT()	Extract part of a date
ExtractValue()	Extracts a value from an XML string using XPath notation
FIELD()	Return the index (position) of the first argument in the subsequent arguments
FIND_IN_SET()	Return the index position of the first argument within the second argument
FLOOR()	Return the largest integer value not greater than the argument
FORMAT()	Return a number formatted to specified number of decimal places
FOUND_ROWS()	For a SELECT with a LIMIT clause, the number of rows that would be returned were there no LIMIT clause
FROM_DAYS()	Convert a day number to a date
FROM_UNIXTIME()	Format Unix timestamp as a date
GeomCollFromText(), GeometryCollectionFromText()	Return geometry collection from WKT
GeomCollFromWKB(), GeometryCollectionFromWKB()	Return geometry collection from WKB
GeometryCollection()	Construct geometry collection from geometries
GeometryN()	Return N-th geometry from geometry collection
GeometryType()	Return name of geometry type
GeomFromText(), GeometryFromText()	Return geometry from WKT
GeomFromWKB(), GeometryFromWKB()	Return geometry from WKB
GET_FORMAT()	Return a date format string
GET_LOCK()	Get a named lock
GLength()	Return length of LineString
>	Greater than operator
>=	Greater than or equal operator
GREATEST()	Return the largest argument
GROUP_CONCAT()	Return a concatenated string
HEX()	Return a hexadecimal representation of a decimal or string value
HOUR()	Extract the hour
IF()	If/else construct
IFNULL()	Null if/else construct
IN()	Check whether a value is within a set of values
INET_ATON()	Return the numeric value of an IP address
INET_NTOA()	Return the IP address from a numeric value

Name	Description
INSERT()	Insert a substring at the specified position up to the specified number of characters
INSTR()	Return the index of the first occurrence of substring
InteriorRingN()	Return N-th interior ring of Polygon
Intersects()	Whether MBRs of two geometries intersect
INTERVAL()	Return the index of the argument that is less than the first argument
IS	Test a value against a boolean
IS_FREE_LOCK()	Whether the named lock is free
IS NOT	Test a value against a boolean
IS NOT NULL	NOT NULL value test
IS NULL	NULL value test
IS_USED_LOCK()	Whether the named lock is in use; return connection identifier if true
IsClosed()	Whether a geometry is closed and simple
IsEmpty()	Placeholder function
ISNULL()	Test whether the argument is NULL
IsSimple()	Whether a geometry is simple
LAST_DAY	Return the last day of the month for the argument
LAST_INSERT_ID()	Value of the AUTOINCREMENT column for the last INSERT
LCASE()	Synonym for LOWER()
LEAST()	Return the smallest argument
LEFT()	Return the leftmost number of characters as specified
<<	Left shift
LENGTH()	Return the length of a string in bytes
<	Less than operator
<=	Less than or equal operator
LIKE	Simple pattern matching
LineFromText(), LineStringFromText()	Construct LineString from WKT
LineFromWKB(), LineStringFromWKB()	Construct LineString from WKB
LineString()	Construct LineString from Point values
LN()	Return the natural logarithm of the argument
LOAD_FILE()	Load the named file
LOCALTIME(), LOCALTIME	Synonym for NOW()
LOCALTIMESTAMP, LOCALTIMESTAMP()	Synonym for NOW()
LOCATE()	Return the position of the first occurrence of substring
LOG()	Return the natural logarithm of the first argument
LOG10()	Return the base-10 logarithm of the argument
LOG2()	Return the base-2 logarithm of the argument

Name	Description
LOWER()	Return the argument in lowercase
LPAD()	Return the string argument, left-padded with the specified string
LTRIM()	Remove leading spaces
MAKE_SET()	Return a set of comma-separated strings that have the corresponding bit in bits set
MAKEDATE()	Create a date from the year and day of year
MAKETIME()	Create time from hour, minute, second
MASTER_POS_WAIT()	Block until the slave has read and applied all updates up to the specified position
MATCH	Perform full-text search
MAX()	Return the maximum value
MBRContains()	Whether MBR of one geometry contains MBR of another
MBRDisjoint()	Whether MBRs of two geometries are disjoint
MBREqual()	Whether MBRs of two geometries are equal
MBRIntersects()	Whether MBRs of two geometries intersect
MBROverlaps()	Whether MBRs of two geometries overlap
MBRTouches()	Whether MBRs of two geometries touch
MBRWithin()	Whether MBR of one geometry is within MBR of another
MD5()	Calculate MD5 checksum
MICROSECOND()	Return the microseconds from argument
MID()	Return a substring starting from the specified position
MIN()	Return the minimum value
-	Minus operator
MINUTE()	Return the minute from the argument
MLineFromText(), MultiLineStringFromText()	Construct MultiLineString from WKT
MLineFromWKB(), MultiLineStringFromWKB()	Construct MultiLineString from WKB
MOD()	Return the remainder
%, MOD	Modulo operator
MONTH()	Return the month from the date passed
MONTHNAME()	Return the name of the month
MPointFromText(), MultiPointFromText()	Construct MultiPoint from WKT
MPointFromWKB(), MultiPointFromWKB()	Construct MultiPoint from WKB
MPolyFromText(), MultiPolygonFromText()	Construct MultiPolygon from WKT
MPolyFromWKB(), MultiPolygonFromWKB()	Construct MultiPolygon from WKB
MultiLineString()	Contruct MultiLineString from LineString values
MultiPoint()	Construct MultiPoint from Point values

Name	Description
MultiPolygon()	Construct MultiPolygon from Polygon values
NAME_CONST()	Causes the column to have the given name
NOT, !	Negates value
NOT BETWEEN ... AND ...	Check whether a value is not within a range of values
!=, <>	Not equal operator
NOT IN()	Check whether a value is not within a set of values
NOT LIKE	Negation of simple pattern matching
NOT REGEXP	Negation of REGEXP
NOW()	Return the current date and time
NULLIF()	Return NULL if expr1 = expr2
NumGeometries()	Return number of geometries in geometry collection
NumInteriorRings()	Return number of interior rings in Polygon
NumPoints()	Return number of points in LineString
OCT()	Return a string containing octal representation of a number
OCTET_LENGTH()	Synonym for LENGTH()
OLD_PASSWORD()	Return the value of the pre-4.1 implementation of PASSWORD
||, OR	Logical OR
ORD()	Return character code for leftmost character of the argument
Overlaps()	Whether MBRs of two geometries overlap
PASSWORD()	Calculate and return a password string
PERIOD_ADD()	Add a period to a year-month
PERIOD_DIFF()	Return the number of months between periods
PI()	Return the value of pi
+	Addition operator
Point()	Construct Point from coordinates
PointFromText()	Construct Point from WKT
PointFromWKB()	Construct Point from WKB
PointN()	Return N-th point from LineString
PolyFromText(), PolygonFromText()	Construct Polygon from WKT
PolyFromWKB(), PolygonFromWKB()	Construct Polygon from WKB
Polygon()	Construct Polygon from LineString arguments
POSITION()	Synonym for LOCATE()
POW()	Return the argument raised to the specified power
POWER()	Return the argument raised to the specified power
PROCEDURE ANALYSE()	Analyze the results of a query
QUARTER()	Return the quarter from a date argument
QUOTE()	Escape the argument for use in an SQL statement
RADIANS()	Return argument converted to radians
RAND()	Return a random floating-point value

Name	Description
REGEXP	Pattern matching using regular expressions
RELEASE_LOCK()	Releases the named lock
REPEAT()	Repeat a string the specified number of times
REPLACE()	Replace occurrences of a specified string
REVERSE()	Reverse the characters in a string
RIGHT()	Return the specified rightmost number of characters
>>	Right shift
RLIKE	Synonym for REGEXP
ROUND()	Round the argument
ROW_COUNT()	The number of rows updated
RPAD()	Append string the specified number of times
RTRIM()	Remove trailing spaces
SCHEMA()	Synonym for DATABASE()
SEC_TO_TIME()	Converts seconds to 'HH:MM:SS' format
SECOND()	Return the second (0-59)
SESSION_USER()	Synonym for USER()
SHA1(), SHA()	Calculate an SHA-1 160-bit checksum
SHA2()	Calculate an SHA-2 checksum
SIGN()	Return the sign of the argument
SIN()	Return the sine of the argument
SLEEP()	Sleep for a number of seconds
SOUNDEX()	Return a soundex string
SOUNDS LIKE	Compare sounds
SPACE()	Return a string of the specified number of spaces
SQRT()	Return the square root of the argument
SRID()	Return spatial reference system ID for geometry
StartPoint()	Start Point of LineString
STD()	Return the population standard deviation
STDDEV()	Return the population standard deviation
STDDEV_POP()	Return the population standard deviation
STDDEV_SAMP()	Return the sample standard deviation
STR_TO_DATE()	Convert a string to a date
STRCMP()	Compare two strings
SUBDATE()	Synonym for DATE_SUB() when invoked with three arguments
SUBSTR()	Return the substring as specified
SUBSTRING()	Return the substring as specified
SUBSTRING_INDEX()	Return a substring from a string before the specified number of occurrences of the delimiter
SUBTIME()	Subtract times
SUM()	Return the sum

Name	Description
SYSDATE()	Return the time at which the function executes
SYSTEM_USER()	Synonym for USER()
TAN()	Return the tangent of the argument
TIME()	Extract the time portion of the expression passed
TIME_FORMAT()	Format as time
TIME_TO_SEC()	Return the argument converted to seconds
TIMEDIFF()	Subtract time
*	Multiplication operator
TIMESTAMP()	With a single argument, this function returns the date or datetime expression; with two arguments, the sum of the arguments
TIMESTAMPADD()	Add an interval to a datetime expression
TIMESTAMPDIFF()	Subtract an interval from a datetime expression
TO_DAYS()	Return the date argument converted to days
TO_SECONDS()	Return the date or datetime argument converted to seconds since Year 0
Touches()	Whether one geometry touches another
TRIM()	Remove leading and trailing spaces
TRUNCATE()	Truncate to specified number of decimal places
UCASE()	Synonym for UPPER()
-	Change the sign of the argument
UNCOMPRESS()	Uncompress a string compressed
UNCOMPRESSED_LENGTH()	Return the length of a string before compression
UNHEX()	Return a string containing hex representation of a number
UNIX_TIMESTAMP()	Return a Unix timestamp
UpdateXML()	Return replaced XML fragment
UPPER()	Convert to uppercase
USER()	The user name and host name provided by the client
UTC_DATE()	Return the current UTC date
UTC_TIME()	Return the current UTC time
UTC_TIMESTAMP()	Return the current UTC date and time
UUID()	Return a Universal Unique Identifier (UUID)
UUID_SHORT()	Return an integer-valued universal identifier
VALUES()	Defines the values to be used during an INSERT
VAR_POP()	Return the population standard variance
VAR_SAMP()	Return the sample variance
VARIANCE()	Return the population standard variance
VERSION()	Return a string that indicates the MySQL server version
WEEK()	Return the week number
WEEKDAY()	Return the weekday index
WEEKOFYEAR()	Return the calendar week of the date (1-53)
Within()	Whether MBR of one geometry is within MBR of another

Name	Description
X()	Return X coordinate of Point
XOR	Logical XOR
Y()	Return Y coordinate of Point
YEAR()	Return the year
YEARWEEK()	Return the year and week

12.2 Type Conversion in Expression Evaluation

When an operator is used with operands of different types, type conversion occurs to make the operands compatible. Some conversions occur implicitly. For example, MySQL automatically converts numbers to strings as necessary, and vice versa.

```
mysql> SELECT 1+'1';
        -> 2
mysql> SELECT CONCAT(2,' test');
        -> '2 test'
```

It is also possible to convert a number to a string explicitly using the CAST() function. Conversion occurs implicitly with the CONCAT() function because it expects string arguments.

```
mysql> SELECT 38.8, CAST(38.8 AS CHAR);
        -> 38.8, '38.8'
mysql> SELECT 38.8, CONCAT(38.8);
        -> 38.8, '38.8'
```

See later in this section for information about the character set of implicit number-to-string conversions, and for modified rules that apply to CREATE TABLE ... SELECT statements.

The following rules describe how conversion occurs for comparison operations:

- If one or both arguments are NULL, the result of the comparison is NULL, except for the NULL-safe <=> equality comparison operator. For NULL <=> NULL, the result is true. No conversion is needed.
- If both arguments in a comparison operation are strings, they are compared as strings.
- If both arguments are integers, they are compared as integers.
- Hexadecimal values are treated as binary strings if not compared to a number.
- If one of the arguments is a TIMESTAMP or DATETIME column and the other argument is a constant, the constant is converted to a timestamp before the comparison is performed. This is done to be more ODBC-friendly. This is not done for the arguments to IN(). To be safe, always use complete datetime, date, or time strings when doing comparisons. For example, to achieve best results when using BETWEEN with date or time values, use CAST() to explicitly convert the values to the desired data type.
- If one of the arguments is a decimal value, comparison depends on the other argument. The arguments are compared as decimal values if the other argument is a decimal or integer value, or as floating-point values if the other argument is a floating-point value.
- In all other cases, the arguments are compared as floating-point (real) numbers.

For information about conversion of values from one temporal type to another, see Section 11.3.7, “Conversion Between Date and Time Types”.

The following examples illustrate conversion of strings to numbers for comparison operations:

```
mysql> SELECT 1 > '6x';
```

```
        -> 0
mysql> SELECT 7 > '6x';
        -> 1
mysql> SELECT 0 > 'x6';
        -> 0
mysql> SELECT 0 = 'x6';
        -> 1
```

For comparisons of a string column with a number, MySQL cannot use an index on the column to look up the value quickly. If *`str_col`* is an indexed string column, the index cannot be used when performing the lookup in the following statement:

```
SELECT * FROM tbl_name WHERE str_col=1;
```

The reason for this is that there are many different strings that may convert to the value `1`, such as `'1'`, `' 1'`, or `'1a'`.

Comparisons that use floating-point numbers (or values that are converted to floating-point numbers) are approximate because such numbers are inexact. This might lead to results that appear inconsistent:

```
mysql> SELECT '18015376320243458' = 18015376320243458;
        -> 1
mysql> SELECT '18015376320243459' = 18015376320243459;
        -> 0
```

Such results can occur because the values are converted to floating-point numbers, which have only 53 bits of precision and are subject to rounding:

```
mysql> SELECT '18015376320243459'+0.0;
        -> 1.8015376320243e+16
```

Furthermore, the conversion from string to floating-point and from integer to floating-point do not necessarily occur the same way. The integer may be converted to floating-point by the CPU, whereas the string is converted digit by digit in an operation that involves floating-point multiplications.

The results shown will vary on different systems, and can be affected by factors such as computer architecture or the compiler version or optimization level. One way to avoid such problems is to use `CAST()` so that a value is not converted implicitly to a float-point number:

```
mysql> SELECT CAST('18015376320243459' AS UNSIGNED) = 18015376320243459;
        -> 1
```

For more information about floating-point comparisons, see Section B.5.4.8, “Problems with Floating-Point Values”.

The server includes `dtoa`, a conversion library that provides the basis for improved conversion between string or `DECIMAL` values and approximate-value (`FLOAT`/`DOUBLE`) numbers:

- Consistent conversion results across platforms, which eliminates, for example, Unix versus Windows conversion differences.
- Accurate representation of values in cases where results previously did not provide sufficient precision, such as for values close to IEEE limits.
- Conversion of numbers to string format with the best possible precision. The precision of `dtoa` is always the same or better than that of the standard C library functions.

Because the conversions produced by this library differ in some cases from non-`dtoa` results, the potential exists for incompatibilities in applications that rely on previous results. For example, applications that depend on a specific exact result from previous conversions might need adjustment to accommodate additional precision.

The dtoa library provides conversions with the following properties. *D* represents a value with a DECIMAL or string representation, and *F* represents a floating-point number in native binary (IEEE) format.

- *F* -> *D* conversion is done with the best possible precision, returning *D* as the shortest string that yields *F* when read back in and rounded to the nearest value in native binary format as specified by IEEE.
- *D* -> *F* conversion is done such that *F* is the nearest native binary number to the input decimal string *D*.

These properties imply that *F* -> *D* -> *F* conversions are lossless unless *F* is -inf, +inf, or NaN. The latter values are not supported because the SQL standard defines them as invalid values for FLOAT or DOUBLE.

For *D* -> *F* -> *D* conversions, a sufficient condition for losslessness is that *D* uses 15 or fewer digits of precision, is not a denormal value, -inf, +inf, or NaN. In some cases, the conversion is lossless even if *D* has more than 15 digits of precision, but this is not always the case.

Implicit conversion of a numeric or temporal value to string produces a value that has a character set and collation determined by the character_set_connection and collation_connection system variables. (These variables commonly are set with SET NAMES. For information about connection character sets, see Section 10.1.4, “Connection Character Sets and Collations”.)

This means that such a conversion results in a character (nonbinary) string (a CHAR, VARCHAR, or LONGTEXT value), except in the case that the connection character set is set to binary. In that case, the conversion result is a binary string (a BINARY, VARBINARY, or LONGBLOB value).

12.3 Operators

Table 12.2 Operators

Name	Description
AND, &&	Logical AND
=	Assign a value (as part of a SET statement, or as part of the SET clause in an UPDATE statement)
:=	Assign a value
BETWEEN ... AND ...	Check whether a value is within a range of values
BINARY	Cast a string to a binary string
&	Bitwise AND
~	Bitwise inversion
|	Bitwise OR
^	Bitwise XOR
CASE	Case operator
DIV	Integer division
/	Division operator
=	Equal operator
<=>	NULL-safe equal to operator
>	Greater than operator
>=	Greater than or equal operator
IS	Test a value against a boolean
IS NOT	Test a value against a boolean

Name	Description
IS NOT NULL	NOT NULL value test
IS NULL	NULL value test
<<	Left shift
<	Less than operator
<=	Less than or equal operator
LIKE	Simple pattern matching
-	Minus operator
%, MOD	Modulo operator
NOT, !	Negates value
NOT BETWEEN ... AND ...	Check whether a value is not within a range of values
!=, <>	Not equal operator
NOT LIKE	Negation of simple pattern matching
NOT REGEXP	Negation of REGEXP
||, OR	Logical OR
+	Addition operator
REGEXP	Pattern matching using regular expressions
>>	Right shift
RLIKE	Synonym for REGEXP
SOUNDS LIKE	Compare sounds
*	Multiplication operator
-	Change the sign of the argument
XOR	Logical XOR

12.3.1 Operator Precedence

Operator precedences are shown in the following list, from highest precedence to the lowest. Operators that are shown together on a line have the same precedence.

```
INTERVAL
BINARY, COLLATE
!
- (unary minus), ~ (unary bit inversion)
^
*, /, DIV, %, MOD
-, +
<<, >>
&
|
= (comparison), <=>, >=, >, <=, <, <>, !=, IS, LIKE, REGEXP, IN
BETWEEN, CASE, WHEN, THEN, ELSE
NOT
AND, &&
XOR
OR, ||
= (assignment), :=
```

The precedence of = depends on whether it is used as a comparison operator (=) or as an assignment operator (=). When used as a comparison operator, it has the same precedence as <=>, >=, >, <=, <, <>, !=, IS, LIKE, REGEXP, and IN. When used as an assignment operator, it has the same precedence as :=. Section 13.7.4.1, “SET Syntax for Variable Assignment”, and Section 9.4, “User-Defined Variables”, explain how MySQL determines which interpretation of = should apply.

For operators that occur at the same precedence level within an expression, evaluation proceeds left to right, with the exception that assignments evaluate right to left.

The meaning of some operators depends on the SQL mode:

- By default, `||` is a logical `OR` operator. With `PIPES_AS_CONCAT` enabled, `||` is string concatenation, with a precedence between `^` and the unary operators.
- By default, `!` has a higher precedence than `NOT`. With `HIGH_NOT_PRECEDENCE` enabled, `!` and `NOT` have the same precedence.

See Section 5.1.8, “Server SQL Modes”.

The precedence of operators determines the order of evaluation of terms in an expression. To override this order and group terms explicitly, use parentheses. For example:

```
mysql> SELECT 1+2*3;
        -> 7
mysql> SELECT (1+2)*3;
        -> 9
```

12.3.2 Comparison Functions and Operators

Table 12.3 Comparison Operators

Name	Description
`BETWEEN ... AND ...`	Check whether a value is within a range of values
`COALESCE()`	Return the first non-NULL argument
`=`	Equal operator
`<=>`	NULL-safe equal to operator
`>`	Greater than operator
`>=`	Greater than or equal operator
`GREATEST()`	Return the largest argument
`IN()`	Check whether a value is within a set of values
`INTERVAL()`	Return the index of the argument that is less than the first argument
`IS`	Test a value against a boolean
`IS NOT`	Test a value against a boolean
`IS NOT NULL`	NOT NULL value test
`IS NULL`	NULL value test
`ISNULL()`	Test whether the argument is NULL
`LEAST()`	Return the smallest argument
`<`	Less than operator
`<=`	Less than or equal operator
`LIKE`	Simple pattern matching
`NOT BETWEEN ... AND ...`	Check whether a value is not within a range of values
`!=`, `<>`	Not equal operator
`NOT IN()`	Check whether a value is not within a set of values
`NOT LIKE`	Negation of simple pattern matching
`STRCMP()`	Compare two strings

Comparison operations result in a value of `1` (`TRUE`), `0` (`FALSE`), or `NULL`. These operations work for both numbers and strings. Strings are automatically converted to numbers and numbers to strings as necessary.

The following relational comparison operators can be used to compare not only scalar operands, but row operands:

```
=  >  <  >=  <=  <>  !=
```

The descriptions for those operators later in this section detail how they work with row operands. For additional examples of row comparisons in the context of row subqueries, see Section 13.2.10.5, “Row Subqueries”.

Some of the functions in this section return values other than `1` (`TRUE`), `0` (`FALSE`), or `NULL`. `LEAST()` and `GREATEST()` are examples of such functions; Section 12.2, “Type Conversion in Expression Evaluation”, describes the rules for comparison operations performed by these and similar functions for determining their return values.

To convert a value to a specific type for comparison purposes, you can use the `CAST()` function. String values can be converted to a different character set using `CONVERT()`. See Section 12.10, “Cast Functions and Operators”.

By default, string comparisons are not case sensitive and use the current character set. The default is `latin1` (cp1252 West European), which also works well for English.

- `=`

  Equal:

  ```
  mysql> SELECT 1 = 0;
          -> 0
  mysql> SELECT '0' = 0;
          -> 1
  mysql> SELECT '0.0' = 0;
          -> 1
  mysql> SELECT '0.01' = 0;
          -> 0
  mysql> SELECT '.01' = 0.01;
          -> 1
  ```

  For row comparisons, `(a, b) = (x, y)` is equivalent to:

  ```
  (a = x) AND (b = y)
  ```

- `<=>`

  `NULL`-safe equal. This operator performs an equality comparison like the `=` operator, but returns `1` rather than `NULL` if both operands are `NULL`, and `0` rather than `NULL` if one operand is `NULL`.

  The `<=>` operator is equivalent to the standard SQL `IS NOT DISTINCT FROM` operator.

  ```
  mysql> SELECT 1 <=> 1, NULL <=> NULL, 1 <=> NULL;
          -> 1, 1, 0
  mysql> SELECT 1 = 1, NULL = NULL, 1 = NULL;
          -> 1, NULL, NULL
  ```

  For row comparisons, `(a, b) <=> (x, y)` is equivalent to:

  ```
  (a <=> x) AND (b <=> y)
  ```

- `<>`, `!=`

  Not equal:

```
mysql> SELECT '.01' <> '0.01';
        -> 1
mysql> SELECT .01 <> '0.01';
        -> 0
mysql> SELECT 'zapp' <> 'zappp';
        -> 1
```

  For row comparisons, `(a, b) <> (x, y)` and `(a, b) != (x, y)` are equivalent to:

```
(a <> x) OR (b <> y)
```

- `<=`

  Less than or equal:

```
mysql> SELECT 0.1 <= 2;
        -> 1
```

  For row comparisons, `(a, b) <= (x, y)` is equivalent to:

```
(a < x) OR ((a = x) AND (b <= y))
```

- `<`

  Less than:

```
mysql> SELECT 2 < 2;
        -> 0
```

  For row comparisons, `(a, b) < (x, y)` is equivalent to:

```
(a < x) OR ((a = x) AND (b < y))
```

- `>=`

  Greater than or equal:

```
mysql> SELECT 2 >= 2;
        -> 1
```

  For row comparisons, `(a, b) >= (x, y)` is equivalent to:

```
(a > x) OR ((a = x) AND (b >= y))
```

- `>`

  Greater than:

```
mysql> SELECT 2 > 2;
        -> 0
```

  For row comparisons, `(a, b) > (x, y)` is equivalent to:

```
(a > x) OR ((a = x) AND (b > y))
```

- `IS boolean_value`

  Tests a value against a boolean value, where `boolean_value` can be `TRUE`, `FALSE`, or `UNKNOWN`.

```
mysql> SELECT 1 IS TRUE, 0 IS FALSE, NULL IS UNKNOWN;
        -> 1, 1, 1
```

- `IS NOT boolean_value`

  Tests a value against a boolean value, where `boolean_value` can be `TRUE`, `FALSE`, or `UNKNOWN`.

```
mysql> SELECT 1 IS NOT UNKNOWN, 0 IS NOT UNKNOWN, NULL IS NOT UNKNOWN;
        -> 1, 1, 0
```

- `IS NULL`

  Tests whether a value is `NULL`.

```
mysql> SELECT 1 IS NULL, 0 IS NULL, NULL IS NULL;
        -> 0, 0, 1
```

  To work well with ODBC programs, MySQL supports the following extra features when using `IS NULL`:

  - If `sql_auto_is_null` variable is set to 1, then after a statement that successfully inserts an automatically generated `AUTO_INCREMENT` value, you can find that value by issuing a statement of the following form:

```
SELECT * FROM tbl_name WHERE auto_col IS NULL
```

    If the statement returns a row, the value returned is the same as if you invoked the `LAST_INSERT_ID()` function. For details, including the return value after a multiple-row insert, see Section 12.14, “Information Functions”. If no `AUTO_INCREMENT` value was successfully inserted, the `SELECT` statement returns no row.

    The behavior of retrieving an `AUTO_INCREMENT` value by using an `IS NULL` comparison can be disabled by setting `sql_auto_is_null = 0`. See Section 5.1.5, “Server System Variables”.

    The default value of `sql_auto_is_null` is 0.

  - For `DATE` and `DATETIME` columns that are declared as `NOT NULL`, you can find the special date `'0000-00-00'` by using a statement like this:

```
SELECT * FROM tbl_name WHERE date_column IS NULL
```

    This is needed to get some ODBC applications to work because ODBC does not support a `'0000-00-00'` date value.

    See Obtaining Auto-Increment Values, and the description for the `FLAG_AUTO_IS_NULL` option at Connector/ODBC Connection Parameters.

- `IS NOT NULL`

  Tests whether a value is not `NULL`.

```
mysql> SELECT 1 IS NOT NULL, 0 IS NOT NULL, NULL IS NOT NULL;
        -> 1, 1, 0
```

- `expr BETWEEN min AND max`

If *expr* is greater than or equal to *min* and *expr* is less than or equal to *max*, BETWEEN returns 1, otherwise it returns 0. This is equivalent to the expression (*min* <= *expr* AND *expr* <= *max*) if all the arguments are of the same type. Otherwise type conversion takes place according to the rules described in Section 12.2, “Type Conversion in Expression Evaluation”, but applied to all the three arguments.

```
mysql> SELECT 2 BETWEEN 1 AND 3, 2 BETWEEN 3 and 1;
        -> 1, 0
mysql> SELECT 1 BETWEEN 2 AND 3;
        -> 0
mysql> SELECT 'b' BETWEEN 'a' AND 'c';
        -> 1
mysql> SELECT 2 BETWEEN 2 AND '3';
        -> 1
mysql> SELECT 2 BETWEEN 2 AND 'x-3';
        -> 0
```

For best results when using BETWEEN with date or time values, use CAST() to explicitly convert the values to the desired data type. Examples: If you compare a DATETIME to two DATE values, convert the DATE values to DATETIME values. If you use a string constant such as '2001-1-1' in a comparison to a DATE, cast the string to a DATE.

- *expr* NOT BETWEEN *min* AND *max*

  This is the same as NOT (*expr* BETWEEN *min* AND *max*).

- COALESCE(*value*,...)

  Returns the first non-NULL value in the list, or NULL if there are no non-NULL values.

  The return type of COALESCE() is the aggregated type of the argument types.

```
mysql> SELECT COALESCE(NULL,1);
        -> 1
mysql> SELECT COALESCE(NULL,NULL,NULL);
        -> NULL
```

- GREATEST(*value1*,*value2*,...)

  With two or more arguments, returns the largest (maximum-valued) argument. The arguments are compared using the same rules as for LEAST().

```
mysql> SELECT GREATEST(2,0);
        -> 2
mysql> SELECT GREATEST(34.0,3.0,5.0,767.0);
        -> 767.0
mysql> SELECT GREATEST('B','A','C');
        -> 'C'
```

  GREATEST() returns NULL if any argument is NULL.

- *expr* IN (*value*,...)

  Returns 1 if *expr* is equal to any of the values in the IN list, else returns 0. If all values are constants, they are evaluated according to the type of *expr* and sorted. The search for the item then is done using a binary search. This means IN is very quick if the IN value list consists entirely of constants. Otherwise, type conversion takes place according to the rules described in Section 12.2, “Type Conversion in Expression Evaluation”, but applied to all the arguments.

```
mysql> SELECT 2 IN (0,3,5,7);
        -> 0
```

```
mysql> SELECT 'wefwf' IN ('wee','wefwf','weg');
        -> 1
```

`IN` can be used to compare row constructors:

```
mysql> SELECT (3,4) IN ((1,2), (3,4));
        -> 1
mysql> SELECT (3,4) IN ((1,2), (3,5));
        -> 0
```

You should never mix quoted and unquoted values in an `IN` list because the comparison rules for quoted values (such as strings) and unquoted values (such as numbers) differ. Mixing types may therefore lead to inconsistent results. For example, do not write an `IN` expression like this:

```
SELECT val1 FROM tbl1 WHERE val1 IN (1,2,'a');
```

Instead, write it like this:

```
SELECT val1 FROM tbl1 WHERE val1 IN ('1','2','a');
```

The number of values in the `IN` list is only limited by the `max_allowed_packet` value.

To comply with the SQL standard, `IN` returns `NULL` not only if the expression on the left hand side is `NULL`, but also if no match is found in the list and one of the expressions in the list is `NULL`.

`IN()` syntax can also be used to write certain types of subqueries. See Section 13.2.10.3, “Subqueries with ANY, IN, or SOME”.

- *`expr`* `NOT IN (`*`value`*`,...)`

  This is the same as `NOT (`*`expr`* `IN (`*`value`*`,...))`.

- `ISNULL(`*`expr`*`)`

  If *`expr`* is `NULL`, `ISNULL()` returns `1`, otherwise it returns `0`.

  ```
  mysql> SELECT ISNULL(1+1);
          -> 0
  mysql> SELECT ISNULL(1/0);
          -> 1
  ```

  `ISNULL()` can be used instead of `=` to test whether a value is `NULL`. (Comparing a value to `NULL` using `=` always yields `NULL`.)

  The `ISNULL()` function shares some special behaviors with the `IS NULL` comparison operator. See the description of `IS NULL`.

- `INTERVAL(`*`N`*`,`*`N1`*`,`*`N2`*`,`*`N3`*`,...)`

  Returns `0` if *`N`* < *`N1`*, `1` if *`N`* < *`N2`* and so on or `-1` if *`N`* is `NULL`. All arguments are treated as integers. It is required that *`N1`* < *`N2`* < *`N3`* < `...` < *`Nn`* for this function to work correctly. This is because a binary search is used (very fast).

  ```
  mysql> SELECT INTERVAL(23, 1, 15, 17, 30, 44, 200);
          -> 3
  mysql> SELECT INTERVAL(10, 1, 10, 100, 1000);
          -> 2
  mysql> SELECT INTERVAL(22, 23, 30, 44, 200);
          -> 0
  ```

- `LEAST(`*`value1`*`,`*`value2`*`,...)`

With two or more arguments, returns the smallest (minimum-valued) argument. The arguments are compared using the following rules:

- If any argument is `NULL`, the result is `NULL`. No comparison is needed.
- If all arguments are integer-valued, they are compared as integers.
- If at least one argument is double precision, they are compared as double-precision values. Otherwise, if at least one argument is a `DECIMAL` value, they are compared as `DECIMAL` values.
- If the arguments comprise a mix of numbers and strings, they are compared as numbers.
- If any argument is a nonbinary (character) string, the arguments are compared as nonbinary strings.
- In all other cases, the arguments are compared as binary strings.

The return type of `LEAST()` is the aggregated type of the comparison argument types.

```
mysql> SELECT LEAST(2,0);
        -> 0
mysql> SELECT LEAST(34.0,3.0,5.0,767.0);
        -> 3.0
mysql> SELECT LEAST('B','A','C');
        -> 'A'
```

12.3.3 Logical Operators

Table 12.4 Logical Operators

Name	Description
`AND`, `&&`	Logical AND
`NOT`, `!`	Negates value
`||`, `OR`	Logical OR
`XOR`	Logical XOR

In SQL, all logical operators evaluate to `TRUE`, `FALSE`, or `NULL` (`UNKNOWN`). In MySQL, these are implemented as 1 (`TRUE`), 0 (`FALSE`), and `NULL`. Most of this is common to different SQL database servers, although some servers may return any nonzero value for `TRUE`.

MySQL evaluates any nonzero, non-`NULL` value to `TRUE`. For example, the following statements all assess to `TRUE`:

```
mysql> SELECT 10 IS TRUE;
-> 1
mysql> SELECT -10 IS TRUE;
-> 1
mysql> SELECT 'string' IS NOT NULL;
-> 1
```

- `NOT`, `!`

  Logical NOT. Evaluates to `1` if the operand is `0`, to `0` if the operand is nonzero, and `NOT NULL` returns `NULL`.

```
mysql> SELECT NOT 10;
        -> 0
mysql> SELECT NOT 0;
        -> 1
mysql> SELECT NOT NULL;
```

```
        -> NULL
mysql> SELECT ! (1+1);
        -> 0
mysql> SELECT ! 1+1;
        -> 1
```

The last example produces `1` because the expression evaluates the same way as `(!1)+1`.

- `AND`, `&&`

  Logical AND. Evaluates to `1` if all operands are nonzero and not `NULL`, to `0` if one or more operands are `0`, otherwise `NULL` is returned.

```
mysql> SELECT 1 AND 1;
        -> 1
mysql> SELECT 1 AND 0;
        -> 0
mysql> SELECT 1 AND NULL;
        -> NULL
mysql> SELECT 0 AND NULL;
        -> 0
mysql> SELECT NULL AND 0;
        -> 0
```

- `OR`, `||`

  Logical OR. When both operands are non-`NULL`, the result is `1` if any operand is nonzero, and `0` otherwise. With a `NULL` operand, the result is `1` if the other operand is nonzero, and `NULL` otherwise. If both operands are `NULL`, the result is `NULL`.

```
mysql> SELECT 1 OR 1;
        -> 1
mysql> SELECT 1 OR 0;
        -> 1
mysql> SELECT 0 OR 0;
        -> 0
mysql> SELECT 0 OR NULL;
        -> NULL
mysql> SELECT 1 OR NULL;
        -> 1
```

- `XOR`

  Logical XOR. Returns `NULL` if either operand is `NULL`. For non-`NULL` operands, evaluates to `1` if an odd number of operands is nonzero, otherwise `0` is returned.

```
mysql> SELECT 1 XOR 1;
        -> 0
mysql> SELECT 1 XOR 0;
        -> 1
mysql> SELECT 1 XOR NULL;
        -> NULL
mysql> SELECT 1 XOR 1 XOR 1;
        -> 1
```

`a XOR b` is mathematically equal to `(a AND (NOT b)) OR ((NOT a) and b)`.

12.3.4 Assignment Operators

Table 12.5 Assignment Operators

Name	Description
`=`	Assign a value (as part of a `SET` statement, or as part of the `SET` clause in an `UPDATE` statement)

Name	Description
`:=`	Assign a value

- `:=`

  Assignment operator. Causes the user variable on the left hand side of the operator to take on the value to its right. The value on the right hand side may be a literal value, another variable storing a value, or any legal expression that yields a scalar value, including the result of a query (provided that this value is a scalar value). You can perform multiple assignments in the same `SET` statement. You can perform multiple assignments in the same statement.

  Unlike `=`, the `:=` operator is never interpreted as a comparison operator. This means you can use `:=` in any valid SQL statement (not just in `SET` statements) to assign a value to a variable.

```
mysql> SELECT @var1, @var2;
        -> NULL, NULL
mysql> SELECT @var1 := 1, @var2;
        -> 1, NULL
mysql> SELECT @var1, @var2;
        -> 1, NULL
mysql> SELECT @var1, @var2 := @var1;
        -> 1, 1
mysql> SELECT @var1, @var2;
        -> 1, 1

mysql> SELECT @var1:=COUNT(*) FROM t1;
        -> 4
mysql> SELECT @var1;
        -> 4
```

  You can make value assignments using `:=` in other statements besides `SELECT`, such as `UPDATE`, as shown here:

```
mysql> SELECT @var1;
        -> 4
mysql> SELECT * FROM t1;
        -> 1, 3, 5, 7

mysql> UPDATE t1 SET c1 = 2 WHERE c1 = @var1:= 1;
Query OK, 1 row affected (0.00 sec)
Rows matched: 1  Changed: 1  Warnings: 0

mysql> SELECT @var1;
        -> 1
mysql> SELECT * FROM t1;
        -> 2, 3, 5, 7
```

  While it is also possible both to set and to read the value of the same variable in a single SQL statement using the `:=` operator, this is not recommended. Section 9.4, “User-Defined Variables”, explains why you should avoid doing this.

- `=`

  This operator is used to perform value assignments in two cases, described in the next two paragraphs.

  Within a `SET` statement, `=` is treated as an assignment operator that causes the user variable on the left hand side of the operator to take on the value to its right. (In other words, when used in a `SET` statement, `=` is treated identically to `:=`.) The value on the right hand side may be a literal value, another variable storing a value, or any legal expression that yields a scalar value, including the result of a query (provided that this value is a scalar value). You can perform multiple assignments in the same `SET` statement.

In the SET clause of an UPDATE statement, = also acts as an assignment operator; in this case, however, it causes the column named on the left hand side of the operator to assume the value given to the right, provided any WHERE conditions that are part of the UPDATE are met. You can make multiple assignments in the same SET clause of an UPDATE statement.

In any other context, = is treated as a comparison operator.

```
mysql> SELECT @var1, @var2;
        -> NULL, NULL
mysql> SELECT @var1 := 1, @var2;
        -> 1, NULL
mysql> SELECT @var1, @var2;
        -> 1, NULL
mysql> SELECT @var1, @var2 := @var1;
        -> 1, 1
mysql> SELECT @var1, @var2;
        -> 1, 1
```

For more information, see Section 13.7.4.1, “SET Syntax for Variable Assignment”, Section 13.2.11, “UPDATE Syntax”, and Section 13.2.10, “Subquery Syntax”.

12.4 Control Flow Functions

Table 12.6 Flow Control Operators

Name	Description
CASE	Case operator
IF()	If/else construct
IFNULL()	Null if/else construct
NULLIF()	Return NULL if expr1 = expr2

- `CASE value WHEN [compare_value] THEN result [WHEN [compare_value] THEN result ...] [ELSE result] END`

  `CASE WHEN [condition] THEN result [WHEN [condition] THEN result ...] [ELSE result] END`

  The first CASE syntax returns the *result* for the first *value=compare_value* comparison that is true. The second syntax returns the result for the first condition that is true. If no comparison or condition is true, the result after ELSE is returned, or NULL if there is no ELSE part.

  Note

  The syntax of the CASE *expression* described here differs slightly from that of the SQL CASE *statement* described in Section 13.6.5.1, “CASE Syntax”, for use inside stored programs. The CASE statement cannot have an ELSE NULL clause, and it is terminated with END CASE instead of END.

  The return type of a CASE expression result is the aggregated type of all result values.

```
mysql> SELECT CASE 1 WHEN 1 THEN 'one'
    ->     WHEN 2 THEN 'two' ELSE 'more' END;
        -> 'one'
mysql> SELECT CASE WHEN 1>0 THEN 'true' ELSE 'false' END;
        -> 'true'
mysql> SELECT CASE BINARY 'B'
    ->     WHEN 'a' THEN 1 WHEN 'b' THEN 2 END;
        -> NULL
```

- `IF(expr1,expr2,expr3)`

If *expr1* is TRUE (*expr1* <> 0 and *expr1* <> NULL), IF() returns *expr2*. Otherwise, it returns *expr3*.

Note

There is also an IF *statement*, which differs from the IF() *function* described here. See Section 13.6.5.2, “IF Syntax”.

If only one of *expr2* or *expr3* is explicitly NULL, the result type of the IF() function is the type of the non-NULL expression.

The default return type of IF() (which may matter when it is stored into a temporary table) is calculated as follows:

- If *expr2* or *expr3* produce a string, the result is a string.

  If *expr2* and *expr3* are both strings, the result is case sensitive if either string is case sensitive.

- If *expr2* or *expr3* produce a floating-point value, the result is a floating-point value.

- If *expr2* or *expr3* produce an integer, the result is an integer.

```
mysql> SELECT IF(1>2,2,3);
        -> 3
mysql> SELECT IF(1<2,'yes','no');
        -> 'yes'
mysql> SELECT IF(STRCMP('test','test1'),'no','yes');
        -> 'no'
```

- IFNULL(*expr1*,*expr2*)

If *expr1* is not NULL, IFNULL() returns *expr1*; otherwise it returns *expr2*.

```
mysql> SELECT IFNULL(1,0);
        -> 1
mysql> SELECT IFNULL(NULL,10);
        -> 10
mysql> SELECT IFNULL(1/0,10);
        -> 10
mysql> SELECT IFNULL(1/0,'yes');
        -> 'yes'
```

The default return type of IFNULL(*expr1*,*expr2*) is the more “general” of the two expressions, in the order STRING, REAL, or INTEGER. Consider the case of a table based on expressions or where MySQL must internally store a value returned by IFNULL() in a temporary table:

```
mysql> CREATE TABLE tmp SELECT IFNULL(1,'test') AS test;
mysql> DESCRIBE tmp;
+-------+-------------+------+-----+---------+-------+
| Field | Type        | Null | Key | Default | Extra |
+-------+-------------+------+-----+---------+-------+
| test  | varbinary(4) | NO   |     |         |       |
+-------+-------------+------+-----+---------+-------+
```

In this example, the type of the test column is VARBINARY(4) (a string type).

- NULLIF(*expr1*,*expr2*)

Returns NULL if *expr1* = *expr2* is true, otherwise returns *expr1*. This is the same as CASE WHEN *expr1* = *expr2* THEN NULL ELSE *expr1* END.

The return value has the same type as the first argument.

```
mysql> SELECT NULLIF(1,1);
        -> NULL
mysql> SELECT NULLIF(1,2);
        -> 1
```

Note

MySQL evaluates *`expr1`* twice if the arguments are not equal.

12.5 String Functions

Table 12.7 String Operators

Name	Description
ASCII()	Return numeric value of left-most character
BIN()	Return a string containing binary representation of a number
BIT_LENGTH()	Return length of argument in bits
CHAR()	Return the character for each integer passed
CHAR_LENGTH()	Return number of characters in argument
CHARACTER_LENGTH()	Synonym for CHAR_LENGTH()
CONCAT()	Return concatenated string
CONCAT_WS()	Return concatenate with separator
ELT()	Return string at index number
EXPORT_SET()	Return a string such that for every bit set in the value bits, you get an on string and for every unset bit, you get an off string
FIELD()	Return the index (position) of the first argument in the subsequent arguments
FIND_IN_SET()	Return the index position of the first argument within the second argument
FORMAT()	Return a number formatted to specified number of decimal places
HEX()	Return a hexadecimal representation of a decimal or string value
INSERT()	Insert a substring at the specified position up to the specified number of characters
INSTR()	Return the index of the first occurrence of substring
LCASE()	Synonym for LOWER()
LEFT()	Return the leftmost number of characters as specified
LENGTH()	Return the length of a string in bytes
LIKE	Simple pattern matching
LOAD_FILE()	Load the named file
LOCATE()	Return the position of the first occurrence of substring
LOWER()	Return the argument in lowercase
LPAD()	Return the string argument, left-padded with the specified string

Name	Description
LTRIM()	Remove leading spaces
MAKE_SET()	Return a set of comma-separated strings that have the corresponding bit in bits set
MATCH	Perform full-text search
MID()	Return a substring starting from the specified position
NOT LIKE	Negation of simple pattern matching
NOT REGEXP	Negation of REGEXP
OCT()	Return a string containing octal representation of a number
OCTET_LENGTH()	Synonym for LENGTH()
ORD()	Return character code for leftmost character of the argument
POSITION()	Synonym for LOCATE()
QUOTE()	Escape the argument for use in an SQL statement
REGEXP	Pattern matching using regular expressions
REPEAT()	Repeat a string the specified number of times
REPLACE()	Replace occurrences of a specified string
REVERSE()	Reverse the characters in a string
RIGHT()	Return the specified rightmost number of characters
RLIKE	Synonym for REGEXP
RPAD()	Append string the specified number of times
RTRIM()	Remove trailing spaces
SOUNDEX()	Return a soundex string
SOUNDS LIKE	Compare sounds
SPACE()	Return a string of the specified number of spaces
STRCMP()	Compare two strings
SUBSTR()	Return the substring as specified
SUBSTRING()	Return the substring as specified
SUBSTRING_INDEX()	Return a substring from a string before the specified number of occurrences of the delimiter
TRIM()	Remove leading and trailing spaces
UCASE()	Synonym for UPPER()
UNHEX()	Return a string containing hex representation of a number
UPPER()	Convert to uppercase

String-valued functions return `NULL` if the length of the result would be greater than the value of the `max_allowed_packet` system variable. See Section 5.1.1, “Configuring the Server”.

For functions that operate on string positions, the first position is numbered 1.

For functions that take length arguments, noninteger arguments are rounded to the nearest integer.

- `ASCII(str)`

  Returns the numeric value of the leftmost character of the string *`str`*. Returns `0` if *`str`* is the empty string. Returns `NULL` if *`str`* is `NULL`. `ASCII()` works for 8-bit characters.

```
mysql> SELECT ASCII('2');
```

```
       -> 50
mysql> SELECT ASCII(2);
       -> 50
mysql> SELECT ASCII('dx');
       -> 100
```

See also the `ORD()` function.

- `BIN(N)`

  Returns a string representation of the binary value of *`N`*, where *`N`* is a longlong (`BIGINT`) number. This is equivalent to `CONV(N,10,2)`. Returns `NULL` if *`N`* is `NULL`.

```
mysql> SELECT BIN(12);
       -> '1100'
```

- `BIT_LENGTH(str)`

  Returns the length of the string *`str`* in bits.

```
mysql> SELECT BIT_LENGTH('text');
       -> 32
```

- `CHAR(N,... [USING charset_name])`

  `CHAR()` interprets each argument *`N`* as an integer and returns a string consisting of the characters given by the code values of those integers. `NULL` values are skipped.

```
mysql> SELECT CHAR(77,121,83,81,'76');
       -> 'MySQL'
mysql> SELECT CHAR(77,77.3,'77.3');
       -> 'MMM'
```

  `CHAR()` arguments larger than 255 are converted into multiple result bytes. For example, `CHAR(256)` is equivalent to `CHAR(1,0)`, and `CHAR(256*256)` is equivalent to `CHAR(1,0,0)`:

```
mysql> SELECT HEX(CHAR(1,0)), HEX(CHAR(256));
+----------------+----------------+
| HEX(CHAR(1,0)) | HEX(CHAR(256)) |
+----------------+----------------+
| 0100           | 0100           |
+----------------+----------------+
mysql> SELECT HEX(CHAR(1,0,0)), HEX(CHAR(256*256));
+------------------+--------------------+
| HEX(CHAR(1,0,0)) | HEX(CHAR(256*256)) |
+------------------+--------------------+
| 010000           | 010000             |
+------------------+--------------------+
```

  By default, `CHAR()` returns a binary string. To produce a string in a given character set, use the optional `USING` clause:

```
mysql> SELECT CHARSET(CHAR(X'65')), CHARSET(CHAR(X'65' USING utf8));
+----------------------+--------------------------------+
| CHARSET(CHAR(X'65')) | CHARSET(CHAR(X'65' USING utf8)) |
+----------------------+--------------------------------+
| binary               | utf8                           |
+----------------------+--------------------------------+
```

  If `USING` is given and the result string is illegal for the given character set, a warning is issued. Also, if strict SQL mode is enabled, the result from `CHAR()` becomes `NULL`.

- `CHAR_LENGTH(str)`

Returns the length of the string *str*, measured in characters. A multibyte character counts as a single character. This means that for a string containing five 2-byte characters, LENGTH() returns 10, whereas CHAR_LENGTH() returns 5.

- CHARACTER_LENGTH(*str*)

  CHARACTER_LENGTH() is a synonym for CHAR_LENGTH().

- CONCAT(*str1*,*str2*,...)

  Returns the string that results from concatenating the arguments. May have one or more arguments. If all arguments are nonbinary strings, the result is a nonbinary string. If the arguments include any binary strings, the result is a binary string. A numeric argument is converted to its equivalent nonbinary string form.

  CONCAT() returns NULL if any argument is NULL.

```
mysql> SELECT CONCAT('My', 'S', 'QL');
        -> 'MySQL'
mysql> SELECT CONCAT('My', NULL, 'QL');
        -> NULL
mysql> SELECT CONCAT(14.3);
        -> '14.3'
```

  For quoted strings, concatenation can be performed by placing the strings next to each other:

```
mysql> SELECT 'My' 'S' 'QL';
        -> 'MySQL'
```

- CONCAT_WS(*separator*,*str1*,*str2*,...)

  CONCAT_WS() stands for Concatenate With Separator and is a special form of CONCAT(). The first argument is the separator for the rest of the arguments. The separator is added between the strings to be concatenated. The separator can be a string, as can the rest of the arguments. If the separator is NULL, the result is NULL.

```
mysql> SELECT CONCAT_WS(',','First name','Second name','Last Name');
        -> 'First name,Second name,Last Name'
mysql> SELECT CONCAT_WS(',','First name',NULL,'Last Name');
        -> 'First name,Last Name'
```

  CONCAT_WS() does not skip empty strings. However, it does skip any NULL values after the separator argument.

- ELT(*N*,*str1*,*str2*,*str3*,...)

  ELT() returns the *N*th element of the list of strings: *str1* if *N* = 1, *str2* if *N* = 2, and so on. Returns NULL if *N* is less than 1 or greater than the number of arguments. ELT() is the complement of FIELD().

```
mysql> SELECT ELT(1, 'ej', 'Heja', 'hej', 'foo');
        -> 'ej'
mysql> SELECT ELT(4, 'ej', 'Heja', 'hej', 'foo');
        -> 'foo'
```

- EXPORT_SET(*bits*,*on*,*off*[,*separator*[,*number_of_bits*]])

  Returns a string such that for every bit set in the value *bits*, you get an *on* string and for every bit not set in the value, you get an *off* string. Bits in *bits* are examined from right to left (from low-order to high-order bits). Strings are added to the result from left to right, separated by the

separator string (the default being the comma character ,). The number of bits examined is given by *number_of_bits*, which has a default of 64 if not specified. *number_of_bits* is silently clipped to 64 if larger than 64. It is treated as an unsigned integer, so a value of −1 is effectively the same as 64.

```
mysql> SELECT EXPORT_SET(5,'Y','N',',',4);
        -> 'Y,N,Y,N'
mysql> SELECT EXPORT_SET(6,'1','0',',',10);
        -> '0,1,1,0,0,0,0,0,0,0'
```

- `FIELD(str,str1,str2,str3,...)`

  Returns the index (position) of *str* in the *str1*, *str2*, *str3*, ... list. Returns 0 if *str* is not found.

  If all arguments to `FIELD()` are strings, all arguments are compared as strings. If all arguments are numbers, they are compared as numbers. Otherwise, the arguments are compared as double.

  If *str* is `NULL`, the return value is 0 because `NULL` fails equality comparison with any value. `FIELD()` is the complement of `ELT()`.

```
mysql> SELECT FIELD('ej', 'Hej', 'ej', 'Heja', 'hej', 'foo');
        -> 2
mysql> SELECT FIELD('fo', 'Hej', 'ej', 'Heja', 'hej', 'foo');
        -> 0
```

- `FIND_IN_SET(str,strlist)`

  Returns a value in the range of 1 to *N* if the string *str* is in the string list *strlist* consisting of *N* substrings. A string list is a string composed of substrings separated by , characters. If the first argument is a constant string and the second is a column of type `SET`, the `FIND_IN_SET()` function is optimized to use bit arithmetic. Returns 0 if *str* is not in *strlist* or if *strlist* is the empty string. Returns `NULL` if either argument is `NULL`. This function does not work properly if the first argument contains a comma (,) character.

```
mysql> SELECT FIND_IN_SET('b','a,b,c,d');
        -> 2
```

- `FORMAT(X,D[,locale])`

  Formats the number *X* to a format like `'#,###,###.##'`, rounded to *D* decimal places, and returns the result as a string. If *D* is 0, the result has no decimal point or fractional part.

  The optional third parameter enables a locale to be specified to be used for the result number's decimal point, thousands separator, and grouping between separators. Permissible locale values are the same as the legal values for the `lc_time_names` system variable (see Section 10.7, “MySQL Server Locale Support”). If no locale is specified, the default is `'en_US'`.

```
mysql> SELECT FORMAT(12332.123456, 4);
        -> '12,332.1235'
mysql> SELECT FORMAT(12332.1,4);
        -> '12,332.1000'
mysql> SELECT FORMAT(12332.2,0);
        -> '12,332'
mysql> SELECT FORMAT(12332.2,2,'de_DE');
        -> '12.332,20'
```

- `HEX(str)`, `HEX(N)`

  For a string argument *str*, `HEX()` returns a hexadecimal string representation of *str* where each byte of each character in *str* is converted to two hexadecimal digits. (Multibyte characters therefore become more than two digits.) The inverse of this operation is performed by the `UNHEX()` function.

For a numeric argument *N*, `HEX()` returns a hexadecimal string representation of the value of *N* treated as a longlong (`BIGINT`) number. This is equivalent to `CONV(N,10,16)`. The inverse of this operation is performed by `CONV(HEX(N),16,10)`.

```
mysql> SELECT X'616263', HEX('abc'), UNHEX(HEX('abc'));
        -> 'abc', 616263, 'abc'
mysql> SELECT HEX(255), CONV(HEX(255),16,10);
        -> 'FF', 255
```

- `INSERT(str,pos,len,newstr)`

  Returns the string *str*, with the substring beginning at position *pos* and *len* characters long replaced by the string *newstr*. Returns the original string if *pos* is not within the length of the string. Replaces the rest of the string from position *pos* if *len* is not within the length of the rest of the string. Returns `NULL` if any argument is `NULL`.

  ```
  mysql> SELECT INSERT('Quadratic', 3, 4, 'What');
          -> 'QuWhattic'
  mysql> SELECT INSERT('Quadratic', -1, 4, 'What');
          -> 'Quadratic'
  mysql> SELECT INSERT('Quadratic', 3, 100, 'What');
          -> 'QuWhat'
  ```

  This function is multibyte safe.

- `INSTR(str,substr)`

  Returns the position of the first occurrence of substring *substr* in string *str*. This is the same as the two-argument form of `LOCATE()`, except that the order of the arguments is reversed.

  ```
  mysql> SELECT INSTR('foobarbar', 'bar');
          -> 4
  mysql> SELECT INSTR('xbar', 'foobar');
          -> 0
  ```

  This function is multibyte safe, and is case sensitive only if at least one argument is a binary string.

- `LCASE(str)`

  `LCASE()` is a synonym for `LOWER()`.

- `LEFT(str,len)`

  Returns the leftmost *len* characters from the string *str*, or `NULL` if any argument is `NULL`.

  ```
  mysql> SELECT LEFT('foobarbar', 5);
          -> 'fooba'
  ```

  This function is multibyte safe.

- `LENGTH(str)`

  Returns the length of the string *str*, measured in bytes. A multibyte character counts as multiple bytes. This means that for a string containing five 2-byte characters, `LENGTH()` returns `10`, whereas `CHAR_LENGTH()` returns `5`.

  ```
  mysql> SELECT LENGTH('text');
          -> 4
  ```

Note

The `Length()` OpenGIS spatial function is named `GLength()` in MySQL.

- `LOAD_FILE(file_name)`

  Reads the file and returns the file contents as a string. To use this function, the file must be located on the server host, you must specify the full path name to the file, and you must have the `FILE` privilege. The file must be readable by all and its size less than `max_allowed_packet` bytes. If the `secure_file_priv` system variable is set to a nonempty directory name, the file to be loaded must be located in that directory.

  If the file does not exist or cannot be read because one of the preceding conditions is not satisfied, the function returns `NULL`.

  The `character_set_filesystem` system variable controls interpretation of file names that are given as literal strings.

```
mysql> UPDATE t
           SET blob_col=LOAD_FILE('/tmp/picture')
           WHERE id=1;
```

- `LOCATE(substr,str)`, `LOCATE(substr,str,pos)`

  The first syntax returns the position of the first occurrence of substring *`substr`* in string *`str`*. The second syntax returns the position of the first occurrence of substring *`substr`* in string *`str`*, starting at position *`pos`*. Returns `0` if *`substr`* is not in *`str`*. Returns `NULL` if *`substr`* or *`str`* is `NULL`.

```
mysql> SELECT LOCATE('bar', 'foobarbar');
        -> 4
mysql> SELECT LOCATE('xbar', 'foobar');
        -> 0
mysql> SELECT LOCATE('bar', 'foobarbar', 5);
        -> 7
```

  This function is multibyte safe, and is case-sensitive only if at least one argument is a binary string.

- `LOWER(str)`

  Returns the string *`str`* with all characters changed to lowercase according to the current character set mapping. The default is `latin1` (cp1252 West European).

```
mysql> SELECT LOWER('QUADRATICALLY');
        -> 'quadratically'
```

  `LOWER()` (and `UPPER()`) are ineffective when applied to binary strings (`BINARY`, `VARBINARY`, `BLOB`). To perform lettercase conversion, convert the string to a nonbinary string:

```
mysql> SET @str = BINARY 'New York';
mysql> SELECT LOWER(@str), LOWER(CONVERT(@str USING latin1));
+-------------+-----------------------------------+
| LOWER(@str) | LOWER(CONVERT(@str USING latin1)) |
+-------------+-----------------------------------+
| New York    | new york                          |
+-------------+-----------------------------------+
```

  This function is multibyte safe.

- `LPAD(str,len,padstr)`

Returns the string *str*, left-padded with the string *padstr* to a length of *len* characters. If *str* is longer than *len*, the return value is shortened to *len* characters.

```
mysql> SELECT LPAD('hi',4,'??');
        -> '??hi'
mysql> SELECT LPAD('hi',1,'??');
        -> 'h'
```

- `LTRIM(str)`

  Returns the string *str* with leading space characters removed.

```
mysql> SELECT LTRIM('  barbar');
        -> 'barbar'
```

  This function is multibyte safe.

- `MAKE_SET(bits,str1,str2,...)`

  Returns a set value (a string containing substrings separated by `,` characters) consisting of the strings that have the corresponding bit in *bits* set. *str1* corresponds to bit 0, *str2* to bit 1, and so on. `NULL` values in *str1*, *str2*, `...` are not appended to the result.

```
mysql> SELECT MAKE_SET(1,'a','b','c');
        -> 'a'
mysql> SELECT MAKE_SET(1 | 4,'hello','nice','world');
        -> 'hello,world'
mysql> SELECT MAKE_SET(1 | 4,'hello','nice',NULL,'world');
        -> 'hello'
mysql> SELECT MAKE_SET(0,'a','b','c');
        -> ''
```

- `MID(str,pos,len)`

  `MID(str,pos,len)` is a synonym for `SUBSTRING(str,pos,len)`.

- `OCT(N)`

  Returns a string representation of the octal value of *N*, where *N* is a longlong (`BIGINT`) number. This is equivalent to `CONV(N,10,8)`. Returns `NULL` if *N* is `NULL`.

```
mysql> SELECT OCT(12);
        -> '14'
```

- `OCTET_LENGTH(str)`

  `OCTET_LENGTH()` is a synonym for `LENGTH()`.

- `ORD(str)`

  If the leftmost character of the string *str* is a multibyte character, returns the code for that character, calculated from the numeric values of its constituent bytes using this formula:

```
  (1st byte code)
+ (2nd byte code * 256)
+ (3rd byte code * 256^2) ...
```

  If the leftmost character is not a multibyte character, `ORD()` returns the same value as the `ASCII()` function.

```
```

```
mysql> SELECT ORD('2');
        -> 50
```

- `POSITION(substr IN str)`

  `POSITION(substr IN str)` is a synonym for `LOCATE(substr,str)`.

- `QUOTE(str)`

  Quotes a string to produce a result that can be used as a properly escaped data value in an SQL statement. The string is returned enclosed by single quotation marks and with each instance of backslash (\), single quote ('), ASCII `NUL`, and Control+Z preceded by a backslash. If the argument is `NULL`, the return value is the word "NULL" without enclosing single quotation marks.

  ```
  mysql> SELECT QUOTE('Don\'t!');
          -> 'Don\'t!'
  mysql> SELECT QUOTE(NULL);
          -> NULL
  ```

  For comparison, see the quoting rules for literal strings and within the C API in Section 9.1.1, "String Literals", and Section 23.8.7.53, "mysql_real_escape_string()".

- `REPEAT(str,count)`

  Returns a string consisting of the string *`str`* repeated *`count`* times. If *`count`* is less than 1, returns an empty string. Returns `NULL` if *`str`* or *`count`* are `NULL`.

  ```
  mysql> SELECT REPEAT('MySQL', 3);
          -> 'MySQLMySQLMySQL'
  ```

- `REPLACE(str,from_str,to_str)`

  Returns the string *`str`* with all occurrences of the string *`from_str`* replaced by the string *`to_str`*. `REPLACE()` performs a case-sensitive match when searching for *`from_str`*.

  ```
  mysql> SELECT REPLACE('www.mysql.com', 'w', 'Ww');
          -> 'WwWwWw.mysql.com'
  ```

  This function is multibyte safe.

- `REVERSE(str)`

  Returns the string *`str`* with the order of the characters reversed.

  ```
  mysql> SELECT REVERSE('abc');
          -> 'cba'
  ```

  This function is multibyte safe.

- `RIGHT(str,len)`

  Returns the rightmost *`len`* characters from the string *`str`*, or `NULL` if any argument is `NULL`.

  ```
  mysql> SELECT RIGHT('foobarbar', 4);
          -> 'rbar'
  ```

  This function is multibyte safe.

- `RPAD(str,len,padstr)`

Returns the string *str*, right-padded with the string *padstr* to a length of *len* characters. If *str* is longer than *len*, the return value is shortened to *len* characters.

```
mysql> SELECT RPAD('hi',5,'?');
        -> 'hi???'
mysql> SELECT RPAD('hi',1,'?');
        -> 'h'
```

This function is multibyte safe.

- `RTRIM(str)`

  Returns the string *str* with trailing space characters removed.

```
mysql> SELECT RTRIM('barbar   ');
        -> 'barbar'
```

  This function is multibyte safe.

- `SOUNDEX(str)`

  Returns a soundex string from *str*. Two strings that sound almost the same should have identical soundex strings. A standard soundex string is four characters long, but the `SOUNDEX()` function returns an arbitrarily long string. You can use `SUBSTRING()` on the result to get a standard soundex string. All nonalphabetic characters in *str* are ignored. All international alphabetic characters outside the A-Z range are treated as vowels.

Important

When using `SOUNDEX()`, you should be aware of the following limitations:

  - This function, as currently implemented, is intended to work well with strings that are in the English language only. Strings in other languages may not produce reliable results.
  - This function is not guaranteed to provide consistent results with strings that use multibyte character sets, including `utf-8`. See Bug #22638 for more information.

```
mysql> SELECT SOUNDEX('Hello');
        -> 'H400'
mysql> SELECT SOUNDEX('Quadratically');
        -> 'Q36324'
```

Note

This function implements the original Soundex algorithm, not the more popular enhanced version (also described by D. Knuth). The difference is that original version discards vowels first and duplicates second, whereas the enhanced version discards duplicates first and vowels second.

- *expr1* `SOUNDS LIKE` *expr2*

  This is the same as `SOUNDEX(expr1) = SOUNDEX(expr2)`.

- `SPACE(N)`

  Returns a string consisting of *N* space characters.

```
mysql> SELECT SPACE(6);
        -> '      '
```

- `SUBSTR(str,pos)`, `SUBSTR(str FROM pos)`, `SUBSTR(str,pos,len)`, `SUBSTR(str FROM pos FOR len)`

  `SUBSTR()` is a synonym for `SUBSTRING()`.

- `SUBSTRING(str,pos)`, `SUBSTRING(str FROM pos)`, `SUBSTRING(str,pos,len)`, `SUBSTRING(str FROM pos FOR len)`

  The forms without a *`len`* argument return a substring from string *`str`* starting at position *`pos`*. The forms with a *`len`* argument return a substring *`len`* characters long from string *`str`*, starting at position *`pos`*. The forms that use `FROM` are standard SQL syntax. It is also possible to use a negative value for *`pos`*. In this case, the beginning of the substring is *`pos`* characters from the end of the string, rather than the beginning. A negative value may be used for *`pos`* in any of the forms of this function.

  For all forms of `SUBSTRING()`, the position of the first character in the string from which the substring is to be extracted is reckoned as `1`.

```
mysql> SELECT SUBSTRING('Quadratically',5);
        -> 'ratically'
mysql> SELECT SUBSTRING('foobarbar' FROM 4);
        -> 'barbar'
mysql> SELECT SUBSTRING('Quadratically',5,6);
        -> 'ratica'
mysql> SELECT SUBSTRING('Sakila', -3);
        -> 'ila'
mysql> SELECT SUBSTRING('Sakila', -5, 3);
        -> 'aki'
mysql> SELECT SUBSTRING('Sakila' FROM -4 FOR 2);
        -> 'ki'
```

  This function is multibyte safe.

  If *`len`* is less than 1, the result is the empty string.

- `SUBSTRING_INDEX(str,delim,count)`

  Returns the substring from string *`str`* before *`count`* occurrences of the delimiter *`delim`*. If *`count`* is positive, everything to the left of the final delimiter (counting from the left) is returned. If *`count`* is negative, everything to the right of the final delimiter (counting from the right) is returned. `SUBSTRING_INDEX()` performs a case-sensitive match when searching for *`delim`*.

```
mysql> SELECT SUBSTRING_INDEX('www.mysql.com', '.', 2);
        -> 'www.mysql'
mysql> SELECT SUBSTRING_INDEX('www.mysql.com', '.', -2);
        -> 'mysql.com'
```

  This function is multibyte safe.

- `TRIM([{BOTH | LEADING | TRAILING} [remstr] FROM] str)`, `TRIM([remstr FROM] str)`

  Returns the string *`str`* with all *`remstr`* prefixes or suffixes removed. If none of the specifiers `BOTH`, `LEADING`, or `TRAILING` is given, `BOTH` is assumed. *`remstr`* is optional and, if not specified, spaces are removed.

```
mysql> SELECT TRIM('  bar   ');
        -> 'bar'
mysql> SELECT TRIM(LEADING 'x' FROM 'xxxbarxxx');
        -> 'barxxx'
mysql> SELECT TRIM(BOTH 'x' FROM 'xxxbarxxx');
        -> 'bar'
mysql> SELECT TRIM(TRAILING 'xyz' FROM 'barxxyz');
```

```
        -> 'barx'
```

This function is multibyte safe.

- `UCASE(str)`

  `UCASE()` is a synonym for `UPPER()`.

- `UNHEX(str)`

  For a string argument *`str`*, `UNHEX(str)` interprets each pair of characters in the argument as a hexadecimal number and converts it to the byte represented by the number. The return value is a binary string.

```
mysql> SELECT UNHEX('4D7953514C');
        -> 'MySQL'
mysql> SELECT X'4D7953514C';
        -> 'MySQL'
mysql> SELECT UNHEX(HEX('string'));
        -> 'string'
mysql> SELECT HEX(UNHEX('1267'));
        -> '1267'
```

  The characters in the argument string must be legal hexadecimal digits: `'0'` .. `'9'`, `'A'` .. `'F'`, `'a'` .. `'f'`. If the argument contains any nonhexadecimal digits, the result is `NULL`:

```
mysql> SELECT UNHEX('GG');
+-------------+
| UNHEX('GG') |
+-------------+
| NULL        |
+-------------+
```

  A `NULL` result can occur if the argument to `UNHEX()` is a `BINARY` column, because values are padded with 0x00 bytes when stored but those bytes are not stripped on retrieval. For example, `'41'` is stored into a `CHAR(3)` column as `'41 '` and retrieved as `'41'` (with the trailing pad space stripped), so `UNHEX()` for the column value returns `'A'`. By contrast `'41'` is stored into a `BINARY(3)` column as `'41\0'` and retrieved as `'41\0'` (with the trailing pad `0x00` byte not stripped). `'\0'` is not a legal hexadecimal digit, so `UNHEX()` for the column value returns `NULL`.

  For a numeric argument *`N`*, the inverse of `HEX(N)` is not performed by `UNHEX()`. Use `CONV(HEX(N),16,10)` instead. See the description of `HEX()`.

- `UPPER(str)`

  Returns the string *`str`* with all characters changed to uppercase according to the current character set mapping. The default is `latin1` (cp1252 West European).

```
mysql> SELECT UPPER('Hej');
        -> 'HEJ'
```

  See the description of `LOWER()` for information that also applies to `UPPER()`, such as information about how to perform lettercase conversion of binary strings (`BINARY`, `VARBINARY`, `BLOB`) for which these functions are ineffective.

  This function is multibyte safe.

12.5.1 String Comparison Functions

Table 12.8 String Comparison Operators

Name	Description
LIKE	Simple pattern matching
NOT LIKE	Negation of simple pattern matching
STRCMP()	Compare two strings

If a string function is given a binary string as an argument, the resulting string is also a binary string. A number converted to a string is treated as a binary string. This affects only comparisons.

Normally, if any expression in a string comparison is case sensitive, the comparison is performed in case-sensitive fashion.

- *expr* LIKE *pat* [ESCAPE '*escape_char*']

  Pattern matching using an SQL pattern. Returns 1 (TRUE) or 0 (FALSE). If either *expr* or *pat* is NULL, the result is NULL.

  The pattern need not be a literal string. For example, it can be specified as a string expression or table column.

  Per the SQL standard, LIKE performs matching on a per-character basis, thus it can produce results different from the = comparison operator:

```
mysql> SELECT 'ä' LIKE 'ae' COLLATE latin1_german2_ci;
+-----------------------------------------+
| 'ä' LIKE 'ae' COLLATE latin1_german2_ci |
+-----------------------------------------+
|                                       0 |
+-----------------------------------------+
mysql> SELECT 'ä' = 'ae' COLLATE latin1_german2_ci;
+--------------------------------------+
| 'ä' = 'ae' COLLATE latin1_german2_ci |
+--------------------------------------+
|                                    1 |
+--------------------------------------+
```

  In particular, trailing spaces are significant, which is not true for CHAR or VARCHAR comparisons performed with the = operator:

```
mysql> SELECT 'a' = 'a ', 'a' LIKE 'a ';
+------------+---------------+
| 'a' = 'a ' | 'a' LIKE 'a ' |
+------------+---------------+
|          1 |             0 |
+------------+---------------+
1 row in set (0.00 sec)
```

  With LIKE you can use the following two wildcard characters in the pattern:

  - % matches any number of characters, even zero characters.
  - _ matches exactly one character.

```
mysql> SELECT 'David!' LIKE 'David_';
        -> 1
mysql> SELECT 'David!' LIKE '%D%v%';
        -> 1
```

  To test for literal instances of a wildcard character, precede it by the escape character. If you do not specify the ESCAPE character, \ is assumed.

- `\%` matches one `%` character.
- `\_` matches one `_` character.

```
mysql> SELECT 'David!' LIKE 'David\_';
        -> 0
mysql> SELECT 'David_' LIKE 'David\_';
        -> 1
```

To specify a different escape character, use the `ESCAPE` clause:

```
mysql> SELECT 'David_' LIKE 'David|_' ESCAPE '|';
        -> 1
```

The escape sequence should be empty or one character long. The expression must evaluate as a constant at execution time. If the `NO_BACKSLASH_ESCAPES` SQL mode is enabled, the sequence cannot be empty.

The following two statements illustrate that string comparisons are not case sensitive unless one of the operands is a case sensitive (uses a case-sensitive collation or is a binary string):

```
mysql> SELECT 'abc' LIKE 'ABC';
        -> 1
mysql> SELECT 'abc' LIKE _latin1 'ABC' COLLATE latin1_general_cs;
        -> 0
mysql> SELECT 'abc' LIKE _latin1 'ABC' COLLATE latin1_bin;
        -> 0
mysql> SELECT 'abc' LIKE BINARY 'ABC';
        -> 0
```

As an extension to standard SQL, MySQL permits `LIKE` on numeric expressions.

```
mysql> SELECT 10 LIKE '1%';
        -> 1
```

Note

Because MySQL uses C escape syntax in strings (for example, `\n` to represent a newline character), you must double any `\` that you use in `LIKE` strings. For example, to search for `\n`, specify it as `\\n`. To search for `\`, specify it as `\\\\`; this is because the backslashes are stripped once by the parser and again when the pattern match is made, leaving a single backslash to be matched against.

Exception: At the end of the pattern string, backslash can be specified as `\\`. At the end of the string, backslash stands for itself because there is nothing following to escape. Suppose that a table contains the following values:

```
mysql> SELECT filename FROM t1;
+--------------+
| filename     |
+--------------+
| C:           |
| C:\          |
| C:\Programs  |
| C:\Programs\ |
+--------------+
```

To test for values that end with backslash, you can match the values using either of the following patterns:

```
mysql> SELECT filename, filename LIKE '%\\' FROM t1;
+-------------+---------------------+
| filename    | filename LIKE '%\\' |
+-------------+---------------------+
| C:          |                   0 |
| C:\         |                   1 |
| C:\Programs |                   0 |
| C:\Programs\|                   1 |
+-------------+---------------------+

mysql> SELECT filename, filename LIKE '%\\\\' FROM t1;
+-------------+----------------------+
| filename    | filename LIKE '%\\\\' |
+-------------+----------------------+
| C:          |                    0 |
| C:\         |                    1 |
| C:\Programs |                    0 |
| C:\Programs\|                    1 |
+-------------+----------------------+
```

- *`expr`* `NOT LIKE` *`pat`* `[ESCAPE '`*`escape_char`*`']`

  This is the same as `NOT (`*`expr`* `LIKE` *`pat`* `[ESCAPE '`*`escape_char`*`'])`.

Note

Aggregate queries involving `NOT LIKE` comparisons with columns containing `NULL` may yield unexpected results. For example, consider the following table and data:

```
CREATE TABLE foo (bar VARCHAR(10));

INSERT INTO foo VALUES (NULL), (NULL);
```

The query `SELECT COUNT(*) FROM foo WHERE bar LIKE '%baz%';` returns `0`. You might assume that `SELECT COUNT(*) FROM foo WHERE bar NOT LIKE '%baz%';` would return `2`. However, this is not the case: The second query returns `0`. This is because `NULL NOT LIKE` *`expr`* always returns `NULL`, regardless of the value of *`expr`*. The same is true for aggregate queries involving `NULL` and comparisons using `NOT RLIKE` or `NOT REGEXP`. In such cases, you must test explicitly for `NOT NULL` using `OR` (and not `AND`), as shown here:

```
SELECT COUNT(*) FROM foo WHERE bar NOT LIKE '%baz%' OR bar IS NULL;
```

- `STRCMP(`*`expr1`*`,`*`expr2`*`)`

  `STRCMP()` returns `0` if the strings are the same, `-1` if the first argument is smaller than the second according to the current sort order, and `1` otherwise.

```
mysql> SELECT STRCMP('text', 'text2');
        -> -1
mysql> SELECT STRCMP('text2', 'text');
        -> 1
mysql> SELECT STRCMP('text', 'text');
        -> 0
```

  `STRCMP()` performs the comparison using the collation of the arguments.

```
mysql> SET @s1 = _latin1 'x' COLLATE latin1_general_ci;
mysql> SET @s2 = _latin1 'X' COLLATE latin1_general_ci;
mysql> SET @s3 = _latin1 'x' COLLATE latin1_general_cs;
```

```
mysql> SET @s4 = _latin1 'X' COLLATE latin1_general_cs;
mysql> SELECT STRCMP(@s1, @s2), STRCMP(@s3, @s4);
+------------------+------------------+
| STRCMP(@s1, @s2) | STRCMP(@s3, @s4) |
+------------------+------------------+
|                0 |                1 |
+------------------+------------------+
```

If the collations are incompatible, one of the arguments must be converted to be compatible with the other. See Section 10.1.8.4, “Collation Coercibility in Expressions”.

```
mysql> SELECT STRCMP(@s1, @s3);
ERROR 1267 (HY000): Illegal mix of collations (latin1_general_ci,IMPLICIT)
and (latin1_general_cs,IMPLICIT) for operation 'strcmp'
mysql> SELECT STRCMP(@s1, @s3 COLLATE latin1_general_ci);
+-------------------------------------------+
| STRCMP(@s1, @s3 COLLATE latin1_general_ci) |
+-------------------------------------------+
|                                         0 |
+-------------------------------------------+
```

12.5.2 Regular Expressions

Table 12.9 String Regular Expression Operators

Name	Description
`NOT REGEXP`	Negation of REGEXP
`REGEXP`	Pattern matching using regular expressions
`RLIKE`	Synonym for REGEXP

A regular expression is a powerful way of specifying a pattern for a complex search.

MySQL uses Henry Spencer's implementation of regular expressions, which is aimed at conformance with POSIX 1003.2. MySQL uses the extended version to support pattern-matching operations performed with the `REGEXP` operator in SQL statements.

This section summarizes, with examples, the special characters and constructs that can be used in MySQL for `REGEXP` operations. It does not contain all the details that can be found in Henry Spencer's `regex(7)` manual page. That manual page is included in MySQL source distributions, in the `regex.7` file under the `regex` directory. See also Section 3.3.4.7, “Pattern Matching”.

Regular Expression Operators

- *`expr`* `NOT REGEXP` *`pat`*, *`expr`* `NOT RLIKE` *`pat`*

  This is the same as `NOT (`*`expr`* `REGEXP` *`pat`*`)`.

- *`expr`* `REGEXP` *`pat`*, *`expr`* `RLIKE` *`pat`*

  Performs a pattern match of a string expression *`expr`* against a pattern *`pat`*. The pattern can be an extended regular expression, the syntax for which is discussed later in this section. Returns `1` if *`expr`* matches *`pat`*; otherwise it returns `0`. If either *`expr`* or *`pat`* is `NULL`, the result is `NULL`. `RLIKE` is a synonym for `REGEXP`, provided for `mSQL` compatibility.

  The pattern need not be a literal string. For example, it can be specified as a string expression or table column.

Note

Because MySQL uses the C escape syntax in strings (for example, `\n` to represent the newline character), you must double any `\` that you use in your `REGEXP` strings.

`REGEXP` is not case sensitive, except when used with binary strings.

```
mysql> SELECT 'Michael!' REGEXP '.*';
        -> 1
mysql> SELECT 'new*\n*line' REGEXP 'new\\*.\\*line';
        -> 1
mysql> SELECT 'a' REGEXP 'A', 'a' REGEXP BINARY 'A';
        -> 1  0
mysql> SELECT 'a' REGEXP '^[a-d]';
        -> 1
```

`REGEXP` and `RLIKE` use the character set and collations of the arguments when deciding the type of a character and performing the comparison. If the arguments have different character sets or collations, coercibility rules apply as described in Section 10.1.8.4, “Collation Coercibility in Expressions”.

Warning

The `REGEXP` and `RLIKE` operators work in byte-wise fashion, so they are not multibyte safe and may produce unexpected results with multibyte character sets. In addition, these operators compare characters by their byte values and accented characters may not compare as equal even if a given collation treats them as equal.

Syntax of Regular Expressions

A regular expression describes a set of strings. The simplest regular expression is one that has no special characters in it. For example, the regular expression `hello` matches `hello` and nothing else.

Nontrivial regular expressions use certain special constructs so that they can match more than one string. For example, the regular expression `hello|word` matches either the string `hello` or the string `word`.

As a more complex example, the regular expression `B[an]*s` matches any of the strings `Bananas`, `Baaaaas`, `Bs`, and any other string starting with a `B`, ending with an `s`, and containing any number of `a` or `n` characters in between.

A regular expression for the `REGEXP` operator may use any of the following special characters and constructs:

- `^`

  Match the beginning of a string.

  ```
  mysql> SELECT 'fo\nfo' REGEXP '^fo$';                    -> 0
  mysql> SELECT 'fofo' REGEXP '^fo';                       -> 1
  ```

- `$`

  Match the end of a string.

  ```
  mysql> SELECT 'fo\no' REGEXP '^fo\no$';                  -> 1
  mysql> SELECT 'fo\no' REGEXP '^fo$';                     -> 0
  ```

- `.`

  Match any character (including carriage return and newline).

  ```
  mysql> SELECT 'fofo' REGEXP '^f.*$';                     -> 1
  mysql> SELECT 'fo\r\nfo' REGEXP '^f.*$';                 -> 1
  ```

- `a*`

  Match any sequence of zero or more `a` characters.

```
mysql> SELECT 'Ban' REGEXP '^Ba*n';                    -> 1
mysql> SELECT 'Baaan' REGEXP '^Ba*n';                  -> 1
mysql> SELECT 'Bn' REGEXP '^Ba*n';                     -> 1
```

- `a+`

  Match any sequence of one or more `a` characters.

```
mysql> SELECT 'Ban' REGEXP '^Ba+n';                    -> 1
mysql> SELECT 'Bn' REGEXP '^Ba+n';                     -> 0
```

- `a?`

  Match either zero or one `a` character.

```
mysql> SELECT 'Bn' REGEXP '^Ba?n';                     -> 1
mysql> SELECT 'Ban' REGEXP '^Ba?n';                    -> 1
mysql> SELECT 'Baan' REGEXP '^Ba?n';                   -> 0
```

- `de|abc`

  Match either of the sequences `de` or `abc`.

```
mysql> SELECT 'pi' REGEXP 'pi|apa';                    -> 1
mysql> SELECT 'axe' REGEXP 'pi|apa';                   -> 0
mysql> SELECT 'apa' REGEXP 'pi|apa';                   -> 1
mysql> SELECT 'apa' REGEXP '^(pi|apa)$';               -> 1
mysql> SELECT 'pi' REGEXP '^(pi|apa)$';                -> 1
mysql> SELECT 'pix' REGEXP '^(pi|apa)$';               -> 0
```

- `(abc)*`

  Match zero or more instances of the sequence `abc`.

```
mysql> SELECT 'pi' REGEXP '^(pi)*$';                   -> 1
mysql> SELECT 'pip' REGEXP '^(pi)*$';                  -> 0
mysql> SELECT 'pipi' REGEXP '^(pi)*$';                 -> 1
```

- `{1}`, `{2,3}`

  `{n}` or `{m,n}` notation provides a more general way of writing regular expressions that match many occurrences of the previous atom (or “piece”) of the pattern. `m` and `n` are integers.

  - `a*`

    Can be written as `a{0,}`.

  - `a+`

    Can be written as `a{1,}`.

  - `a?`

    Can be written as `a{0,1}`.

  To be more precise, `a{n}` matches exactly `n` instances of `a`. `a{n,}` matches `n` or more instances of `a`. `a{m,n}` matches `m` through `n` instances of `a`, inclusive.

`m` and `n` must be in the range from `0` to `RE_DUP_MAX` (default 255), inclusive. If both `m` and `n` are given, `m` must be less than or equal to `n`.

```
mysql> SELECT 'abcde' REGEXP 'a[bcd]{2}e';            -> 0
mysql> SELECT 'abcde' REGEXP 'a[bcd]{3}e';            -> 1
mysql> SELECT 'abcde' REGEXP 'a[bcd]{1,10}e';         -> 1
```

- `[a-dX]`, `[^a-dX]`

  Matches any character that is (or is not, if ^ is used) either `a`, `b`, `c`, `d` or `X`. A `-` character between two other characters forms a range that matches all characters from the first character to the second. For example, `[0-9]` matches any decimal digit. To include a literal `]` character, it must immediately follow the opening bracket `[`. To include a literal `-` character, it must be written first or last. Any character that does not have a defined special meaning inside a `[]` pair matches only itself.

```
mysql> SELECT 'aXbc' REGEXP '[a-dXYZ]';               -> 1
mysql> SELECT 'aXbc' REGEXP '^[a-dXYZ]$';             -> 0
mysql> SELECT 'aXbc' REGEXP '^[a-dXYZ]+$';            -> 1
mysql> SELECT 'aXbc' REGEXP '^[^a-dXYZ]+$';           -> 0
mysql> SELECT 'gheis' REGEXP '^[^a-dXYZ]+$';          -> 1
mysql> SELECT 'gheisa' REGEXP '^[^a-dXYZ]+$';         -> 0
```

- `[.characters.]`

  Within a bracket expression (written using `[` and `]`), matches the sequence of characters of that collating element. `characters` is either a single character or a character name like `newline`. The following table lists the permissible character names.

  The following table shows the permissible character names and the characters that they match. For characters given as numeric values, the values are represented in octal.

Name	Character	Name	Character
NUL	0	SOH	001
STX	002	ETX	003
EOT	004	ENQ	005
ACK	006	BEL	007
alert	007	BS	010
backspace	'\b'	HT	011
tab	'\t'	LF	012
newline	'\n'	VT	013
vertical-tab	'\v'	FF	014
form-feed	'\f'	CR	015
carriage-return	'\r'	SO	016
SI	017	DLE	020
DC1	021	DC2	022
DC3	023	DC4	024
NAK	025	SYN	026
ETB	027	CAN	030
EM	031	SUB	032
ESC	033	IS4	034
FS	034	IS3	035

Name	Character	Name	Character
GS	035	IS2	036
RS	036	IS1	037
US	037	space	' '
exclamation-mark	'!'	quotation-mark	'"'
number-sign	'#'	dollar-sign	'$'
percent-sign	'%'	ampersand	'&'
apostrophe	'\''	left-parenthesis	'('
right-parenthesis	')'	asterisk	'*'
plus-sign	'+'	comma	','
hyphen	'-'	hyphen-minus	'-'
period	'.'	full-stop	'.'
slash	'/'	solidus	'/'
zero	'0'	one	'1'
two	'2'	three	'3'
four	'4'	five	'5'
six	'6'	seven	'7'
eight	'8'	nine	'9'
colon	':'	semicolon	';'
less-than-sign	'<'	equals-sign	'='
greater-than-sign	'>'	question-mark	'?'
commercial-at	'@'	left-square-bracket	'['
backslash	'\\'	reverse-solidus	'\\'
right-square-bracket	']'	circumflex	'^'
circumflex-accent	'^'	underscore	'_'
low-line	'_'	grave-accent	'`'
left-brace	'{'	left-curly-bracket	'{'
vertical-line	'|'	right-brace	'}'
right-curly-bracket	'}'	tilde	'~'
DEL	177		

```
mysql> SELECT '~' REGEXP '[[.~.]]';                    -> 1
mysql> SELECT '~' REGEXP '[[.tilde.]]';                 -> 1
```

- `[=character_class=]`

  Within a bracket expression (written using `[` and `]`), `[=character_class=]` represents an equivalence class. It matches all characters with the same collation value, including itself. For example, if `o` and `(+)` are the members of an equivalence class, `[[=o=]]`, `[[=(+)=]]`, and `[o(+)]` are all synonymous. An equivalence class may not be used as an endpoint of a range.

- `[:character_class:]`

Within a bracket expression (written using `[` and `]`), `[:character_class:]` represents a character class that matches all characters belonging to that class. The following table lists the standard class names. These names stand for the character classes defined in the `ctype(3)` manual page. A particular locale may provide other class names. A character class may not be used as an endpoint of a range.

Character Class Name	Meaning
`alnum`	Alphanumeric characters
`alpha`	Alphabetic characters
`blank`	Whitespace characters
`cntrl`	Control characters
`digit`	Digit characters
`graph`	Graphic characters
`lower`	Lowercase alphabetic characters
`print`	Graphic or space characters
`punct`	Punctuation characters
`space`	Space, tab, newline, and carriage return
`upper`	Uppercase alphabetic characters
`xdigit`	Hexadecimal digit characters

```
mysql> SELECT 'justalnums' REGEXP '[[:alnum:]]+';       -> 1
mysql> SELECT '!!' REGEXP '[[:alnum:]]+';               -> 0
```

- `[[:<:]]`, `[[:>:]]`

  These markers stand for word boundaries. They match the beginning and end of words, respectively. A word is a sequence of word characters that is not preceded by or followed by word characters. A word character is an alphanumeric character in the `alnum` class or an underscore (_).

```
mysql> SELECT 'a word a' REGEXP '[[:<:]]word[[:>:]]';   -> 1
mysql> SELECT 'a xword a' REGEXP '[[:<:]]word[[:>:]]';  -> 0
```

To use a literal instance of a special character in a regular expression, precede it by two backslash (\) characters. The MySQL parser interprets one of the backslashes, and the regular expression library interprets the other. For example, to match the string `1+2` that contains the special `+` character, only the last of the following regular expressions is the correct one:

```
mysql> SELECT '1+2' REGEXP '1+2';                       -> 0
mysql> SELECT '1+2' REGEXP '1\+2';                      -> 0
mysql> SELECT '1+2' REGEXP '1\\+2';                     -> 1
```

12.5.3 Character Set and Collation of Function Results

MySQL has many operators and functions that return a string. This section answers the question: What is the character set and collation of such a string?

For simple functions that take string input and return a string result as output, the output's character set and collation are the same as those of the principal input value. For example, `UPPER(X)` returns a string with the same character string and collation as *X*. The same applies for `INSTR()`, `LCASE()`, `LOWER()`, `LTRIM()`, `MID()`, `REPEAT()`, `REPLACE()`, `REVERSE()`, `RIGHT()`, `RPAD()`, `RTRIM()`, `SOUNDEX()`, `SUBSTRING()`, `TRIM()`, `UCASE()`, and `UPPER()`.

Note

The `REPLACE()` function, unlike all other functions, always ignores the collation of the string input and performs a case-sensitive comparison.

If a string input or function result is a binary string, the string has the `binary` character set and collation. This can be checked by using the `CHARSET()` and `COLLATION()` functions, both of which return `binary` for a binary string argument:

```
mysql> SELECT CHARSET(BINARY 'a'), COLLATION(BINARY 'a');
+--------------------+----------------------+
| CHARSET(BINARY 'a') | COLLATION(BINARY 'a') |
+--------------------+----------------------+
| binary              | binary               |
+--------------------+----------------------+
```

For operations that combine multiple string inputs and return a single string output, the “aggregation rules” of standard SQL apply for determining the collation of the result:

- If an explicit `COLLATE Y` occurs, use *Y*.
- If explicit `COLLATE Y` and `COLLATE Z` occur, raise an error.
- Otherwise, if all collations are *Y*, use *Y*.
- Otherwise, the result has no collation.

For example, with `CASE ... WHEN a THEN b WHEN b THEN c COLLATE X END`, the resulting collation is *X*. The same applies for `UNION`, `||`, `CONCAT()`, `ELT()`, `GREATEST()`, `IF()`, and `LEAST()`.

For operations that convert to character data, the character set and collation of the strings that result from the operations are defined by the `character_set_connection` and `collation_connection` system variables that determine the default connection character set and collation (see Section 10.1.4, “Connection Character Sets and Collations”). This applies only to `CAST()`, `CONV()`, `FORMAT()`, `HEX()`, and `SPACE()`.

If there is any question about the character set or collation of the result returned by a string function, use the `CHARSET()` or `COLLATION()` function to find out:

```
mysql> SELECT USER(), CHARSET(USER()), COLLATION(USER());
+---------------+-----------------+-------------------+
| USER()        | CHARSET(USER()) | COLLATION(USER()) |
+---------------+-----------------+-------------------+
| test@localhost | utf8            | utf8_general_ci   |
+---------------+-----------------+-------------------+
mysql> SELECT CHARSET(COMPRESS('abc')), COLLATION(COMPRESS('abc'));
+-------------------------+---------------------------+
| CHARSET(COMPRESS('abc')) | COLLATION(COMPRESS('abc')) |
+-------------------------+---------------------------+
| binary                  | binary                    |
+-------------------------+---------------------------+
```

12.6 Numeric Functions and Operators

Table 12.10 Numeric Functions and Operators

Name	Description
`ABS()`	Return the absolute value
`ACOS()`	Return the arc cosine
`ASIN()`	Return the arc sine
`ATAN()`	Return the arc tangent

Name	Description
ATAN2(), ATAN()	Return the arc tangent of the two arguments
CEIL()	Return the smallest integer value not less than the argument
CEILING()	Return the smallest integer value not less than the argument
CONV()	Convert numbers between different number bases
COS()	Return the cosine
COT()	Return the cotangent
CRC32()	Compute a cyclic redundancy check value
DEGREES()	Convert radians to degrees
DIV	Integer division
/	Division operator
EXP()	Raise to the power of
FLOOR()	Return the largest integer value not greater than the argument
LN()	Return the natural logarithm of the argument
LOG()	Return the natural logarithm of the first argument
LOG10()	Return the base-10 logarithm of the argument
LOG2()	Return the base-2 logarithm of the argument
-	Minus operator
MOD()	Return the remainder
%, MOD	Modulo operator
PI()	Return the value of pi
+	Addition operator
POW()	Return the argument raised to the specified power
POWER()	Return the argument raised to the specified power
RADIANS()	Return argument converted to radians
RAND()	Return a random floating-point value
ROUND()	Round the argument
SIGN()	Return the sign of the argument
SIN()	Return the sine of the argument
SQRT()	Return the square root of the argument
TAN()	Return the tangent of the argument
*	Multiplication operator
TRUNCATE()	Truncate to specified number of decimal places
-	Change the sign of the argument

12.6.1 Arithmetic Operators

Table 12.11 Arithmetic Operators

Name	Description
DIV	Integer division
/	Division operator
-	Minus operator

Name	Description
`%, MOD`	Modulo operator
`+`	Addition operator
`*`	Multiplication operator
`-`	Change the sign of the argument

The usual arithmetic operators are available. The result is determined according to the following rules:

- In the case of `-`, `+`, and `*`, the result is calculated with `BIGINT` (64-bit) precision if both operands are integers.
- If both operands are integers and any of them are unsigned, the result is an unsigned integer. For subtraction, if the `NO_UNSIGNED_SUBTRACTION` SQL mode is enabled, the result is signed even if any operand is unsigned.
- If any of the operands of a `+`, `-`, `/`, `*`, `%` is a real or string value, the precision of the result is the precision of the operand with the maximum precision.
- In division performed with `/`, the scale of the result when using two exact-value operands is the scale of the first operand plus the value of the `div_precision_increment` system variable (which is 4 by default). For example, the result of the expression `5.05 / 0.014` has a scale of six decimal places (`360.714286`).

These rules are applied for each operation, such that nested calculations imply the precision of each component. Hence, `(14620 / 9432456) / (24250 / 9432456)`, resolves first to `(0.0014) / (0.0026)`, with the final result having 8 decimal places (`0.60288653`).

Because of these rules and the way they are applied, care should be taken to ensure that components and subcomponents of a calculation use the appropriate level of precision. See Section 12.10, “Cast Functions and Operators”.

For information about handling of overflow in numeric expression evaluation, see Section 11.2.6, “Out-of-Range and Overflow Handling”.

Arithmetic operators apply to numbers. For other types of values, alternative operations may be available. For example, to add date values, use `DATE_ADD()`; see Section 12.7, “Date and Time Functions”.

- `+`

  Addition:

```
mysql> SELECT 3+5;
        -> 8
```

- `-`

  Subtraction:

```
mysql> SELECT 3-5;
        -> -2
```

- `-`

  Unary minus. This operator changes the sign of the operand.

```
mysql> SELECT - 2;
        -> -2
```

Note

If this operator is used with a `BIGINT`, the return value is also a `BIGINT`. This means that you should avoid using `-` on integers that may have the value of -2^{63}.

- `*`

  Multiplication:

```
mysql> SELECT 3*5;
        -> 15
mysql> SELECT 18014398509481984*18014398509481984.0;
        -> 324518553658426726783156020576256.0
mysql> SELECT 18014398509481984*18014398509481984;
        -> out-of-range error
```

  The last expression produces an error because the result of the integer multiplication exceeds the 64-bit range of `BIGINT` calculations. (See Section 11.2, “Numeric Types”.)

- `/`

  Division:

```
mysql> SELECT 3/5;
        -> 0.60
```

  Division by zero produces a `NULL` result:

```
mysql> SELECT 102/(1-1);
        -> NULL
```

  A division is calculated with `BIGINT` arithmetic only if performed in a context where its result is converted to an integer.

- `DIV`

  Integer division. Discards from the division result any fractional part to the right of the decimal point.

  If either operand has a noninteger type, the operands are converted to `DECIMAL` and divided using `DECIMAL` arithmetic before converting the result to `BIGINT`. If the result exceeds `BIGINT` range, an error occurs.

```
mysql> SELECT 5 DIV 2, -5 DIV 2, 5 DIV -2, -5 DIV -2;
        -> 2, -2, -2, 2
```

- *`N`* `%` *`M`*, *`N`* `MOD` *`M`*

  Modulo operation. Returns the remainder of *`N`* divided by *`M`*. For more information, see the description for the `MOD()` function in Section 12.6.2, “Mathematical Functions”.

12.6.2 Mathematical Functions

Table 12.12 Mathematical Functions

Name	Description
`ABS()`	Return the absolute value
`ACOS()`	Return the arc cosine
`ASIN()`	Return the arc sine

Name	Description
ATAN()	Return the arc tangent
ATAN2(), ATAN()	Return the arc tangent of the two arguments
CEIL()	Return the smallest integer value not less than the argument
CEILING()	Return the smallest integer value not less than the argument
CONV()	Convert numbers between different number bases
COS()	Return the cosine
COT()	Return the cotangent
CRC32()	Compute a cyclic redundancy check value
DEGREES()	Convert radians to degrees
EXP()	Raise to the power of
FLOOR()	Return the largest integer value not greater than the argument
LN()	Return the natural logarithm of the argument
LOG()	Return the natural logarithm of the first argument
LOG10()	Return the base-10 logarithm of the argument
LOG2()	Return the base-2 logarithm of the argument
MOD()	Return the remainder
PI()	Return the value of pi
POW()	Return the argument raised to the specified power
POWER()	Return the argument raised to the specified power
RADIANS()	Return argument converted to radians
RAND()	Return a random floating-point value
ROUND()	Round the argument
SIGN()	Return the sign of the argument
SIN()	Return the sine of the argument
SQRT()	Return the square root of the argument
TAN()	Return the tangent of the argument
TRUNCATE()	Truncate to specified number of decimal places

All mathematical functions return NULL in the event of an error.

- ABS(*X*)

  Returns the absolute value of *X*.

```
mysql> SELECT ABS(2);
        -> 2
mysql> SELECT ABS(-32);
        -> 32
```

  This function is safe to use with BIGINT values.

- ACOS(*X*)

  Returns the arc cosine of *X*, that is, the value whose cosine is *X*. Returns NULL if *X* is not in the range -1 to 1.

```
mysql> SELECT ACOS(1);
        -> 0
mysql> SELECT ACOS(1.0001);
        -> NULL
mysql> SELECT ACOS(0);
        -> 1.5707963267949
```

- `ASIN(X)`

  Returns the arc sine of *X*, that is, the value whose sine is *X*. Returns `NULL` if *X* is not in the range `-1` to `1`.

```
mysql> SELECT ASIN(0.2);
        -> 0.20135792079033
mysql> SELECT ASIN('foo');

+-------------+
| ASIN('foo') |
+-------------+
|           0 |
+-------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+----------------------------------------+
| Level   | Code | Message                                |
+---------+------+----------------------------------------+
| Warning | 1292 | Truncated incorrect DOUBLE value: 'foo' |
+---------+------+----------------------------------------+
```

- `ATAN(X)`

  Returns the arc tangent of *X*, that is, the value whose tangent is *X*.

```
mysql> SELECT ATAN(2);
        -> 1.1071487177941
mysql> SELECT ATAN(-2);
        -> -1.1071487177941
```

- `ATAN(Y,X)`, `ATAN2(Y,X)`

  Returns the arc tangent of the two variables *X* and *Y*. It is similar to calculating the arc tangent of *Y* / *X*, except that the signs of both arguments are used to determine the quadrant of the result.

```
mysql> SELECT ATAN(-2,2);
        -> -0.78539816339745
mysql> SELECT ATAN2(PI(),0);
        -> 1.5707963267949
```

- `CEIL(X)`

  `CEIL()` is a synonym for `CEILING()`.

- `CEILING(X)`

  Returns the smallest integer value not less than *X*.

```
mysql> SELECT CEILING(1.23);
        -> 2
mysql> SELECT CEILING(-1.23);
        -> -1
```

  For exact-value numeric arguments, the return value has an exact-value numeric type. For string or floating-point arguments, the return value has a floating-point type.

- `CONV(N,from_base,to_base)`

  Converts numbers between different number bases. Returns a string representation of the number *`N`*, converted from base *`from_base`* to base *`to_base`*. Returns `NULL` if any argument is `NULL`. The argument *`N`* is interpreted as an integer, but may be specified as an integer or a string. The minimum base is `2` and the maximum base is `36`. If *`from_base`* is a negative number, *`N`* is regarded as a signed number. Otherwise, *`N`* is treated as unsigned. `CONV()` works with 64-bit precision.

```
mysql> SELECT CONV('a',16,2);
        -> '1010'
mysql> SELECT CONV('6E',18,8);
        -> '172'
mysql> SELECT CONV(-17,10,-18);
        -> '-H'
mysql> SELECT CONV(10+'10'+'10'+X'0a',10,10);
        -> '40'
```

- `COS(X)`

  Returns the cosine of *`X`*, where *`X`* is given in radians.

```
mysql> SELECT COS(PI());
        -> -1
```

- `COT(X)`

  Returns the cotangent of *`X`*.

```
mysql> SELECT COT(12);
        -> -1.5726734063977
mysql> SELECT COT(0);
        -> out-of-range error
```

- `CRC32(expr)`

  Computes a cyclic redundancy check value and returns a 32-bit unsigned value. The result is `NULL` if the argument is `NULL`. The argument is expected to be a string and (if possible) is treated as one if it is not.

```
mysql> SELECT CRC32('MySQL');
        -> 3259397556
mysql> SELECT CRC32('mysql');
        -> 2501908538
```

- `DEGREES(X)`

  Returns the argument *`X`*, converted from radians to degrees.

```
mysql> SELECT DEGREES(PI());
        -> 180
mysql> SELECT DEGREES(PI() / 2);
        -> 90
```

- `EXP(X)`

  Returns the value of *e* (the base of natural logarithms) raised to the power of *`X`*. The inverse of this function is `LOG()` (using a single argument only) or `LN()`.

```
mysql> SELECT EXP(2);
        -> 7.3890560989307
mysql> SELECT EXP(-2);
        -> 0.13533528323661
```

```
mysql> SELECT EXP(0);
        -> 1
```

- `FLOOR(X)`

  Returns the largest integer value not greater than *X*.

```
mysql> SELECT FLOOR(1.23), FLOOR(-1.23);
        -> 1, -2
```

  For exact-value numeric arguments, the return value has an exact-value numeric type. For string or floating-point arguments, the return value has a floating-point type.

- `FORMAT(X,D)`

  Formats the number *X* to a format like `'#,###,###.##'`, rounded to *D* decimal places, and returns the result as a string. For details, see Section 12.5, “String Functions”.

- `HEX(N_or_S)`

  This function can be used to obtain a hexadecimal representation of a decimal number or a string; the manner in which it does so varies according to the argument's type. See this function's description in Section 12.5, “String Functions”, for details.

- `LN(X)`

  Returns the natural logarithm of *X*; that is, the base-*e* logarithm of *X*. If *X* is less than or equal to 0, then `NULL` is returned.

```
mysql> SELECT LN(2);
        -> 0.69314718055995
mysql> SELECT LN(-2);
        -> NULL
```

  This function is synonymous with `LOG(X)`. The inverse of this function is the `EXP()` function.

- `LOG(X)`, `LOG(B,X)`

  If called with one parameter, this function returns the natural logarithm of *X*. If *X* is less than or equal to 0, then `NULL` is returned.

  The inverse of this function (when called with a single argument) is the `EXP()` function.

```
mysql> SELECT LOG(2);
        -> 0.69314718055995
mysql> SELECT LOG(-2);
        -> NULL
```

  If called with two parameters, this function returns the logarithm of *X* to the base *B*. If *X* is less than or equal to 0, or if *B* is less than or equal to 1, then `NULL` is returned.

```
mysql> SELECT LOG(2,65536);
        -> 16
mysql> SELECT LOG(10,100);
        -> 2
mysql> SELECT LOG(1,100);
        -> NULL
```

  `LOG(B,X)` is equivalent to `LOG(X) / LOG(B)`.

- `LOG2(X)`

Returns the base-2 logarithm of *X*.

```
mysql> SELECT LOG2(65536);
        -> 16
mysql> SELECT LOG2(-100);
        -> NULL
```

`LOG2()` is useful for finding out how many bits a number requires for storage. This function is equivalent to the expression `LOG(X) / LOG(2)`.

- `LOG10(X)`

  Returns the base-10 logarithm of *X*.

  ```
  mysql> SELECT LOG10(2);
          -> 0.30102999566398
  mysql> SELECT LOG10(100);
          -> 2
  mysql> SELECT LOG10(-100);
          -> NULL
  ```

  `LOG10(X)` is equivalent to `LOG(10,X)`.

- `MOD(N,M)`, `N % M`, `N MOD M`

  Modulo operation. Returns the remainder of *N* divided by *M*.

  ```
  mysql> SELECT MOD(234, 10);
          -> 4
  mysql> SELECT 253 % 7;
          -> 1
  mysql> SELECT MOD(29,9);
          -> 2
  mysql> SELECT 29 MOD 9;
          -> 2
  ```

  This function is safe to use with `BIGINT` values.

  `MOD()` also works on values that have a fractional part and returns the exact remainder after division:

  ```
  mysql> SELECT MOD(34.5,3);
          -> 1.5
  ```

  `MOD(N,0)` returns `NULL`.

- `PI()`

  Returns the value of π (pi). The default number of decimal places displayed is seven, but MySQL uses the full double-precision value internally.

  ```
  mysql> SELECT PI();
          -> 3.141593
  mysql> SELECT PI()+0.00000000000000000;
          -> 3.141592653589793116
  ```

- `POW(X,Y)`

  Returns the value of *X* raised to the power of *Y*.

  ```
  mysql> SELECT POW(2,2);
  ```

```
       -> 4
mysql> SELECT POW(2,-2);
       -> 0.25
```

- `POWER(X,Y)`

  This is a synonym for `POW()`.

- `RADIANS(X)`

  Returns the argument *X*, converted from degrees to radians. (Note that π radians equals 180 degrees.)

```
mysql> SELECT RADIANS(90);
       -> 1.5707963267949
```

- `RAND([N])`

  Returns a random floating-point value *v* in the range `0` <= *v* < `1.0`. To obtain a random integer *R* in the range *i* <= *R* < *j*, use the expression `FLOOR(i + RAND() * (j − i))`. For example, to obtain a random integer in the range the range `7` <= *R* < `12`, use the following statement:

```
SELECT FLOOR(7 + (RAND() * 5));
```

  If an integer argument *N* is specified, it is used as the seed value:

  - With a constant initializer argument, the seed is initialized once when the statement is prepared, prior to execution.
  - With a nonconstant initializer argument (such as a column name), the seed is initialized with the value for each invocation of `RAND()`.

  One implication of this behavior is that for equal argument values, `RAND(N)` returns the same value each time, and thus produces a repeatable sequence of column values. In the following example, the sequence of values produced by `RAND(3)` is the same both places it occurs.

```
mysql> CREATE TABLE t (i INT);
Query OK, 0 rows affected (0.42 sec)

mysql> INSERT INTO t VALUES(1),(2),(3);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT i, RAND() FROM t;
+------+------------------+
| i    | RAND()           |
+------+------------------+
|    1 | 0.61914388706828 |
|    2 | 0.93845168309142 |
|    3 | 0.83482678498591 |
+------+------------------+
3 rows in set (0.00 sec)

mysql> SELECT i, RAND(3) FROM t;
+------+------------------+
| i    | RAND(3)          |
+------+------------------+
|    1 | 0.90576975597606 |
|    2 | 0.37307905813035 |
|    3 | 0.14808605345719 |
+------+------------------+
3 rows in set (0.00 sec)

mysql> SELECT i, RAND() FROM t;
```

```
+------+------------------+
| i    | RAND()           |
+------+------------------+
|    1 | 0.35877890638893 |
|    2 | 0.28941420772058 |
|    3 | 0.37073435016976 |
+------+------------------+
3 rows in set (0.00 sec)

mysql> SELECT i, RAND(3) FROM t;
+------+------------------+
| i    | RAND(3)          |
+------+------------------+
|    1 | 0.90576975597606 |
|    2 | 0.37307905813035 |
|    3 | 0.14808605345719 |
+------+------------------+
3 rows in set (0.01 sec)
```

`RAND()` in a `WHERE` clause is evaluated for every row (when selecting from one table) or combination of rows (when selecting from a multiple-table join). Thus, for optimizer purposes, `RAND()` is not a constant value and cannot be used for index optimizations. For more information, see Section 8.2.1.14, “Function Call Optimization”.

Use of a column with `RAND()` values in an `ORDER BY` or `GROUP BY` clause may yield unexpected results because for either clause a `RAND()` expression can be evaluated multiple times for the same row, each time returning a different result. If the goal is to retrieve rows in random order, you can use a statement like this:

```
SELECT * FROM tbl_name ORDER BY RAND();
```

To select a random sample from a set of rows, combine `ORDER BY RAND()` with `LIMIT`:

```
SELECT * FROM table1, table2 WHERE a=b AND c<d ORDER BY RAND() LIMIT 1000;
```

`RAND()` is not meant to be a perfect random generator. It is a fast way to generate random numbers on demand that is portable between platforms for the same MySQL version.

This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #49222)

- `ROUND(X)`, `ROUND(X,D)`

  Rounds the argument *X* to *D* decimal places. The rounding algorithm depends on the data type of *X*. *D* defaults to 0 if not specified. *D* can be negative to cause *D* digits left of the decimal point of the value *X* to become zero.

```
mysql> SELECT ROUND(-1.23);
        -> -1
mysql> SELECT ROUND(-1.58);
        -> -2
mysql> SELECT ROUND(1.58);
        -> 2
mysql> SELECT ROUND(1.298, 1);
        -> 1.3
mysql> SELECT ROUND(1.298, 0);
        -> 1
mysql> SELECT ROUND(23.298, -1);
        -> 20
```

The return value has the same type as the first argument (assuming that it is integer, double, or decimal). This means that for an integer argument, the result is an integer (no decimal places):

```
mysql> SELECT ROUND(150.000,2), ROUND(150,2);
+------------------+--------------+
| ROUND(150.000,2) | ROUND(150,2) |
+------------------+--------------+
|           150.00 |          150 |
+------------------+--------------+
```

`ROUND()` uses the following rules depending on the type of the first argument:

- For exact-value numbers, `ROUND()` uses the “round half away from zero” or “round toward nearest” rule: A value with a fractional part of .5 or greater is rounded up to the next integer if positive or down to the next integer if negative. (In other words, it is rounded away from zero.) A value with a fractional part less than .5 is rounded down to the next integer if positive or up to the next integer if negative.
- For approximate-value numbers, the result depends on the C library. On many systems, this means that `ROUND()` uses the "round to nearest even" rule: A value with any fractional part is rounded to the nearest even integer.

The following example shows how rounding differs for exact and approximate values:

```
mysql> SELECT ROUND(2.5), ROUND(25E-1);
+------------+--------------+
| ROUND(2.5) | ROUND(25E-1) |
+------------+--------------+
| 3          |            2 |
+------------+--------------+
```

For more information, see Section 12.18, “Precision Math”.

- `SIGN(X)`

  Returns the sign of the argument as `-1`, `0`, or `1`, depending on whether *X* is negative, zero, or positive.

```
mysql> SELECT SIGN(-32);
        -> -1
mysql> SELECT SIGN(0);
        -> 0
mysql> SELECT SIGN(234);
        -> 1
```

- `SIN(X)`

  Returns the sine of *X*, where *X* is given in radians.

```
mysql> SELECT SIN(PI());
        -> 1.2246063538224e-16
mysql> SELECT ROUND(SIN(PI()));
        -> 0
```

- `SQRT(X)`

  Returns the square root of a nonnegative number *X*.

```
mysql> SELECT SQRT(4);
        -> 2
mysql> SELECT SQRT(20);
        -> 4.4721359549996
mysql> SELECT SQRT(-16);
        -> NULL
```

- `TAN(X)`

Returns the tangent of *X*, where *X* is given in radians.

```
mysql> SELECT TAN(PI());
        -> -1.2246063538224e-16
mysql> SELECT TAN(PI()+1);
        -> 1.5574077246549
```

- `TRUNCATE(X,D)`

  Returns the number *X*, truncated to *D* decimal places. If *D* is `0`, the result has no decimal point or fractional part. *D* can be negative to cause *D* digits left of the decimal point of the value *X* to become zero.

```
mysql> SELECT TRUNCATE(1.223,1);
        -> 1.2
mysql> SELECT TRUNCATE(1.999,1);
        -> 1.9
mysql> SELECT TRUNCATE(1.999,0);
        -> 1
mysql> SELECT TRUNCATE(-1.999,1);
        -> -1.9
mysql> SELECT TRUNCATE(122,-2);
       -> 100
mysql> SELECT TRUNCATE(10.28*100,0);
       -> 1028
```

  All numbers are rounded toward zero.

12.7 Date and Time Functions

This section describes the functions that can be used to manipulate temporal values. See Section 11.3, "Date and Time Types", for a description of the range of values each date and time type has and the valid formats in which values may be specified.

Table 12.13 Date and Time Functions

Name	Description
`ADDDATE()`	Add time values (intervals) to a date value
`ADDTIME()`	Add time
`CONVERT_TZ()`	Convert from one time zone to another
`CURDATE()`	Return the current date
`CURRENT_DATE()`, `CURRENT_DATE`	Synonyms for CURDATE()
`CURRENT_TIME()`, `CURRENT_TIME`	Synonyms for CURTIME()
`CURRENT_TIMESTAMP()`, `CURRENT_TIMESTAMP`	Synonyms for NOW()
`CURTIME()`	Return the current time
`DATE()`	Extract the date part of a date or datetime expression
`DATE_ADD()`	Add time values (intervals) to a date value
`DATE_FORMAT()`	Format date as specified
`DATE_SUB()`	Subtract a time value (interval) from a date
`DATEDIFF()`	Subtract two dates
`DAY()`	Synonym for DAYOFMONTH()
`DAYNAME()`	Return the name of the weekday
`DAYOFMONTH()`	Return the day of the month (0-31)

Name	Description
DAYOFWEEK()	Return the weekday index of the argument
DAYOFYEAR()	Return the day of the year (1-366)
EXTRACT()	Extract part of a date
FROM_DAYS()	Convert a day number to a date
FROM_UNIXTIME()	Format Unix timestamp as a date
GET_FORMAT()	Return a date format string
HOUR()	Extract the hour
LAST_DAY	Return the last day of the month for the argument
LOCALTIME(), LOCALTIME	Synonym for NOW()
LOCALTIMESTAMP, LOCALTIMESTAMP()	Synonym for NOW()
MAKEDATE()	Create a date from the year and day of year
MAKETIME()	Create time from hour, minute, second
MICROSECOND()	Return the microseconds from argument
MINUTE()	Return the minute from the argument
MONTH()	Return the month from the date passed
MONTHNAME()	Return the name of the month
NOW()	Return the current date and time
PERIOD_ADD()	Add a period to a year-month
PERIOD_DIFF()	Return the number of months between periods
QUARTER()	Return the quarter from a date argument
SEC_TO_TIME()	Converts seconds to 'HH:MM:SS' format
SECOND()	Return the second (0-59)
STR_TO_DATE()	Convert a string to a date
SUBDATE()	Synonym for DATE_SUB() when invoked with three arguments
SUBTIME()	Subtract times
SYSDATE()	Return the time at which the function executes
TIME()	Extract the time portion of the expression passed
TIME_FORMAT()	Format as time
TIME_TO_SEC()	Return the argument converted to seconds
TIMEDIFF()	Subtract time
TIMESTAMP()	With a single argument, this function returns the date or datetime expression; with two arguments, the sum of the arguments
TIMESTAMPADD()	Add an interval to a datetime expression
TIMESTAMPDIFF()	Subtract an interval from a datetime expression
TO_DAYS()	Return the date argument converted to days
TO_SECONDS()	Return the date or datetime argument converted to seconds since Year 0
UNIX_TIMESTAMP()	Return a Unix timestamp
UTC_DATE()	Return the current UTC date

Name	Description
UTC_TIME()	Return the current UTC time
UTC_TIMESTAMP()	Return the current UTC date and time
WEEK()	Return the week number
WEEKDAY()	Return the weekday index
WEEKOFYEAR()	Return the calendar week of the date (1-53)
YEAR()	Return the year
YEARWEEK()	Return the year and week

Here is an example that uses date functions. The following query selects all rows with a *date_col* value from within the last 30 days:

```
mysql> SELECT something FROM tbl_name
    -> WHERE DATE_SUB(CURDATE(),INTERVAL 30 DAY) <= date_col;
```

The query also selects rows with dates that lie in the future.

Functions that expect date values usually accept datetime values and ignore the time part. Functions that expect time values usually accept datetime values and ignore the date part.

Functions that return the current date or time each are evaluated only once per query at the start of query execution. This means that multiple references to a function such as NOW() within a single query always produce the same result. (For our purposes, a single query also includes a call to a stored program (stored routine, trigger, or event) and all subprograms called by that program.) This principle also applies to CURDATE(), CURTIME(), UTC_DATE(), UTC_TIME(), UTC_TIMESTAMP(), and to any of their synonyms.

The CURRENT_TIMESTAMP(), CURRENT_TIME(), CURRENT_DATE(), and FROM_UNIXTIME() functions return values in the connection's current time zone, which is available as the value of the time_zone system variable. In addition, UNIX_TIMESTAMP() assumes that its argument is a datetime value in the current time zone. See Section 10.6, “MySQL Server Time Zone Support”.

Some date functions can be used with “zero” dates or incomplete dates such as '2001-11-00', whereas others cannot. Functions that extract parts of dates typically work with incomplete dates and thus can return 0 when you might otherwise expect a nonzero value. For example:

```
mysql> SELECT DAYOFMONTH('2001-11-00'), MONTH('2005-00-00');
        -> 0, 0
```

Other functions expect complete dates and return NULL for incomplete dates. These include functions that perform date arithmetic or that map parts of dates to names. For example:

```
mysql> SELECT DATE_ADD('2006-05-00',INTERVAL 1 DAY);
        -> NULL
mysql> SELECT DAYNAME('2006-05-00');
        -> NULL
```

Note

From MySQL 5.5.16 to 5.5.20, a change in handling of a date-related assertion caused several functions to become more strict when passed a DATE() function value as their argument and reject incomplete dates with a day part of zero. These functions are affected: CONVERT_TZ(), DATE_ADD(), DATE_SUB(), DAYOFYEAR(), LAST_DAY(), TIMESTAMPDIFF(), TO_DAYS(), TO_SECONDS(), WEEK(), WEEKDAY(), WEEKOFYEAR(), YEARWEEK().

Because this changes date-handling behavior in General Availability-status series MySQL 5.5, the change was reverted in 5.5.21.

- `ADDDATE(date,INTERVAL expr unit)`, `ADDDATE(expr,days)`

  When invoked with the `INTERVAL` form of the second argument, `ADDDATE()` is a synonym for `DATE_ADD()`. The related function `SUBDATE()` is a synonym for `DATE_SUB()`. For information on the `INTERVAL unit` argument, see the discussion for `DATE_ADD()`.

```
mysql> SELECT DATE_ADD('2008-01-02', INTERVAL 31 DAY);
        -> '2008-02-02'
mysql> SELECT ADDDATE('2008-01-02', INTERVAL 31 DAY);
        -> '2008-02-02'
```

  When invoked with the *days* form of the second argument, MySQL treats it as an integer number of days to be added to *expr*.

```
mysql> SELECT ADDDATE('2008-01-02', 31);
        -> '2008-02-02'
```

- `ADDTIME(expr1,expr2)`

  `ADDTIME()` adds *expr2* to *expr1* and returns the result. *expr1* is a time or datetime expression, and *expr2* is a time expression.

```
mysql> SELECT ADDTIME('2007-12-31 23:59:59.999999', '1 1:1:1.000002');
        -> '2008-01-02 01:01:01.000001'
mysql> SELECT ADDTIME('01:00:00.999999', '02:00:00.999998');
        -> '03:00:01.999997'
```

- `CONVERT_TZ(dt,from_tz,to_tz)`

  `CONVERT_TZ()` converts a datetime value *dt* from the time zone given by *from_tz* to the time zone given by *to_tz* and returns the resulting value. Time zones are specified as described in Section 10.6, “MySQL Server Time Zone Support”. This function returns `NULL` if the arguments are invalid.

  If the value falls out of the supported range of the `TIMESTAMP` type when converted from *from_tz* to UTC, no conversion occurs. The `TIMESTAMP` range is described in Section 11.1.2, “Date and Time Type Overview”.

```
mysql> SELECT CONVERT_TZ('2004-01-01 12:00:00','GMT','MET');
        -> '2004-01-01 13:00:00'
mysql> SELECT CONVERT_TZ('2004-01-01 12:00:00','+00:00','+10:00');
        -> '2004-01-01 22:00:00'
```

Note

To use named time zones such as `'MET'` or `'Europe/Moscow'`, the time zone tables must be properly set up. See Section 10.6, “MySQL Server Time Zone Support”, for instructions.

- `CURDATE()`

  Returns the current date as a value in `'YYYY-MM-DD'` or `YYYYMMDD` format, depending on whether the function is used in a string or numeric context.

```
mysql> SELECT CURDATE();
        -> '2008-06-13'
mysql> SELECT CURDATE() + 0;
        -> 20080613
```

- `CURRENT_DATE`, `CURRENT_DATE()`

  `CURRENT_DATE` and `CURRENT_DATE()` are synonyms for `CURDATE()`.

- `CURRENT_TIME`, `CURRENT_TIME()`

  `CURRENT_TIME` and `CURRENT_TIME()` are synonyms for `CURTIME()`.

- `CURRENT_TIMESTAMP`, `CURRENT_TIMESTAMP()`

  `CURRENT_TIMESTAMP` and `CURRENT_TIMESTAMP()` are synonyms for `NOW()`.

- `CURTIME()`

  Returns the current time as a value in `'HH:MM:SS'` or `HHMMSS.uuuuuu` format, depending on whether the function is used in a string or numeric context. The value is expressed in the current time zone.

```
mysql> SELECT CURTIME();
        -> '23:50:26'
mysql> SELECT CURTIME() + 0;
        -> 235026.000000
```

- `DATE(expr)`

  Extracts the date part of the date or datetime expression *`expr`*.

```
mysql> SELECT DATE('2003-12-31 01:02:03');
        -> '2003-12-31'
```

- `DATEDIFF(expr1,expr2)`

  `DATEDIFF()` returns *`expr1`* − *`expr2`* expressed as a value in days from one date to the other. *`expr1`* and *`expr2`* are date or date-and-time expressions. Only the date parts of the values are used in the calculation.

```
mysql> SELECT DATEDIFF('2007-12-31 23:59:59','2007-12-30');
        -> 1
mysql> SELECT DATEDIFF('2010-11-30 23:59:59','2010-12-31');
        -> -31
```

- `DATE_ADD(date,INTERVAL expr unit)`, `DATE_SUB(date,INTERVAL expr unit)`

  These functions perform date arithmetic. The *`date`* argument specifies the starting date or datetime value. *`expr`* is an expression specifying the interval value to be added or subtracted from the starting date. *`expr`* is a string; it may start with a `-` for negative intervals. *`unit`* is a keyword indicating the units in which the expression should be interpreted.

  The `INTERVAL` keyword and the *`unit`* specifier are not case sensitive.

  The following table shows the expected form of the *`expr`* argument for each *`unit`* value.

***`unit`* Value**	**Expected *`expr`* Format**
`MICROSECOND`	`MICROSECONDS`
`SECOND`	`SECONDS`
`MINUTE`	`MINUTES`
`HOUR`	`HOURS`
`DAY`	`DAYS`
`WEEK`	`WEEKS`

unit Value	Expected *expr* Format
MONTH	MONTHS
QUARTER	QUARTERS
YEAR	YEARS
SECOND_MICROSECOND	'SECONDS.MICROSECONDS'
MINUTE_MICROSECOND	'MINUTES:SECONDS.MICROSECONDS'
MINUTE_SECOND	'MINUTES:SECONDS'
HOUR_MICROSECOND	'HOURS:MINUTES:SECONDS.MICROSECONDS'
HOUR_SECOND	'HOURS:MINUTES:SECONDS'
HOUR_MINUTE	'HOURS:MINUTES'
DAY_MICROSECOND	'DAYS HOURS:MINUTES:SECONDS.MICROSECONDS'
DAY_SECOND	'DAYS HOURS:MINUTES:SECONDS'
DAY_MINUTE	'DAYS HOURS:MINUTES'
DAY_HOUR	'DAYS HOURS'
YEAR_MONTH	'YEARS-MONTHS'

The return value depends on the arguments:

- DATETIME if the first argument is a DATETIME (or TIMESTAMP) value, or if the first argument is a DATE and the *unit* value uses HOURS, MINUTES, or SECONDS.
- String otherwise.

To ensure that the result is DATETIME, you can use CAST() to convert the first argument to DATETIME.

MySQL permits any punctuation delimiter in the *expr* format. Those shown in the table are the suggested delimiters. If the *date* argument is a DATE value and your calculations involve only YEAR, MONTH, and DAY parts (that is, no time parts), the result is a DATE value. Otherwise, the result is a DATETIME value.

Date arithmetic also can be performed using INTERVAL together with the + or - operator:

```
date + INTERVAL expr unit
date - INTERVAL expr unit
```

INTERVAL *expr unit* is permitted on either side of the + operator if the expression on the other side is a date or datetime value. For the - operator, INTERVAL *expr unit* is permitted only on the right side, because it makes no sense to subtract a date or datetime value from an interval.

```
mysql> SELECT '2008-12-31 23:59:59' + INTERVAL 1 SECOND;
        -> '2009-01-01 00:00:00'
mysql> SELECT INTERVAL 1 DAY + '2008-12-31';
        -> '2009-01-01'
mysql> SELECT '2005-01-01' - INTERVAL 1 SECOND;
        -> '2004-12-31 23:59:59'
mysql> SELECT DATE_ADD('2000-12-31 23:59:59',
    ->                 INTERVAL 1 SECOND);
        -> '2001-01-01 00:00:00'
mysql> SELECT DATE_ADD('2010-12-31 23:59:59',
    ->                 INTERVAL 1 DAY);
        -> '2011-01-01 23:59:59'
mysql> SELECT DATE_ADD('2100-12-31 23:59:59',
    ->                 INTERVAL '1:1' MINUTE_SECOND);
```

```
        -> '2101-01-01 00:01:00'
mysql> SELECT DATE_SUB('2005-01-01 00:00:00',
    ->                 INTERVAL '1 1:1:1' DAY_SECOND);
        -> '2004-12-30 22:58:59'
mysql> SELECT DATE_ADD('1900-01-01 00:00:00',
    ->                 INTERVAL '-1 10' DAY_HOUR);
        -> '1899-12-30 14:00:00'
mysql> SELECT DATE_SUB('1998-01-02', INTERVAL 31 DAY);
        -> '1997-12-02'
mysql> SELECT DATE_ADD('1992-12-31 23:59:59.000002',
    ->            INTERVAL '1.999999' SECOND_MICROSECOND);
        -> '1993-01-01 00:00:01.000001'
```

If you specify an interval value that is too short (does not include all the interval parts that would be expected from the *`unit`* keyword), MySQL assumes that you have left out the leftmost parts of the interval value. For example, if you specify a *`unit`* of `DAY_SECOND`, the value of *`expr`* is expected to have days, hours, minutes, and seconds parts. If you specify a value like `'1:10'`, MySQL assumes that the days and hours parts are missing and the value represents minutes and seconds. In other words, `'1:10' DAY_SECOND` is interpreted in such a way that it is equivalent to `'1:10' MINUTE_SECOND`. This is analogous to the way that MySQL interprets `TIME` values as representing elapsed time rather than as a time of day.

Because *`expr`* is treated as a string, be careful if you specify a nonstring value with `INTERVAL`. For example, with an interval specifier of `HOUR_MINUTE`, `6/4` evaluates to `1.5000` and is treated as 1 hour, 5000 minutes:

```
mysql> SELECT 6/4;
        -> 1.5000
mysql> SELECT DATE_ADD('2009-01-01', INTERVAL 6/4 HOUR_MINUTE);
        -> '2009-01-04 12:20:00'
```

To ensure interpretation of the interval value as you expect, a `CAST()` operation may be used. To treat `6/4` as 1 hour, 5 minutes, cast it to a `DECIMAL` value with a single fractional digit:

```
mysql> SELECT CAST(6/4 AS DECIMAL(3,1));
        -> 1.5
mysql> SELECT DATE_ADD('1970-01-01 12:00:00',
    ->                 INTERVAL CAST(6/4 AS DECIMAL(3,1)) HOUR_MINUTE);
        -> '1970-01-01 13:05:00'
```

If you add to or subtract from a date value something that contains a time part, the result is automatically converted to a datetime value:

```
mysql> SELECT DATE_ADD('2013-01-01', INTERVAL 1 DAY);
        -> '2013-01-02'
mysql> SELECT DATE_ADD('2013-01-01', INTERVAL 1 HOUR);
        -> '2013-01-01 01:00:00'
```

If you add `MONTH`, `YEAR_MONTH`, or `YEAR` and the resulting date has a day that is larger than the maximum day for the new month, the day is adjusted to the maximum days in the new month:

```
mysql> SELECT DATE_ADD('2009-01-30', INTERVAL 1 MONTH);
        -> '2009-02-28'
```

Date arithmetic operations require complete dates and do not work with incomplete dates such as `'2006-07-00'` or badly malformed dates:

```
mysql> SELECT DATE_ADD('2006-07-00', INTERVAL 1 DAY);
        -> NULL
mysql> SELECT '2005-03-32' + INTERVAL 1 MONTH;
        -> NULL
```

- `DATE_FORMAT(date,format)`

  Formats the *`date`* value according to the *`format`* string.

  The following specifiers may be used in the *`format`* string. The `%` character is required before format specifier characters.

Specifier	Description
`%a`	Abbreviated weekday name (`Sun`..`Sat`)
`%b`	Abbreviated month name (`Jan`..`Dec`)
`%c`	Month, numeric (`0`..`12`)
`%D`	Day of the month with English suffix (`0th`, `1st`, `2nd`, `3rd`, ...)
`%d`	Day of the month, numeric (`00`..`31`)
`%e`	Day of the month, numeric (`0`..`31`)
`%f`	Microseconds (`000000`..`999999`)
`%H`	Hour (`00`..`23`)
`%h`	Hour (`01`..`12`)
`%I`	Hour (`01`..`12`)
`%i`	Minutes, numeric (`00`..`59`)
`%j`	Day of year (`001`..`366`)
`%k`	Hour (`0`..`23`)
`%l`	Hour (`1`..`12`)
`%M`	Month name (`January`..`December`)
`%m`	Month, numeric (`00`..`12`)
`%p`	`AM` or `PM`
`%r`	Time, 12-hour (`hh:mm:ss` followed by `AM` or `PM`)
`%S`	Seconds (`00`..`59`)
`%s`	Seconds (`00`..`59`)
`%T`	Time, 24-hour (`hh:mm:ss`)
`%U`	Week (`00`..`53`), where Sunday is the first day of the week; `WEEK()` mode 0
`%u`	Week (`00`..`53`), where Monday is the first day of the week; `WEEK()` mode 1
`%V`	Week (`01`..`53`), where Sunday is the first day of the week; `WEEK()` mode 2; used with `%X`
`%v`	Week (`01`..`53`), where Monday is the first day of the week; `WEEK()` mode 3; used with `%x`
`%W`	Weekday name (`Sunday`..`Saturday`)
`%w`	Day of the week (`0`=Sunday..`6`=Saturday)
`%X`	Year for the week where Sunday is the first day of the week, numeric, four digits; used with `%V`
`%x`	Year for the week, where Monday is the first day of the week, numeric, four digits; used with `%v`
`%Y`	Year, numeric, four digits
`%y`	Year, numeric (two digits)
`%%`	A literal `%` character
`%x`	*`x`*, for any “*`x`*” not listed above

Ranges for the month and day specifiers begin with zero due to the fact that MySQL permits the storing of incomplete dates such as `'2014-00-00'`.

The language used for day and month names and abbreviations is controlled by the value of the `lc_time_names` system variable (Section 10.7, “MySQL Server Locale Support”).

For the `%U`, `%u`, `%V`, and `%v` specifiers, see the description of the `WEEK()` function for information about the mode values. The mode affects how week numbering occurs.

`DATE_FORMAT()` returns a string with a character set and collation given by `character_set_connection` and `collation_connection` so that it can return month and weekday names containing non-ASCII characters.

```
mysql> SELECT DATE_FORMAT('2009-10-04 22:23:00', '%W %M %Y');
        -> 'Sunday October 2009'
mysql> SELECT DATE_FORMAT('2007-10-04 22:23:00', '%H:%i:%s');
        -> '22:23:00'
mysql> SELECT DATE_FORMAT('1900-10-04 22:23:00',
    ->                 '%D %y %a %d %m %b %j');
        -> '4th 00 Thu 04 10 Oct 277'
mysql> SELECT DATE_FORMAT('1997-10-04 22:23:00',
    ->                 '%H %k %I %r %T %S %w');
        -> '22 22 10 10:23:00 PM 22:23:00 00 6'
mysql> SELECT DATE_FORMAT('1999-01-01', '%X %V');
        -> '1998 52'
mysql> SELECT DATE_FORMAT('2006-06-00', '%d');
        -> '00'
```

- `DATE_SUB(`*`date`*`,INTERVAL `*`expr unit`*`)`

  See the description for `DATE_ADD()`.

- `DAY(`*`date`*`)`

  `DAY()` is a synonym for `DAYOFMONTH()`.

- `DAYNAME(`*`date`*`)`

  Returns the name of the weekday for *`date`*. The language used for the name is controlled by the value of the `lc_time_names` system variable (Section 10.7, “MySQL Server Locale Support”).

  ```
  mysql> SELECT DAYNAME('2007-02-03');
          -> 'Saturday'
  ```

- `DAYOFMONTH(`*`date`*`)`

  Returns the day of the month for *`date`*, in the range `1` to `31`, or `0` for dates such as `'0000-00-00'` or `'2008-00-00'` that have a zero day part.

  ```
  mysql> SELECT DAYOFMONTH('2007-02-03');
          -> 3
  ```

- `DAYOFWEEK(`*`date`*`)`

  Returns the weekday index for *`date`* (`1` = Sunday, `2` = Monday, …, `7` = Saturday). These index values correspond to the ODBC standard.

  ```
  mysql> SELECT DAYOFWEEK('2007-02-03');
          -> 7
  ```

- `DAYOFYEAR(`*`date`*`)`

Returns the day of the year for *date*, in the range 1 to 366.

```
mysql> SELECT DAYOFYEAR('2007-02-03');
        -> 34
```

- EXTRACT(*unit* FROM *date*)

  The EXTRACT() function uses the same kinds of unit specifiers as DATE_ADD() or DATE_SUB(), but extracts parts from the date rather than performing date arithmetic.

```
mysql> SELECT EXTRACT(YEAR FROM '2009-07-02');
       -> 2009
mysql> SELECT EXTRACT(YEAR_MONTH FROM '2009-07-02 01:02:03');
       -> 200907
mysql> SELECT EXTRACT(DAY_MINUTE FROM '2009-07-02 01:02:03');
       -> 20102
mysql> SELECT EXTRACT(MICROSECOND
    ->                FROM '2003-01-02 10:30:00.000123');
        -> 123
```

- FROM_DAYS(*N*)

  Given a day number *N*, returns a DATE value.

```
mysql> SELECT FROM_DAYS(730669);
        -> '2007-07-03'
```

  Use FROM_DAYS() with caution on old dates. It is not intended for use with values that precede the advent of the Gregorian calendar (1582). See Section 12.8, “What Calendar Is Used By MySQL?”.

- FROM_UNIXTIME(*unix_timestamp*), FROM_UNIXTIME(*unix_timestamp*,*format*)

  Returns a representation of the *unix_timestamp* argument as a value in 'YYYY-MM-DD HH:MM:SS' or YYYYMMDDHHMMSS.uuuuuu format, depending on whether the function is used in a string or numeric context. The value is expressed in the current time zone. *unix_timestamp* is an internal timestamp value such as is produced by the UNIX_TIMESTAMP() function.

  If *format* is given, the result is formatted according to the *format* string, which is used the same way as listed in the entry for the DATE_FORMAT() function.

```
mysql> SELECT FROM_UNIXTIME(1447430881);
        -> '2015-11-13 10:08:01'
mysql> SELECT FROM_UNIXTIME(1447430881) + 0;
        -> 20151113100801
mysql> SELECT FROM_UNIXTIME(UNIX_TIMESTAMP(),
    ->                      '%Y %D %M %h:%i:%s %x');
        -> '2015 13th November 10:08:01 2015'
```

  Note: If you use UNIX_TIMESTAMP() and FROM_UNIXTIME() to convert between TIMESTAMP values and Unix timestamp values, the conversion is lossy because the mapping is not one-to-one in both directions. For details, see the description of the UNIX_TIMESTAMP() function.

- GET_FORMAT({DATE|TIME|DATETIME}, {'EUR'|'USA'|'JIS'|'ISO'|'INTERNAL'})

  Returns a format string. This function is useful in combination with the DATE_FORMAT() and the STR_TO_DATE() functions.

  The possible values for the first and second arguments result in several possible format strings (for the specifiers used, see the table in the DATE_FORMAT() function description). ISO format refers to ISO 9075, not ISO 8601.

Function Call	Result
GET_FORMAT(DATE,'USA')	'%m.%d.%Y'
GET_FORMAT(DATE,'JIS')	'%Y-%m-%d'
GET_FORMAT(DATE,'ISO')	'%Y-%m-%d'
GET_FORMAT(DATE,'EUR')	'%d.%m.%Y'
GET_FORMAT(DATE,'INTERNAL')	'%Y%m%d'
GET_FORMAT(DATETIME,'USA')	'%Y-%m-%d %H.%i.%s'
GET_FORMAT(DATETIME,'JIS')	'%Y-%m-%d %H:%i:%s'
GET_FORMAT(DATETIME,'ISO')	'%Y-%m-%d %H:%i:%s'
GET_FORMAT(DATETIME,'EUR')	'%Y-%m-%d %H.%i.%s'
GET_FORMAT(DATETIME,'INTERNAL')	'%Y%m%d%H%i%s'
GET_FORMAT(TIME,'USA')	'%h:%i:%s %p'
GET_FORMAT(TIME,'JIS')	'%H:%i:%s'
GET_FORMAT(TIME,'ISO')	'%H:%i:%s'
GET_FORMAT(TIME,'EUR')	'%H.%i.%s'
GET_FORMAT(TIME,'INTERNAL')	'%H%i%s'

TIMESTAMP can also be used as the first argument to GET_FORMAT(), in which case the function returns the same values as for DATETIME.

```
mysql> SELECT DATE_FORMAT('2003-10-03',GET_FORMAT(DATE,'EUR'));
        -> '03.10.2003'
mysql> SELECT STR_TO_DATE('10.31.2003',GET_FORMAT(DATE,'USA'));
        -> '2003-10-31'
```

- HOUR(*time*)

  Returns the hour for *time*. The range of the return value is 0 to 23 for time-of-day values. However, the range of TIME values actually is much larger, so HOUR can return values greater than 23.

```
mysql> SELECT HOUR('10:05:03');
        -> 10
mysql> SELECT HOUR('272:59:59');
        -> 272
```

- LAST_DAY(*date*)

  Takes a date or datetime value and returns the corresponding value for the last day of the month. Returns NULL if the argument is invalid.

```
mysql> SELECT LAST_DAY('2003-02-05');
        -> '2003-02-28'
mysql> SELECT LAST_DAY('2004-02-05');
        -> '2004-02-29'
mysql> SELECT LAST_DAY('2004-01-01 01:01:01');
        -> '2004-01-31'
mysql> SELECT LAST_DAY('2003-03-32');
        -> NULL
```

- LOCALTIME, LOCALTIME()

  LOCALTIME and LOCALTIME() are synonyms for NOW().

- LOCALTIMESTAMP, LOCALTIMESTAMP()

`LOCALTIMESTAMP` and `LOCALTIMESTAMP()` are synonyms for `NOW()`.

- `MAKEDATE(year,dayofyear)`

  Returns a date, given year and day-of-year values. *`dayofyear`* must be greater than 0 or the result is `NULL`.

```
mysql> SELECT MAKEDATE(2011,31), MAKEDATE(2011,32);
        -> '2011-01-31', '2011-02-01'
mysql> SELECT MAKEDATE(2011,365), MAKEDATE(2014,365);
        -> '2011-12-31', '2014-12-31'
mysql> SELECT MAKEDATE(2011,0);
        -> NULL
```

- `MAKETIME(hour,minute,second)`

  Returns a time value calculated from the *`hour`*, *`minute`*, and *`second`* arguments.

```
mysql> SELECT MAKETIME(12,15,30);
        -> '12:15:30'
```

- `MICROSECOND(expr)`

  Returns the microseconds from the time or datetime expression *`expr`* as a number in the range from `0` to `999999`.

```
mysql> SELECT MICROSECOND('12:00:00.123456');
        -> 123456
mysql> SELECT MICROSECOND('2009-12-31 23:59:59.000010');
        -> 10
```

- `MINUTE(time)`

  Returns the minute for *`time`*, in the range `0` to `59`.

```
mysql> SELECT MINUTE('2008-02-03 10:05:03');
        -> 5
```

- `MONTH(date)`

  Returns the month for *`date`*, in the range `1` to `12` for January to December, or `0` for dates such as `'0000-00-00'` or `'2008-00-00'` that have a zero month part.

```
mysql> SELECT MONTH('2008-02-03');
        -> 2
```

- `MONTHNAME(date)`

  Returns the full name of the month for *`date`*. The language used for the name is controlled by the value of the `lc_time_names` system variable (Section 10.7, “MySQL Server Locale Support”).

```
mysql> SELECT MONTHNAME('2008-02-03');
        -> 'February'
```

- `NOW()`

  Returns the current date and time as a value in `'YYYY-MM-DD HH:MM:SS'` or `YYYYMMDDHHMMSS.uuuuuu` format, depending on whether the function is used in a string or numeric context. The value is expressed in the current time zone.

```
```

```
mysql> SELECT NOW();
        -> '2007-12-15 23:50:26'
mysql> SELECT NOW() + 0;
        -> 20071215235026.000000
```

`NOW()` returns a constant time that indicates the time at which the statement began to execute. (Within a stored function or trigger, `NOW()` returns the time at which the function or triggering statement began to execute.) This differs from the behavior for `SYSDATE()`, which returns the exact time at which it executes.

```
mysql> SELECT NOW(), SLEEP(2), NOW();
+---------------------+----------+---------------------+
| NOW()               | SLEEP(2) | NOW()               |
+---------------------+----------+---------------------+
| 2006-04-12 13:47:36 |        0 | 2006-04-12 13:47:36 |
+---------------------+----------+---------------------+

mysql> SELECT SYSDATE(), SLEEP(2), SYSDATE();
+---------------------+----------+---------------------+
| SYSDATE()           | SLEEP(2) | SYSDATE()           |
+---------------------+----------+---------------------+
| 2006-04-12 13:47:44 |        0 | 2006-04-12 13:47:46 |
+---------------------+----------+---------------------+
```

In addition, the `SET TIMESTAMP` statement affects the value returned by `NOW()` but not by `SYSDATE()`. This means that timestamp settings in the binary log have no effect on invocations of `SYSDATE()`. Setting the timestamp to a nonzero value causes each subsequent invocation of `NOW()` to return that value. Setting the timestamp to zero cancels this effect so that `NOW()` once again returns the current date and time.

See the description for `SYSDATE()` for additional information about the differences between the two functions.

- `PERIOD_ADD(P,N)`

  Adds *`N`* months to period *`P`* (in the format `YYMM` or `YYYYMM`). Returns a value in the format `YYYYMM`. Note that the period argument *`P`* is *not* a date value.

  ```
  mysql> SELECT PERIOD_ADD(200801,2);
          -> 200803
  ```

- `PERIOD_DIFF(P1,P2)`

  Returns the number of months between periods *`P1`* and *`P2`*. *`P1`* and *`P2`* should be in the format `YYMM` or `YYYYMM`. Note that the period arguments *`P1`* and *`P2`* are *not* date values.

  ```
  mysql> SELECT PERIOD_DIFF(200802,200703);
          -> 11
  ```

- `QUARTER(date)`

  Returns the quarter of the year for *`date`*, in the range `1` to `4`.

  ```
  mysql> SELECT QUARTER('2008-04-01');
          -> 2
  ```

- `SECOND(time)`

  Returns the second for *`time`*, in the range `0` to `59`.

  ```
  mysql> SELECT SECOND('10:05:03');
          -> 3
  ```

- `SEC_TO_TIME(seconds)`

  Returns the *`seconds`* argument, converted to hours, minutes, and seconds, as a `TIME` value. The range of the result is constrained to that of the `TIME` data type. A warning occurs if the argument corresponds to a value outside that range.

```
mysql> SELECT SEC_TO_TIME(2378);
        -> '00:39:38'
mysql> SELECT SEC_TO_TIME(2378) + 0;
        -> 3938
```

- `STR_TO_DATE(str,format)`

  This is the inverse of the `DATE_FORMAT()` function. It takes a string *`str`* and a format string *`format`*. `STR_TO_DATE()` returns a `DATETIME` value if the format string contains both date and time parts, or a `DATE` or `TIME` value if the string contains only date or time parts. If the date, time, or datetime value extracted from *`str`* is illegal, `STR_TO_DATE()` returns `NULL` and produces a warning.

  The server scans *`str`* attempting to match *`format`* to it. The format string can contain literal characters and format specifiers beginning with `%`. Literal characters in *`format`* must match literally in *`str`*. Format specifiers in *`format`* must match a date or time part in *`str`*. For the specifiers that can be used in *`format`*, see the `DATE_FORMAT()` function description.

```
mysql> SELECT STR_TO_DATE('01,5,2013','%d,%m,%Y');
        -> '2013-05-01'
mysql> SELECT STR_TO_DATE('May 1, 2013','%M %d,%Y');
        -> '2013-05-01'
```

  Scanning starts at the beginning of *`str`* and fails if *`format`* is found not to match. Extra characters at the end of *`str`* are ignored.

```
mysql> SELECT STR_TO_DATE('a09:30:17','a%h:%i:%s');
        -> '09:30:17'
mysql> SELECT STR_TO_DATE('a09:30:17','%h:%i:%s');
        -> NULL
mysql> SELECT STR_TO_DATE('09:30:17a','%h:%i:%s');
        -> '09:30:17'
```

  Unspecified date or time parts have a value of 0, so incompletely specified values in *`str`* produce a result with some or all parts set to 0:

```
mysql> SELECT STR_TO_DATE('abc','abc');
        -> '0000-00-00'
mysql> SELECT STR_TO_DATE('9','%m');
        -> '0000-09-00'
mysql> SELECT STR_TO_DATE('9','%s');
        -> '00:00:09'
```

  Range checking on the parts of date values is as described in Section 11.3.1, “The DATE, DATETIME, and TIMESTAMP Types”. This means, for example, that “zero” dates or dates with part values of 0 are permitted unless the SQL mode is set to disallow such values.

```
mysql> SELECT STR_TO_DATE('00/00/0000', '%m/%d/%Y');
        -> '0000-00-00'
mysql> SELECT STR_TO_DATE('04/31/2004', '%m/%d/%Y');
        -> '2004-04-31'
```

  If the `NO_ZERO_DATE` or `NO_ZERO_IN_DATE` SQL mode is enabled, zero dates or part of dates are disallowed. In that case, `STR_TO_DATE()` returns `NULL` and generates a warning:

```
mysql> SET sql_mode = '';
mysql> SELECT STR_TO_DATE('15:35:00', '%H:%i:%s');
+-----------------------------------+
| STR_TO_DATE('15:35:00', '%H:%i:%s') |
+-----------------------------------+
| 15:35:00                          |
+-----------------------------------+
mysql> SET sql_mode = 'NO_ZERO_IN_DATE';
mysql> SELECT STR_TO_DATE('15:35:00', '%h:%i:%s');
+-----------------------------------+
| STR_TO_DATE('15:35:00', '%h:%i:%s') |
+-----------------------------------+
| NULL                              |
+-----------------------------------+
mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1411
Message: Incorrect datetime value: '15:35:00' for function str_to_date
```

Note

You cannot use format `"%X%V"` to convert a year-week string to a date because the combination of a year and week does not uniquely identify a year and month if the week crosses a month boundary. To convert a year-week to a date, you should also specify the weekday:

```
mysql> SELECT STR_TO_DATE('200442 Monday', '%X%V %W');
       -> '2004-10-18'
```

- `SUBDATE(`*`date`*`,INTERVAL` *`expr unit`*`)`, `SUBDATE(`*`expr`*`,`*`days`*`)`

  When invoked with the `INTERVAL` form of the second argument, `SUBDATE()` is a synonym for `DATE_SUB()`. For information on the `INTERVAL` *`unit`* argument, see the discussion for `DATE_ADD()`.

```
mysql> SELECT DATE_SUB('2008-01-02', INTERVAL 31 DAY);
       -> '2007-12-02'
mysql> SELECT SUBDATE('2008-01-02', INTERVAL 31 DAY);
       -> '2007-12-02'
```

  The second form enables the use of an integer value for *`days`*. In such cases, it is interpreted as the number of days to be subtracted from the date or datetime expression *`expr`*.

```
mysql> SELECT SUBDATE('2008-01-02 12:00:00', 31);
       -> '2007-12-02 12:00:00'
```

- `SUBTIME(`*`expr1`*`,`*`expr2`*`)`

  `SUBTIME()` returns *`expr1`* − *`expr2`* expressed as a value in the same format as *`expr1`*. *`expr1`* is a time or datetime expression, and *`expr2`* is a time expression.

```
mysql> SELECT SUBTIME('2007-12-31 23:59:59.999999','1 1:1:1.000002');
       -> '2007-12-30 22:58:58.999997'
mysql> SELECT SUBTIME('01:00:00.999999', '02:00:00.999998');
       -> '-00:59:59.999999'
```

- `SYSDATE()`

  Returns the current date and time as a value in `'YYYY-MM-DD HH:MM:SS'` or `YYYYMMDDHHMMSS.uuuuuu` format, depending on whether the function is used in a string or numeric context.

`SYSDATE()` returns the time at which it executes. This differs from the behavior for `NOW()`, which returns a constant time that indicates the time at which the statement began to execute. (Within a stored function or trigger, `NOW()` returns the time at which the function or triggering statement began to execute.)

```
mysql> SELECT NOW(), SLEEP(2), NOW();
+---------------------+----------+---------------------+
| NOW()               | SLEEP(2) | NOW()               |
+---------------------+----------+---------------------+
| 2006-04-12 13:47:36 |        0 | 2006-04-12 13:47:36 |
+---------------------+----------+---------------------+

mysql> SELECT SYSDATE(), SLEEP(2), SYSDATE();
+---------------------+----------+---------------------+
| SYSDATE()           | SLEEP(2) | SYSDATE()           |
+---------------------+----------+---------------------+
| 2006-04-12 13:47:44 |        0 | 2006-04-12 13:47:46 |
+---------------------+----------+---------------------+
```

In addition, the `SET TIMESTAMP` statement affects the value returned by `NOW()` but not by `SYSDATE()`. This means that timestamp settings in the binary log have no effect on invocations of `SYSDATE()`.

Because `SYSDATE()` can return different values even within the same statement, and is not affected by `SET TIMESTAMP`, it is nondeterministic and therefore unsafe for replication if statement-based binary logging is used. If that is a problem, you can use row-based logging.

Alternatively, you can use the `--sysdate-is-now` option to cause `SYSDATE()` to be an alias for `NOW()`. This works if the option is used on both the master and the slave.

The nondeterministic nature of `SYSDATE()` also means that indexes cannot be used for evaluating expressions that refer to it.

- `TIME(`*`expr`*`)`

  Extracts the time part of the time or datetime expression *`expr`* and returns it as a string.

  This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

```
mysql> SELECT TIME('2003-12-31 01:02:03');
        -> '01:02:03'
mysql> SELECT TIME('2003-12-31 01:02:03.000123');
        -> '01:02:03.000123'
```

- `TIMEDIFF(`*`expr1`*`,`*`expr2`*`)`

  `TIMEDIFF()` returns *`expr1`* − *`expr2`* expressed as a time value. *`expr1`* and *`expr2`* are time or date-and-time expressions, but both must be of the same type.

  The result returned by `TIMEDIFF()` is limited to the range allowed for `TIME` values. Alternatively, you can use either of the functions `TIMESTAMPDIFF()` and `UNIX_TIMESTAMP()`, both of which return integers.

```
mysql> SELECT TIMEDIFF('2000:01:01 00:00:00',
    ->                 '2000:01:01 00:00:00.000001');
        -> '-00:00:00.000001'
mysql> SELECT TIMEDIFF('2008-12-31 23:59:59.000001',
    ->                 '2008-12-30 01:01:01.000002');
        -> '46:58:57.999999'
```

- `TIMESTAMP(`*`expr`*`)`, `TIMESTAMP(`*`expr1`*`,`*`expr2`*`)`

With a single argument, this function returns the date or datetime expression *expr* as a datetime value. With two arguments, it adds the time expression *expr2* to the date or datetime expression *expr1* and returns the result as a datetime value.

```
mysql> SELECT TIMESTAMP('2003-12-31');
        -> '2003-12-31 00:00:00'
mysql> SELECT TIMESTAMP('2003-12-31 12:00:00','12:00:00');
        -> '2004-01-01 00:00:00'
```

- TIMESTAMPADD(*unit*,*interval*,*datetime_expr*)

  Adds the integer expression *interval* to the date or datetime expression *datetime_expr*. The unit for *interval* is given by the *unit* argument, which should be one of the following values: MICROSECOND (microseconds), SECOND, MINUTE, HOUR, DAY, WEEK, MONTH, QUARTER, or YEAR.

  The *unit* value may be specified using one of keywords as shown, or with a prefix of SQL_TSI_. For example, DAY and SQL_TSI_DAY both are legal.

```
mysql> SELECT TIMESTAMPADD(MINUTE,1,'2003-01-02');
        -> '2003-01-02 00:01:00'
mysql> SELECT TIMESTAMPADD(WEEK,1,'2003-01-02');
        -> '2003-01-09'
```

- TIMESTAMPDIFF(*unit*,*datetime_expr1*,*datetime_expr2*)

  Returns *datetime_expr2* − *datetime_expr1*, where *datetime_expr1* and *datetime_expr2* are date or datetime expressions. One expression may be a date and the other a datetime; a date value is treated as a datetime having the time part '00:00:00' where necessary. The unit for the result (an integer) is given by the *unit* argument. The legal values for *unit* are the same as those listed in the description of the TIMESTAMPADD() function.

```
mysql> SELECT TIMESTAMPDIFF(MONTH,'2003-02-01','2003-05-01');
        -> 3
mysql> SELECT TIMESTAMPDIFF(YEAR,'2002-05-01','2001-01-01');
        -> -1
mysql> SELECT TIMESTAMPDIFF(MINUTE,'2003-02-01','2003-05-01 12:05:55');
        -> 128885
```

Note

The order of the date or datetime arguments for this function is the opposite of that used with the TIMESTAMP() function when invoked with 2 arguments.

- TIME_FORMAT(*time*,*format*)

  This is used like the DATE_FORMAT() function, but the *format* string may contain format specifiers only for hours, minutes, seconds, and microseconds. Other specifiers produce a NULL value or 0.

  If the *time* value contains an hour part that is greater than 23, the %H and %k hour format specifiers produce a value larger than the usual range of 0..23. The other hour format specifiers produce the hour value modulo 12.

```
mysql> SELECT TIME_FORMAT('100:00:00', '%H %k %h %I %l');
        -> '100 100 04 04 4'
```

- TIME_TO_SEC(*time*)

  Returns the *time* argument, converted to seconds.

```
mysql> SELECT TIME_TO_SEC('22:23:00');
```

```
        -> 80580
mysql> SELECT TIME_TO_SEC('00:39:38');
        -> 2378
```

- `TO_DAYS(date)`

  Given a date *`date`*, returns a day number (the number of days since year 0).

```
mysql> SELECT TO_DAYS(950501);
        -> 728779
mysql> SELECT TO_DAYS('2007-10-07');
        -> 733321
```

  `TO_DAYS()` is not intended for use with values that precede the advent of the Gregorian calendar (1582), because it does not take into account the days that were lost when the calendar was changed. For dates before 1582 (and possibly a later year in other locales), results from this function are not reliable. See Section 12.8, “What Calendar Is Used By MySQL?”, for details.

  Remember that MySQL converts two-digit year values in dates to four-digit form using the rules in Section 11.3, “Date and Time Types”. For example, `'2008-10-07'` and `'08-10-07'` are seen as identical dates:

```
mysql> SELECT TO_DAYS('2008-10-07'), TO_DAYS('08-10-07');
        -> 733687, 733687
```

  In MySQL, the zero date is defined as `'0000-00-00'`, even though this date is itself considered invalid. This means that, for `'0000-00-00'` and `'0000-01-01'`, `TO_DAYS()` returns the values shown here:

```
mysql> SELECT TO_DAYS('0000-00-00');
+-----------------------+
| to_days('0000-00-00') |
+-----------------------+
|                  NULL |
+-----------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+---------------------------------------+
| Level   | Code | Message                               |
+---------+------+---------------------------------------+
| Warning | 1292 | Incorrect datetime value: '0000-00-00' |
+---------+------+---------------------------------------+
1 row in set (0.00 sec)


mysql> SELECT TO_DAYS('0000-01-01');
+-----------------------+
| to_days('0000-01-01') |
+-----------------------+
|                     1 |
+-----------------------+
1 row in set (0.00 sec)
```

  This is true whether or not the `ALLOW_INVALID_DATES` SQL server mode is enabled.

- `TO_SECONDS(expr)`

  Given a date or datetime *`expr`*, returns a the number of seconds since the year 0. If *`expr`* is not a valid date or datetime value, returns `NULL`.

```
mysql> SELECT TO_SECONDS(950501);
        -> 62966505600
mysql> SELECT TO_SECONDS('2009-11-29');
```

```
        -> 63426672000
mysql> SELECT TO_SECONDS('2009-11-29 13:43:32');
        -> 63426721412
mysql> SELECT TO_SECONDS( NOW() );
        -> 63426721458
```

Like `TO_DAYS()`, `TO_SECONDS()` is not intended for use with values that precede the advent of the Gregorian calendar (1582), because it does not take into account the days that were lost when the calendar was changed. For dates before 1582 (and possibly a later year in other locales), results from this function are not reliable. See Section 12.8, “What Calendar Is Used By MySQL?”, for details.

Like `TO_DAYS()`, `TO_SECONDS()`, converts two-digit year values in dates to four-digit form using the rules in Section 11.3, “Date and Time Types”.

In MySQL, the zero date is defined as `'0000-00-00'`, even though this date is itself considered invalid. This means that, for `'0000-00-00'` and `'0000-01-01'`, `TO_SECONDS()` returns the values shown here:

```
mysql> SELECT TO_SECONDS('0000-00-00');
+--------------------------+
| TO_SECONDS('0000-00-00') |
+--------------------------+
|                     NULL |
+--------------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+----------------------------------------+
| Level   | Code | Message                                |
+---------+------+----------------------------------------+
| Warning | 1292 | Incorrect datetime value: '0000-00-00' |
+---------+------+----------------------------------------+
1 row in set (0.00 sec)


mysql> SELECT TO_SECONDS('0000-01-01');
+--------------------------+
| TO_SECONDS('0000-01-01') |
+--------------------------+
|                    86400 |
+--------------------------+
1 row in set (0.00 sec)
```

This is true whether or not the `ALLOW_INVALID_DATES` SQL server mode is enabled.

- `UNIX_TIMESTAMP()`, `UNIX_TIMESTAMP(`*`date`*`)`

  If called with no argument, returns a Unix timestamp (seconds since `'1970-01-01 00:00:00'` UTC) as an unsigned integer. If `UNIX_TIMESTAMP()` is called with a *`date`* argument, it returns the value of the argument as seconds since `'1970-01-01 00:00:00'` UTC. The *`date`* argument may be a `DATE`, `DATETIME`, or `TIMESTAMP` string, or a number in `YYMMDD`, `YYMMDDHHMMSS`, `YYYYMMDD`, or `YYYYMMDDHHMMSS` format. The server interprets *`date`* as a value in the current time zone and converts it to an internal value in UTC. Clients can set their time zone as described in Section 10.6, “MySQL Server Time Zone Support”.

  ```
  mysql> SELECT UNIX_TIMESTAMP();
          -> 1447431666
  mysql> SELECT UNIX_TIMESTAMP('2015-11-13 10:20:19');
          -> 1447431619
  ```

  When `UNIX_TIMESTAMP()` is used on a `TIMESTAMP` column, the function returns the internal timestamp value directly, with no implicit “string-to-Unix-timestamp” conversion. If you pass an out-of-range date to `UNIX_TIMESTAMP()`, it returns `0`. The valid range of values is the same

as for the TIMESTAMP data type: '1970-01-01 00:00:01.000000' UTC to '2038-01-19 03:14:07.999999' UTC.

Note: If you use UNIX_TIMESTAMP() and FROM_UNIXTIME() to convert between TIMESTAMP values and Unix timestamp values, the conversion is lossy because the mapping is not one-to-one in both directions. For example, due to conventions for local time zone changes, it is possible for two UNIX_TIMESTAMP() to map two TIMESTAMP values to the same Unix timestamp value. FROM_UNIXTIME() will map that value back to only one of the original TIMESTAMP values. Here is an example, using TIMESTAMP values in the CET time zone:

```
mysql> SELECT UNIX_TIMESTAMP('2005-03-27 03:00:00');
+---------------------------------------+
| UNIX_TIMESTAMP('2005-03-27 03:00:00') |
+---------------------------------------+
|                            1111885200 |
+---------------------------------------+
mysql> SELECT UNIX_TIMESTAMP('2005-03-27 02:00:00');
+---------------------------------------+
| UNIX_TIMESTAMP('2005-03-27 02:00:00') |
+---------------------------------------+
|                            1111885200 |
+---------------------------------------+
mysql> SELECT FROM_UNIXTIME(1111885200);
+---------------------------+
| FROM_UNIXTIME(1111885200) |
+---------------------------+
| 2005-03-27 03:00:00       |
+---------------------------+
```

If you want to subtract UNIX_TIMESTAMP() columns, you might want to cast the result to signed integers. See Section 12.10, “Cast Functions and Operators”.

- UTC_DATE, UTC_DATE()

  Returns the current UTC date as a value in 'YYYY-MM-DD' or YYYYMMDD format, depending on whether the function is used in a string or numeric context.

```
mysql> SELECT UTC_DATE(), UTC_DATE() + 0;
        -> '2003-08-14', 20030814
```

- UTC_TIME, UTC_TIME()

  Returns the current UTC time as a value in 'HH:MM:SS' or HHMMSS.uuuuuu format, depending on whether the function is used in a string or numeric context.

```
mysql> SELECT UTC_TIME(), UTC_TIME() + 0;
        -> '18:07:53', 180753.000000
```

- UTC_TIMESTAMP, UTC_TIMESTAMP()

  Returns the current UTC date and time as a value in 'YYYY-MM-DD HH:MM:SS' or YYYYMMDDHHMMSS.uuuuuu format, depending on whether the function is used in a string or numeric context.

```
mysql> SELECT UTC_TIMESTAMP(), UTC_TIMESTAMP() + 0;
        -> '2003-08-14 18:08:04', 20030814180804.000000
```

- WEEK(*date*[,*mode*])

  This function returns the week number for *date*. The two-argument form of WEEK() enables you to specify whether the week starts on Sunday or Monday and whether the return value should

be in the range from `0` to `53` or from `1` to `53`. If the *`mode`* argument is omitted, the value of the `default_week_format` system variable is used. See Section 5.1.5, “Server System Variables”.

The following table describes how the *`mode`* argument works.

Mode	First day of week	Range	Week 1 is the first week …
0	Sunday	0-53	with a Sunday in this year
1	Monday	0-53	with 4 or more days this year
2	Sunday	1-53	with a Sunday in this year
3	Monday	1-53	with 4 or more days this year
4	Sunday	0-53	with 4 or more days this year
5	Monday	0-53	with a Monday in this year
6	Sunday	1-53	with 4 or more days this year
7	Monday	1-53	with a Monday in this year

For *`mode`* values with a meaning of “with 4 or more days this year,” weeks are numbered according to ISO 8601:1988:

- If the week containing January 1 has 4 or more days in the new year, it is week 1.
- Otherwise, it is the last week of the previous year, and the next week is week 1.

```
mysql> SELECT WEEK('2008-02-20');
        -> 7
mysql> SELECT WEEK('2008-02-20',0);
        -> 7
mysql> SELECT WEEK('2008-02-20',1);
        -> 8
mysql> SELECT WEEK('2008-12-31',1);
        -> 53
```

Note that if a date falls in the last week of the previous year, MySQL returns `0` if you do not use `2`, `3`, `6`, or `7` as the optional *`mode`* argument:

```
mysql> SELECT YEAR('2000-01-01'), WEEK('2000-01-01',0);
        -> 2000, 0
```

One might argue that `WEEK()` should return `52` because the given date actually occurs in the 52nd week of 1999. `WEEK()` returns `0` instead so that the return value is “the week number in the given year.” This makes use of the `WEEK()` function reliable when combined with other functions that extract a date part from a date.

If you prefer a result evaluated with respect to the year that contains the first day of the week for the given date, use `0`, `2`, `5`, or `7` as the optional *`mode`* argument.

```
mysql> SELECT WEEK('2000-01-01',2);
        -> 52
```

Alternatively, use the `YEARWEEK()` function:

```
mysql> SELECT YEARWEEK('2000-01-01');
        -> 199952
mysql> SELECT MID(YEARWEEK('2000-01-01'),5,2);
        -> '52'
```

- `WEEKDAY(`*`date`*`)`

Returns the weekday index for *`date`* (`0` = Monday, `1` = Tuesday, … `6` = Sunday).

```
mysql> SELECT WEEKDAY('2008-02-03 22:23:00');
        -> 6
mysql> SELECT WEEKDAY('2007-11-06');
        -> 1
```

- `WEEKOFYEAR(`*`date`*`)`

  Returns the calendar week of the date as a number in the range from `1` to `53`. `WEEKOFYEAR()` is a compatibility function that is equivalent to `WEEK(`*`date`*`,3)`.

```
mysql> SELECT WEEKOFYEAR('2008-02-20');
        -> 8
```

- `YEAR(`*`date`*`)`

  Returns the year for *`date`*, in the range `1000` to `9999`, or `0` for the “zero” date.

```
mysql> SELECT YEAR('1987-01-01');
        -> 1987
```

- `YEARWEEK(`*`date`*`)`, `YEARWEEK(`*`date`*`,`*`mode`*`)`

  Returns year and week for a date. The year in the result may be different from the year in the date argument for the first and the last week of the year.

  The *`mode`* argument works exactly like the *`mode`* argument to `WEEK()`. For the single-argument syntax, a *`mode`* value of 0 is used. Unlike `WEEK()`, the value of `default_week_format` does not influence `YEARWEEK()`.

```
mysql> SELECT YEARWEEK('1987-01-01');
        -> 198652
```

  Note that the week number is different from what the `WEEK()` function would return (`0`) for optional arguments `0` or `1`, as `WEEK()` then returns the week in the context of the given year.

12.8 What Calendar Is Used By MySQL?

MySQL uses what is known as a *proleptic Gregorian calendar*.

Every country that has switched from the Julian to the Gregorian calendar has had to discard at least ten days during the switch. To see how this works, consider the month of October 1582, when the first Julian-to-Gregorian switch occurred.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	2	3	4	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

There are no dates between October 4 and October 15. This discontinuity is called the *cutover*. Any dates before the cutover are Julian, and any dates following the cutover are Gregorian. Dates during a cutover are nonexistent.

A calendar applied to dates when it was not actually in use is called *proleptic*. Thus, if we assume there was never a cutover and Gregorian rules always rule, we have a proleptic Gregorian calendar. This is what is used by MySQL, as is required by standard SQL. For this reason, dates prior to the cutover stored as MySQL `DATE` or `DATETIME` values must be adjusted to compensate for the difference. It

is important to realize that the cutover did not occur at the same time in all countries, and that the later it happened, the more days were lost. For example, in Great Britain, it took place in 1752, when Wednesday September 2 was followed by Thursday September 14. Russia remained on the Julian calendar until 1918, losing 13 days in the process, and what is popularly referred to as its “October Revolution” occurred in November according to the Gregorian calendar.

For integer expressions, the preceding remarks about expression *evaluation* apply somewhat differently for expression *assignment*; for example, in a statement such as this:

```
CREATE TABLE t SELECT integer_expr;
```

In this case, the table in the column resulting from the expression has type `INT` or `BIGINT` depending on the length of the integer expression. If the maximum length of the expression does not fit in an `INT`, `BIGINT` is used instead. The length is taken from the `max_length` value of the `SELECT` result set metadata (see Section 23.8.5, “C API Data Structures”). This means that you can force a `BIGINT` rather than `INT` by use of a sufficiently long expression:

```
CREATE TABLE t SELECT 00000000000000000000;
```

12.9 Full-Text Search Functions

```
MATCH (col1,col2,...) AGAINST (expr [search_modifier])
```

```
search_modifier:
  {
       IN NATURAL LANGUAGE MODE
     | IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION
     | IN BOOLEAN MODE
     | WITH QUERY EXPANSION
  }
```

MySQL has support for full-text indexing and searching:

- A full-text index in MySQL is an index of type `FULLTEXT`.
- Full-text indexes can be used only with `MyISAM` tables. (In MySQL 5.6 and up, they can also be used with `InnoDB` tables.) Full-text indexes can be created only for `CHAR`, `VARCHAR`, or `TEXT` columns.
- A `FULLTEXT` index definition can be given in the `CREATE TABLE` statement when a table is created, or added later using `ALTER TABLE` or `CREATE INDEX`.
- For large data sets, it is much faster to load your data into a table that has no `FULLTEXT` index and then create the index after that, than to load data into a table that has an existing `FULLTEXT` index.

Full-text searching is performed using `MATCH() ... AGAINST` syntax. `MATCH()` takes a comma-separated list that names the columns to be searched. `AGAINST` takes a string to search for, and an optional modifier that indicates what type of search to perform. The search string must be a string value that is constant during query evaluation. This rules out, for example, a table column because that can differ for each row.

There are three types of full-text searches:

- A natural language search interprets the search string as a phrase in natural human language (a phrase in free text). There are no special operators, with the exception of double quote (") characters. The stopword list applies. In addition, words that are present in 50% or more of the rows are considered common and do not match.

  Full-text searches are natural language searches if the `IN NATURAL LANGUAGE MODE` modifier is given or if no modifier is given. For more information, see Section 12.9.1, “Natural Language Full-Text Searches”.

- A boolean search interprets the search string using the rules of a special query language. The string contains the words to search for. It can also contain operators that specify requirements such that a word must be present or absent in matching rows, or that it should be weighted higher or lower than usual. Common words such as “some” or “then” are stopwords and do not match if present in the search string. The `IN BOOLEAN MODE` modifier specifies a boolean search. For more information, see Section 12.9.2, “Boolean Full-Text Searches”.

- A query expansion search is a modification of a natural language search. The search string is used to perform a natural language search. Then words from the most relevant rows returned by the search are added to the search string and the search is done again. The query returns the rows from the second search. The `IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION` or `WITH QUERY EXPANSION` modifier specifies a query expansion search. For more information, see Section 12.9.3, “Full-Text Searches with Query Expansion”.

Constraints on full-text searching are listed in Section 12.9.5, “Full-Text Restrictions”.

The `myisam_ftdump` utility can be used to dump the contents of a full-text index. This may be helpful for debugging full-text queries. See Section 4.6.2, “`myisam_ftdump` — Display Full-Text Index information”.

12.9.1 Natural Language Full-Text Searches

By default or with the `IN NATURAL LANGUAGE MODE` modifier, the `MATCH()` function performs a natural language search for a string against a *text collection*. A collection is a set of one or more columns included in a `FULLTEXT` index. The search string is given as the argument to `AGAINST()`. For each row in the table, `MATCH()` returns a relevance value; that is, a similarity measure between the search string and the text in that row in the columns named in the `MATCH()` list.

```
mysql> CREATE TABLE articles (
          id INT UNSIGNED AUTO_INCREMENT NOT NULL PRIMARY KEY,
          title VARCHAR(200),
          body TEXT,
          FULLTEXT (title,body)
        ) ENGINE=InnoDB;
Query OK, 0 rows affected (0.08 sec)

mysql> INSERT INTO articles (title,body) VALUES
        ('MySQL Tutorial','DBMS stands for DataBase ...'),
        ('How To Use MySQL Well','After you went through a ...'),
        ('Optimizing MySQL','In this tutorial we will show ...'),
        ('1001 MySQL Tricks','1. Never run mysqld as root. 2. ...'),
        ('MySQL vs. YourSQL','In the following database comparison ...'),
        ('MySQL Security','When configured properly, MySQL ...');
Query OK, 6 rows affected (0.01 sec)
Records: 6  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM articles
        WHERE MATCH (title,body)
        AGAINST ('database' IN NATURAL LANGUAGE MODE);
+----+-------------------+------------------------------------------+
| id | title             | body                                     |
+----+-------------------+------------------------------------------+
|  1 | MySQL Tutorial    | DBMS stands for DataBase ...             |
|  5 | MySQL vs. YourSQL | In the following database comparison ... |
+----+-------------------+------------------------------------------+
2 rows in set (0.00 sec)
```

By default, the search is performed in case-insensitive fashion. However, you can perform a case-sensitive full-text search by using a binary collation for the indexed columns. For example, a column that uses the `latin1` character set of can be assigned a collation of `latin1_bin` to make it case sensitive for full-text searches.

When `MATCH()` is used in a `WHERE` clause, as in the example shown earlier, the rows returned are automatically sorted with the highest relevance first. Relevance values are nonnegative floating-

point numbers. Zero relevance means no similarity. Relevance is computed based on the number of words in the row (document), the number of unique words in the row, the total number of words in the collection, and the number of rows that contain a particular word.

Note

The term “document” may be used interchangeably with the term “row”, and both terms refer to the indexed part of the row. The term “collection” refers to the indexed columns and encompasses all rows.

To simply count matches, you could use a query like this:

```
mysql> SELECT COUNT(*) FROM articles
    -> WHERE MATCH (title,body)
    -> AGAINST ('database' IN NATURAL LANGUAGE MODE);
+----------+
| COUNT(*) |
+----------+
|        2 |
+----------+
1 row in set (0.00 sec)
```

However, you might find it quicker to rewrite the query as follows:

```
mysql> SELECT
    -> COUNT(IF(MATCH (title,body) AGAINST ('database' IN NATURAL LANGUAGE MODE), 1, NULL))
    -> AS count
    -> FROM articles;
+-------+
| count |
+-------+
|     2 |
+-------+
1 row in set (0.03 sec)
```

The first query sorts the results by relevance whereas the second does not. However, the second query performs a full table scan and the first does not. The first may be faster if the search matches few rows; otherwise, the second may be faster because it would read many rows anyway.

For natural-language full-text searches, it is a requirement that the columns named in the `MATCH()` function be the same columns included in some `FULLTEXT` index in your table. For the preceding query, note that the columns named in the `MATCH()` function (`title` and `body`) are the same as those named in the definition of the `article` table's `FULLTEXT` index. If you wanted to search the `title` or `body` separately, you would need to create separate `FULLTEXT` indexes for each column.

It is also possible to perform a boolean search or a search with query expansion. These search types are described in Section 12.9.2, “Boolean Full-Text Searches”, and Section 12.9.3, “Full-Text Searches with Query Expansion”.

A full-text search that uses an index can name columns only from a single table in the `MATCH()` clause because an index cannot span multiple tables. A boolean search can be done in the absence of an index (albeit more slowly), in which case it is possible to name columns from multiple tables.

The preceding example is a basic illustration that shows how to use the `MATCH()` function where rows are returned in order of decreasing relevance. The next example shows how to retrieve the relevance values explicitly. Returned rows are not ordered because the `SELECT` statement includes neither `WHERE` nor `ORDER BY` clauses:

```
mysql> SELECT id, MATCH (title,body)
    -> AGAINST ('Tutorial' IN NATURAL LANGUAGE MODE) AS score
    -> FROM articles;
+----+-------------------+
```

```
| id | score            |
+----+------------------+
|  1 | 0.65545833110809 |
|  2 |                0 |
|  3 | 0.66266459226608 |
|  4 |                0 |
|  5 |                0 |
|  6 |                0 |
+----+------------------+
6 rows in set (0.00 sec)
```

The following example is more complex. The query returns the relevance values and it also sorts the rows in order of decreasing relevance. To achieve this result, specify `MATCH()` twice: once in the `SELECT` list and once in the `WHERE` clause. This causes no additional overhead, because the MySQL optimizer notices that the two `MATCH()` calls are identical and invokes the full-text search code only once.

```
mysql> SELECT id, body, MATCH (title,body) AGAINST
    -> ('Security implications of running MySQL as root'
    -> IN NATURAL LANGUAGE MODE) AS score
    -> FROM articles WHERE MATCH (title,body) AGAINST
    -> ('Security implications of running MySQL as root'
    -> IN NATURAL LANGUAGE MODE);
+----+-------------------------------------+-----------------+
| id | body                                | score           |
+----+-------------------------------------+-----------------+
|  4 | 1. Never run mysqld as root. 2. ... | 1.5219271183014 |
|  6 | When configured properly, MySQL ... | 1.3114095926285 |
+----+-------------------------------------+-----------------+
2 rows in set (0.00 sec)
```

A phrase that is enclosed within double quote (`"`) characters matches only rows that contain the phrase *literally, as it was typed*. The full-text engine splits the phrase into words and performs a search in the `FULLTEXT` index for the words. Nonword characters need not be matched exactly: Phrase searching requires only that matches contain exactly the same words as the phrase and in the same order. For example, `"test phrase"` matches `"test, phrase"`. If the phrase contains no words that are in the index, the result is empty. For example, if all words are either stopwords or shorter than the minimum length of indexed words, the result is empty.

The MySQL `FULLTEXT` implementation regards any sequence of true word characters (letters, digits, and underscores) as a word. That sequence may also contain apostrophes (`'`), but not more than one in a row. This means that `aaa'bbb` is regarded as one word, but `aaa''bbb` is regarded as two words. Apostrophes at the beginning or the end of a word are stripped by the `FULLTEXT` parser; `'aaa'bbb'` would be parsed as `aaa'bbb`.

The `FULLTEXT` parser determines where words start and end by looking for certain delimiter characters; for example, (space), `,` (comma), and `.` (period). If words are not separated by delimiters (as in, for example, Chinese), the `FULLTEXT` parser cannot determine where a word begins or ends. To be able to add words or other indexed terms in such languages to a `FULLTEXT` index, you must preprocess them so that they are separated by some arbitrary delimiter.

It is possible to write a plugin that replaces the built-in full-text parser. For details, see Section 24.2, “The MySQL Plugin API”. For example parser plugin source code, see the `plugin/fulltext` directory of a MySQL source distribution.

Some words are ignored in full-text searches:

- Any word that is too short is ignored. The default minimum length of words that are found by full-text searches is four characters.
- Words in the stopword list are ignored. A stopword is a word such as “the” or “some” that is so common that it is considered to have zero semantic value. There is a built-in stopword list, but it can be overwritten by a user-defined list.

The default stopword list is given in Section 12.9.4, “Full-Text Stopwords”. The default minimum word length and stopword list can be changed as described in Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”.

Every correct word in the collection and in the query is weighted according to its significance in the collection or query. Consequently, a word that is present in many documents has a lower weight (and may even have a zero weight), because it has lower semantic value in this particular collection. Conversely, if the word is rare, it receives a higher weight. The weights of the words are combined to compute the relevance of the row.

Such a technique works best with large collections (in fact, it was carefully tuned this way). For very small tables, word distribution does not adequately reflect their semantic value, and this model may sometimes produce bizarre results. For example, although the word “MySQL” is present in every row of the `articles` table shown earlier, a search for the word produces no results:

```
mysql> SELECT * FROM articles
    -> WHERE MATCH (title,body)
    -> AGAINST ('MySQL' IN NATURAL LANGUAGE MODE);
Empty set (0.00 sec)
```

The search result is empty because the word “MySQL” is present in at least 50% of the rows. As such, it is effectively treated as a stopword. For large data sets, this is the most desirable behavior: A natural language query should not return every second row from a 1GB table. For small data sets, it may be less desirable.

A word that matches half of the rows in a table is less likely to locate relevant documents. In fact, it most likely finds plenty of irrelevant documents. We all know this happens far too often when we are trying to find something on the Internet with a search engine. It is with this reasoning that rows containing the word are assigned a low semantic value for *the particular data set in which they occur*. A given word may reach the 50% threshold in one data set but not another.

The 50% threshold has a significant implication when you first try full-text searching to see how it works: If you create a table and insert only one or two rows of text into it, every word in the text occurs in at least 50% of the rows. As a result, no search returns any results. Be sure to insert at least three rows, and preferably many more. Users who need to bypass the 50% limitation can use the boolean search mode; see Section 12.9.2, “Boolean Full-Text Searches”.

12.9.2 Boolean Full-Text Searches

MySQL can perform boolean full-text searches using the `IN BOOLEAN MODE` modifier. With this modifier, certain characters have special meaning at the beginning or end of words in the search string. In the following query, the `+` and `-` operators indicate that a word is required to be present or absent, respectively, for a match to occur. Thus, the query retrieves all the rows that contain the word “MySQL” but that do *not* contain the word “YourSQL”:

```
mysql> SELECT * FROM articles WHERE MATCH (title,body)
    -> AGAINST ('+MySQL -YourSQL' IN BOOLEAN MODE);
+----+-----------------------+-------------------------------------+
| id | title                 | body                                |
+----+-----------------------+-------------------------------------+
|  1 | MySQL Tutorial        | DBMS stands for DataBase ...        |
|  2 | How To Use MySQL Well | After you went through a ...        |
|  3 | Optimizing MySQL      | In this tutorial we will show ...   |
|  4 | 1001 MySQL Tricks     | 1. Never run mysqld as root. 2. ... |
|  6 | MySQL Security        | When configured properly, MySQL ... |
+----+-----------------------+-------------------------------------+
```

Note

In implementing this feature, MySQL uses what is sometimes referred to as *implied Boolean logic*, in which

- `+` stands for `AND`
- `-` stands for `NOT`
- [*no operator*] implies `OR`

Boolean full-text searches have these characteristics:

- They do not use the 50% threshold.
- They do not automatically sort rows in order of decreasing relevance. You can see this from the preceding query result: The row with the highest relevance is the one that contains “MySQL” twice, but it is listed last, not first.
- They can work even without a `FULLTEXT` index, although a search executed in this fashion would be quite slow.
- The minimum and maximum word length full-text parameters apply.
- The stopword list applies.

The boolean full-text search capability supports the following operators:

- `+`

  A leading plus sign indicates that this word *must* be present in each row that is returned.

- `-`

  A leading minus sign indicates that this word must *not* be present in any of the rows that are returned.

  Note: The `-` operator acts only to exclude rows that are otherwise matched by other search terms. Thus, a boolean-mode search that contains only terms preceded by `-` returns an empty result. It does not return “all rows except those containing any of the excluded terms.”

- (no operator)

  By default (when neither `+` nor `-` is specified) the word is optional, but the rows that contain it are rated higher. This mimics the behavior of `MATCH() ... AGAINST()` without the `IN BOOLEAN MODE` modifier.

- `> <`

  These two operators are used to change a word's contribution to the relevance value that is assigned to a row. The `>` operator increases the contribution and the `<` operator decreases it. See the example following this list.

- `( )`

  Parentheses group words into subexpressions. Parenthesized groups can be nested.

- `~`

  A leading tilde acts as a negation operator, causing the word's contribution to the row's relevance to be negative. This is useful for marking “noise” words. A row containing such a word is rated lower than others, but is not excluded altogether, as it would be with the `-` operator.

- `*`

  The asterisk serves as the truncation (or wildcard) operator. Unlike the other operators, it should be *appended* to the word to be affected. Words match if they begin with the word preceding the `*` operator.

If a word is specified with the truncation operator, it is not stripped from a boolean query, even if it is too short (as determined from the `ft_min_word_len` setting) or a stopword. This occurs because the word is not seen as too short or a stopword, but as a prefix that must be present in the document in the form of a word that begins with the prefix. Suppose that `ft_min_word_len=4`. Then a search for `'+word +the*'` will likely return fewer rows than a search for `'+word +the'`:

- The former query remains as is and requires both *`word`* and `the*` (a word starting with `the`) to be present in the document.
- The latter query is transformed to `+word` (requiring only *`word`* to be present). `the` is both too short and a stopword, and either condition is enough to cause it to be ignored.

- `"`

  A phrase that is enclosed within double quote (`"`) characters matches only rows that contain the phrase *literally, as it was typed*. The full-text engine splits the phrase into words and performs a search in the `FULLTEXT` index for the words. Nonword characters need not be matched exactly: Phrase searching requires only that matches contain exactly the same words as the phrase and in the same order. For example, `"test phrase"` matches `"test, phrase"`.

  If the phrase contains no words that are in the index, the result is empty. For example, if all words are either stopwords or shorter than the minimum length of indexed words, the result is empty.

The following examples demonstrate some search strings that use boolean full-text operators:

- `'apple banana'`

  Find rows that contain at least one of the two words.

- `'+apple +juice'`

  Find rows that contain both words.

- `'+apple macintosh'`

  Find rows that contain the word “apple”, but rank rows higher if they also contain “macintosh”.

- `'+apple -macintosh'`

  Find rows that contain the word “apple” but not “macintosh”.

- `'+apple ~macintosh'`

  Find rows that contain the word “apple”, but if the row also contains the word “macintosh”, rate it lower than if row does not. This is “softer” than a search for `'+apple -macintosh'`, for which the presence of “macintosh” causes the row not to be returned at all.

- `'+apple +(>turnover <strudel)'`

  Find rows that contain the words “apple” and “turnover”, or “apple” and “strudel” (in any order), but rank “apple turnover” higher than “apple strudel”.

- `'apple*'`

  Find rows that contain words such as “apple”, “apples”, “applesauce”, or “applet”.

- `'"some words"'`

  Find rows that contain the exact phrase “some words” (for example, rows that contain “some words of wisdom” but not “some noise words”). Note that the `"` characters that enclose the phrase are operator characters that delimit the phrase. They are not the quotation marks that enclose the search string itself.

12.9.3 Full-Text Searches with Query Expansion

Full-text search supports query expansion (and in particular, its variant “blind query expansion”). This is generally useful when a search phrase is too short, which often means that the user is relying on implied knowledge that the full-text search engine lacks. For example, a user searching for “database” may really mean that “MySQL”, “Oracle”, “DB2”, and “RDBMS” all are phrases that should match “databases” and should be returned, too. This is implied knowledge.

Blind query expansion (also known as automatic relevance feedback) is enabled by adding `WITH QUERY EXPANSION` or `IN NATURAL LANGUAGE MODE WITH QUERY EXPANSION` following the search phrase. It works by performing the search twice, where the search phrase for the second search is the original search phrase concatenated with the few most highly relevant documents from the first search. Thus, if one of these documents contains the word “databases” and the word “MySQL”, the second search finds the documents that contain the word “MySQL” even if they do not contain the word “database”. The following example shows this difference:

```
mysql> SELECT * FROM articles
    -> WHERE MATCH (title,body)
    -> AGAINST ('database' IN NATURAL LANGUAGE MODE);
+----+-------------------+---------------------------------------+
| id | title             | body                                  |
+----+-------------------+---------------------------------------+
|  5 | MySQL vs. YourSQL | In the following database comparison ... |
|  1 | MySQL Tutorial    | DBMS stands for DataBase ...          |
+----+-------------------+---------------------------------------+
2 rows in set (0.00 sec)

mysql> SELECT * FROM articles
    -> WHERE MATCH (title,body)
    -> AGAINST ('database' WITH QUERY EXPANSION);
+----+-------------------+---------------------------------------+
| id | title             | body                                  |
+----+-------------------+---------------------------------------+
|  1 | MySQL Tutorial    | DBMS stands for DataBase ...          |
|  5 | MySQL vs. YourSQL | In the following database comparison ... |
|  3 | Optimizing MySQL  | In this tutorial we will show ...     |
+----+-------------------+---------------------------------------+
3 rows in set (0.00 sec)
```

Another example could be searching for books by Georges Simenon about Maigret, when a user is not sure how to spell “Maigret”. A search for “Megre and the reluctant witnesses” finds only “Maigret and the Reluctant Witnesses” without query expansion. A search with query expansion finds all books with the word “Maigret” on the second pass.

Note

Because blind query expansion tends to increase noise significantly by returning nonrelevant documents, it is meaningful to use only when a search phrase is rather short.

12.9.4 Full-Text Stopwords

The stopword list is loaded and searched for full-text queries using the server character set and collation (the values of the `character_set_server` and `collation_server` system variables). False hits or misses may occur for stopword lookups if the stopword file or columns used for full-text indexing or searches have a character set or collation different from `character_set_server` or `collation_server`.

Case sensitivity of stopword lookups depends on the server collation. For example, lookups are case insensitive if the collation is `latin1_swedish_ci`, whereas lookups are case sensitive if the collation is `latin1_general_cs` or `latin1_bin`.

The stopword file is loaded and searched using `latin1` if `character_set_server` is `ucs2`, `utf16`, or `utf32`.

The following table shows the default list of full-text stopwords. In a MySQL source distribution, you can find this list in the `storage/myisam/ft_static.c` file.

a's	able	about	above	according
accordingly	across	actually	after	afterwards
again	against	ain't	all	allow
allows	almost	alone	along	already
also	although	always	am	among
amongst	an	and	another	any
anybody	anyhow	anyone	anything	anyway
anyways	anywhere	apart	appear	appreciate
appropriate	are	aren't	around	as
aside	ask	asking	associated	at
available	away	awfully	be	became
because	become	becomes	becoming	been
before	beforehand	behind	being	believe
below	beside	besides	best	better
between	beyond	both	brief	but
by	c'mon	c's	came	can
can't	cannot	cant	cause	causes
certain	certainly	changes	clearly	co
com	come	comes	concerning	consequently
consider	considering	contain	containing	contains
corresponding	could	couldn't	course	currently
definitely	described	despite	did	didn't
different	do	does	doesn't	doing
don't	done	down	downwards	during
each	edu	eg	eight	either
else	elsewhere	enough	entirely	especially
et	etc	even	ever	every
everybody	everyone	everything	everywhere	ex
exactly	example	except	far	few
fifth	first	five	followed	following
follows	for	former	formerly	forth
four	from	further	furthermore	get
gets	getting	given	gives	go
goes	going	gone	got	gotten
greetings	had	hadn't	happens	hardly
has	hasn't	have	haven't	having
he	he's	hello	help	hence
her	here	here's	hereafter	hereby
herein	hereupon	hers	herself	hi
him	himself	his	hither	hopefully

how	howbeit	however	i'd	i'll
i'm	i've	ie	if	ignored
immediate	in	inasmuch	inc	indeed
indicate	indicated	indicates	inner	insofar
instead	into	inward	is	isn't
it	it'd	it'll	it's	its
itself	just	keep	keeps	kept
know	known	knows	last	lately
later	latter	latterly	least	less
lest	let	let's	like	liked
likely	little	look	looking	looks
ltd	mainly	many	may	maybe
me	mean	meanwhile	merely	might
more	moreover	most	mostly	much
must	my	myself	name	namely
nd	near	nearly	necessary	need
needs	neither	never	nevertheless	new
next	nine	no	nobody	non
none	noone	nor	normally	not
nothing	novel	now	nowhere	obviously
of	off	often	oh	ok
okay	old	on	once	one
ones	only	onto	or	other
others	otherwise	ought	our	ours
ourselves	out	outside	over	overall
own	particular	particularly	per	perhaps
placed	please	plus	possible	presumably
probably	provides	que	quite	qv
rather	rd	re	really	reasonably
regarding	regardless	regards	relatively	respectively
right	said	same	saw	say
saying	says	second	secondly	see
seeing	seem	seemed	seeming	seems
seen	self	selves	sensible	sent
serious	seriously	seven	several	shall
she	should	shouldn't	since	six
so	some	somebody	somehow	someone
something	sometime	sometimes	somewhat	somewhere
soon	sorry	specified	specify	specifying
still	sub	such	sup	sure
t's	take	taken	tell	tends
th	than	thank	thanks	thanx

that	that's	thats	the	their
theirs	them	themselves	then	thence
there	there's	thereafter	thereby	therefore
therein	theres	thereupon	these	they
they'd	they'll	they're	they've	think
third	this	thorough	thoroughly	those
though	three	through	throughout	thru
thus	to	together	too	took
toward	towards	tried	tries	truly
try	trying	twice	two	un
under	unfortunately	unless	unlikely	until
unto	up	upon	us	use
used	useful	uses	using	usually
value	various	very	via	viz
vs	want	wants	was	wasn't
way	we	we'd	we'll	we're
we've	welcome	well	went	were
weren't	what	what's	whatever	when
whence	whenever	where	where's	whereafter
whereas	whereby	wherein	whereupon	wherever
whether	which	while	whither	who
who's	whoever	whole	whom	whose
why	will	willing	wish	with
within	without	won't	wonder	would
wouldn't	yes	yet	you	you'd
you'll	you're	you've	your	yours
yourself	yourselves	zero		

12.9.5 Full-Text Restrictions

- Full-text searches are supported for `MyISAM` tables only. (In MySQL 5.6 and up, they can also be used with `InnoDB` tables.)
- Full-text searches are not supported for partitioned tables. See Section 19.5, “Restrictions and Limitations on Partitioning”.
- Full-text searches can be used with most multibyte character sets. The exception is that for Unicode, the `utf8` character set can be used, but not the `ucs2` character set. However, although `FULLTEXT` indexes on `ucs2` columns cannot be used, you can perform `IN BOOLEAN MODE` searches on a `ucs2` column that has no such index.

  The remarks for `utf8` also apply to `utf8mb4`, and the remarks for `ucs2` also apply to `utf16` and `utf32`.
- Ideographic languages such as Chinese and Japanese do not have word delimiters. Therefore, the `FULLTEXT` parser *cannot determine where words begin and end in these and other such languages*. The implications of this and some workarounds for the problem are described in Section 12.9, “Full-Text Search Functions”.

- Although the use of multiple character sets within a single table is supported, all columns in a `FULLTEXT` index must use the same character set and collation.
- The `MATCH()` column list must match exactly the column list in some `FULLTEXT` index definition for the table, unless this `MATCH()` is `IN BOOLEAN MODE`. Boolean-mode searches can be done on nonindexed columns, although they are likely to be slow.
- The argument to `AGAINST()` must be a string value that is constant during query evaluation. This rules out, for example, a table column because that can differ for each row.
- Index hints are more limited for `FULLTEXT` searches than for non-`FULLTEXT` searches. See Section 8.9.3, “Index Hints”.
- The '%' character is not a supported wildcard character for full-text searches.

12.9.6 Fine-Tuning MySQL Full-Text Search

MySQL's full-text search capability has few user-tunable parameters. You can exert more control over full-text searching behavior if you have a MySQL source distribution because some changes require source code modifications. See Section 2.9, “Installing MySQL from Source”.

Full-text search is carefully tuned for the most effectiveness. Modifying the default behavior in most cases can actually decrease effectiveness. *Do not alter the MySQL sources unless you know what you are doing*.

Most full-text variables described in this section must be set at server startup time. A server restart is required to change them; they cannot be modified while the server is running.

Some variable changes require that you rebuild the `FULLTEXT` indexes in your tables. Instructions for doing so are given later in this section.

- The minimum and maximum lengths of words to be indexed are defined by the `ft_min_word_len` and `ft_max_word_len` system variables. (See Section 5.1.5, “Server System Variables”.) The default minimum value is four characters; the default maximum is version dependent. If you change either value, you must rebuild your `FULLTEXT` indexes. For example, if you want three-character words to be searchable, you can set the `ft_min_word_len` variable by putting the following lines in an option file:

  ```
  [mysqld]
  ft_min_word_len=3
  ```

  Then restart the server and rebuild your `FULLTEXT` indexes. Note particularly the remarks regarding `myisamchk` in the instructions following this list.

- To override the default stopword list, set the `ft_stopword_file` system variable. (See Section 5.1.5, “Server System Variables”.) The variable value should be the path name of the file containing the stopword list, or the empty string to disable stopword filtering. The server looks for the file in the data directory unless an absolute path name is given to specify a different directory. After changing the value of this variable or the contents of the stopword file, restart the server and rebuild your `FULLTEXT` indexes.

  The stopword list is free-form. That is, you may use any nonalphanumeric character such as newline, space, or comma to separate stopwords. Exceptions are the underscore character (_) and a single apostrophe (') which are treated as part of a word. The character set of the stopword list is the server's default character set; see Section 10.1.3.2, “Server Character Set and Collation”.

- The 50% threshold for natural language searches is determined by the particular weighting scheme chosen. To disable it, look for the following line in `storage/myisam/ftdefs.h`:

  ```
  ```

```
#define GWS_IN_USE GWS_PROB
```

Change that line to this:

```
#define GWS_IN_USE GWS_FREQ
```

Then recompile MySQL. There is no need to rebuild the indexes in this case.

Note

By making this change, you *severely* decrease MySQL's ability to provide adequate relevance values for the `MATCH()` function. If you really need to search for such common words, it would be better to search using `IN BOOLEAN MODE` instead, which does not observe the 50% threshold.

- To change the operators used for boolean full-text searches, set the `ft_boolean_syntax` system variable. This variable can be changed while the server is running, but you must have the `SUPER` privilege to do so. No rebuilding of indexes is necessary in this case. See Section 5.1.5, “Server System Variables”, which describes the rules governing how to set this variable.

- If you want to change the set of characters that are considered word characters, you can do so in several ways, as described in the following list. After making the modification, you must rebuild the indexes for each table that contains any `FULLTEXT` indexes. Suppose that you want to treat the hyphen character ('-') as a word character. Use one of these methods:

  - Modify the MySQL source: In `storage/myisam/ftdefs.h`, see the `true_word_char()` and `misc_word_char()` macros. Add `'-'` to one of those macros and recompile MySQL.

  - Modify a character set file: This requires no recompilation. The `true_word_char()` macro uses a “character type” table to distinguish letters and numbers from other characters. . You can edit the contents of the `<ctype><map>` array in one of the character set XML files to specify that `'-'` is a “letter.” Then use the given character set for your `FULLTEXT` indexes. For information about the `<ctype><map>` array format, see Section 10.3.1, “Character Definition Arrays”.

  - Add a new collation for the character set used by the indexed columns, and alter the columns to use that collation. For general information about adding collations, see Section 10.4, “Adding a Collation to a Character Set”. For an example specific to full-text indexing, see Section 12.9.7, “Adding a Collation for Full-Text Indexing”.

If you modify full-text variables that affect indexing (`ft_min_word_len`, `ft_max_word_len`, or `ft_stopword_file`), or if you change the stopword file itself, you must rebuild your `FULLTEXT` indexes after making the changes and restarting the server. To rebuild the indexes in this case, it is sufficient to do a `QUICK` repair operation:

```
mysql> REPAIR TABLE tbl_name QUICK;
```

Alternatively, use `ALTER TABLE` with the `DROP INDEX` and `ADD INDEX` options to drop and re-create each `FULLTEXT` index. In some cases, this may be faster than a repair operation.

Each table that contains any `FULLTEXT` index must be repaired as just shown. Otherwise, queries for the table may yield incorrect results, and modifications to the table will cause the server to see the table as corrupt and in need of repair.

If you use `myisamchk` to perform an operation that modifies table indexes (such as repair or analyze), the `FULLTEXT` indexes are rebuilt using the *default* full-text parameter values for minimum word length, maximum word length, and stopword file unless you specify otherwise. This can result in queries failing.

The problem occurs because these parameters are known only by the server. They are not stored in `MyISAM` index files. To avoid the problem if you have modified the minimum or maximum word length

or stopword file values used by the server, specify the same `ft_min_word_len`, `ft_max_word_len`, and `ft_stopword_file` values for `myisamchk` that you use for `mysqld`. For example, if you have set the minimum word length to 3, you can repair a table with `myisamchk` like this:

```
shell> myisamchk --recover --ft_min_word_len=3 tbl_name.MYI
```

To ensure that `myisamchk` and the server use the same values for full-text parameters, place each one in both the `[mysqld]` and `[myisamchk]` sections of an option file:

```
[mysqld]
ft_min_word_len=3

[myisamchk]
ft_min_word_len=3
```

An alternative to using `myisamchk` for index modification is to use the `REPAIR TABLE`, `ANALYZE TABLE`, `OPTIMIZE TABLE`, or `ALTER TABLE` statements. These statements are performed by the server, which knows the proper full-text parameter values to use.

12.9.7 Adding a Collation for Full-Text Indexing

This section describes how to add a new collation for full-text searches. The sample collation is like `latin1_swedish_ci` but treats the `'-'` character as a letter rather than as a punctuation character so that it can be indexed as a word character. General information about adding collations is given in Section 10.4, “Adding a Collation to a Character Set”; it is assumed that you have read it and are familiar with the files involved.

To add a collation for full-text indexing, use the following procedure. The instructions here add a collation for a simple character set, which as discussed in Section 10.4, “Adding a Collation to a Character Set”, can be created using a configuration file that describes the character set properties. For a complex character set such as Unicode, create collations using C source files that describe the character set properties.

1. Add a collation to the `Index.xml` file. The collation ID must be unused, so choose a value different from 62 if that ID is already taken on your system.

   ```
   <charset name="latin1">
   ...
   <collation name="latin1_fulltext_ci" id="62"/>
   </charset>
   ```

2. Declare the sort order for the collation in the `latin1.xml` file. In this case, the order can be copied from `latin1_swedish_ci`:

   ```
   <collation name="latin1_fulltext_ci">
   <map>
   00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
   10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F
   20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F
   30 31 32 33 34 35 36 37 38 39 3A 3B 3C 3D 3E 3F
   40 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
   50 51 52 53 54 55 56 57 58 59 5A 5B 5C 5D 5E 5F
   60 41 42 43 44 45 46 47 48 49 4A 4B 4C 4D 4E 4F
   50 51 52 53 54 55 56 57 58 59 5A 7B 7C 7D 7E 7F
   80 81 82 83 84 85 86 87 88 89 8A 8B 8C 8D 8E 8F
   90 91 92 93 94 95 96 97 98 99 9A 9B 9C 9D 9E 9F
   A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 AA AB AC AD AE AF
   B0 B1 B2 B3 B4 B5 B6 B7 B8 B9 BA BB BC BD BE BF
   41 41 41 41 5C 5B 5C 43 45 45 45 45 49 49 49 49
   44 4E 4F 4F 4F 4F 5D D7 D8 55 55 55 59 59 DE DF
   41 41 41 41 5C 5B 5C 43 45 45 45 45 49 49 49 49
   ```

```
44 4E 4F 4F 4F 4F 5D F7 D8 55 55 55 59 59 DE FF
</map>
</collation>
```

3. Modify the `ctype` array in `latin1.xml`. Change the value corresponding to 0x2D (which is the code for the `'-'` character) from 10 (punctuation) to 01 (small letter). In the following array, this is the element in the fourth row down, third value from the end.

```
<ctype>
<map>
00
20 20 20 20 20 20 20 20 20 28 28 28 28 28 20 20
20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20
48 10 10 10 10 10 10 10 10 10 10 10 10 01 10 10
84 84 84 84 84 84 84 84 84 10 10 10 10 10 10 10
10 81 81 81 81 81 81 01 01 01 01 01 01 01 01 01
01 01 01 01 01 01 01 01 01 01 10 10 10 10 10 10
10 82 82 82 82 82 82 02 02 02 02 02 02 02 02 02
02 02 02 02 02 02 02 02 02 02 10 10 10 10 20 20
10 00 10 02 10 10 10 10 10 10 01 10 01 00 01 00
00 10 10 10 10 10 10 10 10 10 02 10 02 00 02 01
48 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01
01 01 01 01 01 01 01 10 01 01 01 01 01 01 01 02
02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02
02 02 02 02 02 02 02 10 02 02 02 02 02 02 02 02
</map>
</ctype>
```

4. Restart the server.

5. To employ the new collation, include it in the definition of columns that are to use it:

```
mysql> DROP TABLE IF EXISTS t1;
Query OK, 0 rows affected (0.13 sec)

mysql> CREATE TABLE t1 (
    -> a TEXT CHARACTER SET latin1 COLLATE latin1_fulltext_ci,
    -> FULLTEXT INDEX(a)
    -> ) ENGINE=MyISAM;
Query OK, 0 rows affected (0.47 sec)
```

6. Test the collation to verify that hyphen is considered as a word character:

```
mysql> INSERT INTO t1 VALUEs ('----'),('....'),('abcd');
Query OK, 3 rows affected (0.22 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM t1 WHERE MATCH a AGAINST ('----' IN BOOLEAN MODE);
+------+
| a    |
+------+
| ---- |
+------+
1 row in set (0.00 sec)
```

12.10 Cast Functions and Operators

Table 12.14 Cast Functions and Operators

Name	Description
`BINARY`	Cast a string to a binary string
`CAST()`	Cast a value as a certain type

Name	Description
CONVERT()	Cast a value as a certain type

Cast functions and operators enable conversion of values from one data type to another.

CONVERT() with a USING clause provides a way to convert data between different character sets:

```
CONVERT(expr USING transcoding_name)
```

In MySQL, transcoding names are the same as the corresponding character set names.

Examples:

```
SELECT CONVERT(_latin1'Müller' USING utf8);
INSERT INTO utf8_table (utf8_column)
    SELECT CONVERT(latin1_column USING utf8) FROM latin1_table;
```

You can also use CONVERT() without USING or CAST() to convert strings between different character sets:

```
CONVERT(string, CHAR[(N)] CHARACTER SET charset_name)
CAST(string AS CHAR[(N)] CHARACTER SET charset_name)
```

Examples:

```
SELECT CONVERT('test', CHAR CHARACTER SET utf8);
SELECT CAST('test' AS CHAR CHARACTER SET utf8);
```

If you specify CHARACTER SET *charset_name* as just shown, the resulting character set and collation are *charset_name* and the default collation of *charset_name*. If you omit CHARACTER SET *charset_name*, the resulting character set and collation are defined by the character_set_connection and collation_connection system variables that determine the default connection character set and collation (see Section 10.1.4, “Connection Character Sets and Collations”).

A COLLATE clause is not permitted within a CONVERT() or CAST() call, but you can apply it to the function result. For example, this is legal:

```
SELECT CAST('test' AS CHAR CHARACTER SET utf8) COLLATE utf8_bin;
```

But this is illegal:

```
SELECT CAST('test' AS CHAR CHARACTER SET utf8 COLLATE utf8_bin);
```

Normally, you cannot compare a BLOB value or other binary string in case-insensitive fashion because binary strings use the binary character set, which has no collation with the concept of lettercase. To perform a case-insensitive comparison, use the CONVERT() or CAST() function to convert the value to a nonbinary string. Comparisons of the resulting string use its collation. For example, if the conversion result character set has a case-insensitive collation, a LIKE operation is not case sensitive:

```
SELECT 'A' LIKE CONVERT(blob_col USING latin1)
  FROM tbl_name;
```

To use a different character set, substitute its name for latin1 in the preceding statement. To specify a particular collation for the converted string, use a COLLATE clause following the CONVERT() call:

```
SELECT 'A' LIKE CONVERT(blob_col USING latin1) COLLATE latin1_german1_ci
  FROM tbl_name;
```

`CONVERT()` and `CAST()` can be used more generally for comparing strings that are represented in different character sets. For example, a comparison of these strings results in an error because they have different character sets:

```
mysql> SET @s1 = _latin1 'abc', @s2 = _latin2 'abc';
mysql> SELECT @s1 = @s2;
ERROR 1267 (HY000): Illegal mix of collations (latin1_swedish_ci,IMPLICIT)
and (latin2_general_ci,IMPLICIT) for operation '='
```

Converting one of the strings to a character set compatible with the other enables the comparison to occur without error:

```
mysql> SELECT @s1 = CONVERT(@s2 USING latin1);
+--------------------------------+
| @s1 = CONVERT(@s2 USING latin1) |
+--------------------------------+
|                              1 |
+--------------------------------+
```

For string literals, another way to specify the character set is to use a character set introducer (`_latin1` and `_latin2` in the preceding example are instances of introducers). Unlike conversion functions such as `CAST()`, or `CONVERT()`, which convert a string from one character set to another, an introducer designates a string literal as having a particular character set, with no conversion involved. For more information, see Section 10.1.3.8, “Character Set Introducers”.

Character set conversion is also useful preceding lettercase conversion of binary strings. `LOWER()` and `UPPER()` are ineffective when applied directly to binary strings because the concept of lettercase does not apply. To perform lettercase conversion of a binary string, first convert it to a nonbinary string:

```
mysql> SET @str = BINARY 'New York';
mysql> SELECT LOWER(@str), LOWER(CONVERT(@str USING latin1));
+-------------+-----------------------------------+
| LOWER(@str) | LOWER(CONVERT(@str USING latin1)) |
+-------------+-----------------------------------+
| New York    | new york                          |
+-------------+-----------------------------------+
```

If you convert an indexed column using `BINARY`, `CAST()`, or `CONVERT()`, MySQL may not be able to use the index efficiently.

The cast functions are useful for creating a column with a specific type in a `CREATE TABLE ... SELECT` statement:

```
mysql> CREATE TABLE new_table SELECT CAST('2000-01-01' AS DATE) AS c1;
mysql> SHOW CREATE TABLE new_table\G
*************************** 1. row ***************************
       Table: new_table
Create Table: CREATE TABLE `new_table` (
  `c1` date DEFAULT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1
```

The cast functions are useful for sorting `ENUM` columns in lexical order. Normally, sorting of `ENUM` columns occurs using the internal numeric values. Casting the values to `CHAR` results in a lexical sort:

```
SELECT enum_col FROM tbl_name ORDER BY CAST(enum_col AS CHAR);
```

`CAST()` also changes the result if you use it as part of a more complex expression such as `CONCAT('Date: ',CAST(NOW() AS DATE))`.

For temporal values, there is little need to use `CAST()` to extract data in different formats. Instead, use a function such as `EXTRACT()`, `DATE_FORMAT()`, or `TIME_FORMAT()`. See Section 12.7, “Date and Time Functions”.

To cast a string to a number, you normally need do nothing other than use the string value in numeric context:

```
mysql> SELECT 1+'1';
       -> 2
```

That is also true for hexadecimal and bit literals, which are binary strings by default:

```
mysql> SELECT X'41', X'41'+0;
        -> 'A', 65
mysql> SELECT b'1100001', b'1100001'+0;
        -> 'a', 97
```

A string used in an arithmetic operation is converted to a floating-point number during expression evaluation.

A number used in string context is converted to a string:

```
mysql> SELECT CONCAT('hello you ',2);
        -> 'hello you 2'
```

For information about implicit conversion of numbers to strings, see Section 12.2, “Type Conversion in Expression Evaluation”.

When using an explicit `CAST()` on a `TIMESTAMP` value in a statement that does not select from any tables, the value is treated by MySQL as a string prior to performing any conversion. This results in the value being truncated when casting to a numeric type, as shown here:

```
mysql> SELECT CAST(TIMESTAMP '2014-09-08 18:07:54' AS SIGNED);
+-----------------------------------------------+
| CAST(TIMESTAMP '2014-09-08 18:07:54' AS SIGNED) |
+-----------------------------------------------+
|                                          2014 |
+-----------------------------------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+-------------------------------------------------------------+
| Level   | Code | Message                                                     |
+---------+------+-------------------------------------------------------------+
| Warning | 1292 | Truncated incorrect INTEGER value: '2014-09-08 18:07:54' |
+---------+------+-------------------------------------------------------------+
1 row in set (0.00 sec)
```

This does not apply when selecting rows from a table, as shown here:

```
mysql> USE test;

Database changed
mysql> CREATE TABLE c_test (col TIMESTAMP);
Query OK, 0 rows affected (0.07 sec)

mysql> INSERT INTO c_test VALUES ('2014-09-08 18:07:54');
Query OK, 1 row affected (0.05 sec)

mysql> SELECT col, CAST(col AS UNSIGNED) AS c_col FROM c_test;
+---------------------+----------------+
| col                 | c_col          |
+---------------------+----------------+
| 2014-09-08 18:07:54 | 20140908180754 |
+---------------------+----------------+
1 row in set (0.00 sec)
```

This is a known issue which is resolved in MySQL 5.6.

MySQL supports arithmetic with both signed and unsigned 64-bit values. For numeric operators (such as + or -) where one of the operands is an unsigned integer, the result is unsigned by default (see Section 12.6.1, “Arithmetic Operators”). To override this, use the SIGNED or UNSIGNED cast operator to cast a value to a signed or unsigned 64-bit integer, respectively.

```
mysql> SELECT 1 - 2;
        -> -1
mysql> SELECT CAST(1 - 2 AS UNSIGNED);
        -> 18446744073709551615
mysql> SELECT CAST(CAST(1 - 2 AS UNSIGNED) AS SIGNED);
        -> -1
```

If either operand is a floating-point value, the result is a floating-point value and is not affected by the preceding rule. (In this context, DECIMAL column values are regarded as floating-point values.)

```
mysql> SELECT CAST(1 AS UNSIGNED) - 2.0;
        -> -1.0
```

The SQL mode affects the result of conversion operations (see Section 5.1.8, “Server SQL Modes”). Examples:

- For conversion of a “zero” date string to a date, CONVERT() and CAST() return NULL and produce a warning when the NO_ZERO_DATE SQL mode is enabled.
- For integer subtraction, if the NO_UNSIGNED_SUBTRACTION SQL mode is enabled, the subtraction result is signed even if any operand is unsigned.

The following list describes the available cast functions and operators:

- BINARY *expr*

  The BINARY operator converts the expression to a binary string. A common use for BINARY is to force a character string comparison to be done byte by byte rather than character by character, in effect becoming case sensitive. The BINARY operator also causes trailing spaces in comparisons to be significant.

  ```
  mysql> SELECT 'a' = 'A';
          -> 1
  mysql> SELECT BINARY 'a' = 'A';
          -> 0
  mysql> SELECT 'a' = 'a ';
          -> 1
  mysql> SELECT BINARY 'a' = 'a ';
          -> 0
  ```

  In a comparison, BINARY affects the entire operation; it can be given before either operand with the same result.

  For purposes of converting a string expression to a binary string, these constructs are equivalent:

  ```
  BINARY expr
  CAST(expr AS BINARY)
  CONVERT(expr USING BINARY)
  ```

  If a value is a string literal, it can be designated as a binary string without performing any conversion by using the _binary character set introducer:

  ```
  mysql> SELECT 'a' = 'A';
          -> 1
  mysql> SELECT _binary 'a' = 'A';
          -> 0
  ```

For information about introducers, see Section 10.1.3.8, “Character Set Introducers”.

The BINARY operator in expressions differs in effect from the BINARY attribute in character column definitions. A character column defined with the BINARY attribute is assigned table default character set and the binary (_bin) collation of that character set. Every nonbinary character set has a _bin collation. For example, the binary collation for the utf8 character set is utf8_bin, so if the table default character set is utf8, these two column definitions are equivalent:

```
CHAR(10) BINARY
CHAR(10) CHARACTER SET utf8 COLLATE utf8_bin
```

The use of CHARACTER SET binary in the definition of a CHAR, VARCHAR, or TEXT column causes the column to be treated as the corresponding binary string data type. For example, the following pairs of definitions are equivalent:

```
CHAR(10) CHARACTER SET binary
BINARY(10)

VARCHAR(10) CHARACTER SET binary
VARBINARY(10)

TEXT CHARACTER SET binary
BLOB
```

- CAST(*expr* AS *type*)

  The CAST() function takes an expression of any type and produces a result value of the specified type, similar to CONVERT(). For more information, see the description of CONVERT().

  CAST() is standard SQL syntax.

- CONVERT(*expr*,*type*), CONVERT(*expr* USING *transcoding_name*)

  The CONVERT() function takes an expression of any type and produces a result value of the specified type.

  Discussion of CONVERT(*expr*, *type*) syntax here also applies to CAST(*expr* AS *type*), which is equivalent.

  CONVERT(... USING ...) is standard SQL syntax. The non-USING form of CONVERT() is ODBC syntax.

  CONVERT() with USING converts data between different character sets. In MySQL, transcoding names are the same as the corresponding character set names. For example, this statement converts the string 'abc' in the default character set to the corresponding string in the utf8 character set:

  ```
  SELECT CONVERT('abc' USING utf8);
  ```

  CONVERT() without USING and CAST() take an expression and a *type* value specifying the result type. These *type* values are permitted:

  - BINARY[(*N*)]

    Produces a string with the BINARY data type. See Section 11.4.2, “The BINARY and VARBINARY Types” for a description of how this affects comparisons. If the optional length *N* is given, BINARY(*N*) causes the cast to use no more than *N* bytes of the argument. Values shorter than *N* bytes are padded with 0x00 bytes to a length of *N*.

  - CHAR[(*N*)] [*charset_info*]

Produces a string with the `CHAR` data type. If the optional length *`N`* is given, `CHAR(N)` causes the cast to use no more than *`N`* characters of the argument. No padding occurs for values shorter than *`N`* characters.

With no *`charset_info`* clause, `CHAR` produces a string with the default character set. To specify the character set explicitly, these *`charset_info`* values are permitted:

- `CHARACTER SET charset_name`: Produces a string with the given character set.
- `ASCII`: Shorthand for `CHARACTER SET latin1`.
- `UNICODE`: Shorthand for `CHARACTER SET ucs2`.

In all cases, the string has the default collation for the character set.

- `DATE`

  Produces a `DATE` value.

- `DATETIME`

  Produces a `DATETIME` value.

- `DECIMAL[(M[,D])]`

  Produces a `DECIMAL` value. If the optional *`M`* and *`D`* values are given, they specify the maximum number of digits (the precision) and the number of digits following the decimal point (the scale).

- `NCHAR[(N)]`

  Like `CHAR`, but produces a string with the national character set. See Section 10.1.3.7, “The National Character Set”.

  Unlike `CHAR`, `NCHAR` does not permit trailing character set information to be specified.

- `SIGNED [INTEGER]`

  Produces a signed integer value.

- `TIME`

  Produces a `TIME` value.

- `UNSIGNED [INTEGER]`

  Produces an unsigned integer value.

12.11 XML Functions

Table 12.15 XML Functions

Name	Description
`ExtractValue()`	Extracts a value from an XML string using XPath notation
`UpdateXML()`	Return replaced XML fragment

This section discusses XML and related functionality in MySQL.

Note

It is possible to obtain XML-formatted output from MySQL in the `mysql` and `mysqldump` clients by invoking them with the `--xml` option. See Section 4.5.1,

> "`mysql` — The MySQL Command-Line Tool", and Section 4.5.4, "`mysqldump` — A Database Backup Program".

Two functions providing basic XPath 1.0 (XML Path Language, version 1.0) capabilities are available. Some basic information about XPath syntax and usage is provided later in this section; however, an in-depth discussion of these topics is beyond the scope of this manual, and you should refer to the XML Path Language (XPath) 1.0 standard for definitive information. A useful resource for those new to XPath or who desire a refresher in the basics is the Zvon.org XPath Tutorial, which is available in several languages.

Note

These functions remain under development. We continue to improve these and other aspects of XML and XPath functionality in MySQL 5.5 and onwards. You may discuss these, ask questions about them, and obtain help from other users with them in the MySQL XML User Forum.

XPath expressions used with these functions support user variables and local stored program variables. User variables are weakly checked; variables local to stored programs are strongly checked (see also Bug #26518):

- **User variables (weak checking).** Variables using the syntax `$@variable_name` (that is, user variables) are not checked. No warnings or errors are issued by the server if a variable has the wrong type or has previously not been assigned a value. This also means the user is fully responsible for any typographical errors, since no warnings will be given if (for example) `$@myvariable` is used where `$@myvariable` was intended.

  Example:

```
mysql> SET @xml = '<a><b>X</b><b>Y</b></a>';
Query OK, 0 rows affected (0.00 sec)

mysql> SET @i =1, @j = 2;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @i, ExtractValue(@xml, '//b[$@i]');
+------+-------------------------------+
| @i   | ExtractValue(@xml, '//b[$@i]') |
+------+-------------------------------+
|    1 | X                             |
+------+-------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @j, ExtractValue(@xml, '//b[$@j]');
+------+-------------------------------+
| @j   | ExtractValue(@xml, '//b[$@j]') |
+------+-------------------------------+
|    2 | Y                             |
+------+-------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @k, ExtractValue(@xml, '//b[$@k]');
+------+-------------------------------+
| @k   | ExtractValue(@xml, '//b[$@k]') |
+------+-------------------------------+
| NULL |                               |
+------+-------------------------------+
1 row in set (0.00 sec)
```

- **Variables in stored programs (strong checking).** Variables using the syntax `$variable_name` can be declared and used with these functions when they are called inside stored programs. Such variables are local to the stored program in which they are defined, and are strongly checked for type and value.

  Example:

```
mysql> DELIMITER |

mysql> CREATE PROCEDURE myproc ()
    -> BEGIN
    ->   DECLARE i INT DEFAULT 1;
    ->   DECLARE xml VARCHAR(25) DEFAULT '<a>X</a><a>Y</a><a>Z</a>';
    ->
    ->   WHILE i < 4 DO
    ->     SELECT xml, i, ExtractValue(xml, '//a[$i]');
    ->     SET i = i+1;
    ->   END WHILE;
    -> END |
Query OK, 0 rows affected (0.01 sec)

mysql> DELIMITER ;

mysql> CALL myproc();
+-------------------------+---+-----------------------------+
| xml                     | i | ExtractValue(xml, '//a[$i]') |
+-------------------------+---+-----------------------------+
| <a>X</a><a>Y</a><a>Z</a> | 1 | X                           |
+-------------------------+---+-----------------------------+
1 row in set (0.00 sec)

+-------------------------+---+-----------------------------+
| xml                     | i | ExtractValue(xml, '//a[$i]') |
+-------------------------+---+-----------------------------+
| <a>X</a><a>Y</a><a>Z</a> | 2 | Y                           |
+-------------------------+---+-----------------------------+
1 row in set (0.01 sec)

+-------------------------+---+-----------------------------+
| xml                     | i | ExtractValue(xml, '//a[$i]') |
+-------------------------+---+-----------------------------+
| <a>X</a><a>Y</a><a>Z</a> | 3 | Z                           |
+-------------------------+---+-----------------------------+
1 row in set (0.01 sec)
```

Parameters. Variables used in XPath expressions inside stored routines that are passed in as parameters are also subject to strong checking.

Expressions containing user variables or variables local to stored programs must otherwise (except for notation) conform to the rules for XPath expressions containing variables as given in the XPath 1.0 specification.

Note

A user variable used to store an XPath expression is treated as an empty string. Because of this, it is not possible to store an XPath expression as a user variable. (Bug #32911)

- `ExtractValue(xml_frag, xpath_expr)`

  `ExtractValue()` takes two string arguments, a fragment of XML markup *`xml_frag`* and an XPath expression *`xpath_expr`* (also known as a *locator*); it returns the text (`CDATA`) of the first text node which is a child of the element or elements matched by the XPath expression. In MySQL 5.5, the XPath expression can contain at most 127 characters. (This limitation is lifted in MySQL 5.6.)

  Using this function is the equivalent of performing a match using the *`xpath_expr`* after appending `/text()`. In other words, `ExtractValue('<a><b>Sakila</b></a>', '/a/b')` and `ExtractValue('<a><b>Sakila</b></a>', '/a/b/text()')` produce the same result.

  If multiple matches are found, the content of the first child text node of each matching element is returned (in the order matched) as a single, space-delimited string.

If no matching text node is found for the expression (including the implicit `/text()`)—for whatever reason, as long as *`xpath_expr`* is valid, and *`xml_frag`* consists of elements which are properly nested and closed—an empty string is returned. No distinction is made between a match on an empty element and no match at all. This is by design.

If you need to determine whether no matching element was found in *`xml_frag`* or such an element was found but contained no child text nodes, you should test the result of an expression that uses the XPath `count()` function. For example, both of these statements return an empty string, as shown here:

```
mysql> SELECT ExtractValue('<a><b/></a>', '/a/b');
+-------------------------------------+
| ExtractValue('<a><b/></a>', '/a/b') |
+-------------------------------------+
|                                     |
+-------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue('<a><c/></a>', '/a/b');
+-------------------------------------+
| ExtractValue('<a><c/></a>', '/a/b') |
+-------------------------------------+
|                                     |
+-------------------------------------+
1 row in set (0.00 sec)
```

However, you can determine whether there was actually a matching element using the following:

```
mysql> SELECT ExtractValue('<a><b/></a>', 'count(/a/b)');
+-------------------------------------+
| ExtractValue('<a><b/></a>', 'count(/a/b)') |
+-------------------------------------+
| 1                                   |
+-------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue('<a><c/></a>', 'count(/a/b)');
+-------------------------------------+
| ExtractValue('<a><c/></a>', 'count(/a/b)') |
+-------------------------------------+
| 0                                   |
+-------------------------------------+
1 row in set (0.01 sec)
```

Important

`ExtractValue()` returns only `CDATA`, and does not return any tags that might be contained within a matching tag, nor any of their content (see the result returned as `val1` in the following example).

```
mysql> SELECT
    ->   ExtractValue('<a>ccc<b>ddd</b></a>', '/a') AS val1,
    ->   ExtractValue('<a>ccc<b>ddd</b></a>', '/a/b') AS val2,
    ->   ExtractValue('<a>ccc<b>ddd</b></a>', '//b') AS val3,
    ->   ExtractValue('<a>ccc<b>ddd</b></a>', '/b') AS val4,
    ->   ExtractValue('<a>ccc<b>ddd</b><b>eee</b></a>', '//b') AS val5;

+------+------+------+------+---------+
| val1 | val2 | val3 | val4 | val5    |
+------+------+------+------+---------+
| ccc  | ddd  | ddd  |      | ddd eee |
+------+------+------+------+---------+
```

This function uses the current SQL collation for making comparisons with `contains()`, performing the same collation aggregation as other string functions (such as `CONCAT()`), in taking into account the collation coercibility of their arguments; see Section 10.1.8.4, “Collation Coercibility in Expressions”, for an explanation of the rules governing this behavior.

(Previously, binary—that is, case-sensitive—comparison was always used.)

`NULL` is returned if *`xml_frag`* contains elements which are not properly nested or closed, and a warning is generated, as shown in this example:

```
mysql> SELECT ExtractValue('<a>c</a><b', '//a');
+-----------------------------------+
| ExtractValue('<a>c</a><b', '//a') |
+-----------------------------------+
| NULL                              |
+-----------------------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1525
Message: Incorrect XML value: 'parse error at line 1 pos 11:
         END-OF-INPUT unexpected ('>' wanted)'
1 row in set (0.00 sec)

mysql> SELECT ExtractValue('<a>c</a><b/>', '//a');
+-------------------------------------+
| ExtractValue('<a>c</a><b/>', '//a') |
+-------------------------------------+
| c                                   |
+-------------------------------------+
1 row in set (0.00 sec)
```

- `UpdateXML(`*`xml_target`*`, `*`xpath_expr`*`, `*`new_xml`*`)`

  This function replaces a single portion of a given fragment of XML markup *`xml_target`* with a new XML fragment *`new_xml`*, and then returns the changed XML. The portion of *`xml_target`* that is replaced matches an XPath expression *`xpath_expr`* supplied by the user. In MySQL 5.5, the XPath expression can contain at most 127 characters. (This limitation is lifted in MySQL 5.6.)

  If no expression matching *`xpath_expr`* is found, or if multiple matches are found, the function returns the original *`xml_target`* XML fragment. All three arguments should be strings.

```
mysql> SELECT
    ->   UpdateXML('<a><b>ccc</b><d></d></a>', '/a', '<e>fff</e>') AS val1,
    ->   UpdateXML('<a><b>ccc</b><d></d></a>', '/b', '<e>fff</e>') AS val2,
    ->   UpdateXML('<a><b>ccc</b><d></d></a>', '//b', '<e>fff</e>') AS val3,
    ->   UpdateXML('<a><b>ccc</b><d></d></a>', '/a/d', '<e>fff</e>') AS val4,
    ->   UpdateXML('<a><d></d><b>ccc</b><d></d></a>', '/a/d', '<e>fff</e>') AS val5
    -> \G

*************************** 1. row ***************************
val1: <e>fff</e>
val2: <a><b>ccc</b><d></d></a>
val3: <a><e>fff</e><d></d></a>
val4: <a><b>ccc</b><e>fff</e></a>
val5: <a><d></d><b>ccc</b><d></d></a>
```

Note

A discussion in depth of XPath syntax and usage are beyond the scope of this manual. Please see the XML Path Language (XPath) 1.0 specification for definitive information. A useful resource for those new to XPath or who

are wishing a refresher in the basics is the Zvon.org XPath Tutorial, which is available in several languages.

Descriptions and examples of some basic XPath expressions follow:

- */tag*

  Matches *<tag/>* if and only if *<tag/>* is the root element.

  Example: */a* has a match in *<a>* because it matches the outermost (root) tag. It does not match the inner *a* element in *<a/>* because in this instance it is the child of another element.

- */tag1/tag2*

  Matches *<tag2/>* if and only if it is a child of *<tag1/>*, and *<tag1/>* is the root element.

  Example: */a/b* matches the *b* element in the XML fragment *<a>* because it is a child of the root element *a*. It does not have a match in *<a/>* because in this case, *b* is the root element (and hence the child of no other element). Nor does the XPath expression have a match in *<a><c></c>*; here, *b* is a descendant of *a*, but not actually a child of *a*.

  This construct is extendable to three or more elements. For example, the XPath expression */a/b/c* matches the *c* element in the fragment *<a><c/>*.

- *//tag*

  Matches any instance of *<tag>*.

  Example: *//a* matches the *a* element in any of the following: *<a><c/>*; *<c><a>*; *<c><a/></c>*.

  // can be combined with */*. For example, *//a/b* matches the *b* element in either of the fragments *<a>* or *<c><a></c>*.

Note

//tag is the equivalent of */descendant-or-self::*/tag*. A common error is to confuse this with */descendant-or-self::tag*, although the latter expression can actually lead to very different results, as can be seen here:

```
mysql> SET @xml = '<a><b><c>w</c><b>x</b><d>y</d>z</b></a>';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @xml;
+----------------------------------------+
| @xml                                   |
+----------------------------------------+
| <a><b><c>w</c><b>x</b><d>y</d>z</b></a> |
+----------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue(@xml, '//b[1]');
+-------------------------------+
| ExtractValue(@xml, '//b[1]') |
+-------------------------------+
| x z                           |
+-------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue(@xml, '//b[2]');
+-------------------------------+
| ExtractValue(@xml, '//b[2]') |
+-------------------------------+
```

```
|                              |
+------------------------------+
1 row in set (0.01 sec)

mysql> SELECT ExtractValue(@xml, '/descendant-or-self::*/b[1]');
+-------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::*/b[1]') |
+-------------------------------------------------+
| x z                                             |
+-------------------------------------------------+
1 row in set (0.06 sec)

mysql> SELECT ExtractValue(@xml, '/descendant-or-self::*/b[2]');
+-------------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::*/b[2]') |
+-------------------------------------------------+
|                                                 |
+-------------------------------------------------+
1 row in set (0.00 sec)


mysql> SELECT ExtractValue(@xml, '/descendant-or-self::b[1]');
+-----------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::b[1]') |
+-----------------------------------------------+
| z                                             |
+-----------------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT ExtractValue(@xml, '/descendant-or-self::b[2]');
+-----------------------------------------------+
| ExtractValue(@xml, '/descendant-or-self::b[2]') |
+-----------------------------------------------+
| x                                             |
+-----------------------------------------------+
1 row in set (0.00 sec)
```

- The `*` operator acts as a “wildcard” that matches any element. For example, the expression `/*/b` matches the *b* element in either of the XML fragments `<a><b/></a>` or `<c><b/></c>`. However, the expression does not produce a match in the fragment `<b><a/></b>` because *b* must be a child of some other element. The wildcard may be used in any position: The expression `/*/b/*` will match any child of a *b* element that is itself not the root element.

- You can match any of several locators using the `|` (`UNION`) operator. For example, the expression `//b|//c` matches all *b* and *c* elements in the XML target.

- It is also possible to match an element based on the value of one or more of its attributes. This done using the syntax *`tag[@attribute="value"]`*. For example, the expression `//b[@id="idB"]` matches the second *b* element in the fragment `<a><b id="idA"/><c/><b id="idB"/></a>`. To match against *any* element having *`attribute="value"`*, use the XPath expression `//*[attribute="value"]`.

  To filter multiple attribute values, simply use multiple attribute-comparison clauses in succession. For example, the expression `//b[@c="x"][@d="y"]` matches the element `<b c="x" d="y"/>` occurring anywhere in a given XML fragment.

  To find elements for which the same attribute matches any of several values, you can use multiple locators joined by the `|` operator. For example, to match all *b* elements whose *c* attributes have either of the values 23 or 17, use the expression `//b[@c="23"]|//b[@c="17"]`. You can also use the logical `or` operator for this purpose: `//b[@c="23" or @c="17"]`.

Note

The difference between `or` and `|` is that `or` joins conditions, while `|` joins result sets.

XPath Limitations. The XPath syntax supported by these functions is currently subject to the following limitations:

- Nodeset-to-nodeset comparison (such as `'/a/b[@c=@d]'`) is not supported.
- All of the standard XPath comparison operators are supported. (Bug #22823)
- Relative locator expressions are resolved in the context of the root node. For example, consider the following query and result:

```
mysql> SELECT ExtractValue(
    ->   '<a><b c="1">X</b><b c="2">Y</b></a>',
    ->    'a/b'
    -> ) AS result;
+--------+
| result |
+--------+
| X Y    |
+--------+
1 row in set (0.03 sec)
```

  In this case, the locator `a/b` resolves to `/a/b`.

  Relative locators are also supported within predicates. In the following example, `d[../@c="1"]` is resolved as `/a/b[@c="1"]/d`:

```
mysql> SELECT ExtractValue(
    ->      '<a>
    ->        <b c="1"><d>X</d></b>
    ->        <b c="2"><d>X</d></b>
    ->      </a>',
    ->      'a/b/d[../@c="1"]')
    -> AS result;
+--------+
| result |
+--------+
| X      |
+--------+
1 row in set (0.00 sec)
```

- Locators prefixed with expressions that evaluate as scalar values—including variable references, literals, numbers, and scalar function calls—are not permitted, and their use results in an error.
- The `::` operator is not supported in combination with node types such as the following:
  - *`axis`*`::comment()`
  - *`axis`*`::text()`
  - *`axis`*`::processing-instructions()`
  - *`axis`*`::node()`

  However, name tests (such as *`axis`*`::`*`name`* and *`axis`*`::*`) are supported, as shown in these examples:

```
mysql> SELECT ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::b');
+-----------------------------------------------------+
| ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::b') |
+-----------------------------------------------------+
| x                                                   |
+-----------------------------------------------------+
1 row in set (0.02 sec)

mysql> SELECT ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::*');
```

```
+-----------------------------------------------------+
| ExtractValue('<a><b>x</b><c>y</c></a>','/a/child::*') |
+-----------------------------------------------------+
| x y                                                 |
+-----------------------------------------------------+
1 row in set (0.01 sec)
```

- “Up-and-down” navigation is not supported in cases where the path would lead “above” the root element. That is, you cannot use expressions which match on descendants of ancestors of a given element, where one or more of the ancestors of the current element is also an ancestor of the root element (see Bug #16321).
- The following XPath functions are not supported, or have known issues as indicated:
  - `id()`
  - `lang()`
  - `local-name()`
  - `name()`
  - `namespace-uri()`
  - `normalize-space()`
  - `starts-with()`
  - `string()`
  - `substring-after()`
  - `substring-before()`
  - `translate()`
- The following axes are not supported:
  - `following-sibling`
  - `following`
  - `preceding-sibling`
  - `preceding`

XPath expressions passed as arguments to `ExtractValue()` and `UpdateXML()` may contain the colon character (`:`) in element selectors, which enables their use with markup employing XML namespaces notation. For example:

```
mysql> SET @xml = '<a>111<b:c>222<d>333</d><e:f>444</e:f></b:c></a>';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT ExtractValue(@xml, '//e:f');
+----------------------------+
| ExtractValue(@xml, '//e:f') |
+----------------------------+
| 444                        |
+----------------------------+
1 row in set (0.00 sec)

mysql> SELECT UpdateXML(@xml, '//b:c', '<g:h>555</g:h>');
+-------------------------------------------+
| UpdateXML(@xml, '//b:c', '<g:h>555</g:h>') |
+-------------------------------------------+
```

```
| <a>111<g:h>555</g:h></a>                  |
+-------------------------------------------+
1 row in set (0.00 sec)
```

This is similar in some respects to what is permitted by Apache Xalan and some other parsers, and is much simpler than requiring namespace declarations or the use of the `namespace-uri()` and `local-name()` functions.

Error handling. For both `ExtractValue()` and `UpdateXML()`, the XPath locator used must be valid and the XML to be searched must consist of elements which are properly nested and closed. If the locator is invalid, an error is generated:

```
mysql> SELECT ExtractValue('<a>c</a><b/>', '/&a');
ERROR 1105 (HY000): XPATH syntax error: '&a'
```

If *`xml_frag`* does not consist of elements which are properly nested and closed, `NULL` is returned and a warning is generated, as shown in this example:

```
mysql> SELECT ExtractValue('<a>c</a><b', '//a');
+---------------------------------+
| ExtractValue('<a>c</a><b', '//a') |
+---------------------------------+
| NULL                            |
+---------------------------------+
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1525
Message: Incorrect XML value: 'parse error at line 1 pos 11:
         END-OF-INPUT unexpected ('>' wanted)'
1 row in set (0.00 sec)

mysql> SELECT ExtractValue('<a>c</a><b/>', '//a');
+-----------------------------------+
| ExtractValue('<a>c</a><b/>', '//a') |
+-----------------------------------+
| c                                 |
+-----------------------------------+
1 row in set (0.00 sec)
```

Important

The replacement XML used as the third argument to `UpdateXML()` is *not* checked to determine whether it consists solely of elements which are properly nested and closed.

XPath Injection. *code injection* occurs when malicious code is introduced into the system to gain unauthorized access to privileges and data. It is based on exploiting assumptions made by developers about the type and content of data input from users. XPath is no exception in this regard.

A common scenario in which this can happen is the case of application which handles authorization by matching the combination of a login name and password with those found in an XML file, using an XPath expression like this one:

```
//user[login/text()='neapolitan' and password/text()='1c3cr34m']/attribute::id
```

This is the XPath equivalent of an SQL statement like this one:

```
SELECT id FROM users WHERE login='neapolitan' AND password='1c3cr34m';
```

A PHP application employing XPath might handle the login process like this:

```
```

```
<?php

  $file     =   "users.xml";

  $login    =   $POST["login"];
  $password =   $POST["password"];

  $xpath = "//user[login/text()=$login and password/text()=$password]/attribute::id";

  if( file_exists($file) )
  {
    $xml = simplexml_load_file($file);

    if($result = $xml->xpath($xpath))
      echo "You are now logged in as user $result[0].";
    else
      echo "Invalid login name or password.";
  }
  else
    exit("Failed to open $file.");

?>
```

No checks are performed on the input. This means that a malevolent user can “short-circuit” the test by entering `' or 1=1` for both the login name and password, resulting in `$xpath` being evaluated as shown here:

```
//user[login/text()='' or 1=1 and password/text()='' or 1=1]/attribute::id
```

Since the expression inside the square brackets always evaluates as `true`, it is effectively the same as this one, which matches the `id` attribute of every `user` element in the XML document:

```
//user/attribute::id
```

One way in which this particular attack can be circumvented is simply by quoting the variable names to be interpolated in the definition of `$xpath`, forcing the values passed from a Web form to be converted to strings:

```
$xpath = "//user[login/text()='$login' and password/text()='$password']/attribute::id";
```

This is the same strategy that is often recommended for preventing SQL injection attacks. In general, the practices you should follow for preventing XPath injection attacks are the same as for preventing SQL injection:

- Never accepted untested data from users in your application.
- Check all user-submitted data for type; reject or convert data that is of the wrong type
- Test numeric data for out of range values; truncate, round, or reject values that are out of range. Test strings for illegal characters and either strip them out or reject input containing them.
- Do not output explicit error messages that might provide an unauthorized user with clues that could be used to compromise the system; log these to a file or database table instead.

Just as SQL injection attacks can be used to obtain information about database schemas, so can XPath injection be used to traverse XML files to uncover their structure, as discussed in Amit Klein's paper Blind XPath Injection (PDF file, 46KB).

It is also important to check the output being sent back to the client. Consider what can happen when we use the MySQL `ExtractValue()` function:

```
mysql> SELECT ExtractValue(
    ->     LOAD_FILE('users.xml'),
    ->     '//user[login/text()="" or 1=1 and password/text()="" or 1=1]/attribute::id'
    -> ) AS id;
```

```
+------------------------------+
| id                           |
+------------------------------+
| 00327 13579 02403 42354 28570 |
+------------------------------+
1 row in set (0.01 sec)
```

Because `ExtractValue()` returns multiple matches as a single space-delimited string, this injection attack provides every valid ID contained within `users.xml` to the user as a single row of output. As an extra safeguard, you should also test output before returning it to the user. Here is a simple example:

```
mysql> SELECT @id = ExtractValue(
    ->     LOAD_FILE('users.xml'),
    ->     '//user[login/text()="" or 1=1 and password/text()="" or 1=1]/attribute::id'
    -> );
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT IF(
    ->     INSTR(@id, ' ') = 0,
    ->     @id,
    ->     'Unable to retrieve user ID')
    -> AS singleID;
+---------------------------+
| singleID                  |
+---------------------------+
| Unable to retrieve user ID |
+---------------------------+
1 row in set (0.00 sec)
```

In general, the guidelines for returning data to users securely are the same as for accepting user input. These can be summed up as:

- Always test outgoing data for type and permissible values.
- Never permit unauthorized users to view error messages that might provide information about the application that could be used to exploit it.

12.12 Bit Functions and Operators

Table 12.16 Bit Functions and Operators

Name	Description
`BIT_COUNT()`	Return the number of bits that are set
`&`	Bitwise AND
`~`	Bitwise inversion
`|`	Bitwise OR
`^`	Bitwise XOR
`<<`	Left shift
`>>`	Right shift

Bit functions and operators comprise `BIT_COUNT()`, `BIT_AND()`, `BIT_OR()`, `BIT_XOR()`, `&`, `|`, `^`, `~`, `<<`, and `>>`. (`BIT_AND()`, `BIT_OR()`, and `BIT_XOR()` are aggregate functions described at Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”.) Bit functions and operators require `BIGINT` (64-bit integer) arguments and return `BIGINT` values, so they have a maximum range of 64 bits. Arguments of other types (such as the `BINARY` and `VARBINARY` binary string types) are converted to `BIGINT` and truncation might occur.

The following list describes available bit functions and operators:

- `|`

  Bitwise OR.

The result is an unsigned 64-bit integer.

```
mysql> SELECT 29 | 15;
        -> 31
```

- `&`

  Bitwise AND.

  The result is an unsigned 64-bit integer.

  ```
  mysql> SELECT 29 & 15;
          -> 13
  ```

- `^`

  Bitwise XOR.

  The result is an unsigned 64-bit integer.

  ```
  mysql> SELECT 1 ^ 1;
          -> 0
  mysql> SELECT 1 ^ 0;
          -> 1
  mysql> SELECT 11 ^ 3;
          -> 8
  ```

- `<<`

  Shifts a longlong (`BIGINT`) number to the left.

  The result is an unsigned 64-bit integer. The value is truncated to 64 bits. In particular, if the shift count is greater or equal to the width of an unsigned 64-bit number, the result is zero.

  ```
  mysql> SELECT 1 << 2;
          -> 4
  ```

- `>>`

  Shifts a longlong (`BIGINT`) number to the right.

  The result is an unsigned 64-bit integer. The value is truncated to 64 bits. In particular, if the shift count is greater or equal to the width of an unsigned 64-bit number, the result is zero.

  ```
  mysql> SELECT 4 >> 2;
          -> 1
  ```

- `~`

  Invert all bits.

  The result is an unsigned 64-bit integer.

  ```
  mysql> SELECT 5 & ~1;
          -> 4
  ```

- `BIT_COUNT(N)`

  Returns the number of bits that are set in the argument *`N`* as an unsigned 64-bit integer, or `NULL` if the argument is `NULL`.

```
mysql> SELECT BIT_COUNT(29), BIT_COUNT(b'101010');
        -> 4, 3
```

12.13 Encryption and Compression Functions

Table 12.17 Encryption Functions

Name	Description
AES_DECRYPT()	Decrypt using AES
AES_ENCRYPT()	Encrypt using AES
COMPRESS()	Return result as a binary string
DECODE()	Decodes a string encrypted using ENCODE()
DES_DECRYPT()	Decrypt a string
DES_ENCRYPT()	Encrypt a string
ENCODE()	Encode a string
ENCRYPT()	Encrypt a string
MD5()	Calculate MD5 checksum
OLD_PASSWORD()	Return the value of the pre-4.1 implementation of PASSWORD
PASSWORD()	Calculate and return a password string
SHA1(), SHA()	Calculate an SHA-1 160-bit checksum
SHA2()	Calculate an SHA-2 checksum
UNCOMPRESS()	Uncompress a string compressed
UNCOMPRESSED_LENGTH()	Return the length of a string before compression

Many encryption and compression functions return strings for which the result might contain arbitrary byte values. If you want to store these results, use a column with a VARBINARY or BLOB binary string data type. This will avoid potential problems with trailing space removal or character set conversion that would change data values, such as may occur if you use a nonbinary string data type (CHAR, VARCHAR, TEXT).

Some encryption functions return strings of ASCII characters: MD5(), OLD_PASSWORD(), PASSWORD(), SHA(), SHA1(). Their return value is a string that has a character set and collation determined by the character_set_connection and collation_connection system variables. This is a nonbinary string unless the character set is binary.

If an application stores values from a function such as MD5() or SHA1() that returns a string of hex digits, more efficient storage and comparisons can be obtained by converting the hex representation to binary using UNHEX() and storing the result in a BINARY(*N*) column. Each pair of hexadecimal digits requires one byte in binary form, so the value of *N* depends on the length of the hex string. *N* is 16 for an MD5() value and 20 for a SHA1() value. For SHA2(), *N* ranges from 28 to 32 depending on the argument specifying the desired bit length of the result.

The size penalty for storing the hex string in a CHAR column is at least two times, up to eight times if the value is stored in a column that uses the utf8 character set (where each character uses 4 bytes). Storing the string also results in slower comparisons because of the larger values and the need to take character set collation rules into account.

Suppose that an application stores MD5() string values in a CHAR(32) column:

```
CREATE TABLE md5_tbl (md5_val CHAR(32), ...);
```

```
INSERT INTO md5_tbl (md5_val, ...) VALUES(MD5('abcdef'), ...);
```

To convert hex strings to more compact form, modify the application to use `UNHEX()` and `BINARY(16)` instead as follows:

```
CREATE TABLE md5_tbl (md5_val BINARY(16), ...);
INSERT INTO md5_tbl (md5_val, ...) VALUES(UNHEX(MD5('abcdef')), ...);
```

Applications should be prepared to handle the very rare case that a hashing function produces the same value for two different input values. One way to make collisions detectable is to make the hash column a primary key.

Note

Exploits for the MD5 and SHA-1 algorithms have become known. You may wish to consider using another one-way encryption function described in this section instead, such as `SHA2()`.

Caution

Passwords or other sensitive values supplied as arguments to encryption functions are sent in cleartext to the MySQL server unless an SSL connection is used. Also, such values will appear in any MySQL logs to which they are written. To avoid these types of exposure, applications can encrypt sensitive values on the client side before sending them to the server. The same considerations apply to encryption keys. To avoid exposing these, applications can use stored procedures to encrypt and decrypt values on the server side.

- `AES_DECRYPT(`*`crypt_str`*`,`*`key_str`*`)`

  This function decrypts data using the official AES (Advanced Encryption Standard) algorithm. For more information, see the description of `AES_ENCRYPT()`.

- `AES_ENCRYPT(`*`str`*`,`*`key_str`*`)`

  `AES_ENCRYPT()` and `AES_DECRYPT()` implement encryption and decryption of data using the official AES (Advanced Encryption Standard) algorithm, previously known as “Rijndael.” The AES standard permits various key lengths. These functions implement AES with a 128-bit key length, but you can extend them to 256 bits by modifying the source. The key length is a trade off between performance and security.

  `AES_ENCRYPT()` encrypts the string *`str`* using the key string *`key_str`* and returns a binary string containing the encrypted output. `AES_DECRYPT()` decrypts the encrypted string *`crypt_str`* using the key string *`key_str`* and returns the original cleartext string. If either function argument is `NULL`, the function returns `NULL`.

  The *`str`* and *`crypt_str`* arguments can be any length, and padding is automatically added to *`str`* so it is a multiple of a block as required by block-based algorithms such as AES. This padding is automatically removed by the `AES_DECRYPT()` function. The length of *`crypt_str`* can be calculated using this formula:

  ```
  16 * (trunc(string_length / 16) + 1)
  ```

  For a key length of 128 bits, the most secure way to pass a key to the *`key_str`* argument is to create a truly random 128-bit value and pass it as a binary value. For example:

  ```
  INSERT INTO t
  VALUES (1,AES_ENCRYPT('text',UNHEX('F3229A0B371ED2D9441B830D21A390C3')));
  ```

  A passphrase can be used to generate an AES key by hashing the passphrase. For example:

```
INSERT INTO t
VALUES (1,AES_ENCRYPT('text', UNHEX(SHA2('My secret passphrase',512))));
```

Do not pass a password or passphrase directly to *crypt_str*, hash it first. Previous versions of this documentation suggested the former approach, but it is no longer recommended as the examples shown here are more secure.

If AES_DECRYPT() detects invalid data or incorrect padding, it returns NULL. However, it is possible for AES_DECRYPT() to return a non-NULL value (possibly garbage) if the input data or the key is invalid.

- COMPRESS(*string_to_compress*)

  Compresses a string and returns the result as a binary string. This function requires MySQL to have been compiled with a compression library such as zlib. Otherwise, the return value is always NULL. The compressed string can be uncompressed with UNCOMPRESS().

```
mysql> SELECT LENGTH(COMPRESS(REPEAT('a',1000)));
        -> 21
mysql> SELECT LENGTH(COMPRESS(''));
        -> 0
mysql> SELECT LENGTH(COMPRESS('a'));
        -> 13
mysql> SELECT LENGTH(COMPRESS(REPEAT('a',16)));
        -> 15
```

  The compressed string contents are stored the following way:

  - Empty strings are stored as empty strings.
  - Nonempty strings are stored as a 4-byte length of the uncompressed string (low byte first), followed by the compressed string. If the string ends with space, an extra . character is added to avoid problems with endspace trimming should the result be stored in a CHAR or VARCHAR column. (However, use of nonbinary string data types such as CHAR or VARCHAR to store compressed strings is not recommended anyway because character set conversion may occur. Use a VARBINARY or BLOB binary string column instead.)

- DECODE(*crypt_str*,*pass_str*)

  Decrypts the encrypted string *crypt_str* using *pass_str* as the password. *crypt_str* should be a string returned from ENCODE().

- DES_DECRYPT(*crypt_str*[,*key_str*])

  Decrypts a string encrypted with DES_ENCRYPT(). If an error occurs, this function returns NULL.

  This function works only if MySQL has been configured with SSL support. See Section 6.4, “Using Encrypted Connections”.

  If no *key_str* argument is given, DES_DECRYPT() examines the first byte of the encrypted string to determine the DES key number that was used to encrypt the original string, and then reads the key from the DES key file to decrypt the message. For this to work, the user must have the SUPER privilege. The key file can be specified with the --des-key-file server option.

  If you pass this function a *key_str* argument, that string is used as the key for decrypting the message.

  If the *crypt_str* argument does not appear to be an encrypted string, MySQL returns the given *crypt_str*.

- DES_ENCRYPT(*str*[,{*key_num*|*key_str*}])

Encrypts the string with the given key using the Triple-DES algorithm.

This function works only if MySQL has been configured with SSL support. See Section 6.4, “Using Encrypted Connections”.

The encryption key to use is chosen based on the second argument to `DES_ENCRYPT()`, if one was given. With no argument, the first key from the DES key file is used. With a *`key_num`* argument, the given key number (0 to 9) from the DES key file is used. With a *`key_str`* argument, the given key string is used to encrypt *`str`*.

The key file can be specified with the `--des-key-file` server option.

The return string is a binary string where the first character is `CHAR(128 | key_num)`. If an error occurs, `DES_ENCRYPT()` returns `NULL`.

The 128 is added to make it easier to recognize an encrypted key. If you use a string key, *`key_num`* is 127.

The string length for the result is given by this formula:

```
new_len = orig_len + (8 - (orig_len % 8)) + 1
```

Each line in the DES key file has the following format:

```
key_num des_key_str
```

Each *`key_num`* value must be a number in the range from `0` to `9`. Lines in the file may be in any order. *`des_key_str`* is the string that is used to encrypt the message. There should be at least one space between the number and the key. The first key is the default key that is used if you do not specify any key argument to `DES_ENCRYPT()`.

You can tell MySQL to read new key values from the key file with the `FLUSH DES_KEY_FILE` statement. This requires the `RELOAD` privilege.

One benefit of having a set of default keys is that it gives applications a way to check for the existence of encrypted column values, without giving the end user the right to decrypt those values.

```
mysql> SELECT customer_address FROM customer_table
    > WHERE crypted_credit_card = DES_ENCRYPT('credit_card_number');
```

- `ENCODE(str,pass_str)`

  Encrypt *`str`* using *`pass_str`* as the password. The result is a binary string of the same length as *`str`*. To decrypt the result, use `DECODE()`.

  The `ENCODE()` function should no longer be used. If you still need to use `ENCODE()`, a salt value must be used with it to reduce risk. For example:

  ```
  ENCODE('cleartext', CONCAT('my_random_salt','my_secret_password'))
  ```

  A new random salt value must be used whenever a password is updated.

- `ENCRYPT(str[,salt])`

  Encrypts *`str`* using the Unix `crypt()` system call and returns a binary string. The *`salt`* argument must be a string with at least two characters or the result will be `NULL`. If no *`salt`* argument is given, a random value is used.

  ```
  ```

```
mysql> SELECT ENCRYPT('hello');
        -> 'VxuFAJXVARROc'
```

`ENCRYPT()` ignores all but the first eight characters of *`str`*, at least on some systems. This behavior is determined by the implementation of the underlying `crypt()` system call.

The use of `ENCRYPT()` with the `ucs2`, `utf16`, or `utf32` multibyte character sets is not recommended because the system call expects a string terminated by a zero byte.

If `crypt()` is not available on your system (as is the case with Windows), `ENCRYPT()` always returns `NULL`.

- `MD5(`*`str`*`)`

  Calculates an MD5 128-bit checksum for the string. The value is returned as a string of 32 hexadecimal digits, or `NULL` if the argument was `NULL`. The return value can, for example, be used as a hash key. See the notes at the beginning of this section about storing hash values efficiently.

  The return value is a string in the connection character set.

  ```
  mysql> SELECT MD5('testing');
          -> 'ae2b1fca515949e5d54fb22b8ed95575'
  ```

  This is the "RSA Data Security, Inc. MD5 Message-Digest Algorithm."

  See the note regarding the MD5 algorithm at the beginning this section.

- `OLD_PASSWORD(`*`str`*`)`

  `OLD_PASSWORD()` was added when the implementation of `PASSWORD()` was changed in MySQL 4.1 to improve security. `OLD_PASSWORD()` returns the value of the pre-4.1 implementation of `PASSWORD()` as a string, and is intended to permit you to reset passwords for any pre-4.1 clients that need to connect to your MySQL server without locking them out. See Section 6.1.2.4, "Password Hashing in MySQL".

  The return value is a string in the connection character set.

  Note

  Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

- `PASSWORD(`*`str`*`)`

  Returns a hashed password string calculated from the cleartext password *`str`*. The return value is a string in the connection character set, or `NULL` if the argument is `NULL`. This function is the SQL interface to the algorithm used by the server to encrypt MySQL passwords for storage in the `mysql.user` grant table.

  The `old_passwords` system variable controls the password hashing method used by the `PASSWORD()` function. It also influences password hashing performed by `CREATE USER` and `GRANT` statements that specify a password using an `IDENTIFIED BY` clause.

  The following table shows, for each password hashing method, the permitted value of `old_passwords` and which authentication plugins use the hashing method.

Password Hashing Method	old_passwords Value	Associated Authentication Plugin
MySQL 4.1 native hashing	`0` or `OFF`	`mysql_native_password`

Password Hashing Method	old_passwords Value	Associated Authentication Plugin
Pre-4.1 (“old”) hashing	`1` or `ON`	`mysql_old_password`

If `old_passwords=1`, `PASSWORD(str)` returns the same value as `OLD_PASSWORD(str)`. The latter function is not affected by the value of `old_passwords`.

```
mysql> SET old_passwords = 0;
mysql> SELECT PASSWORD('mypass'), OLD_PASSWORD('mypass');
+-------------------------------------------+----------------------+
| PASSWORD('mypass')                        | OLD_PASSWORD('mypass') |
+-------------------------------------------+----------------------+
| *6C8989366EAF75BB670AD8EA7A7FC1176A95CEF4 | 6f8c114b58f2ce9e       |
+-------------------------------------------+----------------------+

mysql> SET old_passwords = 1;
mysql> SELECT PASSWORD('mypass'), OLD_PASSWORD('mypass');
+-------------------+----------------------+
| PASSWORD('mypass') | OLD_PASSWORD('mypass') |
+-------------------+----------------------+
| 6f8c114b58f2ce9e   | 6f8c114b58f2ce9e       |
+-------------------+----------------------+
```

Encryption performed by `PASSWORD()` is one-way (not reversible). It is not the same type of encryption as used for Unix passwords; for that, use `ENCRYPT()`.

Note

`PASSWORD()` is used by the authentication system in MySQL Server; you should *not* use it in your own applications. For that purpose, consider a more secure function such as `AES_ENCRYPT()` or `SHA2()` instead. Also see RFC 2195, section 2 (Challenge-Response Authentication Mechanism (CRAM)), for more information about handling passwords and authentication securely in your applications.

Note

Passwords that use the pre-4.1 hashing method are less secure than passwords that use the native password hashing method and should be avoided.

Caution

Statements that invoke `PASSWORD()` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, “Passwords and Logging”. For similar information about client-side logging, see Section 4.5.1.3, “mysql Logging”.

- `SHA1(str)`, `SHA(str)`

  Calculates an SHA-1 160-bit checksum for the string, as described in RFC 3174 (Secure Hash Algorithm). The value is returned as a string of 40 hexadecimal digits, or `NULL` if the argument was `NULL`. One of the possible uses for this function is as a hash key. See the notes at the beginning of this section about storing hash values efficiently. You can also use `SHA1()` as a cryptographic function for storing passwords. `SHA()` is synonymous with `SHA1()`.

  The return value is a string in the connection character set.

```
mysql> SELECT SHA1('abc');
```

```
        -> 'a9993e364706816aba3e25717850c26c9cd0d89d'
```

`SHA1()` can be considered a cryptographically more secure equivalent of `MD5()`. However, see the note regarding the MD5 and SHA-1 algorithms at the beginning this section.

- `SHA2(str, hash_length)`

  Calculates the SHA-2 family of hash functions (SHA-224, SHA-256, SHA-384, and SHA-512). The first argument is the cleartext string to be hashed. The second argument indicates the desired bit length of the result, which must have a value of 224, 256, 384, 512, or 0 (which is equivalent to 256). If either argument is `NULL` or the hash length is not one of the permitted values, the return value is `NULL`. Otherwise, the function result is a hash value containing the desired number of bits. See the notes at the beginning of this section about storing hash values efficiently.

  The return value is a string in the connection character set.

  ```
  mysql> SELECT SHA2('abc', 224);
          -> '23097d223405d8228642a477bda255b32aadbce4bda0b3f7e36c9da7'
  ```

  This function works only if MySQL has been configured with SSL support. See Section 6.4, “Using Encrypted Connections”.

  `SHA2()` can be considered cryptographically more secure than `MD5()` or `SHA1()`.

- `UNCOMPRESS(string_to_uncompress)`

  Uncompresses a string compressed by the `COMPRESS()` function. If the argument is not a compressed value, the result is `NULL`. This function requires MySQL to have been compiled with a compression library such as `zlib`. Otherwise, the return value is always `NULL`.

  ```
  mysql> SELECT UNCOMPRESS(COMPRESS('any string'));
          -> 'any string'
  mysql> SELECT UNCOMPRESS('any string');
          -> NULL
  ```

- `UNCOMPRESSED_LENGTH(compressed_string)`

  Returns the length that the compressed string had before being compressed.

  ```
  mysql> SELECT UNCOMPRESSED_LENGTH(COMPRESS(REPEAT('a',30)));
          -> 30
  ```

12.14 Information Functions

Table 12.18 Information Functions

Name	Description
`BENCHMARK()`	Repeatedly execute an expression
`CHARSET()`	Return the character set of the argument
`COERCIBILITY()`	Return the collation coercibility value of the string argument
`COLLATION()`	Return the collation of the string argument
`CONNECTION_ID()`	Return the connection ID (thread ID) for the connection
`CURRENT_USER()`, `CURRENT_USER`	The authenticated user name and host name
`DATABASE()`	Return the default (current) database name
`FOUND_ROWS()`	For a SELECT with a LIMIT clause, the number of rows that would be returned were there no LIMIT clause
`LAST_INSERT_ID()`	Value of the AUTOINCREMENT column for the last INSERT

Name	Description
ROW_COUNT()	The number of rows updated
SCHEMA()	Synonym for DATABASE()
SESSION_USER()	Synonym for USER()
SYSTEM_USER()	Synonym for USER()
USER()	The user name and host name provided by the client
VERSION()	Return a string that indicates the MySQL server version

- BENCHMARK(*count*,*expr*)

  The BENCHMARK() function executes the expression *expr* repeatedly *count* times. It may be used to time how quickly MySQL processes the expression. The result value is always 0. The intended use is from within the mysql client, which reports query execution times:

```
mysql> SELECT BENCHMARK(1000000,AES_ENCRYPT('hello','goodbye'));
+-------------------------------------------------+
| BENCHMARK(1000000,AES_ENCRYPT('hello','goodbye')) |
+-------------------------------------------------+
|                                               0 |
+-------------------------------------------------+
1 row in set (4.74 sec)
```

  The time reported is elapsed time on the client end, not CPU time on the server end. It is advisable to execute BENCHMARK() several times, and to interpret the result with regard to how heavily loaded the server machine is.

  BENCHMARK() is intended for measuring the runtime performance of scalar expressions, which has some significant implications for the way that you use it and interpret the results:

  - Only scalar expressions can be used. Although the expression can be a subquery, it must return a single column and at most a single row. For example, BENCHMARK(10, (SELECT * FROM t)) will fail if the table t has more than one column or more than one row.
  - Executing a SELECT *expr* statement *N* times differs from executing SELECT BENCHMARK(*N*, *expr*) in terms of the amount of overhead involved. The two have very different execution profiles and you should not expect them to take the same amount of time. The former involves the parser, optimizer, table locking, and runtime evaluation *N* times each. The latter involves only runtime evaluation *N* times, and all the other components just once. Memory structures already allocated are reused, and runtime optimizations such as local caching of results already evaluated for aggregate functions can alter the results. Use of BENCHMARK() thus measures performance of the runtime component by giving more weight to that component and removing the “noise” introduced by the network, parser, optimizer, and so forth.

- CHARSET(*str*)

  Returns the character set of the string argument.

```
mysql> SELECT CHARSET('abc');
        -> 'latin1'
mysql> SELECT CHARSET(CONVERT('abc' USING utf8));
        -> 'utf8'
mysql> SELECT CHARSET(USER());
        -> 'utf8'
```

- COERCIBILITY(*str*)

  Returns the collation coercibility value of the string argument.

```
mysql> SELECT COERCIBILITY('abc' COLLATE latin1_swedish_ci);
        -> 0
mysql> SELECT COERCIBILITY(USER());
        -> 3
mysql> SELECT COERCIBILITY('abc');
        -> 4
mysql> SELECT COERCIBILITY(1000);
        -> 5
```

The return values have the meanings shown in the following table. Lower values have higher precedence.

Coercibility	Meaning	Example
0	Explicit collation	Value with COLLATE clause
1	No collation	Concatenation of strings with different collations
2	Implicit collation	Column value, stored routine parameter or local variable
3	System constant	USER() return value
4	Coercible	Literal string
5	Numeric	Numeric or temporal value
5	Ignorable	NULL or an expression derived from NULL

For more information, see Section 10.1.8.4, “Collation Coercibility in Expressions”.

- `COLLATION(str)`

  Returns the collation of the string argument.

```
mysql> SELECT COLLATION('abc');
        -> 'latin1_swedish_ci'
mysql> SELECT COLLATION(_utf8'abc');
        -> 'utf8_general_ci'
```

- `CONNECTION_ID()`

  Returns the connection ID (thread ID) for the connection. Every connection has an ID that is unique among the set of currently connected clients.

  The value returned by `CONNECTION_ID()` is the same type of value as displayed in the `ID` column of the `INFORMATION_SCHEMA.PROCESSLIST` table, the `Id` column of `SHOW PROCESSLIST` output, and the `PROCESSLIST_ID` column of the Performance Schema `threads` table.

```
mysql> SELECT CONNECTION_ID();
        -> 23786
```

- `CURRENT_USER`, `CURRENT_USER()`

  Returns the user name and host name combination for the MySQL account that the server used to authenticate the current client. This account determines your access privileges. The return value is a string in the `utf8` character set.

  The value of `CURRENT_USER()` can differ from the value of `USER()`.

```
mysql> SELECT USER();
        -> 'davida@localhost'
mysql> SELECT * FROM mysql.user;
ERROR 1044: Access denied for user ''@'localhost' to
```

```
database 'mysql'
mysql> SELECT CURRENT_USER();
        -> '@localhost'
```

The example illustrates that although the client specified a user name of `davida` (as indicated by the value of the `USER()` function), the server authenticated the client using an anonymous user account (as seen by the empty user name part of the `CURRENT_USER()` value). One way this might occur is that there is no account listed in the grant tables for `davida`.

Within a stored program or view, `CURRENT_USER()` returns the account for the user who defined the object (as given by its `DEFINER` value) unless defined with the `SQL SECURITY INVOKER` characteristic. In the latter case, `CURRENT_USER()` returns the object's invoker.

Triggers and events have no option to define the `SQL SECURITY` characteristic, so for these objects, `CURRENT_USER()` returns the account for the user who defined the object. To return the invoker, use `USER()` or `SESSION_USER()`.

The following statements support use of the `CURRENT_USER()` function to take the place of the name of (and, possibly, a host for) an affected user or a definer; in such cases, `CURRENT_USER()` is expanded where and as needed:

- `DROP USER`
- `RENAME USER`
- `GRANT`
- `REVOKE`
- `CREATE FUNCTION`
- `CREATE PROCEDURE`
- `CREATE TRIGGER`
- `CREATE EVENT`
- `CREATE VIEW`
- `ALTER EVENT`
- `ALTER VIEW`
- `SET PASSWORD`

For information about the implications that this expansion of `CURRENT_USER()` has for replication, see Section 17.4.1.8, “Replication of CURRENT_USER()”.

- `DATABASE()`

  Returns the default (current) database name as a string in the `utf8` character set. If there is no default database, `DATABASE()` returns `NULL`. Within a stored routine, the default database is the database that the routine is associated with, which is not necessarily the same as the database that is the default in the calling context.

  ```
  mysql> SELECT DATABASE();
          -> 'test'
  ```

  If there is no default database, `DATABASE()` returns `NULL`.

- `FOUND_ROWS()`

A SELECT statement may include a LIMIT clause to restrict the number of rows the server returns to the client. In some cases, it is desirable to know how many rows the statement would have returned without the LIMIT, but without running the statement again. To obtain this row count, include an SQL_CALC_FOUND_ROWS option in the SELECT statement, and then invoke FOUND_ROWS() afterward:

```
mysql> SELECT SQL_CALC_FOUND_ROWS * FROM tbl_name
    -> WHERE id > 100 LIMIT 10;
mysql> SELECT FOUND_ROWS();
```

The second SELECT returns a number indicating how many rows the first SELECT would have returned had it been written without the LIMIT clause.

In the absence of the SQL_CALC_FOUND_ROWS option in the most recent successful SELECT statement, FOUND_ROWS() returns the number of rows in the result set returned by that statement. If the statement includes a LIMIT clause, FOUND_ROWS() returns the number of rows up to the limit. For example, FOUND_ROWS() returns 10 or 60, respectively, if the statement includes LIMIT 10 or LIMIT 50, 10.

The row count available through FOUND_ROWS() is transient and not intended to be available past the statement following the SELECT SQL_CALC_FOUND_ROWS statement. If you need to refer to the value later, save it:

```
mysql> SELECT SQL_CALC_FOUND_ROWS * FROM ... ;
mysql> SET @rows = FOUND_ROWS();
```

If you are using SELECT SQL_CALC_FOUND_ROWS, MySQL must calculate how many rows are in the full result set. However, this is faster than running the query again without LIMIT, because the result set need not be sent to the client.

SQL_CALC_FOUND_ROWS and FOUND_ROWS() can be useful in situations when you want to restrict the number of rows that a query returns, but also determine the number of rows in the full result set without running the query again. An example is a Web script that presents a paged display containing links to the pages that show other sections of a search result. Using FOUND_ROWS() enables you to determine how many other pages are needed for the rest of the result.

The use of SQL_CALC_FOUND_ROWS and FOUND_ROWS() is more complex for UNION statements than for simple SELECT statements, because LIMIT may occur at multiple places in a UNION. It may be applied to individual SELECT statements in the UNION, or global to the UNION result as a whole.

The intent of SQL_CALC_FOUND_ROWS for UNION is that it should return the row count that would be returned without a global LIMIT. The conditions for use of SQL_CALC_FOUND_ROWS with UNION are:

- The SQL_CALC_FOUND_ROWS keyword must appear in the first SELECT of the UNION.
- The value of FOUND_ROWS() is exact only if UNION ALL is used. If UNION without ALL is used, duplicate removal occurs and the value of FOUND_ROWS() is only approximate.
- If no LIMIT is present in the UNION, SQL_CALC_FOUND_ROWS is ignored and returns the number of rows in the temporary table that is created to process the UNION.

Beyond the cases described here, the behavior of FOUND_ROWS() is undefined (for example, its value following a SELECT statement that fails with an error).

Important

FOUND_ROWS() is not replicated reliably using statement-based replication. This function is automatically replicated using row-based replication.

- `LAST_INSERT_ID()`, `LAST_INSERT_ID(expr)`

  With no argument, `LAST_INSERT_ID()` returns a 64-bit value representing the first automatically generated value successfully inserted for an `AUTO_INCREMENT` column as a result of the most recently executed `INSERT` statement. The value has a type of `BIGINT UNSIGNED` as of MySQL 5.5.29, `BIGINT` (signed) before that. The value of `LAST_INSERT_ID()` remains unchanged if no rows are successfully inserted.

  With an argument, `LAST_INSERT_ID()` returns an unsigned integer as of MySQL 5.5.29, a signed integer before that.

  For example, after inserting a row that generates an `AUTO_INCREMENT` value, you can get the value like this:

```
mysql> SELECT LAST_INSERT_ID();
        -> 195
```

  The currently executing statement does not affect the value of `LAST_INSERT_ID()`. Suppose that you generate an `AUTO_INCREMENT` value with one statement, and then refer to `LAST_INSERT_ID()` in a multiple-row `INSERT` statement that inserts rows into a table with its own `AUTO_INCREMENT` column. The value of `LAST_INSERT_ID()` will remain stable in the second statement; its value for the second and later rows is not affected by the earlier row insertions. (However, if you mix references to `LAST_INSERT_ID()` and `LAST_INSERT_ID(expr)`, the effect is undefined.)

  If the previous statement returned an error, the value of `LAST_INSERT_ID()` is undefined. For transactional tables, if the statement is rolled back due to an error, the value of `LAST_INSERT_ID()` is left undefined. For manual `ROLLBACK`, the value of `LAST_INSERT_ID()` is not restored to that before the transaction; it remains as it was at the point of the `ROLLBACK`.

  Prior to MySQL 5.5.35, this function was not replicated correctly if replication filtering rules were in use. (Bug #17234370, Bug #69861)

  Within the body of a stored routine (procedure or function) or a trigger, the value of `LAST_INSERT_ID()` changes the same way as for statements executed outside the body of these kinds of objects. The effect of a stored routine or trigger upon the value of `LAST_INSERT_ID()` that is seen by following statements depends on the kind of routine:

  - If a stored procedure executes statements that change the value of `LAST_INSERT_ID()`, the changed value is seen by statements that follow the procedure call.
  - For stored functions and triggers that change the value, the value is restored when the function or trigger ends, so following statements will not see a changed value.

  The ID that was generated is maintained in the server on a *per-connection basis*. This means that the value returned by the function to a given client is the first `AUTO_INCREMENT` value generated for most recent statement affecting an `AUTO_INCREMENT` column *by that client*. This value cannot be affected by other clients, even if they generate `AUTO_INCREMENT` values of their own. This behavior ensures that each client can retrieve its own ID without concern for the activity of other clients, and without the need for locks or transactions.

  The value of `LAST_INSERT_ID()` is not changed if you set the `AUTO_INCREMENT` column of a row to a non-“magic” value (that is, a value that is not `NULL` and not `0`).

  Important

  If you insert multiple rows using a single `INSERT` statement, `LAST_INSERT_ID()` returns the value generated for the *first* inserted row *only*. The reason for this is to make it possible to reproduce easily the same `INSERT` statement against some other server.

For example:

```
mysql> USE test;

mysql> CREATE TABLE t (
       id INT AUTO_INCREMENT NOT NULL PRIMARY KEY,
       name VARCHAR(10) NOT NULL
       );

mysql> INSERT INTO t VALUES (NULL, 'Bob');

mysql> SELECT * FROM t;
+----+------+
| id | name |
+----+------+
|  1 | Bob  |
+----+------+

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                1 |
+------------------+

mysql> INSERT INTO t VALUES
       (NULL, 'Mary'), (NULL, 'Jane'), (NULL, 'Lisa');

mysql> SELECT * FROM t;
+----+------+
| id | name |
+----+------+
|  1 | Bob  |
|  2 | Mary |
|  3 | Jane |
|  4 | Lisa |
+----+------+

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                2 |
+------------------+
```

Although the second `INSERT` statement inserted three new rows into `t`, the ID generated for the first of these rows was `2`, and it is this value that is returned by `LAST_INSERT_ID()` for the following `SELECT` statement.

If you use `INSERT IGNORE` and the row is ignored, the `LAST_INSERT_ID()` remains unchanged from the current value (or 0 is returned if the connection has not yet performed a successful `INSERT`) and, for non-transactional tables, the `AUTO_INCREMENT` counter is not incremented. For `InnoDB` tables, the `AUTO_INCREMENT` counter is incremented if `innodb_autoinc_lock_mode` is set to `1` or `2`, as demonstrated in the following example:

```
mysql> USE test;

mysql> SELECT @@innodb_autoinc_lock_mode;
+----------------------------+
| @@innodb_autoinc_lock_mode |
+----------------------------+
|                          1 |
+----------------------------+

mysql> CREATE TABLE `t` (
       `id` INT(11) NOT NULL AUTO_INCREMENT,
       `val` INT(11) DEFAULT NULL,
```

```
       PRIMARY KEY (`id`),
       UNIQUE KEY `i1` (`val`)
       ) ENGINE=InnoDB DEFAULT CHARSET=latin1;

# Insert two rows

mysql> INSERT INTO t (val) VALUES (1),(2);

# With auto_increment_offset=1, the inserted rows
# result in an AUTO_INCREMENT value of 3

mysql> SHOW CREATE TABLE t\G
*************************** 1. row ***************************
       Table: t
Create Table: CREATE TABLE `t` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `val` int(11) DEFAULT NULL,
  PRIMARY KEY (`id`),
  UNIQUE KEY `i1` (`val`)
) ENGINE=InnoDB AUTO_INCREMENT=3 DEFAULT CHARSET=latin1

# LAST_INSERT_ID() returns the first automatically generated
# value that is successfully inserted for the AUTO_INCREMENT column

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                1 |
+------------------+

# The attempted insertion of duplicate rows fail but errors are ignored

mysql> INSERT IGNORE INTO t (val) VALUES (1),(2);
Query OK, 0 rows affected (0.00 sec)
Records: 2  Duplicates: 2  Warnings: 0

# With innodb_autoinc_lock_mode=1, the AUTO_INCREMENT counter
# is incremented for the ignored rows

mysql> SHOW CREATE TABLE t\G
*************************** 1. row ***************************
       Table: t
Create Table: CREATE TABLE `t` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `val` int(11) DEFAULT NULL,
  PRIMARY KEY (`id`),
  UNIQUE KEY `i1` (`val`)
) ENGINE=InnoDB AUTO_INCREMENT=5 DEFAULT CHARSET=latin1

# The LAST_INSERT_ID is unchanged because the previous insert was unsuccessful

mysql> SELECT LAST_INSERT_ID();
+------------------+
| LAST_INSERT_ID() |
+------------------+
|                1 |
+------------------+
```

For more information, see Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”.

If *`expr`* is given as an argument to `LAST_INSERT_ID()`, the value of the argument is returned by the function and is remembered as the next value to be returned by `LAST_INSERT_ID()`. This can be used to simulate sequences:

1. Create a table to hold the sequence counter and initialize it:

```
mysql> CREATE TABLE sequence (id INT NOT NULL);
mysql> INSERT INTO sequence VALUES (0);
```

2. Use the table to generate sequence numbers like this:

```
mysql> UPDATE sequence SET id=LAST_INSERT_ID(id+1);
mysql> SELECT LAST_INSERT_ID();
```

The `UPDATE` statement increments the sequence counter and causes the next call to `LAST_INSERT_ID()` to return the updated value. The `SELECT` statement retrieves that value. The `mysql_insert_id()` C API function can also be used to get the value. See Section 23.8.7.37, “mysql_insert_id()”.

You can generate sequences without calling `LAST_INSERT_ID()`, but the utility of using the function this way is that the ID value is maintained in the server as the last automatically generated value. It is multi-user safe because multiple clients can issue the `UPDATE` statement and get their own sequence value with the `SELECT` statement (or `mysql_insert_id()`), without affecting or being affected by other clients that generate their own sequence values.

Note that `mysql_insert_id()` is only updated after `INSERT` and `UPDATE` statements, so you cannot use the C API function to retrieve the value for `LAST_INSERT_ID(expr)` after executing other SQL statements like `SELECT` or `SET`.

- `ROW_COUNT()`

  `ROW_COUNT()` returns a value as follows:

  - DDL statements: 0. This applies to statements such as `CREATE TABLE` or `DROP TABLE`.
  - DML statements other than `SELECT`: The number of affected rows. This applies to statements such as `UPDATE`, `INSERT`, or `DELETE` (as before), but now also to statements such as `ALTER TABLE` and `LOAD DATA INFILE`.
  - `SELECT`: -1 if the statement returns a result set, or the number of rows “affected” if it does not. For example, for `SELECT * FROM t1`, `ROW_COUNT()` returns -1. For `SELECT * FROM t1 INTO OUTFILE 'file_name'`, `ROW_COUNT()` returns the number of rows written to the file.
  - `SIGNAL` statements: 0.

  For `UPDATE` statements, the affected-rows value by default is the number of rows actually changed. If you specify the `CLIENT_FOUND_ROWS` flag to `mysql_real_connect()` when connecting to `mysqld`, the affected-rows value is the number of rows “found”; that is, matched by the `WHERE` clause.

  For `REPLACE` statements, the affected-rows value is 2 if the new row replaced an old row, because in this case, one row was inserted after the duplicate was deleted.

  For `INSERT ... ON DUPLICATE KEY UPDATE` statements, the affected-rows value per row is 1 if the row is inserted as a new row, 2 if an existing row is updated, and 0 if an existing row is set to its current values. If you specify the `CLIENT_FOUND_ROWS` flag, the affected-rows value is 1 (not 0) if an existing row is set to its current values.

  The `ROW_COUNT()` value is similar to the value from the `mysql_affected_rows()` C API function and the row count that the `mysql` client displays following statement execution.

```
mysql> INSERT INTO t VALUES(1),(2),(3);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT ROW_COUNT();
+-------------+
| ROW_COUNT() |
+-------------+
```

```
|           3 |
+-------------+
1 row in set (0.00 sec)

mysql> DELETE FROM t WHERE i IN(1,2);
Query OK, 2 rows affected (0.00 sec)

mysql> SELECT ROW_COUNT();
+-------------+
| ROW_COUNT() |
+-------------+
|           2 |
+-------------+
1 row in set (0.00 sec)
```

Important

`ROW_COUNT()` is not replicated reliably using statement-based replication. This function is automatically replicated using row-based replication.

- `SCHEMA()`

  This function is a synonym for `DATABASE()`.

- `SESSION_USER()`

  `SESSION_USER()` is a synonym for `USER()`.

- `SYSTEM_USER()`

  `SYSTEM_USER()` is a synonym for `USER()`.

- `USER()`

  Returns the current MySQL user name and host name as a string in the `utf8` character set.

  ```
  mysql> SELECT USER();
         -> 'davida@localhost'
  ```

  The value indicates the user name you specified when connecting to the server, and the client host from which you connected. The value can be different from that of `CURRENT_USER()`.

- `VERSION()`

  Returns a string that indicates the MySQL server version. The string uses the `utf8` character set. The value might have a suffix in addition to the version number. See the description of the `version` system variable in Section 5.1.5, “Server System Variables”.

  This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

  ```
  mysql> SELECT VERSION();
         -> '5.5.60-standard'
  ```

12.15 Spatial Analysis Functions

MySQL provides functions to perform various operations on spatial data. These functions can be grouped into several major categories according to the type of operation they perform:

- Functions that create geometries in various formats (WKT, WKB, internal)
- Functions that convert geometries between formats
- Functions that access qualitative or quantitative properties of a geometry

- Functions that describe relations between two geometries
- Functions that create new geometries from existing ones

For general background about MySQL support for using spatial data, see Section 11.5, “Spatial Data Types”.

12.15.1 Spatial Function Reference

The following table lists each spatial function and provides a short description of each one.

Table 12.19 Spatial Functions

Name	Description
`Area()`	Return Polygon or MultiPolygon area
`AsBinary()`, `AsWKB()`	Convert from internal geometry format to WKB
`AsText()`, `AsWKT()`	Convert from internal geometry format to WKT
`Centroid()`	Return centroid as a point
`Contains()`	Whether MBR of one geometry contains MBR of another
`Crosses()`	Whether one geometry crosses another
`Dimension()`	Dimension of geometry
`Disjoint()`	Whether MBRs of two geometries are disjoint
`EndPoint()`	End Point of LineString
`Envelope()`	Return MBR of geometry
`Equals()`	Whether MBRs of two geometries are equal
`ExteriorRing()`	Return exterior ring of Polygon
`GeomCollFromText()`, `GeometryCollectionFromText()`	Return geometry collection from WKT
`GeomCollFromWKB()`, `GeometryCollectionFromWKB()`	Return geometry collection from WKB
`GeometryCollection()`	Construct geometry collection from geometries
`GeometryN()`	Return N-th geometry from geometry collection
`GeometryType()`	Return name of geometry type
`GeomFromText()`, `GeometryFromText()`	Return geometry from WKT
`GeomFromWKB()`, `GeometryFromWKB()`	Return geometry from WKB
`GLength()`	Return length of LineString
`InteriorRingN()`	Return N-th interior ring of Polygon
`Intersects()`	Whether MBRs of two geometries intersect
`IsClosed()`	Whether a geometry is closed and simple
`IsEmpty()`	Placeholder function
`IsSimple()`	Whether a geometry is simple
`LineFromText()`, `LineStringFromText()`	Construct LineString from WKT
`LineFromWKB()`, `LineStringFromWKB()`	Construct LineString from WKB
`LineString()`	Construct LineString from Point values
`MBRContains()`	Whether MBR of one geometry contains MBR of another

Name	Description
MBRDisjoint()	Whether MBRs of two geometries are disjoint
MBREqual()	Whether MBRs of two geometries are equal
MBRIntersects()	Whether MBRs of two geometries intersect
MBROverlaps()	Whether MBRs of two geometries overlap
MBRTouches()	Whether MBRs of two geometries touch
MBRWithin()	Whether MBR of one geometry is within MBR of another
MLineFromText(), MultiLineStringFromText()	Construct MultiLineString from WKT
MLineFromWKB(), MultiLineStringFromWKB()	Construct MultiLineString from WKB
MPointFromText(), MultiPointFromText()	Construct MultiPoint from WKT
MPointFromWKB(), MultiPointFromWKB()	Construct MultiPoint from WKB
MPolyFromText(), MultiPolygonFromText()	Construct MultiPolygon from WKT
MPolyFromWKB(), MultiPolygonFromWKB()	Construct MultiPolygon from WKB
MultiLineString()	Contruct MultiLineString from LineString values
MultiPoint()	Construct MultiPoint from Point values
MultiPolygon()	Construct MultiPolygon from Polygon values
NumGeometries()	Return number of geometries in geometry collection
NumInteriorRings()	Return number of interior rings in Polygon
NumPoints()	Return number of points in LineString
Overlaps()	Whether MBRs of two geometries overlap
Point()	Construct Point from coordinates
PointFromText()	Construct Point from WKT
PointFromWKB()	Construct Point from WKB
PointN()	Return N-th point from LineString
PolyFromText(), PolygonFromText()	Construct Polygon from WKT
PolyFromWKB(), PolygonFromWKB()	Construct Polygon from WKB
Polygon()	Construct Polygon from LineString arguments
SRID()	Return spatial reference system ID for geometry
StartPoint()	Start Point of LineString
Touches()	Whether one geometry touches another
Within()	Whether MBR of one geometry is within MBR of another
X()	Return X coordinate of Point
Y()	Return Y coordinate of Point

12.15.2 Argument Handling by Spatial Functions

Spatial values, or geometries, have the properties described at Section 11.5.2.2, “Geometry Class”. The following discussion lists general spatial function argument-handling characteristics. Specific

functions or groups of functions may have additional argument-handling characteristics, as discussed in the sections where those function descriptions occur.

Spatial functions are defined only for valid geometry values. If an invalid geometry is passed to a spatial function, the result is undefined.

The spatial reference identifier (SRID) of a geometry identifies the coordinate space in which the geometry is defined. In MySQL, the SRID value is an integer associated with the geometry value. The maximum usable SRID value is $2^{32}-1$. If a larger value is given, only the lower 32 bits are used.

Geometry values produced by any spatial function inherit the SRID of the geometry arguments.

12.15.3 Functions That Create Geometry Values from WKT Values

These functions take as arguments a Well-Known Text (WKT) representation and, optionally, a spatial reference system identifier (SRID). They return the corresponding geometry.

`GeomFromText()` accepts a WKT value of any geometry type as its first argument. Other functions provide type-specific construction functions for construction of geometry values of each geometry type.

For a description of WKT format, see Well-Known Text (WKT) Format.

- `GeomCollFromText(wkt[, srid])`, `GeometryCollectionFromText(wkt[, srid])`

  Constructs a `GeometryCollection` value using its WKT representation and SRID.

- `GeomFromText(wkt[, srid])`, `GeometryFromText(wkt[, srid])`

  Constructs a geometry value of any type using its WKT representation and SRID.

- `LineFromText(wkt[, srid])`, `LineStringFromText(wkt[, srid])`

  Constructs a `LineString` value using its WKT representation and SRID.

- `MLineFromText(wkt[, srid])`, `MultiLineStringFromText(wkt[, srid])`

  Constructs a `MultiLineString` value using its WKT representation and SRID.

- `MPointFromText(wkt[, srid])`, `MultiPointFromText(wkt[, srid])`

  Constructs a `MultiPoint` value using its WKT representation and SRID.

- `MPolyFromText(wkt[, srid])`, `MultiPolygonFromText(wkt[, srid])`

  Constructs a `MultiPolygon` value using its WKT representation and SRID.

- `PointFromText(wkt[, srid])`

  Constructs a `Point` value using its WKT representation and SRID.

- `PolyFromText(wkt[, srid])`, `PolygonFromText(wkt[, srid])`

  Constructs a `Polygon` value using its WKT representation and SRID.

12.15.4 Functions That Create Geometry Values from WKB Values

These functions take as arguments a `BLOB` containing a Well-Known Binary (WKB) representation and, optionally, a spatial reference system identifier (SRID). They return the corresponding geometry.

`GeomFromWKB()` accepts a WKB value of any geometry type as its first argument. Other functions provide type-specific construction functions for construction of geometry values of each geometry type.

These functions also accept geometry objects as returned by the functions in Section 12.15.5, “MySQL-Specific Functions That Create Geometry Values”. Thus, those functions may be used to provide the first argument to the functions in this section.

For a description of WKB format, see Well-Known Binary (WKB) Format.

- `GeomCollFromWKB(wkb[, srid])`, `GeometryCollectionFromWKB(wkb[, srid])`

  Constructs a `GeometryCollection` value using its WKB representation and SRID.

- `GeomFromWKB(wkb[, srid])`, `GeometryFromWKB(wkb[, srid])`

  Constructs a geometry value of any type using its WKB representation and SRID.

- `LineFromWKB(wkb[, srid])`, `LineStringFromWKB(wkb[, srid])`

  Constructs a `LineString` value using its WKB representation and SRID.

- `MLineFromWKB(wkb[, srid])`, `MultiLineStringFromWKB(wkb[, srid])`

  Constructs a `MultiLineString` value using its WKB representation and SRID.

- `MPointFromWKB(wkb[, srid])`, `MultiPointFromWKB(wkb[, srid])`

  Constructs a `MultiPoint` value using its WKB representation and SRID.

- `MPolyFromWKB(wkb[, srid])`, `MultiPolygonFromWKB(wkb[, srid])`

  Constructs a `MultiPolygon` value using its WKB representation and SRID.

- `PointFromWKB(wkb[, srid])`

  Constructs a `Point` value using its WKB representation and SRID.

- `PolyFromWKB(wkb[, srid])`, `PolygonFromWKB(wkb[, srid])`

  Constructs a `Polygon` value using its WKB representation and SRID.

12.15.5 MySQL-Specific Functions That Create Geometry Values

MySQL provides a set of useful nonstandard functions for creating geometry values. The functions described in this section are MySQL extensions to the OpenGIS specification.

These functions produce geometry objects from either WKB values or geometry objects as arguments. If any argument is not a proper WKB or geometry representation of the proper object type, the return value is `NULL`.

For example, you can insert the geometry return value from `Point()` directly into a `POINT` column:

```
INSERT INTO t1 (pt_col) VALUES(Point(1,2));
```

- `GeometryCollection(g1, g2, ...)`

  Constructs a `GeometryCollection`.

  If the argument contains a nonsupported geometry, the return value is `NULL`.

- `LineString(pt1, pt2, ...)`

  Constructs a `LineString` value from a number of `Point` or WKB `Point` arguments. If the number of arguments is less than two, the return value is `NULL`.

- `MultiLineString(ls1, ls2, ...)`

  Constructs a `MultiLineString` value using `LineString` or WKB `LineString` arguments.

- `MultiPoint(pt1, pt2, ...)`

Constructs a `MultiPoint` value using `Point` or WKB `Point` arguments.

- `MultiPolygon(poly1, poly2, ...)`

  Constructs a `MultiPolygon` value from a set of `Polygon` or WKB `Polygon` arguments.

- `Point(x, y)`

  Constructs a `Point` using its coordinates.

- `Polygon(ls1, ls2, ...)`

  Constructs a `Polygon` value from a number of `LineString` or WKB `LineString` arguments. If any argument does not represent a `LinearRing` (that is, not a closed and simple `LineString`), the return value is `NULL`.

12.15.6 Geometry Format Conversion Functions

MySQL supports the functions listed in this section for converting geometry values from internal geometry format to WKT or WKB format.

There are also functions to convert a string from WKT or WKB format to internal geometry format. See Section 12.15.3, “Functions That Create Geometry Values from WKT Values”, and Section 12.15.4, “Functions That Create Geometry Values from WKB Values”.

- `AsBinary(g)`, `AsWKB(g)`

  Converts a value in internal geometry format to its WKB representation and returns the binary result.

  The result is `NULL` if the geometry argument is `NULL` or not a syntactically well-formed geometry.

```
SELECT AsBinary(g) FROM geom;
```

- `AsText(g)`, `AsWKT(g)`

  Converts a value in internal geometry format to its WKT representation and returns the string result.

  The result is `NULL` if the geometry argument is `NULL` or not a syntactically well-formed geometry.

```
mysql> SET @g = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(GeomFromText(@g));
+--------------------------+
| AsText(GeomFromText(@g)) |
+--------------------------+
| LINESTRING(1 1,2 2,3 3)  |
+--------------------------+
```

12.15.7 Geometry Property Functions

Each function that belongs to this group takes a geometry value as its argument and returns some quantitative or qualitative property of the geometry. Some functions restrict their argument type. Such functions return `NULL` if the argument is of an incorrect geometry type. For example, the `Area()` polygon function returns `NULL` if the object type is neither `Polygon` nor `MultiPolygon`.

12.15.7.1 General Geometry Property Functions

The functions listed in this section do not restrict their argument and accept a geometry value of any type.

- `Dimension(g)`

Returns the inherent dimension of the geometry value *g*. The result can be −1, 0, 1, or 2. The meaning of these values is given in Section 11.5.2.2, “Geometry Class”.

```
mysql> SELECT Dimension(GeomFromText('LineString(1 1,2 2)'));
+---------------------------------------------+
| Dimension(GeomFromText('LineString(1 1,2 2)')) |
+---------------------------------------------+
|                                           1 |
+---------------------------------------------+
```

- `Envelope(g)`

  Returns the minimum bounding rectangle (MBR) for the geometry value *g*. The result is returned as a `Polygon` value that is defined by the corner points of the bounding box:

```
POLYGON((MINX MINY, MAXX MINY, MAXX MAXY, MINX MAXY, MINX MINY))
```

```
mysql> SELECT AsText(Envelope(GeomFromText('LineString(1 1,2 2)')));
+-----------------------------------------------------+
| AsText(Envelope(GeomFromText('LineString(1 1,2 2)'))) |
+-----------------------------------------------------+
| POLYGON((1 1,2 1,2 2,1 2,1 1))                      |
+-----------------------------------------------------+
```

- `GeometryType(g)`

  Returns a binary string indicating the name of the geometry type of which the geometry instance *g* is a member. The name corresponds to one of the instantiable `Geometry` subclasses.

```
mysql> SELECT GeometryType(GeomFromText('POINT(1 1)'));
+---------------------------------------+
| GeometryType(GeomFromText('POINT(1 1)')) |
+---------------------------------------+
| POINT                                 |
+---------------------------------------+
```

- `IsEmpty(g)`

  This function is a placeholder that returns 0 for any valid geometry value, 1 for any invalid geometry value or `NULL`.

  MySQL does not support GIS `EMPTY` values such as `POINT EMPTY`.

- `IsSimple(g)`

  In MySQL 5.5, this function is a placeholder that always returns 0.

  The description of each instantiable geometric class given earlier in the chapter includes the specific conditions that cause an instance of that class to be classified as not simple. (See Section 11.5.2.1, “The Geometry Class Hierarchy”.)

- `SRID(g)`

  Returns an integer indicating the spatial reference system ID associated with the geometry value *g*.

```
mysql> SELECT SRID(GeomFromText('LineString(1 1,2 2)',101));
+-----------------------------------------------+
| SRID(GeomFromText('LineString(1 1,2 2)',101)) |
+-----------------------------------------------+
|                                           101 |
+-----------------------------------------------+
```

12.15.7.2 Point Property Functions

A `Point` consists of X and Y coordinates, which may be obtained using the following functions:

- `X(p)`

  Returns the X-coordinate value for the `Point` object *p* as a double-precision number.

```
mysql> SELECT X(Point(56.7, 53.34));
+----------------------+
| X(Point(56.7, 53.34)) |
+----------------------+
|                 56.7 |
+----------------------+
```

- `Y(p)`

  Returns the Y-coordinate value for the `Point` object *p* as a double-precision number.

```
mysql> SELECT Y(Point(56.7, 53.34));
+----------------------+
| Y(Point(56.7, 53.34)) |
+----------------------+
|                53.34 |
+----------------------+
```

12.15.7.3 LineString and MultiLineString Property Functions

A `LineString` consists of `Point` values. You can extract particular points of a `LineString`, count the number of points that it contains, or obtain its length.

Some functions in this section also work for `MultiLineString` values.

- `EndPoint(ls)`

  Returns the `Point` that is the endpoint of the `LineString` value *ls*. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(EndPoint(GeomFromText(@ls)));
+------------------------------------+
| AsText(EndPoint(GeomFromText(@ls))) |
+------------------------------------+
| POINT(3 3)                         |
+------------------------------------+
```

- `GLength(ls)`

  Returns a double-precision number indicating the length of the `LineString` or `MultiLineString` value *ls* in its associated spatial reference. The length of a `MultiLineString` value is equal to the sum of the lengths of its elements. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT GLength(GeomFromText(@ls));
+---------------------------+
| GLength(GeomFromText(@ls)) |
+---------------------------+
|         2.8284271247461903 |
+---------------------------+

mysql> SET @mls = 'MultiLineString((1 1,2 2,3 3),(4 4,5 5))';
mysql> SELECT GLength(GeomFromText(@mls));
+---------------------------+
```

```
| GLength(GeomFromText(@mls)) |
+-----------------------------+
|           4.242640687119286 |
+-----------------------------+
```

`GLength()` is a nonstandard name. It corresponds to the OpenGIS `Length()` function. (There is an existing SQL function `Length()` that calculates the length of string values.)

- `IsClosed(ls)`

  For a `LineString` value *`ls`*, `IsClosed()` returns 1 if *`ls`* is closed (that is, its `StartPoint()` and `EndPoint()` values are the same). If the argument is `NULL` or an empty geometry, the return value is `NULL`.

  For a `MultiLineString` value *`ls`*, `IsClosed()` returns 1 if *`ls`* is closed (that is, the `StartPoint()` and `EndPoint()` values are the same for each `LineString` in *`ls`*).

  `IsClosed()` returns 0 if *`ls`* is not closed.

```
mysql> SET @ls1 = 'LineString(1 1,2 2,3 3,2 2)';
mysql> SET @ls2 = 'LineString(1 1,2 2,3 3,1 1)';

mysql> SELECT IsClosed(GeomFromText(@ls1));
+------------------------------+
| IsClosed(GeomFromText(@ls1)) |
+------------------------------+
|                            0 |
+------------------------------+

mysql> SELECT IsClosed(GeomFromText(@ls2));
+------------------------------+
| IsClosed(GeomFromText(@ls2)) |
+------------------------------+
|                            1 |
+------------------------------+

mysql> SET @ls3 = 'MultiLineString((1 1,2 2,3 3),(4 4,5 5))';

mysql> SELECT IsClosed(GeomFromText(@ls3));
+------------------------------+
| IsClosed(GeomFromText(@ls3)) |
+------------------------------+
|                            0 |
+------------------------------+
```

- `NumPoints(ls)`

  Returns the number of `Point` objects in the `LineString` value *`ls`*. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT NumPoints(GeomFromText(@ls));
+------------------------------+
| NumPoints(GeomFromText(@ls)) |
+------------------------------+
|                            3 |
+------------------------------+
```

- `PointN(ls, N)`

  Returns the *`N`*-th `Point` in the `Linestring` value *`ls`*. Points are numbered beginning with 1. If any argument is `NULL` or the geometry argument is an empty geometry, the return value is `NULL`.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(PointN(GeomFromText(@ls),2));
+-------------------------------------+
```

```
| AsText(PointN(GeomFromText(@ls),2)) |
+-------------------------------------+
| POINT(2 2)                          |
+-------------------------------------+
```

- `StartPoint(ls)`

  Returns the `Point` that is the start point of the `LineString` value *`ls`*. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @ls = 'LineString(1 1,2 2,3 3)';
mysql> SELECT AsText(StartPoint(GeomFromText(@ls)));
+---------------------------------------+
| AsText(StartPoint(GeomFromText(@ls))) |
+---------------------------------------+
| POINT(1 1)                            |
+---------------------------------------+
```

12.15.7.4 Polygon and MultiPolygon Property Functions

Functions in this section return properties of `Polygon` or `MultiPolygon` values.

- `Area(poly)`

  Returns a double-precision number indicating the area of the argument, as measured in its spatial reference system. For arguments of dimension 0 or 1, the result is 0. If the argument is an empty geometry the return value is 0. If the argument is `NULL` the return value is `NULL`.

```
mysql> SET @poly =
       'Polygon((0 0,0 3,3 0,0 0),(1 1,1 2,2 1,1 1))';
mysql> SELECT Area(GeomFromText(@poly));
+---------------------------+
| Area(GeomFromText(@poly)) |
+---------------------------+
|                         4 |
+---------------------------+

mysql> SET @mpoly =
    -> 'MultiPolygon(((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1 1)))';
mysql> SELECT Area(GeomFromText(@mpoly));
+----------------------------+
| Area(GeomFromText(@mpoly)) |
+----------------------------+
|                          8 |
+----------------------------+
```

- `Centroid(mpoly)`

  Returns the mathematical centroid for the `MultiPolygon` value *`mpoly`* as a `Point`. The result is not guaranteed to be on the `MultiPolygon`. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @poly =
    -> GeomFromText('POLYGON((0 0,10 0,10 10,0 10,0 0),(5 5,7 5,7 7,5 7,5 5))');
mysql> SELECT GeometryType(@poly),AsText(Centroid(@poly));
+--------------------+-----------------------------------------+
| GeometryType(@poly) | AsText(Centroid(@poly))                 |
+--------------------+-----------------------------------------+
| POLYGON            | POINT(4.958333333333333 4.958333333333333) |
+--------------------+-----------------------------------------+
```

- `ExteriorRing(poly)`

  Returns the exterior ring of the `Polygon` value *`poly`* as a `LineString`. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @poly =
    -> 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1 1))';
mysql> SELECT AsText(ExteriorRing(GeomFromText(@poly)));
+-----------------------------------------+
| AsText(ExteriorRing(GeomFromText(@poly))) |
+-----------------------------------------+
| LINESTRING(0 0,0 3,3 3,3 0,0 0)         |
+-----------------------------------------+
```

- `InteriorRingN(poly, N)`

  Returns the *N*-th interior ring for the `Polygon` value *`poly`* as a `LineString`. Rings are numbered beginning with 1. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @poly =
    -> 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1 1))';
mysql> SELECT AsText(InteriorRingN(GeomFromText(@poly),1));
+---------------------------------------------+
| AsText(InteriorRingN(GeomFromText(@poly),1)) |
+---------------------------------------------+
| LINESTRING(1 1,1 2,2 2,2 1,1 1)             |
+---------------------------------------------+
```

- `NumInteriorRings(poly)`

  Returns the number of interior rings in the `Polygon` value *`poly`*. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @poly =
    -> 'Polygon((0 0,0 3,3 3,3 0,0 0),(1 1,1 2,2 2,2 1,1 1))';
mysql> SELECT NumInteriorRings(GeomFromText(@poly));
+--------------------------------------+
| NumInteriorRings(GeomFromText(@poly)) |
+--------------------------------------+
|                                    1 |
+--------------------------------------+
```

12.15.7.5 GeometryCollection Property Functions

These functions return properties of `GeometryCollection` values.

- `GeometryN(gc, N)`

  Returns the *N*-th geometry in the `GeometryCollection` value *`gc`*. Geometries are numbered beginning with 1. If any argument is `NULL` or the geometry argument is an empty geometry, the return value is `NULL`.

```
mysql> SET @gc = 'GeometryCollection(Point(1 1),LineString(2 2, 3 3))';
mysql> SELECT AsText(GeometryN(GeomFromText(@gc),1));
+--------------------------------------+
| AsText(GeometryN(GeomFromText(@gc),1)) |
+--------------------------------------+
| POINT(1 1)                           |
+--------------------------------------+
```

- `NumGeometries(gc)`

  Returns the number of geometries in the `GeometryCollection` value *`gc`*. If the argument is `NULL` or an empty geometry, the return value is `NULL`.

```
mysql> SET @gc = 'GeometryCollection(Point(1 1),LineString(2 2, 3 3))';
mysql> SELECT NumGeometries(GeomFromText(@gc));
+---------------------------------+
```

```
| NumGeometries(GeomFromText(@gc)) |
+----------------------------------+
|                                2 |
+----------------------------------+
```

12.15.8 Spatial Operator Functions

Section 12.15.7, “Geometry Property Functions”, discusses several functions that construct new geometries from existing ones. See that section for descriptions of these functions:

- `Envelope(g)`
- `StartPoint(ls)`
- `EndPoint(ls)`
- `PointN(ls, N)`
- `ExteriorRing(poly)`
- `InteriorRingN(poly, N)`
- `GeometryN(gc, N)`

12.15.9 Functions That Test Spatial Relations Between Geometry Objects

The functions described in this section take two geometries as arguments and return a qualitative or quantitative relation between them.

MySQL implements two sets of functions using function names defined by the OpenGIS specification. One set tests the relationship between two geometry values using precise object shapes, the other set uses object minimum bounding rectangles (MBRs).

There is also a MySQL-specific set of MBR-based functions available to test the relationship between two geometry values.

12.15.9.1 Spatial Relation Functions That Use Object Shapes

The OpenGIS specification defines the following functions to test the relationship between two geometry values `g1` and `g2`, using precise object shapes. The return values 1 and 0 indicate true and false, respectively.

- `Crosses(g1, g2)`

  The term *spatially crosses* denotes a spatial relation between two given geometries that has the following properties:

  - The two geometries intersect.
  - Their intersection results in a geometry that has a dimension that is one less than the maximum dimension of the two given geometries.
  - Their intersection is not equal to either of the two given geometries.

  This function returns 1 or 0 to indicate whether *`g1`* spatially crosses *`g2`*. If `g1` is a `Polygon` or a `MultiPolygon`, or if *`g2`* is a `Point` or a `MultiPoint`, the return value is `NULL`.

- `Touches(g1, g2)`

  Two geometries *spatially touch* if their interiors do not intersect, but the boundary of one of the geometries intersects either the boundary or the interior of the other.

  This function returns 1 or 0 to indicate whether *`g1`* spatially touches *`g2`*.

12.15.9.2 Spatial Relation Functions That Use Minimum Bounding Rectangles

MySQL provides several MySQL-specific functions that test the relationship between minimum bounding rectangles (MBRs) of two geometries `g1` and `g2`. The return values 1 and 0 indicate true and false, respectively.

A corresponding set of MBR functions defined according to the OpenGIS specification is described later in this section.

- `MBRContains(g1, g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangle of *`g1`* contains the minimum bounding rectangle of *`g2`*. This tests the opposite relationship as `MBRWithin()`.

```
mysql> SET @g1 = GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0))');
mysql> SET @g2 = GeomFromText('Point(1 1)');
mysql> SELECT MBRContains(@g1,@g2), MBRWithin(@g2,@g1);
+---------------------+-------------------+
| MBRContains(@g1,@g2) | MBRWithin(@g2,@g1) |
+---------------------+-------------------+
|                   1 |                 1 |
+---------------------+-------------------+
```

- `MBRDisjoint(g1, g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries *`g1`* and *`g2`* are disjoint (do not intersect).

- `MBREqual(g1, g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries *`g1`* and *`g2`* are the same.

- `MBRIntersects(g1, g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries *`g1`* and *`g2`* intersect.

- `MBROverlaps(g1, g2)`

  Two geometries *spatially overlap* if they intersect and their intersection results in a geometry of the same dimension but not equal to either of the given geometries.

  This function returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries *`g1`* and *`g2`* overlap.

- `MBRTouches(g1, g2)`

  Two geometries *spatially touch* if their interiors do not intersect, but the boundary of one of the geometries intersects either the boundary or the interior of the other.

  This function returns 1 or 0 to indicate whether the minimum bounding rectangles of the two geometries *`g1`* and *`g2`* touch.

- `MBRWithin(g1, g2)`

  Returns 1 or 0 to indicate whether the minimum bounding rectangle of *`g1`* is within the minimum bounding rectangle of *`g2`*. This tests the opposite relationship as `MBRContains()`.

```
mysql> SET @g1 = GeomFromText('Polygon((0 0,0 3,3 3,3 0,0 0))');
mysql> SET @g2 = GeomFromText('Polygon((0 0,0 5,5 5,5 0,0 0))');
mysql> SELECT MBRWithin(@g1,@g2), MBRWithin(@g2,@g1);
+-------------------+-------------------+
```

```
| MBRWithin(@g1,@g2) | MBRWithin(@g2,@g1) |
+--------------------+--------------------+
|                  1 |                  0 |
+--------------------+--------------------+
```

The OpenGIS specification defines the following functions that test the relationship between two geometry values `g1` and `g2`. The MySQL implementation uses minimum bounding rectangles, so these functions return the same result as the corresponding MBR-based functions described earlier in this section. The return values 1 and 0 indicate true and false, respectively.

- `Contains(g1, g2)`

  Returns 1 or 0 to indicate whether *`g1`* completely contains *`g2`*. This tests the opposite relationship as `Within()`.

- `Disjoint(g1, g2)`

  Returns 1 or 0 to indicate whether *`g1`* is spatially disjoint from (does not intersect) *`g2`*.

- `Equals(g1, g2)`

  Returns 1 or 0 to indicate whether *`g1`* is spatially equal to *`g2`*.

- `Intersects(g1, g2)`

  Returns 1 or 0 to indicate whether *`g1`* spatially intersects *`g2`*.

- `Overlaps(g1, g2)`

  Two geometries *spatially overlap* if they intersect and their intersection results in a geometry of the same dimension but not equal to either of the given geometries.

  This function returns 1 or 0 to indicate whether *`g1`* spatially overlaps *`g2`*.

- `Within(g1, g2)`

  Returns 1 or 0 to indicate whether *`g1`* is spatially within *`g2`*. This tests the opposite relationship as `Contains()`.

12.16 Aggregate (GROUP BY) Functions

12.16.1 Aggregate (GROUP BY) Function Descriptions

This section describes group (aggregate) functions that operate on sets of values.

Table 12.20 Aggregate (`GROUP BY`) Functions

Name	Description
`AVG()`	Return the average value of the argument
`BIT_AND()`	Return bitwise AND
`BIT_OR()`	Return bitwise OR
`BIT_XOR()`	Return bitwise XOR
`COUNT()`	Return a count of the number of rows returned
`COUNT(DISTINCT)`	Return the count of a number of different values
`GROUP_CONCAT()`	Return a concatenated string
`MAX()`	Return the maximum value
`MIN()`	Return the minimum value
`STD()`	Return the population standard deviation

Name	Description
STDDEV()	Return the population standard deviation
STDDEV_POP()	Return the population standard deviation
STDDEV_SAMP()	Return the sample standard deviation
SUM()	Return the sum
VAR_POP()	Return the population standard variance
VAR_SAMP()	Return the sample variance
VARIANCE()	Return the population standard variance

Unless otherwise stated, group functions ignore NULL values.

If you use a group function in a statement containing no GROUP BY clause, it is equivalent to grouping on all rows. For more information, see Section 12.16.3, “MySQL Handling of GROUP BY”.

For numeric arguments, the variance and standard deviation functions return a DOUBLE value. The SUM() and AVG() functions return a DECIMAL value for exact-value arguments (integer or DECIMAL), and a DOUBLE value for approximate-value arguments (FLOAT or DOUBLE).

The SUM() and AVG() aggregate functions do not work with temporal values. (They convert the values to numbers, losing everything after the first nonnumeric character.) To work around this problem, convert to numeric units, perform the aggregate operation, and convert back to a temporal value. Examples:

```
SELECT SEC_TO_TIME(SUM(TIME_TO_SEC(time_col))) FROM tbl_name;
SELECT FROM_DAYS(SUM(TO_DAYS(date_col))) FROM tbl_name;
```

Functions such as SUM() or AVG() that expect a numeric argument cast the argument to a number if necessary. For SET or ENUM values, the cast operation causes the underlying numeric value to be used.

The BIT_AND(), BIT_OR(), and BIT_XOR() aggregate functions perform bit operations. They require BIGINT (64-bit integer) arguments and return BIGINT values. Arguments of other types are converted to BIGINT and truncation might occur.

- AVG([DISTINCT] *expr*)

  Returns the average value of *expr*. The DISTINCT option can be used to return the average of the distinct values of *expr*.

  If there are no matching rows, AVG() returns NULL.

  ```
  mysql> SELECT student_name, AVG(test_score)
         FROM student
         GROUP BY student_name;
  ```

- BIT_AND(*expr*)

  Returns the bitwise AND of all bits in *expr*. The calculation is performed with 64-bit (BIGINT) precision.

  If there are no matching rows, BIT_AND() returns a neutral value (all bits set to 1).

- BIT_OR(*expr*)

  Returns the bitwise OR of all bits in *expr*. The calculation is performed with 64-bit (BIGINT) precision.

  If there are no matching rows, BIT_OR() returns a neutral value (all bits set to 0).

- `BIT_XOR(expr)`

  Returns the bitwise `XOR` of all bits in *`expr`*. The calculation is performed with 64-bit (`BIGINT`) precision.

  If there are no matching rows, `BIT_XOR()` returns a neutral value (all bits set to 0).

- `COUNT(expr)`

  Returns a count of the number of non-`NULL` values of *`expr`* in the rows retrieved by a `SELECT` statement. The result is a `BIGINT` value.

  If there are no matching rows, `COUNT()` returns `0`.

```
mysql> SELECT student.student_name,COUNT(*)
       FROM student,course
       WHERE student.student_id=course.student_id
       GROUP BY student_name;
```

  `COUNT(*)` is somewhat different in that it returns a count of the number of rows retrieved, whether or not they contain `NULL` values.

  For `MyISAM` tables, `COUNT(*)` is optimized to return very quickly if the `SELECT` retrieves from one table, no other columns are retrieved, and there is no `WHERE` clause. For example:

```
mysql> SELECT COUNT(*) FROM student;
```

  This optimization only applies to `MyISAM` tables, because an exact row count is stored for this storage engine and can be accessed very quickly. `COUNT(1)` is only subject to the same optimization if the first column is defined as `NOT NULL`.

  For transactional storage engines such as `InnoDB`, storing an exact row count is problematic because multiple transactions may be occurring, each of which may affect the count. For more information about how `InnoDB` handles `COUNT(*)` operations, see Section 14.11.1.7, “Limits on InnoDB Tables”.

- `COUNT(DISTINCT expr,[expr...])`

  Returns a count of the number of rows with different non-`NULL` *`expr`* values.

  If there are no matching rows, `COUNT(DISTINCT)` returns `0`.

```
mysql> SELECT COUNT(DISTINCT results) FROM student;
```

  In MySQL, you can obtain the number of distinct expression combinations that do not contain `NULL` by giving a list of expressions. In standard SQL, you would have to do a concatenation of all expressions inside `COUNT(DISTINCT ...)`.

- `GROUP_CONCAT(expr)`

  This function returns a string result with the concatenated non-`NULL` values from a group. It returns `NULL` if there are no non-`NULL` values. The full syntax is as follows:

```
GROUP_CONCAT([DISTINCT] expr [,expr ...]
             [ORDER BY {unsigned_integer | col_name | expr}
                 [ASC | DESC] [,col_name ...]]
             [SEPARATOR str_val])
```

```
mysql> SELECT student_name,
         GROUP_CONCAT(test_score)
```

```
       FROM student
       GROUP BY student_name;
```

Or:

```
mysql> SELECT student_name,
         GROUP_CONCAT(DISTINCT test_score
                      ORDER BY test_score DESC SEPARATOR ' ')
       FROM student
       GROUP BY student_name;
```

In MySQL, you can get the concatenated values of expression combinations. To eliminate duplicate values, use the `DISTINCT` clause. To sort values in the result, use the `ORDER BY` clause. To sort in reverse order, add the `DESC` (descending) keyword to the name of the column you are sorting by in the `ORDER BY` clause. The default is ascending order; this may be specified explicitly using the `ASC` keyword. The default separator between values in a group is comma (`,`). To specify a separator explicitly, use `SEPARATOR` followed by the string literal value that should be inserted between group values. To eliminate the separator altogether, specify `SEPARATOR ''`.

The result is truncated to the maximum length that is given by the `group_concat_max_len` system variable, which has a default value of 1024. The value can be set higher, although the effective maximum length of the return value is constrained by the value of `max_allowed_packet`. The syntax to change the value of `group_concat_max_len` at runtime is as follows, where *`val`* is an unsigned integer:

```
SET [GLOBAL | SESSION] group_concat_max_len = val;
```

The return value is a nonbinary or binary string, depending on whether the arguments are nonbinary or binary strings. The result type is `TEXT` or `BLOB` unless `group_concat_max_len` is less than or equal to 512, in which case the result type is `VARCHAR` or `VARBINARY`.

See also `CONCAT()` and `CONCAT_WS()`: Section 12.5, “String Functions”.

- `MAX([DISTINCT] expr)`

  Returns the maximum value of *`expr`*. `MAX()` may take a string argument; in such cases, it returns the maximum string value. See Section 8.3.1, “How MySQL Uses Indexes”. The `DISTINCT` keyword can be used to find the maximum of the distinct values of *`expr`*, however, this produces the same result as omitting `DISTINCT`.

  If there are no matching rows, `MAX()` returns `NULL`.

```
mysql> SELECT student_name, MIN(test_score), MAX(test_score)
       FROM student
       GROUP BY student_name;
```

  For `MAX()`, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set. This differs from how `ORDER BY` compares them.

- `MIN([DISTINCT] expr)`

  Returns the minimum value of *`expr`*. `MIN()` may take a string argument; in such cases, it returns the minimum string value. See Section 8.3.1, “How MySQL Uses Indexes”. The `DISTINCT` keyword can be used to find the minimum of the distinct values of *`expr`*, however, this produces the same result as omitting `DISTINCT`.

  If there are no matching rows, `MIN()` returns `NULL`.

```
mysql> SELECT student_name, MIN(test_score), MAX(test_score)
       FROM student
```

```
      GROUP BY student_name;
```

For `MIN()`, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set. This differs from how `ORDER BY` compares them.

- `STD(expr)`

  Returns the population standard deviation of *`expr`*. `STD()` is a synonym for the standard SQL function `STDDEV_POP()`, provided as a MySQL extension.

  If there are no matching rows, `STD()` returns `NULL`.

- `STDDEV(expr)`

  Returns the population standard deviation of *`expr`*. `STDDEV()` is a synonym for the standard SQL function `STDDEV_POP()`, provided for compatibility with Oracle.

  If there are no matching rows, `STDDEV()` returns `NULL`.

- `STDDEV_POP(expr)`

  Returns the population standard deviation of *`expr`* (the square root of `VAR_POP()`). You can also use `STD()` or `STDDEV()`, which are equivalent but not standard SQL.

  If there are no matching rows, `STDDEV_POP()` returns `NULL`.

- `STDDEV_SAMP(expr)`

  Returns the sample standard deviation of *`expr`* (the square root of `VAR_SAMP()`.

  If there are no matching rows, `STDDEV_SAMP()` returns `NULL`.

- `SUM([DISTINCT] expr)`

  Returns the sum of *`expr`*. If the return set has no rows, `SUM()` returns `NULL`. The `DISTINCT` keyword can be used to sum only the distinct values of *`expr`*.

  If there are no matching rows, `SUM()` returns `NULL`.

- `VAR_POP(expr)`

  Returns the population standard variance of *`expr`*. It considers rows as the whole population, not as a sample, so it has the number of rows as the denominator. You can also use `VARIANCE()`, which is equivalent but is not standard SQL.

  If there are no matching rows, `VAR_POP()` returns `NULL`.

- `VAR_SAMP(expr)`

  Returns the sample variance of *`expr`*. That is, the denominator is the number of rows minus one.

  If there are no matching rows, `VAR_SAMP()` returns `NULL`.

- `VARIANCE(expr)`

  Returns the population standard variance of *`expr`*. `VARIANCE()` is a synonym for the standard SQL function `VAR_POP()`, provided as a MySQL extension.

  If there are no matching rows, `VARIANCE()` returns `NULL`.

12.16.2 GROUP BY Modifiers

The `GROUP BY` clause permits a `WITH ROLLUP` modifier that causes summary output to include extra rows that represent higher-level (that is, super-aggregate) summary operations. `ROLLUP` thus enables

you to answer questions at multiple levels of analysis with a single query. For example, `ROLLUP` can be used to provide support for OLAP (Online Analytical Processing) operations.

Suppose that a `sales` table has `year`, `country`, `product`, and `profit` columns for recording sales profitability:

```
CREATE TABLE sales
(
    year    INT,
    country VARCHAR(20),
    product VARCHAR(32),
    profit  INT
);
```

To summarize table contents per year, use a simple `GROUP BY` like this:

```
mysql> SELECT year, SUM(profit) AS profit
       FROM sales
       GROUP BY year ASC;
+------+--------+
| year | profit |
+------+--------+
| 2000 |   4525 |
| 2001 |   3010 |
+------+--------+
```

The output shows the total profit for each year. To also determine the total profit summed over all years, you must add up the individual values yourself or run an additional query. Or you can use `ROLLUP`, which provides both levels of analysis with a single query. Adding a `WITH ROLLUP` modifier to the `GROUP BY` clause causes the query to produce another row that shows the grand total over all year values:

```
mysql> SELECT year, SUM(profit) AS profit
       FROM sales
       GROUP BY year ASC WITH ROLLUP;
+------+--------+
| year | profit |
+------+--------+
| 2000 |   4525 |
| 2001 |   3010 |
| NULL |   7535 |
+------+--------+
```

The `NULL` value in the `year` column identifies the grand total super-aggregate line.

`ROLLUP` has a more complex effect when there are multiple `GROUP BY` columns. In this case, each time there is a change in value in any but the last grouping column, the query produces an extra super-aggregate summary row.

For example, without `ROLLUP`, a summary of the `sales` table based on `year`, `country`, and `product` might look like this, where the output indicates summary values only at the year/country/product level of analysis:

```
mysql> SELECT year, country, product, SUM(profit) AS profit
       FROM sales
       GROUP BY year ASC, country ASC, product ASC;
+------+---------+------------+--------+
| year | country | product    | profit |
+------+---------+------------+--------+
| 2000 | Finland | Computer   |   1500 |
| 2000 | Finland | Phone      |    100 |
| 2000 | India   | Calculator |    150 |
| 2000 | India   | Computer   |   1200 |
| 2000 | USA     | Calculator |     75 |
| 2000 | USA     | Computer   |   1500 |
```

```
| 2001 | Finland | Phone      |     10 |
| 2001 | USA     | Calculator |     50 |
| 2001 | USA     | Computer   |   2700 |
| 2001 | USA     | TV         |    250 |
+------+---------+------------+--------+
```

With `ROLLUP` added, the query produces several extra rows:

```
mysql> SELECT year, country, product, SUM(profit) AS profit
       FROM sales
       GROUP BY year ASC, country ASC, product ASC WITH ROLLUP;
+------+---------+------------+--------+
| year | country | product    | profit |
+------+---------+------------+--------+
| 2000 | Finland | Computer   |   1500 |
| 2000 | Finland | Phone      |    100 |
| 2000 | Finland | NULL       |   1600 |
| 2000 | India   | Calculator |    150 |
| 2000 | India   | Computer   |   1200 |
| 2000 | India   | NULL       |   1350 |
| 2000 | USA     | Calculator |     75 |
| 2000 | USA     | Computer   |   1500 |
| 2000 | USA     | NULL       |   1575 |
| 2000 | NULL    | NULL       |   4525 |
| 2001 | Finland | Phone      |     10 |
| 2001 | Finland | NULL       |     10 |
| 2001 | USA     | Calculator |     50 |
| 2001 | USA     | Computer   |   2700 |
| 2001 | USA     | TV         |    250 |
| 2001 | USA     | NULL       |   3000 |
| 2001 | NULL    | NULL       |   3010 |
| NULL | NULL    | NULL       |   7535 |
+------+---------+------------+--------+
```

Now the output includes summary information at four levels of analysis, not just one:

- Following each set of product rows for a given year and country, an extra summary row appears showing the total for all products. These rows have the `product` column set to `NULL`.
- Following each set of rows for a given year, an extra summary row appears showing the total for all countries and products. These rows have the `country` and `products` columns set to `NULL`.
- Finally, following all other rows, an extra summary row appears showing the grand total for all years, countries, and products. This row has the `year`, `country`, and `products` columns set to `NULL`.

Other Considerations When using ROLLUP

The following discussion lists some behaviors specific to the MySQL implementation of `ROLLUP`.

When you use `ROLLUP`, you cannot also use an `ORDER BY` clause to sort the results. In other words, `ROLLUP` and `ORDER BY` are mutually exclusive in MySQL. However, you still have some control over sort order. `GROUP BY` in MySQL implicitly sorts results by default (in the absence of `ASC` or `DESC` designators). However, implicit `GROUP BY` sorting in MySQL is deprecated. To achieve a specific sort order of grouped results:

- Use explicit `ASC` and `DESC` keywords with columns named in the `GROUP BY` list to specify sort order for individual columns. In this case, the super-aggregate summary rows added by `ROLLUP` still appear after the rows from which they are calculated, regardless of the sort order.
- To work around the restriction that prevents using `ROLLUP` with `ORDER BY`, generate the grouped result set as a derived table and apply `ORDER BY` to it. For example:

```
SELECT * FROM
(SELECT year, SUM(profit) FROM sales GROUP BY year WITH ROLLUP) AS dt
ORDER BY year;
```

In this case, the super-aggregate summary rows sort with the rows from which they are calculated, and their placement depends on sort order (at the beginning for ascending sort, at the end for descending sort).

`LIMIT` can be used to restrict the number of rows returned to the client. `LIMIT` is applied after `ROLLUP`, so the limit applies against the extra rows added by `ROLLUP`. For example:

```
mysql> SELECT year, country, product, SUM(profit) AS profit
       FROM sales
       GROUP BY year ASC, country ASC, product ASC WITH ROLLUP
       LIMIT 5;
+------+---------+------------+--------+
| year | country | product    | profit |
+------+---------+------------+--------+
| 2000 | Finland | Computer   |   1500 |
| 2000 | Finland | Phone      |    100 |
| 2000 | Finland | NULL       |   1600 |
| 2000 | India   | Calculator |    150 |
| 2000 | India   | Computer   |   1200 |
+------+---------+------------+--------+
```

Using `LIMIT` with `ROLLUP` may produce results that are more difficult to interpret, because there is less context for understanding the super-aggregate rows.

The `NULL` indicators in each super-aggregate row are produced when the row is sent to the client. The server looks at the columns named in the `GROUP BY` clause following the leftmost one that has changed value. For any column in the result set with a name that matches any of those names, its value is set to `NULL`. (If you specify grouping columns by column position, the server identifies which columns to set to `NULL` by position.)

Because the `NULL` values in the super-aggregate rows are placed into the result set at such a late stage in query processing, you can test them as `NULL` values only in the select list or `HAVING` clause. You cannot test them as `NULL` values in join conditions or the `WHERE` clause to determine which rows to select. For example, you cannot add `WHERE product IS NULL` to the query to eliminate from the output all but the super-aggregate rows.

The `NULL` values do appear as `NULL` on the client side and can be tested as such using any MySQL client programming interface. However, at this point, you cannot distinguish whether a `NULL` represents a regular grouped value or a super-aggregate value.

A MySQL extension permits a column that does not appear in the `GROUP BY` list to be named in the select list. (For information about nonaggregated columns and `GROUP BY`, see Section 12.16.3, “MySQL Handling of GROUP BY”.) In this case, the server is free to choose any value from this nonaggregated column in summary rows, and this includes the extra rows added by `WITH ROLLUP`. For example, in the following query, `country` is a nonaggregated column that does not appear in the `GROUP BY` list and values chosen for this column are indeterminate:

```
mysql> SELECT year, country, SUM(profit) AS profit
       FROM sales
       GROUP BY year ASC WITH ROLLUP;
+------+---------+--------+
| year | country | profit |
+------+---------+--------+
| 2000 | India   |   4525 |
| 2001 | USA     |   3010 |
| NULL | USA     |   7535 |
+------+---------+--------+
```

This behavior is permitted when the `ONLY_FULL_GROUP_BY` SQL mode is not enabled. If that mode is enabled, the server rejects the query as illegal because `country` is not listed in the `GROUP BY` clause.

12.16.3 MySQL Handling of GROUP BY

In standard SQL, a query that includes a `GROUP BY` clause cannot refer to nonaggregated columns in the select list that are not named in the `GROUP BY` clause. For example, this query is illegal in standard SQL because the nonaggregated `name` column in the select list does not appear in the `GROUP BY`:

```
SELECT o.custid, c.name, MAX(o.payment)
  FROM orders AS o, customers AS c
  WHERE o.custid = c.custid
  GROUP BY o.custid;
```

For the query to be legal, the `name` column must be omitted from the select list or named in the `GROUP BY` clause.

MySQL extends the standard SQL use of `GROUP BY` so that the select list can refer to nonaggregated columns not named in the `GROUP BY` clause. This means that the preceding query is legal in MySQL. You can use this feature to get better performance by avoiding unnecessary column sorting and grouping. However, this is useful primarily when all values in each nonaggregated column not named in the `GROUP BY` are the same for each group. The server is free to choose any value from each group, so unless they are the same, the values chosen are indeterminate. Furthermore, the selection of values from each group cannot be influenced by adding an `ORDER BY` clause. Result set sorting occurs after values have been chosen, and `ORDER BY` does not affect which values within each group the server chooses.

A similar MySQL extension applies to the `HAVING` clause. In standard SQL, a query cannot refer to nonaggregated columns in the `HAVING` clause that are not named in the `GROUP BY` clause. To simplify calculations, a MySQL extension permits references to such columns. This extension assumes that the nongrouped columns have the same group-wise values. Otherwise, the result is indeterminate.

To disable the MySQL `GROUP BY` extension and enable standard SQL behavior, enable the `ONLY_FULL_GROUP_BY` SQL mode. In this case, columns not named in the `GROUP BY` clause cannot be used in the select list or `HAVING` clause unless enclosed in an aggregate function.

The select list extension also applies to `ORDER BY`. That is, you can refer to nonaggregated columns in the `ORDER BY` clause that do not appear in the `GROUP BY` clause. (However, as mentioned previously, `ORDER BY` does not affect which values are chosen from nonaggregated columns; it only sorts them after they have been chosen.) This extension does not apply if the `ONLY_FULL_GROUP_BY` SQL mode is enabled.

If a query has aggregate functions and no `GROUP BY` clause, it cannot have nonaggregated columns in the select list, `HAVING` condition, or `ORDER BY` list with `ONLY_FULL_GROUP_BY` enabled:

```
mysql> SELECT name, MAX(age) FROM t;
ERROR 1140 (42000): Mixing of GROUP columns (MIN(),MAX(),COUNT(),...)
with no GROUP columns is illegal if there is no GROUP BY clause
```

Without `GROUP BY`, there is a single group and it is indeterminate which `name` value to choose for the group.

Another MySQL extension to standard SQL permits references in the `HAVING` clause to aliased expressions in the select list. Enabling `ONLY_FULL_GROUP_BY` prevents this. For example, the following query returns `name` values that occur only once in table `orders`; the query is accepted regardless of whether `ONLY_FULL_GROUP_BY` is enabled:

```
SELECT name, COUNT(name) FROM orders
  GROUP BY name
  HAVING COUNT(name) = 1;
```

The following query is accepted only if `ONLY_FULL_GROUP_BY` is disabled.

```
SELECT name, COUNT(name) AS c FROM orders
```

```
  GROUP BY name
  HAVING c = 1;
```

If you are trying to follow standard SQL, you can use only column expressions in `GROUP BY` clauses. As a workaround, use an alias for the expression:

```
SELECT id, FLOOR(value/100) AS val
  FROM tbl_name
  GROUP BY id, val;
```

MySQL permits noncolumn expressions in `GROUP BY` clauses, so the alias is unnecessary:

```
SELECT id, FLOOR(value/100)
  FROM tbl_name
  GROUP BY id, FLOOR(value/100);
```

12.17 Miscellaneous Functions

Table 12.21 Miscellaneous Functions

Name	Description
`DEFAULT()`	Return the default value for a table column
`GET_LOCK()`	Get a named lock
`INET_ATON()`	Return the numeric value of an IP address
`INET_NTOA()`	Return the IP address from a numeric value
`IS_FREE_LOCK()`	Whether the named lock is free
`IS_USED_LOCK()`	Whether the named lock is in use; return connection identifier if true
`MASTER_POS_WAIT()`	Block until the slave has read and applied all updates up to the specified position
`NAME_CONST()`	Causes the column to have the given name
`RAND()`	Return a random floating-point value
`RELEASE_LOCK()`	Releases the named lock
`SLEEP()`	Sleep for a number of seconds
`UUID()`	Return a Universal Unique Identifier (UUID)
`UUID_SHORT()`	Return an integer-valued universal identifier
`VALUES()`	Defines the values to be used during an INSERT

- `DEFAULT(col_name)`

  Returns the default value for a table column. An error results if the column has no default value.

  ```
  mysql> UPDATE t SET i = DEFAULT(i)+1 WHERE id < 100;
  ```

- `FORMAT(X,D)`

  Formats the number *`X`* to a format like `'#,###,###.##'`, rounded to *`D`* decimal places, and returns the result as a string. For details, see Section 12.5, “String Functions”.

- `GET_LOCK(str,timeout)`

  Tries to obtain a lock with a name given by the string *`str`*, using a timeout of *`timeout`* seconds. A negative *`timeout`* value means infinite timeout.

Returns `1` if the lock was obtained successfully, `0` if the attempt timed out (for example, because another client has previously locked the name), or `NULL` if an error occurred (such as running out of memory or the thread was killed with `mysqladmin kill`).

A lock obtained with `GET_LOCK()` is released explicitly by executing `RELEASE_LOCK()` or implicitly when your session terminates (either normally or abnormally).

Locks obtained with `GET_LOCK()` are not released when transactions commit or roll back.

Important

The behavior of `GET_LOCK()` changes in MySQL 5.7. In consideration of future upgrades, limit the *`str`* value to 64 characters or less and do not rely on subsequent calls to `GET_LOCK()` releasing previous locks.

`GET_LOCK()` can be used to implement application locks or to simulate record locks. Names are locked on a server-wide basis. If a name has been locked within one session, `GET_LOCK()` blocks any request by another session for a lock with the same name. This enables clients that agree on a given lock name to use the name to perform cooperative advisory locking. But be aware that it also enables a client that is not among the set of cooperating clients to lock a name, either inadvertently or deliberately, and thus prevent any of the cooperating clients from locking that name. One way to reduce the likelihood of this is to use lock names that are database-specific or application-specific. For example, use lock names of the form *`db_name.str`* or *`app_name.str`*.

```
mysql> SELECT GET_LOCK('lock1',10);
        -> 1
mysql> SELECT IS_FREE_LOCK('lock2');
        -> 1
mysql> SELECT GET_LOCK('lock2',10);
        -> 1
mysql> SELECT RELEASE_LOCK('lock2');
        -> 1
mysql> SELECT RELEASE_LOCK('lock1');
        -> NULL
```

The second `RELEASE_LOCK()` call returns `NULL` because the lock `'lock1'` was automatically released by the second `GET_LOCK()` call.

If multiple clients are waiting for a lock, the order in which they will acquire it is undefined. Applications should not assume that clients will acquire the lock in the same order that they issued the lock requests.

`GET_LOCK()` is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `INET_ATON(`*`expr`*`)`

Given the dotted-quad representation of an IPv4 network address as a string, returns an integer that represents the numeric value of the address in network byte order (big endian). `INET_ATON()` returns `NULL` if it does not understand its argument.

```
mysql> SELECT INET_ATON('10.0.5.9');
        -> 167773449
```

For this example, the return value is calculated as $10\times256^3 + 0\times256^2 + 5\times256 + 9$.

`INET_ATON()` may or may not return a non-`NULL` result for short-form IP addresses (such as `'127.1'` as a representation of `'127.0.0.1'`). Because of this, `INET_ATON()`a should not be used for such addresses.

Note

To store values generated by `INET_ATON()`, use an `INT UNSIGNED` column rather than `INT`, which is signed. If you use a signed column, values corresponding to IP addresses for which the first octet is greater than 127 cannot be stored correctly. See Section 11.2.6, “Out-of-Range and Overflow Handling”.

- `INET_NTOA(expr)`

  Given a numeric IPv4 network address in network byte order, returns the dotted-quad representation of the address as a string. `INET_NTOA()` returns `NULL` if it does not understand its argument.

  The return value is a string in the connection character set.

```
mysql> SELECT INET_NTOA(167773449);
        -> '10.0.5.9'
```

- `IS_FREE_LOCK(str)`

  Checks whether the lock named *`str`* is free to use (that is, not locked). Returns `1` if the lock is free (no one is using the lock), `0` if the lock is in use, and `NULL` if an error occurs (such as an incorrect argument).

  This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `IS_USED_LOCK(str)`

  Checks whether the lock named *`str`* is in use (that is, locked). If so, it returns the connection identifier of the client session that holds the lock. Otherwise, it returns `NULL`.

  This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `MASTER_POS_WAIT(log_name,log_pos[,timeout])`

  This function is useful for control of master/slave synchronization. It blocks until the slave has read and applied all updates up to the specified position in the master log. The return value is the number of log events the slave had to wait for to advance to the specified position. The function returns `NULL` if the slave SQL thread is not started, the slave's master information is not initialized, the arguments are incorrect, or an error occurs. It returns `-1` if the timeout has been exceeded. If the slave SQL thread stops while `MASTER_POS_WAIT()` is waiting, the function returns `NULL`. If the slave is past the specified position, the function returns immediately.

  If a *`timeout`* value is specified, `MASTER_POS_WAIT()` stops waiting when *`timeout`* seconds have elapsed. *`timeout`* must be greater than 0; a zero or negative *`timeout`* means no timeout. The lock is exclusive. While held by one session, other sessions cannot obtain a lock of the same name.

  This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `NAME_CONST(name,value)`

  Returns the given value. When used to produce a result set column, `NAME_CONST()` causes the column to have the given name. The arguments should be constants.

```
mysql> SELECT NAME_CONST('myname', 14);
+--------+
| myname |
```

```
+--------+
|     14 |
+--------+
```

This function is for internal use only. The server uses it when writing statements from stored programs that contain references to local program variables, as described in Section 20.7, “Binary Logging of Stored Programs”. You might see this function in the output from `mysqlbinlog`.

For your applications, you can obtain exactly the same result as in the example just shown by using simple aliasing, like this:

```
mysql> SELECT 14 AS myname;
+--------+
| myname |
+--------+
|     14 |
+--------+
1 row in set (0.00 sec)
```

See Section 13.2.9, “SELECT Syntax”, for more information about column aliases.

- `RELEASE_LOCK(str)`

  Releases the lock named by the string *`str`* that was obtained with `GET_LOCK()`. Returns `1` if the lock was released, `0` if the lock was not established by this thread (in which case the lock is not released), and `NULL` if the named lock did not exist. The lock does not exist if it was never obtained by a call to `GET_LOCK()` or if it has previously been released.

  The `DO` statement is convenient to use with `RELEASE_LOCK()`. See Section 13.2.3, “DO Syntax”.

  This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `SLEEP(duration)`

  Sleeps (pauses) for the number of seconds given by the *`duration`* argument, then returns 0. If `SLEEP()` is interrupted, it returns 1. The duration may have a fractional part.

  When sleep returns normally (without interruption), it returns 0:

```
mysql> SELECT SLEEP(1000);
+-------------+
| SLEEP(1000) |
+-------------+
|           0 |
+-------------+
```

  When `SLEEP()` is the only thing invoked by a query that is interrupted, it returns 1 and the query itself returns no error. This statement is interrupted using `KILL QUERY` from another session:

```
mysql> SELECT SLEEP(1000);
+-------------+
| SLEEP(1000) |
+-------------+
|           1 |
+-------------+
```

  When `SLEEP()` is only part of a query that is interrupted, the query returns an error. This statement is interrupted using `KILL QUERY` from another session:

```
mysql> SELECT 1 FROM t1 WHERE SLEEP(1000);
ERROR 1317 (70100): Query execution was interrupted
```

This function is unsafe for statement-based replication. A warning is logged if you use this function when `binlog_format` is set to `STATEMENT`. (Bug #47995)

- `UUID()`

  Returns a Universal Unique Identifier (UUID) generated according to RFC 4122, "A Universally Unique IDentifier (UUID) URN Namespace" (http://www.ietf.org/rfc/rfc4122.txt).

  A UUID is designed as a number that is globally unique in space and time. Two calls to `UUID()` are expected to generate two different values, even if these calls are performed on two separate devices not connected to each other.

  Warning

  Although `UUID()` values are intended to be unique, they are not necessarily unguessable or unpredictable. If unpredictability is required, UUID values should be generated some other way.

  `UUID()` returns a value that conforms to UUID version 1 as described in RFC 4122. The value is a 128-bit number represented as a `utf8` string of five hexadecimal numbers in `aaaaaaaa-bbbb-cccc-dddd-eeeeeeeeeeee` format:

  - The first three numbers are generated from the low, middle, and high parts of a timestamp. The high part also includes the UUID version number.
  - The fourth number preserves temporal uniqueness in case the timestamp value loses monotonicity (for example, due to daylight saving time).
  - The fifth number is an IEEE 802 node number that provides spatial uniqueness. A random number is substituted if the latter is not available (for example, because the host device has no Ethernet card, or it is unknown how to find the hardware address of an interface on the host operating system). In this case, spatial uniqueness cannot be guaranteed. Nevertheless, a collision should have *very* low probability.

    The MAC address of an interface is taken into account only on FreeBSD and Linux. On other operating systems, MySQL uses a randomly generated 48-bit number.

  ```
  mysql> SELECT UUID();
         -> '6ccd780c-baba-1026-9564-5b8c656024db'
  ```

  Note

  `UUID()` does not work with statement-based replication.

- `UUID_SHORT()`

  Returns a "short" universal identifier as a 64-bit unsigned integer. Values returned by `UUID_SHORT()` differ from the string-format 128-bit identifiers returned by the `UUID()` function and have different uniqueness properties. The value of `UUID_SHORT()` is guaranteed to be unique if the following conditions hold:

  - The `server_id` value of the current server is between 0 and 255 and is unique among your set of master and slave servers
  - You do not set back the system time for your server host between `mysqld` restarts
  - You invoke `UUID_SHORT()` on average fewer than 16 million times per second between `mysqld` restarts

The `UUID_SHORT()` return value is constructed this way:

```
  (server_id & 255) << 56
+ (server_startup_time_in_seconds << 24)
+ incremented_variable++;
```

```
mysql> SELECT UUID_SHORT();
        -> 92395783831158784
```

Note

`UUID_SHORT()` does not work with statement-based replication.

- `VALUES(col_name)`

  In an `INSERT ... ON DUPLICATE KEY UPDATE` statement, you can use the `VALUES(col_name)` function in the `UPDATE` clause to refer to column values from the `INSERT` portion of the statement. In other words, `VALUES(col_name)` in the `UPDATE` clause refers to the value of `col_name` that would be inserted, had no duplicate-key conflict occurred. This function is especially useful in multiple-row inserts. The `VALUES()` function is meaningful only in the `ON DUPLICATE KEY UPDATE` clause of `INSERT` statements and returns `NULL` otherwise. See Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”.

  ```
  mysql> INSERT INTO table (a,b,c) VALUES (1,2,3),(4,5,6)
      -> ON DUPLICATE KEY UPDATE c=VALUES(a)+VALUES(b);
  ```

12.18 Precision Math

MySQL provides support for precision math: numeric value handling that results in extremely accurate results and a high degree control over invalid values. Precision math is based on these two features:

- SQL modes that control how strict the server is about accepting or rejecting invalid data.
- The MySQL library for fixed-point arithmetic.

These features have several implications for numeric operations and provide a high degree of compliance with standard SQL:

- **Precise calculations**: For exact-value numbers, calculations do not introduce floating-point errors. Instead, exact precision is used. For example, MySQL treats a number such as `.0001` as an exact value rather than as an approximation, and summing it 10,000 times produces a result of exactly `1`, not a value that is merely “close” to 1.
- **Well-defined rounding behavior**: For exact-value numbers, the result of `ROUND()` depends on its argument, not on environmental factors such as how the underlying C library works.
- **Platform independence**: Operations on exact numeric values are the same across different platforms such as Windows and Unix.
- **Control over handling of invalid values**: Overflow and division by zero are detectable and can be treated as errors. For example, you can treat a value that is too large for a column as an error rather than having the value truncated to lie within the range of the column's data type. Similarly, you can treat division by zero as an error rather than as an operation that produces a result of `NULL`. The choice of which approach to take is determined by the setting of the server SQL mode.

The following discussion covers several aspects of how precision math works, including possible incompatibilities with older applications. At the end, some examples are given that demonstrate how MySQL handles numeric operations precisely. For information about controlling the SQL mode, see Section 5.1.8, “Server SQL Modes”.

12.18.1 Types of Numeric Values

The scope of precision math for exact-value operations includes the exact-value data types (integer and `DECIMAL` types) and exact-value numeric literals. Approximate-value data types and numeric literals are handled as floating-point numbers.

Exact-value numeric literals have an integer part or fractional part, or both. They may be signed. Examples: `1`, `.2`, `3.4`, `-5`, `-6.78`, `+9.10`.

Approximate-value numeric literals are represented in scientific notation with a mantissa and exponent. Either or both parts may be signed. Examples: `1.2E3`, `1.2E-3`, `-1.2E3`, `-1.2E-3`.

Two numbers that look similar may be treated differently. For example, `2.34` is an exact-value (fixed-point) number, whereas `2.34E0` is an approximate-value (floating-point) number.

The `DECIMAL` data type is a fixed-point type and calculations are exact. In MySQL, the `DECIMAL` type has several synonyms: `NUMERIC`, `DEC`, `FIXED`. The integer types also are exact-value types.

The `FLOAT` and `DOUBLE` data types are floating-point types and calculations are approximate. In MySQL, types that are synonymous with `FLOAT` or `DOUBLE` are `DOUBLE PRECISION` and `REAL`.

12.18.2 DECIMAL Data Type Characteristics

This section discusses the characteristics of the `DECIMAL` data type (and its synonyms), with particular regard to the following topics:

- Maximum number of digits
- Storage format
- Storage requirements
- The nonstandard MySQL extension to the upper range of `DECIMAL` columns

Possible incompatibilities with applications that are written for older versions of MySQL (prior to 5.0.3) are noted throughout this section.

The declaration syntax for a `DECIMAL` column is `DECIMAL(M,D)`. The ranges of values for the arguments are as follows:

- *`M`* is the maximum number of digits (the precision). It has a range of 1 to 65. (Older versions of MySQL permitted a range of 1 to 254.)
- *`D`* is the number of digits to the right of the decimal point (the scale). It has a range of 0 to 30 and must be no larger than *`M`*.

The maximum value of 65 for *`M`* means that calculations on `DECIMAL` values are accurate up to 65 digits. This limit of 65 digits of precision also applies to exact-value numeric literals, so the maximum range of such literals differs from before. (In older versions of MySQL, decimal values could have up to 254 digits. However, calculations were done using floating-point and thus were approximate, not exact.)

Values for `DECIMAL` columns are stored using a binary format that packs nine decimal digits into 4 bytes. The storage requirements for the integer and fractional parts of each value are determined separately. Each multiple of nine digits requires 4 bytes, and any remaining digits left over require some fraction of 4 bytes. The storage required for remaining digits is given by the following table.

Leftover Digits	Number of Bytes
0	0
1–2	1
3–4	2

Leftover Digits	Number of Bytes
5–6	3
7–9	4

For example, a `DECIMAL(18,9)` column has nine digits on either side of the decimal point, so the integer part and the fractional part each require 4 bytes. A `DECIMAL(20,6)` column has fourteen integer digits and six fractional digits. The integer digits require four bytes for nine of the digits and 3 bytes for the remaining five digits. The six fractional digits require 3 bytes.

Unlike some older versions of MySQL, `DECIMAL` columns in MySQL 5.5 do not store a leading `+` character or `-` character or leading `0` digits. If you insert `+0003.1` into a `DECIMAL(5,1)` column, it is stored as `3.1`. For negative numbers, a literal `-` character is not stored. Applications that rely on the older behavior must be modified to account for this change.

`DECIMAL` columns do not permit values larger than the range implied by the column definition. For example, a `DECIMAL(3,0)` column supports a range of `-999` to `999`. A `DECIMAL(M,D)` column permits at most `M - D` digits to the left of the decimal point. This is not compatible with applications relying on older versions of MySQL that permitted storing an extra digit in lieu of a `+` sign.

The SQL standard requires that the precision of `NUMERIC(M,D)` be *exactly* `M` digits. For `DECIMAL(M,D)`, the standard requires a precision of at least `M` digits but permits more. In MySQL, `DECIMAL(M,D)` and `NUMERIC(M,D)` are the same, and both have a precision of exactly `M` digits.

For a full explanation of the internal format of `DECIMAL` values, see the file `strings/decimal.c` in a MySQL source distribution. The format is explained (with an example) in the `decimal2bin()` function.

For more detailed information about porting applications that rely on the old treatment of the `DECIMAL` data type, see the *MySQL 5.0 Reference Manual*.

12.18.3 Expression Handling

With precision math, exact-value numbers are used as given whenever possible. For example, numbers in comparisons are used exactly as given without a change in value. In strict SQL mode, for `INSERT` into a column with an exact data type (`DECIMAL` or integer), a number is inserted with its exact value if it is within the column range. When retrieved, the value should be the same as what was inserted. (If strict SQL mode is not enabled, truncation for `INSERT` is permissible.)

Handling of a numeric expression depends on what kind of values the expression contains:

- If any approximate values are present, the expression is approximate and is evaluated using floating-point arithmetic.
- If no approximate values are present, the expression contains only exact values. If any exact value contains a fractional part (a value following the decimal point), the expression is evaluated using `DECIMAL` exact arithmetic and has a precision of 65 digits. The term “exact” is subject to the limits of what can be represented in binary. For example, `1.0/3.0` can be approximated in decimal notation as `.333...`, but not written as an exact number, so `(1.0/3.0)*3.0` does not evaluate to exactly `1.0`.
- Otherwise, the expression contains only integer values. The expression is exact and is evaluated using integer arithmetic and has a precision the same as `BIGINT` (64 bits).

If a numeric expression contains any strings, they are converted to double-precision floating-point values and the expression is approximate.

Inserts into numeric columns are affected by the SQL mode, which is controlled by the `sql_mode` system variable. (See Section 5.1.8, “Server SQL Modes”.) The following discussion mentions strict mode (selected by the `STRICT_ALL_TABLES` or `STRICT_TRANS_TABLES` mode values) and `ERROR_FOR_DIVISION_BY_ZERO`. To turn on all restrictions, you can simply use `TRADITIONAL` mode, which includes both strict mode values and `ERROR_FOR_DIVISION_BY_ZERO`:

```
mysql> SET sql_mode='TRADITIONAL';
```

If a number is inserted into an exact type column (`DECIMAL` or integer), it is inserted with its exact value if it is within the column range.

If the value has too many digits in the fractional part, rounding occurs and a warning is generated. Rounding is done as described in Section 12.18.4, “Rounding Behavior”.

If the value has too many digits in the integer part, it is too large and is handled as follows:

- If strict mode is not enabled, the value is truncated to the nearest legal value and a warning is generated.
- If strict mode is enabled, an overflow error occurs.

Underflow is not detected, so underflow handling is undefined.

For inserts of strings into numeric columns, conversion from string to number is handled as follows if the string has nonnumeric contents:

- A string that does not begin with a number cannot be used as a number and produces an error in strict mode, or a warning otherwise. This includes the empty string.
- A string that begins with a number can be converted, but the trailing nonnumeric portion is truncated. If the truncated portion contains anything other than spaces, this produces an error in strict mode, or a warning otherwise.

By default, division by zero produces a result of `NULL` and no warning. By setting the SQL mode appropriately, division by zero can be restricted.

With the `ERROR_FOR_DIVISION_BY_ZERO` SQL mode enabled, MySQL handles division by zero differently:

- If strict mode is not enabled, a warning occurs.
- If strict mode is enabled, inserts and updates involving division by zero are prohibited, and an error occurs.

In other words, inserts and updates involving expressions that perform division by zero can be treated as errors, but this requires `ERROR_FOR_DIVISION_BY_ZERO` in addition to strict mode.

Suppose that we have this statement:

```
INSERT INTO t SET i = 1/0;
```

This is what happens for combinations of strict and `ERROR_FOR_DIVISION_BY_ZERO` modes.

`sql_mode` Value	Result
`''` (Default)	No warning, no error; `i` is set to `NULL`.
strict	No warning, no error; `i` is set to `NULL`.
`ERROR_FOR_DIVISION_BY_ZERO`	Warning, no error; `i` is set to `NULL`.
strict,`ERROR_FOR_DIVISION_BY_ZERO`	Error condition; no row is inserted.

12.18.4 Rounding Behavior

This section discusses precision math rounding for the `ROUND()` function and for inserts into columns with exact-value types (`DECIMAL` and integer).

The `ROUND()` function rounds differently depending on whether its argument is exact or approximate:

- For exact-value numbers, `ROUND()` uses the “round half up” rule: A value with a fractional part of .5 or greater is rounded up to the next integer if positive or down to the next integer if negative. (In other words, it is rounded away from zero.) A value with a fractional part less than .5 is rounded down to the next integer if positive or up to the next integer if negative.
- For approximate-value numbers, the result depends on the C library. On many systems, this means that `ROUND()` uses the “round to nearest even” rule: A value with any fractional part is rounded to the nearest even integer.

The following example shows how rounding differs for exact and approximate values:

```
mysql> SELECT ROUND(2.5), ROUND(25E-1);
+------------+--------------+
| ROUND(2.5) | ROUND(25E-1) |
+------------+--------------+
| 3          |            2 |
+------------+--------------+
```

For inserts into a `DECIMAL` or integer column, the target is an exact data type, so rounding uses “round half away from zero,” regardless of whether the value to be inserted is exact or approximate:

```
mysql> CREATE TABLE t (d DECIMAL(10,0));
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t VALUES(2.5),(2.5E0);
Query OK, 2 rows affected, 2 warnings (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 2

mysql> SELECT d FROM t;
+------+
| d    |
+------+
| 3    |
| 3    |
+------+
```

12.18.5 Precision Math Examples

This section provides some examples that show precision math query results in MySQL. These examples demonstrate the principles described in Section 12.18.3, “Expression Handling”, and Section 12.18.4, “Rounding Behavior”.

Example 1. Numbers are used with their exact value as given when possible:

```
mysql> SELECT (.1 + .2) = .3;
+----------------+
| (.1 + .2) = .3 |
+----------------+
|              1 |
+----------------+
```

For floating-point values, results are inexact:

```
mysql> SELECT (.1E0 + .2E0) = .3E0;
+----------------------+
| (.1E0 + .2E0) = .3E0 |
+----------------------+
|                    0 |
+----------------------+
```

Another way to see the difference in exact and approximate value handling is to add a small number to a sum many times. Consider the following stored procedure, which adds `.0001` to a variable 1,000 times.

```
CREATE PROCEDURE p ()
BEGIN
  DECLARE i INT DEFAULT 0;
  DECLARE d DECIMAL(10,4) DEFAULT 0;
  DECLARE f FLOAT DEFAULT 0;
  WHILE i < 10000 DO
    SET d = d + .0001;
    SET f = f + .0001E0;
    SET i = i + 1;
  END WHILE;
  SELECT d, f;
END;
```

The sum for both `d` and `f` logically should be 1, but that is true only for the decimal calculation. The floating-point calculation introduces small errors:

```
+--------+------------------+
| d      | f                |
+--------+------------------+
| 1.0000 | 0.99999999999991 |
+--------+------------------+
```

Example 2. Multiplication is performed with the scale required by standard SQL. That is, for two numbers *`X1`* and *`X2`* that have scale *`S1`* and *`S2`*, the scale of the result is *`S1 + S2`*:

```
mysql> SELECT .01 * .01;
+-----------+
| .01 * .01 |
+-----------+
| 0.0001    |
+-----------+
```

Example 3. Rounding behavior for exact-value numbers is well-defined:

Rounding behavior (for example, with the `ROUND()` function) is independent of the implementation of the underlying C library, which means that results are consistent from platform to platform.

- Rounding for exact-value columns (`DECIMAL` and integer) and exact-valued numbers uses the "round half away from zero" rule. Values with a fractional part of .5 or greater are rounded away from zero to the nearest integer, as shown here:

  ```
  mysql> SELECT ROUND(2.5), ROUND(-2.5);
  +------------+-------------+
  | ROUND(2.5) | ROUND(-2.5) |
  +------------+-------------+
  | 3          | -3          |
  +------------+-------------+
  ```

- Rounding for floating-point values uses the C library, which on many systems uses the "round to nearest even" rule. Values with any fractional part on such systems are rounded to the nearest even integer:

  ```
  mysql> SELECT ROUND(2.5E0), ROUND(-2.5E0);
  +--------------+---------------+
  | ROUND(2.5E0) | ROUND(-2.5E0) |
  +--------------+---------------+
  |            2 |            -2 |
  +--------------+---------------+
  ```

Example 4. In strict mode, inserting a value that is out of range for a column causes an error, rather than truncation to a legal value.

When MySQL is not running in strict mode, truncation to a legal value occurs:

```
mysql> SET sql_mode='';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t (i TINYINT);
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO t SET i = 128;
Query OK, 1 row affected, 1 warning (0.00 sec)

mysql> SELECT i FROM t;
+------+
| i    |
+------+
|  127 |
+------+
1 row in set (0.00 sec)
```

However, an error occurs if strict mode is in effect:

```
mysql> SET sql_mode='STRICT_ALL_TABLES';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t (i TINYINT);
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t SET i = 128;
ERROR 1264 (22003): Out of range value adjusted for column 'i' at row 1

mysql> SELECT i FROM t;
Empty set (0.00 sec)
```

Example 5: In strict mode and with `ERROR_FOR_DIVISION_BY_ZERO` set, division by zero causes an error, not a result of `NULL`.

In nonstrict mode, division by zero has a result of `NULL`:

```
mysql> SET sql_mode='';
Query OK, 0 rows affected (0.01 sec)

mysql> CREATE TABLE t (i TINYINT);
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t SET i = 1 / 0;
Query OK, 1 row affected (0.00 sec)

mysql> SELECT i FROM t;
+------+
| i    |
+------+
| NULL |
+------+
1 row in set (0.03 sec)
```

However, division by zero is an error if the proper SQL modes are in effect:

```
mysql> SET sql_mode='STRICT_ALL_TABLES,ERROR_FOR_DIVISION_BY_ZERO';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t (i TINYINT);
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO t SET i = 1 / 0;
ERROR 1365 (22012): Division by 0

mysql> SELECT i FROM t;
Empty set (0.01 sec)
```

Example 6. Exact-value literals are evaluated as exact values.

Prior to MySQL 5.0.3, exact-value and approximate-value literals both are evaluated as double-precision floating-point values:

```
mysql> SELECT VERSION();
+------------+
| VERSION()  |
+------------+
| 4.1.18-log |
+------------+
1 row in set (0.01 sec)

mysql> CREATE TABLE t SELECT 2.5 AS a, 25E-1 AS b;
Query OK, 1 row affected (0.07 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> DESCRIBE t;
+-------+-------------+------+-----+---------+-------+
| Field | Type        | Null | Key | Default | Extra |
+-------+-------------+------+-----+---------+-------+
| a     | double(3,1) |      |     | 0.0     |       |
| b     | double      |      |     | 0       |       |
+-------+-------------+------+-----+---------+-------+
2 rows in set (0.04 sec)
```

As of MySQL 5.0.3, the approximate-value literal is evaluated using floating point, but the exact-value literal is handled as `DECIMAL`:

```
mysql> SELECT VERSION();
+-----------------+
| VERSION()       |
+-----------------+
| 5.1.6-alpha-log |
+-----------------+
1 row in set (0.11 sec)

mysql> CREATE TABLE t SELECT 2.5 AS a, 25E-1 AS b;
Query OK, 1 row affected (0.01 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> DESCRIBE t;
+-------+----------------------+------+-----+---------+-------+
| Field | Type                 | Null | Key | Default | Extra |
+-------+----------------------+------+-----+---------+-------+
| a     | decimal(2,1) unsigned | NO   |     | 0.0     |       |
| b     | double               | NO   |     | 0       |       |
+-------+----------------------+------+-----+---------+-------+
2 rows in set (0.01 sec)
```

Example 7. If the argument to an aggregate function is an exact numeric type, the result is also an exact numeric type, with a scale at least that of the argument.

Consider these statements:

```
mysql> CREATE TABLE t (i INT, d DECIMAL, f FLOAT);
mysql> INSERT INTO t VALUES(1,1,1);
mysql> CREATE TABLE y SELECT AVG(i), AVG(d), AVG(f) FROM t;
```

Before MySQL 5.0.3, the result is a double no matter the argument type:

```
mysql> DESCRIBE y;
+--------+--------------+------+-----+---------+-------+
| Field  | Type         | Null | Key | Default | Extra |
+--------+--------------+------+-----+---------+-------+
| AVG(i) | double(17,4) | YES  |     | NULL    |       |
```

```
| AVG(d) | double(17,4) | YES  |     | NULL    |       |
| AVG(f) | double       | YES  |     | NULL    |       |
+--------+--------------+------+-----+---------+-------+
```

As of MySQL 5.0.3, the result is a double only for the floating-point argument. For exact type arguments, the result is also an exact type:

```
mysql> DESCRIBE y;
+--------+---------------+------+-----+---------+-------+
| Field  | Type          | Null | Key | Default | Extra |
+--------+---------------+------+-----+---------+-------+
| AVG(i) | decimal(14,4) | YES  |     | NULL    |       |
| AVG(d) | decimal(14,4) | YES  |     | NULL    |       |
| AVG(f) | double        | YES  |     | NULL    |       |
+--------+---------------+------+-----+---------+-------+
```

The result is a double only for the floating-point argument. For exact type arguments, the result is also an exact type.

Chapter 13 SQL Statement Syntax

Table of Contents

13.1 Data Definition Statements 1304
13.1.1 ALTER DATABASE Syntax 1304
13.1.2 ALTER EVENT Syntax 1305
13.1.3 ALTER FUNCTION Syntax 1307
13.1.4 ALTER LOGFILE GROUP Syntax 1307
13.1.5 ALTER PROCEDURE Syntax 1308
13.1.6 ALTER SERVER Syntax 1309
13.1.7 ALTER TABLE Syntax 1309
13.1.8 ALTER TABLESPACE Syntax 1330
13.1.9 ALTER VIEW Syntax 1331
13.1.10 CREATE DATABASE Syntax 1331
13.1.11 CREATE EVENT Syntax 1332
13.1.12 CREATE FUNCTION Syntax 1336
13.1.13 CREATE INDEX Syntax 1337
13.1.14 CREATE LOGFILE GROUP Syntax 1341
13.1.15 CREATE PROCEDURE and CREATE FUNCTION Syntax 1342
13.1.16 CREATE SERVER Syntax 1348
13.1.17 CREATE TABLE Syntax 1349
13.1.18 CREATE TABLESPACE Syntax 1379
13.1.19 CREATE TRIGGER Syntax 1381
13.1.20 CREATE VIEW Syntax 1383
13.1.21 DROP DATABASE Syntax 1387
13.1.22 DROP EVENT Syntax 1388
13.1.23 DROP FUNCTION Syntax 1388
13.1.24 DROP INDEX Syntax 1388
13.1.25 DROP LOGFILE GROUP Syntax 1389
13.1.26 DROP PROCEDURE and DROP FUNCTION Syntax 1389
13.1.27 DROP SERVER Syntax 1390
13.1.28 DROP TABLE Syntax 1390
13.1.29 DROP TABLESPACE Syntax 1391
13.1.30 DROP TRIGGER Syntax 1391
13.1.31 DROP VIEW Syntax 1391
13.1.32 RENAME TABLE Syntax 1392
13.1.33 TRUNCATE TABLE Syntax 1393
13.2 Data Manipulation Statements 1394
13.2.1 CALL Syntax 1394
13.2.2 DELETE Syntax 1395
13.2.3 DO Syntax 1398
13.2.4 HANDLER Syntax 1399
13.2.5 INSERT Syntax 1400
13.2.6 LOAD DATA INFILE Syntax 1409
13.2.7 LOAD XML Syntax 1418
13.2.8 REPLACE Syntax 1426
13.2.9 SELECT Syntax 1428
13.2.10 Subquery Syntax 1443
13.2.11 UPDATE Syntax 1455
13.3 Transactional and Locking Statements 1458
13.3.1 START TRANSACTION, COMMIT, and ROLLBACK Syntax 1458
13.3.2 Statements That Cannot Be Rolled Back 1460
13.3.3 Statements That Cause an Implicit Commit 1460
13.3.4 SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Syntax 1461
13.3.5 LOCK TABLES and UNLOCK TABLES Syntax 1462

13.3.6 SET TRANSACTION Syntax 1468
13.3.7 XA Transactions 1469
13.4 Replication Statements 1472
13.4.1 SQL Statements for Controlling Master Servers 1472
13.4.2 SQL Statements for Controlling Slave Servers 1475
13.5 Prepared SQL Statement Syntax 1481
13.5.1 PREPARE Syntax 1484
13.5.2 EXECUTE Syntax 1485
13.5.3 DEALLOCATE PREPARE Syntax 1485
13.5.4 Automatic Prepared Statement Repreparation 1486
13.6 Compound-Statement Syntax 1486
13.6.1 BEGIN ... END Compound-Statement Syntax 1486
13.6.2 Statement Label Syntax 1487
13.6.3 DECLARE Syntax 1487
13.6.4 Variables in Stored Programs 1488
13.6.5 Flow Control Statements 1489
13.6.6 Cursors 1494
13.6.7 Condition Handling 1495
13.7 Database Administration Statements 1510
13.7.1 Account Management Statements 1510
13.7.2 Table Maintenance Statements 1527
13.7.3 Plugin and User-Defined Function Statements 1536
13.7.4 SET Syntax 1539
13.7.5 SHOW Syntax 1543
13.7.6 Other Administrative Statements 1585
13.8 Utility Statements 1593
13.8.1 DESCRIBE Syntax 1593
13.8.2 EXPLAIN Syntax 1593
13.8.3 HELP Syntax 1594
13.8.4 USE Syntax 1596

This chapter describes the syntax for the SQL statements supported by MySQL.

13.1 Data Definition Statements

13.1.1 ALTER DATABASE Syntax

```
ALTER {DATABASE | SCHEMA} [db_name]
    alter_specification ...
ALTER {DATABASE | SCHEMA} db_name
    UPGRADE DATA DIRECTORY NAME

alter_specification:
    [DEFAULT] CHARACTER SET [=] charset_name
  | [DEFAULT] COLLATE [=] collation_name
```

`ALTER DATABASE` enables you to change the overall characteristics of a database. These characteristics are stored in the `db.opt` file in the database directory. To use `ALTER DATABASE`, you need the `ALTER` privilege on the database. `ALTER SCHEMA` is a synonym for `ALTER DATABASE`.

The database name can be omitted from the first syntax, in which case the statement applies to the default database.

National Language Characteristics

The `CHARACTER SET` clause changes the default database character set. The `COLLATE` clause changes the default database collation. Section 10.1, “Character Set Support”, discusses character set and collation names.

You can see what character sets and collations are available using, respectively, the `SHOW CHARACTER SET` and `SHOW COLLATION` statements. See Section 13.7.5.4, “SHOW CHARACTER SET Syntax”, and Section 13.7.5.5, “SHOW COLLATION Syntax”, for more information.

If you change the default character set or collation for a database, stored routines that use the database defaults must be dropped and recreated so that they use the new defaults. (In a stored routine, variables with character data types use the database defaults if the character set or collation are not specified explicitly. See Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”.)

Upgrading from Versions Older than MySQL 5.1

The syntax that includes the `UPGRADE DATA DIRECTORY NAME` clause updates the name of the directory associated with the database to use the encoding implemented in MySQL 5.1 for mapping database names to database directory names (see Section 9.2.3, “Mapping of Identifiers to File Names”). This clause is for use under these conditions:

- It is intended when upgrading MySQL to 5.1 or later from older versions.
- It is intended to update a database directory name to the current encoding format if the name contains special characters that need encoding.
- The statement is used by `mysqlcheck` (as invoked by `mysql_upgrade`).

For example, if a database in MySQL 5.0 has the name `a-b-c`, the name contains instances of the `-` (dash) character. In MySQL 5.0, the database directory is also named `a-b-c`, which is not necessarily safe for all file systems. In MySQL 5.1 and later, the same database name is encoded as `a@002db@002dc` to produce a file system-neutral directory name.

When a MySQL installation is upgraded to MySQL 5.1 or later from an older version,the server displays a name such as `a-b-c` (which is in the old format) as `#mysql50#a-b-c`, and you must refer to the name using the `#mysql50#` prefix. Use `UPGRADE DATA DIRECTORY NAME` in this case to explicitly tell the server to re-encode the database directory name to the current encoding format:

```
ALTER DATABASE `#mysql50#a-b-c` UPGRADE DATA DIRECTORY NAME;
```

After executing this statement, you can refer to the database as `a-b-c` without the special `#mysql50#` prefix.

13.1.2 ALTER EVENT Syntax

```
ALTER
    [DEFINER = { user | CURRENT_USER }]
    EVENT event_name
    [ON SCHEDULE schedule]
    [ON COMPLETION [NOT] PRESERVE]
    [RENAME TO new_event_name]
    [ENABLE | DISABLE | DISABLE ON SLAVE]
    [COMMENT 'string']
    [DO event_body]
```

The `ALTER EVENT` statement changes one or more of the characteristics of an existing event without the need to drop and recreate it. The syntax for each of the `DEFINER`, `ON SCHEDULE`, `ON COMPLETION`, `COMMENT`, `ENABLE` / `DISABLE`, and `DO` clauses is exactly the same as when used with `CREATE EVENT`. (See Section 13.1.11, “CREATE EVENT Syntax”.)

Any user can alter an event defined on a database for which that user has the `EVENT` privilege. When a user executes a successful `ALTER EVENT` statement, that user becomes the definer for the affected event.

`ALTER EVENT` works only with an existing event:

```
mysql> ALTER EVENT no_such_event
     >     ON SCHEDULE
     >       EVERY '2:3' DAY_HOUR;
ERROR 1517 (HY000): Unknown event 'no_such_event'
```

In each of the following examples, assume that the event named `myevent` is defined as shown here:

```
CREATE EVENT myevent
    ON SCHEDULE
      EVERY 6 HOUR
    COMMENT 'A sample comment.'
    DO
      UPDATE myschema.mytable SET mycol = mycol + 1;
```

The following statement changes the schedule for `myevent` from once every six hours starting immediately to once every twelve hours, starting four hours from the time the statement is run:

```
ALTER EVENT myevent
    ON SCHEDULE
      EVERY 12 HOUR
    STARTS CURRENT_TIMESTAMP + INTERVAL 4 HOUR;
```

It is possible to change multiple characteristics of an event in a single statement. This example changes the SQL statement executed by `myevent` to one that deletes all records from `mytable`; it also changes the schedule for the event such that it executes once, one day after this `ALTER EVENT` statement is run.

```
ALTER EVENT myevent
    ON SCHEDULE
      AT CURRENT_TIMESTAMP + INTERVAL 1 DAY
    DO
      TRUNCATE TABLE myschema.mytable;
```

Specify the options in an `ALTER EVENT` statement only for those characteristics that you want to change; omitted options keep their existing values. This includes any default values for `CREATE EVENT` such as `ENABLE`.

To disable `myevent`, use this `ALTER EVENT` statement:

```
ALTER EVENT myevent
    DISABLE;
```

The `ON SCHEDULE` clause may use expressions involving built-in MySQL functions and user variables to obtain any of the *`timestamp`* or *`interval`* values which it contains. You cannot use stored routines or user-defined functions in such expressions, and you cannot use any table references; however, you can use `SELECT FROM DUAL`. This is true for both `ALTER EVENT` and `CREATE EVENT` statements. References to stored routines, user-defined functions, and tables in such cases are specifically not permitted, and fail with an error (see Bug #22830).

Although an `ALTER EVENT` statement that contains another `ALTER EVENT` statement in its `DO` clause appears to succeed, when the server attempts to execute the resulting scheduled event, the execution fails with an error.

To rename an event, use the `ALTER EVENT` statement's `RENAME TO` clause. This statement renames the event `myevent` to `yourevent`:

```
ALTER EVENT myevent
    RENAME TO yourevent;
```

You can also move an event to a different database using `ALTER EVENT ... RENAME TO ...` and *`db_name.event_name`* notation, as shown here:

```
ALTER EVENT olddb.myevent
    RENAME TO newdb.myevent;
```

To execute the previous statement, the user executing it must have the `EVENT` privilege on both the `olddb` and `newdb` databases.

Note

There is no `RENAME EVENT` statement.

The value `DISABLE ON SLAVE` is used on a replication slave instead of `ENABLE` or `DISABLE` to indicate an event that was created on the master and replicated to the slave, but that is not executed on the slave. Normally, `DISABLE ON SLAVE` is set automatically as required; however, there are some circumstances under which you may want or need to change it manually. See Section 17.4.1.15, “Replication of Invoked Features”, for more information.

13.1.3 ALTER FUNCTION Syntax

```
ALTER FUNCTION func_name [characteristic ...]

characteristic:
    COMMENT 'string'
  | LANGUAGE SQL
  | { CONTAINS SQL | NO SQL | READS SQL DATA | MODIFIES SQL DATA }
  | SQL SECURITY { DEFINER | INVOKER }
```

This statement can be used to change the characteristics of a stored function. More than one change may be specified in an `ALTER FUNCTION` statement. However, you cannot change the parameters or body of a stored function using this statement; to make such changes, you must drop and re-create the function using `DROP FUNCTION` and `CREATE FUNCTION`.

You must have the `ALTER ROUTINE` privilege for the function. (That privilege is granted automatically to the function creator.) If binary logging is enabled, the `ALTER FUNCTION` statement might also require the `SUPER` privilege, as described in Section 20.7, “Binary Logging of Stored Programs”.

13.1.4 ALTER LOGFILE GROUP Syntax

```
ALTER LOGFILE GROUP logfile_group
    ADD UNDOFILE 'file_name'
    [INITIAL_SIZE [=] size]
    [WAIT]
    ENGINE [=] engine_name
```

This statement adds an `UNDO` file named '*`file_name`*' to an existing log file group *`logfile_group`*. An `ALTER LOGFILE GROUP` statement has one and only one `ADD UNDOFILE` clause. No `DROP UNDOFILE` clause is currently supported.

Note

All NDB Cluster Disk Data objects share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and an undo log file with the same name, or an undo log file and a data file with the same name.

The optional `INITIAL_SIZE` parameter sets the `UNDO` file's initial size in bytes; if not specified, the initial size defaults to 134217728 (128 MB). Prior to MySQL NDB Cluster 7.2.14, this value was required to be specified using digits (Bug #13116514, Bug #16104705, Bug #62858); in MySQL NDB Cluster 7.2.14 and later, you may optionally follow *`size`* with a one-letter abbreviation for an order of magnitude, similar to those used in `my.cnf`. Generally, this is one of the letters `M` (megabytes) or `G` (gigabytes).

On 32-bit systems, the maximum supported value for `INITIAL_SIZE` is 4294967296 (4 GB). (Bug #29186)

The minimum allowed value for `INITIAL_SIZE` is 1048576 (1 MB). (Bug #29574)

Note

`WAIT` is parsed but otherwise ignored. This keyword currently has no effect, and is intended for future expansion.

The `ENGINE` parameter (required) determines the storage engine which is used by this log file group, with *`engine_name`* being the name of the storage engine. Currently, the only accepted values for *`engine_name`* are "`NDBCLUSTER`" and "`NDB`". The two values are equivalent.

Here is an example, which assumes that the log file group `lg_3` has already been created using `CREATE LOGFILE GROUP` (see Section 13.1.14, "CREATE LOGFILE GROUP Syntax"):

```
ALTER LOGFILE GROUP lg_3
    ADD UNDOFILE 'undo_10.dat'
    INITIAL_SIZE=32M
    ENGINE=NDBCLUSTER;
```

When `ALTER LOGFILE GROUP` is used with `ENGINE = NDBCLUSTER` (alternatively, `ENGINE = NDB`), an `UNDO` log file is created on each NDB Cluster data node. You can verify that the `UNDO` files were created and obtain information about them by querying the `INFORMATION_SCHEMA.FILES` table. For example:

```
mysql> SELECT FILE_NAME, LOGFILE_GROUP_NUMBER, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE LOGFILE_GROUP_NAME = 'lg_3';
+-------------+--------------------+----------------+
| FILE_NAME   | LOGFILE_GROUP_NUMBER | EXTRA          |
+-------------+--------------------+----------------+
| newdata.dat |                  0 | CLUSTER_NODE=3 |
| newdata.dat |                  0 | CLUSTER_NODE=4 |
| undo_10.dat |                 11 | CLUSTER_NODE=3 |
| undo_10.dat |                 11 | CLUSTER_NODE=4 |
+-------------+--------------------+----------------+
4 rows in set (0.01 sec)
```

(See Section 21.29.1, "The INFORMATION_SCHEMA FILES Table".)

Memory used for `UNDO_BUFFER_SIZE` comes from the global pool whose size is determined by the value of the `SharedGlobalMemory` data node configuration parameter. This includes any default value implied for this option by the setting of the `InitialLogFileGroup` data node configuration parameter.

`ALTER LOGFILE GROUP` is useful only with Disk Data storage for NDB Cluster. For more information, see Section 18.5.12, "NDB Cluster Disk Data Tables".

13.1.5 ALTER PROCEDURE Syntax

```
ALTER PROCEDURE proc_name [characteristic ...]

characteristic:
    COMMENT 'string'
  | LANGUAGE SQL
  | { CONTAINS SQL | NO SQL | READS SQL DATA | MODIFIES SQL DATA }
  | SQL SECURITY { DEFINER | INVOKER }
```

This statement can be used to change the characteristics of a stored procedure. More than one change may be specified in an `ALTER PROCEDURE` statement. However, you cannot change the parameters or

body of a stored procedure using this statement; to make such changes, you must drop and re-create the procedure using `DROP PROCEDURE` and `CREATE PROCEDURE`.

You must have the `ALTER ROUTINE` privilege for the procedure. By default, that privilege is granted automatically to the procedure creator. This behavior can be changed by disabling the `automatic_sp_privileges` system variable. See Section 20.2.2, “Stored Routines and MySQL Privileges”.

13.1.6 ALTER SERVER Syntax

```
ALTER SERVER  server_name
    OPTIONS (option [, option] ...)
```

Alters the server information for *`server_name`*, adjusting any of the options permitted in the `CREATE SERVER` statement. The corresponding fields in the `mysql.servers` table are updated accordingly. This statement requires the `SUPER` privilege.

For example, to update the `USER` option:

```
ALTER SERVER s OPTIONS (USER 'sally');
```

`ALTER SERVER` causes an implicit commit. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

`ALTER SERVER` is not written to the binary log, regardless of the logging format that is in use.

13.1.7 ALTER TABLE Syntax

```
ALTER [ONLINE|OFFLINE] [IGNORE] TABLE tbl_name
    [alter_specification [, alter_specification] ...]
    [partition_options]

alter_specification:
    table_options
  | ADD [COLUMN] col_name column_definition
        [FIRST | AFTER col_name]
  | ADD [COLUMN] (col_name column_definition,...)
  | ADD {INDEX|KEY} [index_name]
        [index_type] (index_col_name,...) [index_option] ...
  | ADD [CONSTRAINT [symbol]] PRIMARY KEY
        [index_type] (index_col_name,...) [index_option] ...
  | ADD [CONSTRAINT [symbol]]
        UNIQUE [INDEX|KEY] [index_name]
        [index_type] (index_col_name,...) [index_option] ...
  | ADD FULLTEXT [INDEX|KEY] [index_name]
        (index_col_name,...) [index_option] ...
  | ADD SPATIAL [INDEX|KEY] [index_name]
        (index_col_name,...) [index_option] ...
  | ADD [CONSTRAINT [symbol]]
        FOREIGN KEY [index_name] (index_col_name,...)
        reference_definition
  | ALTER [COLUMN] col_name {SET DEFAULT literal | DROP DEFAULT}
  | CHANGE [COLUMN] old_col_name new_col_name column_definition
        [FIRST|AFTER col_name]
  | [DEFAULT] CHARACTER SET [=] charset_name [COLLATE [=] collation_name]
  | CONVERT TO CHARACTER SET charset_name [COLLATE collation_name]
  | {DISABLE|ENABLE} KEYS
  | {DISCARD|IMPORT} TABLESPACE
  | DROP [COLUMN] col_name
  | DROP {INDEX|KEY} index_name
  | DROP PRIMARY KEY
  | DROP FOREIGN KEY fk_symbol
  | FORCE
  | MODIFY [COLUMN] col_name column_definition
        [FIRST | AFTER col_name]
  | ORDER BY col_name [, col_name] ...
  | RENAME [TO|AS] new_tbl_name
```

```
  | ADD PARTITION (partition_definition)
  | DROP PARTITION partition_names
  | TRUNCATE PARTITION {partition_names | ALL}
  | COALESCE PARTITION number
  | REORGANIZE PARTITION [partition_names INTO (partition_definitions)]
  | ANALYZE PARTITION {partition_names | ALL}
  | CHECK PARTITION {partition_names | ALL}
  | OPTIMIZE PARTITION {partition_names | ALL}
  | REBUILD PARTITION {partition_names | ALL}
  | REPAIR PARTITION {partition_names | ALL}
  | PARTITION BY partitioning_expression
  | REMOVE PARTITIONING

index_col_name:
    col_name [(length)] [ASC | DESC]

index_type:
    USING {BTREE | HASH}

index_option:
    KEY_BLOCK_SIZE [=] value
  | index_type
  | WITH PARSER parser_name
  | COMMENT 'string'

table_options:
    table_option [[,] table_option] ...

table_option:
    AUTO_INCREMENT [=] value
  | AVG_ROW_LENGTH [=] value
  | [DEFAULT] CHARACTER SET [=] charset_name
  | CHECKSUM [=] {0 | 1}
  | [DEFAULT] COLLATE [=] collation_name
  | COMMENT [=] 'string'
  | CONNECTION [=] 'connect_string'
  | {DATA|INDEX} DIRECTORY [=] 'absolute path to directory'
  | DELAY_KEY_WRITE [=] {0 | 1}
  | ENGINE [=] engine_name
  | INSERT_METHOD [=] { NO | FIRST | LAST }
  | KEY_BLOCK_SIZE [=] value
  | MAX_ROWS [=] value
  | MIN_ROWS [=] value
  | PACK_KEYS [=] {0 | 1 | DEFAULT}
  | PASSWORD [=] 'string'
  | ROW_FORMAT [=] {DEFAULT|DYNAMIC|FIXED|COMPRESSED|REDUNDANT|COMPACT}
  | TABLESPACE tablespace_name [STORAGE {DISK|MEMORY|DEFAULT}]
  | UNION [=] (tbl_name[,tbl_name]...)
```

`ALTER TABLE` changes the structure of a table. For example, you can add or delete columns, create or destroy indexes, change the type of existing columns, or rename columns or the table itself. You can also change characteristics such as the storage engine used for the table or the table comment.

- To use `ALTER TABLE`, you need `ALTER`, `CREATE`, and `INSERT` privileges for the table. Renaming a table requires `ALTER` and `DROP` on the old table, `ALTER`, `CREATE`, and `INSERT` on the new table.
- Following the table name, specify the alterations to be made. If none are given, `ALTER TABLE` does nothing.
- The syntax for many of the permissible alterations is similar to clauses of the `CREATE TABLE` statement. *`column_definition`* clauses use the same syntax for `ADD` and `CHANGE` as for `CREATE TABLE`. For more information, see Section 13.1.17, “CREATE TABLE Syntax”.
- The word `COLUMN` is optional and can be omitted.
- Multiple `ADD`, `ALTER`, `DROP`, and `CHANGE` clauses are permitted in a single `ALTER TABLE` statement, separated by commas. This is a MySQL extension to standard SQL, which permits only one of each clause per `ALTER TABLE` statement. For example, to drop multiple columns in a single statement, do this:

```
ALTER TABLE t2 DROP COLUMN c, DROP COLUMN d;
```

- If a storage engine does not support an attempted `ALTER TABLE` operation, a warning may result. Such warnings can be displayed with `SHOW WARNINGS`. See Section 13.7.5.41, “SHOW WARNINGS Syntax”. For information on troubleshooting `ALTER TABLE`, see Section B.5.6.1, “Problems with ALTER TABLE”.
- For usage examples, see Section 13.1.7.3, “ALTER TABLE Examples”.
- With the `mysql_info()` C API function, you can find out how many rows were copied by `ALTER TABLE`, and (when `IGNORE` is used) how many rows were deleted due to duplication of unique key values. See Section 23.8.7.35, “mysql_info()”.

There are several additional aspects to the `ALTER TABLE` statement, described under the following topics in this section:

- Table Options
- Performance, Storage, and Concurrency Considerations
- Adding and Dropping Columns
- Renaming, Redefining, and Reordering Columns
- Primary Keys and Indexes
- Foreign Keys
- Changing the Character Set
- Discarding and Importing InnoDB Tablespaces
- Row Order for MyISAM Tables
- Partitioning Options

Table Options

`table_options` signifies table options of the kind that can be used in the `CREATE TABLE` statement, such as `ENGINE`, `AUTO_INCREMENT`, `AVG_ROW_LENGTH`, `MAX_ROWS`, or `ROW_FORMAT`.

For descriptions of all table options, see Section 13.1.17, “CREATE TABLE Syntax”. However, `ALTER TABLE` ignores `DATA DIRECTORY` and `INDEX DIRECTORY` when given as table options. `ALTER TABLE` permits them only as partitioning options, and, as of MySQL 5.5.54, requires that you have the `FILE` privilege.

Use of table options with `ALTER TABLE` provides a convenient way of altering single table characteristics. For example:

- If `t1` is currently not an `InnoDB` table, this statement changes its storage engine to `InnoDB`:

```
ALTER TABLE t1 ENGINE = InnoDB;
```

  - See Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB” for considerations when switching tables to the `InnoDB` storage engine.
  - When you specify an `ENGINE` clause, `ALTER TABLE` rebuilds the table. This is true even if the table already has the specified storage engine.
  - You can also use `ALTER TABLE *tbl_name* FORCE` to perform a “null” alter operation that rebuilds the table.

  - The outcome of attempting to change the storage engine of a table is affected by whether the desired storage engine is available and the setting of the `NO_ENGINE_SUBSTITUTION` SQL mode, as described in Section 5.1.8, “Server SQL Modes”.
  - To prevent inadvertent loss of data, `ALTER TABLE` cannot be used to change the storage engine of a table to `MERGE` or `BLACKHOLE`.
- To change the `InnoDB` table to use compressed row-storage format:

```
ALTER TABLE t1 ROW_FORMAT = COMPRESSED;
```

- To reset the current auto-increment value:

```
ALTER TABLE t1 AUTO_INCREMENT = 13;
```

  You cannot reset the counter to a value less than or equal to any that have already been used. For `MyISAM`, if the value is less than or equal to the maximum value currently in the `AUTO_INCREMENT` column, the value is reset to the current maximum plus one. For `InnoDB`, *if the value is less than the current maximum value in the column, no error occurs and the current sequence value is not changed.*

- To change the default table character set:

```
ALTER TABLE t1 CHARACTER SET = utf8;
```

  See also Changing the Character Set.

- To add (or change) a table comment:

```
ALTER TABLE t1 COMMENT = 'New table comment';
```

To verify that the table options were changed as intended, use `SHOW CREATE TABLE`, or query the `INFORMATION_SCHEMA.TABLES` table.

Performance, Storage, and Concurrency Considerations

Some `ALTER TABLE` operations can be performed in place without making a temporary copy of the table. In-place operations tend to be very fast.

Other `ALTER TABLE` operations perform the alteration on a temporary copy of the table, which can require more time, particularly for large tables.

In-place `ALTER TABLE` operations that do not require creating a temporary copy of the original table include:

- For `ALTER TABLE` *`tbl_name`* `RENAME TO` *`new_tbl_name`* without any other options, MySQL renames files that correspond to the table *`tbl_name`* without making a copy. (You can also use the `RENAME TABLE` statement to rename tables. See Section 13.1.32, “RENAME TABLE Syntax”.) Privileges granted specifically for the renamed table are not migrated to the new name. They must be changed manually.
- Alterations that modify only table metadata and not table data are immediate because the server only needs to alter the table `.frm` file, not touch table contents. The following changes are made in this way:
  - Renaming a column, except for the `InnoDB` storage engine.
  - Changing the default value of a column (except for `NDB` tables; see Limitations of `NDBCLUSTER` online operations).

  - Changing the definition of an `ENUM` or `SET` column by adding new enumeration or set members to the *end* of the list of valid member values, as long as the storage size of the data type does not change. For example, adding a member to a `SET` column that has 8 members changes the required storage per value from 1 byte to 2 bytes; this requires a table copy. Adding members in the middle of the list causes renumbering of existing members, which requires a table copy.

- Renaming an index, except for `InnoDB`.
- Adding or dropping an index, for `InnoDB` and `NDB`. See Section 14.16, “InnoDB Fast Index Creation”.
- For `NDBCLUSTER` tables, operations that add and drop indexes on variable-width columns occur online, without table copying and without blocking concurrent DML actions for most of their duration. See Section 13.1.7.2, “ALTER TABLE Online Operations in NDB Cluster 7.2”.

`ALTER TABLE` operations that are **not** performed in place make a temporary copy of the original table. MySQL waits for other operations that are modifying the table, then proceeds. It incorporates the alteration into the copy, deletes the original table, and renames the new one. While `ALTER TABLE` is executing, the original table is readable by other sessions (with the exception noted shortly). Updates and writes to the table that begin after the `ALTER TABLE` operation begins are stalled until the new table is ready, then are automatically redirected to the new table without any failed updates. The temporary copy of the original table is created in the database directory of the new table. This can differ from the database directory of the original table for `ALTER TABLE` operations that rename the table to a different database.

The exception referred to earlier is that `ALTER TABLE` blocks reads (not just writes) at the point where it is ready to install a new version of the table `.frm` file, discard the old file, and clear outdated table structures from the table and table definition caches. At this point, it must acquire an exclusive lock. To do so, it waits for current readers to finish, and blocks new reads (and writes).

For `MyISAM` tables, you can speed up index re-creation (the slowest part of the alteration process) by setting the `myisam_sort_buffer_size` system variable to a high value.

For `InnoDB` tables, a table-copying `ALTER TABLE` operation on table that resides in a shared tablespace such as the system tablespace can increase the amount of space used by the tablespace. Such operations require as much additional space as the data in the table plus indexes. For a table that resides in a shared tablespace, the additional space used during a table-copying `ALTER TABLE` operation is not released back to the operating system as it is for a table that resides in a file-per-table tablespace.

To force use of the table-copy method for an `ALTER TABLE` operation that would otherwise not use it, set the `old_alter_table` system variable to `ON`.

`ALTER TABLE` with `ADD PARTITION`, `DROP PARTITION`, `COALESCE PARTITION`, `REBUILD PARTITION`, or `REORGANIZE PARTITION` does not create temporary tables (except when used with `NDB` tables); however, these operations can and do create temporary partition files.

`ADD` or `DROP` operations for `RANGE` or `LIST` partitions are immediate operations or nearly so. `ADD` or `COALESCE` operations for `HASH` or `KEY` partitions copy data between all partitions, unless `LINEAR HASH` or `LINEAR KEY` was used; this is effectively the same as creating a new table, although the `ADD` or `COALESCE` operation is performed partition by partition. `REORGANIZE` operations copy only changed partitions and do not touch unchanged ones.

Note

Pending `INSERT DELAYED` statements are lost if a table is write locked and `ALTER TABLE` is used to modify the table structure.

Adding and Dropping Columns

Use `ADD` to add new columns to a table, and `DROP` to remove existing columns.

`DROP col_name` is a MySQL extension to standard SQL.

To add a column at a specific position within a table row, use `FIRST` or `AFTER col_name`. The default is to add the column last.

If a table contains only one column, the column cannot be dropped. If what you intend is to remove the table, use the `DROP TABLE` statement instead.

If columns are dropped from a table, the columns are also removed from any index of which they are a part. If all columns that make up an index are dropped, the index is dropped as well.

Renaming, Redefining, and Reordering Columns

The `CHANGE`, `MODIFY`, and `ALTER` clauses enable the names and definitions of existing columns to be altered. They have these comparative characteristics:

- `CHANGE`:
  - Can rename a column and change its definition, or both.
  - Has more capability than `MODIFY`, but at the expense of convenience for some operations. `CHANGE` requires naming the column twice if not renaming it.
  - With `FIRST` or `AFTER`, can reorder columns.
- `MODIFY`:
  - Can change a column definition but not its name.
  - More convenient than `CHANGE` to change a column definition without renaming it.
  - With `FIRST` or `AFTER`, can reorder columns.
- `ALTER`: Used only to change a column default value.

`CHANGE` is a MySQL extension to standard SQL. `MODIFY` is a MySQL extension for Oracle compatibility.

To alter a column to change both its name and definition, use `CHANGE`, specifying the old and new names and the new definition. For example, to rename an `INT NOT NULL` column from `a` to `b` and change its definition to use the `BIGINT` data type while retaining the `NOT NULL` attribute, do this:

```
ALTER TABLE t1 CHANGE a b BIGINT NOT NULL;
```

To change a column definition but not its name, use `CHANGE` or `MODIFY`. With `CHANGE`, the syntax requires two column names, so you must specify the same name twice to leave the name unchanged. For example, to change the definition of column `b`, do this:

```
ALTER TABLE t1 CHANGE b b INT NOT NULL;
```

`MODIFY` is more convenient to change the definition without changing the name because it requires the column name only once:

```
ALTER TABLE t1 MODIFY b INT NOT NULL;
```

To change a column name but not its definition, use `CHANGE`. The syntax requires a column definition, so to leave the definition unchanged, you must respecify the definition the column currently has. For example, to rename an `INT NOT NULL` column from `b` to `a`, do this:

```
ALTER TABLE t1 CHANGE b a INT NOT NULL;
```

For column definition changes using CHANGE or MODIFY, the definition must include the data type and all attributes that should apply to the new column, other than index attributes such as PRIMARY KEY or UNIQUE. Attributes present in the original definition but not specified for the new definition are not carried forward. Suppose that a column col1 is defined as INT UNSIGNED DEFAULT 1 COMMENT 'my column' and you modify the column as follows, intending to change only INT to BIGINT:

```
ALTER TABLE t1 MODIFY col1 BIGINT;
```

That statement changes the data type from INT to BIGINT, but it also drops the UNSIGNED, DEFAULT, and COMMENT attributes. To retain them, the statement must include them explicitly:

```
ALTER TABLE t1 MODIFY col1 BIGINT UNSIGNED DEFAULT 1 COMMENT 'my column';
```

For data type changes using CHANGE or MODIFY, MySQL tries to convert existing column values to the new type as well as possible.

Warning

This conversion may result in alteration of data. For example, if you shorten a string column, values may be truncated. To prevent the operation from succeeding if conversions to the new data type would result in loss of data, enable strict SQL mode before using ALTER TABLE (see Section 5.1.8, “Server SQL Modes”).

If you use CHANGE or MODIFY to shorten a column for which an index exists on the column, and the resulting column length is less than the index length, MySQL shortens the index automatically.

For columns renamed by CHANGE, MySQL automatically renames these references to the renamed column:

- Indexes that refer to the old column, including indexes and disabled MyISAM indexes.

For columns renamed by CHANGE, MySQL does not automatically rename these references to the renamed column:

- Foreign keys that refer to the old column.
- Partition expressions that refer to the renamed column. You must use CHANGE to redefine such expressions in the same ALTER TABLE statement as the one that renames the column.
- Views and stored programs that refer to the renamed column. You must manually alter the definition of these objects to refer to the new column name.

To reorder columns within a table, use FIRST and AFTER in CHANGE or MODIFY operations.

ALTER ... SET DEFAULT or ALTER ... DROP DEFAULT specify a new default value for a column or remove the old default value, respectively. If the old default is removed and the column can be NULL, the new default is NULL. If the column cannot be NULL, MySQL assigns a default value as described in Section 11.6, “Data Type Default Values”.

Primary Keys and Indexes

DROP PRIMARY KEY drops the primary key. If there is no primary key, an error occurs. For information about the performance characteristics of primary keys, especially for InnoDB tables, see Section 8.3.2, “Primary Key Optimization”.

If you add a UNIQUE INDEX or PRIMARY KEY to a table, MySQL stores it before any nonunique index to permit detection of duplicate keys as early as possible.

IGNORE is a MySQL extension to standard SQL. It controls how ALTER TABLE works if there are duplicates on unique keys in the new table or if warnings occur when strict mode is enabled. If IGNORE is not specified, the copy is aborted and rolled back if duplicate-key errors occur. If IGNORE is

specified, only one row is used of rows with duplicates on a unique key. The other conflicting rows are deleted. Incorrect values are truncated to the closest matching acceptable value.

Note

Due to a bug related to Fast Index Creation (Bug #40344), `ALTER IGNORE TABLE ... ADD UNIQUE INDEX` does not delete duplicate rows. The `IGNORE` keyword is ignored. If any duplicate rows exist, the operation fails with a `Duplicate entry` error. A workaround is to set `old_alter_table=1` prior to running an `ALTER IGNORE TABLE ... ADD UNIQUE INDEX` statement.

```
SET SESSION old_alter_table=1
```

`DROP INDEX` removes an index. This is a MySQL extension to standard SQL. See Section 13.1.24, “DROP INDEX Syntax”. To determine index names, use `SHOW INDEX FROM tbl_name`.

Some storage engines permit you to specify an index type when creating an index. The syntax for the *`index_type`* specifier is `USING type_name`. For details about `USING`, see Section 13.1.13, “CREATE INDEX Syntax”. The preferred position is after the column list. Support for use of the option before the column list will be removed in a future MySQL release.

`index_option` values specify additional options for an index. For details about permissible *`index_option`* values, see Section 13.1.13, “CREATE INDEX Syntax”.

If you use `ALTER TABLE` on a `MyISAM` table, all nonunique indexes are created in a separate batch (as for `REPAIR TABLE`). This should make `ALTER TABLE` much faster when you have many indexes.

For `MyISAM` tables, key updating can be controlled explicitly. Use `ALTER TABLE ... DISABLE KEYS` to tell MySQL to stop updating nonunique indexes. Then use `ALTER TABLE ... ENABLE KEYS` to re-create missing indexes. `MyISAM` does this with a special algorithm that is much faster than inserting keys one by one, so disabling keys before performing bulk insert operations should give a considerable speedup. Using `ALTER TABLE ... DISABLE KEYS` requires the `INDEX` privilege in addition to the privileges mentioned earlier.

While the nonunique indexes are disabled, they are ignored for statements such as `SELECT` and `EXPLAIN` that otherwise would use them.

After an `ALTER TABLE` statement, it may be necessary to run `ANALYZE TABLE` to update index cardinality information. See Section 13.7.5.23, “SHOW INDEX Syntax”.

Foreign Keys

If `ALTER TABLE` for an `InnoDB` table results in changes to column values (for example, because a column is truncated), `InnoDB`'s `FOREIGN KEY` constraint checks do not notice possible violations caused by changing the values.

The `FOREIGN KEY` and `REFERENCES` clauses are supported by the `InnoDB` storage engine, which implements `ADD [CONSTRAINT [symbol]] FOREIGN KEY [index_name] (...) REFERENCES ... (...)`. See Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”. For other storage engines, the clauses are parsed but ignored. The `CHECK` clause is parsed but ignored by all storage engines. See Section 13.1.17, “CREATE TABLE Syntax”. The reason for accepting but ignoring syntax clauses is for compatibility, to make it easier to port code from other SQL servers, and to run applications that create tables with references. See Section 1.7.2, “MySQL Differences from Standard SQL”.

For `ALTER TABLE`, unlike `CREATE TABLE`, `ADD FOREIGN KEY` ignores *`index_name`* if given and uses an automatically generated foreign key name. As a workaround, include the `CONSTRAINT` clause to specify the foreign key name:

```
ADD CONSTRAINT name FOREIGN KEY (....) ...
```

Important

MySQL silently ignores inline `REFERENCES` specifications, where the references are defined as part of the column specification. MySQL accepts only `REFERENCES` clauses defined as part of a separate `FOREIGN KEY` specification.

Note

Partitioned `InnoDB` tables do not support foreign keys. For more information, see Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”.

`InnoDB` supports the use of `ALTER TABLE` to drop foreign keys:

```
ALTER TABLE tbl_name DROP FOREIGN KEY fk_symbol;
```

Adding and dropping a foreign key in separate clauses of a single `ALTER TABLE` statement may be problematic in some cases and is therefore unsupported. Use separate statements for each operation.

`ALTER TABLE tbl_name RENAME new_tbl_name` changes internally generated foreign key constraint names and user-defined foreign key constraint names that contain the string “*`tbl_name`*_ibfk_” to reflect the new table name. `InnoDB` interprets foreign key constraint names that contain the string “*`tbl_name`*_ibfk_” as internally generated names.

Changing the Character Set

To change the table default character set and all character columns (`CHAR`, `VARCHAR`, `TEXT`) to a new character set, use a statement like this:

```
ALTER TABLE tbl_name
CONVERT TO CHARACTER SET charset_name [COLLATE collation_name];
```

The statement also changes the collation of all character columns. If you specify no `COLLATE` clause to indicate which collation to use, the statement uses default collation for the character set. If this collation is inappropriate for the intended table use (for example, if it would change from a case-sensitive collation to a case-insensitive collation), specify a collation explicitly.

For a column that has a data type of `VARCHAR` or one of the `TEXT` types, `CONVERT TO CHARACTER SET` changes the data type as necessary to ensure that the new column is long enough to store as many characters as the original column. For example, a `TEXT` column has two length bytes, which store the byte-length of values in the column, up to a maximum of 65,535. For a `latin1 TEXT` column, each character requires a single byte, so the column can store up to 65,535 characters. If the column is converted to `utf8`, each character might require up to three bytes, for a maximum possible length of 3 × 65,535 = 196,605 bytes. That length does not fit in a `TEXT` column's length bytes, so MySQL converts the data type to `MEDIUMTEXT`, which is the smallest string type for which the length bytes can record a value of 196,605. Similarly, a `VARCHAR` column might be converted to `MEDIUMTEXT`.

To avoid data type changes of the type just described, do not use `CONVERT TO CHARACTER SET`. Instead, use `MODIFY` to change individual columns. For example:

```
ALTER TABLE t MODIFY latin1_text_col TEXT CHARACTER SET utf8;
ALTER TABLE t MODIFY latin1_varchar_col VARCHAR(M) CHARACTER SET utf8;
```

If you specify `CONVERT TO CHARACTER SET binary`, the `CHAR`, `VARCHAR`, and `TEXT` columns are converted to their corresponding binary string types (`BINARY`, `VARBINARY`, `BLOB`). This means that the columns no longer will have a character set attribute and a subsequent `CONVERT TO` operation will not apply to them.

If *`charset_name`* is `DEFAULT`, the database character set is used.

Warning

The `CONVERT TO` operation converts column values between the original and named character sets. This is *not* what you want if you have a column in one character set (like `latin1`) but the stored values actually use some other, incompatible character set (like `utf8`). In this case, you have to do the following for each such column:

```
ALTER TABLE t1 CHANGE c1 c1 BLOB;
ALTER TABLE t1 CHANGE c1 c1 TEXT CHARACTER SET utf8;
```

The reason this works is that there is no conversion when you convert to or from `BLOB` columns.

To change only the *default* character set for a table, use this statement:

```
ALTER TABLE tbl_name DEFAULT CHARACTER SET charset_name;
```

The word `DEFAULT` is optional. The default character set is the character set that is used if you do not specify the character set for columns that you add to a table later (for example, with `ALTER TABLE ... ADD column`).

When the `foreign_key_checks` system variable is enabled, which is the default setting, character set conversion is not permitted on tables that include a character string column used in a foreign key constraint. The workaround is to disable `foreign_key_checks` before performing the character set conversion. You must perform the conversion on both tables involved in the foreign key constraint before re-enabling `foreign_key_checks`. If you re-enable `foreign_key_checks` after converting only one of the tables, an `ON DELETE CASCADE` or `ON UPDATE CASCADE` operation could corrupt data in the referencing table due to implicit conversion that occurs during these operations (Bug #45290, Bug #74816).

Discarding and Importing InnoDB Tablespaces

For an `InnoDB` table that is created with its own tablespace in an `.ibd` file, that file can be discarded and imported. To discard the `.ibd` file, use this statement:

```
ALTER TABLE tbl_name DISCARD TABLESPACE;
```

This deletes the current `.ibd` file, so be sure that you have a backup first. Attempting to access the table while the tablespace file is discarded results in an error.

To import the backup `.ibd` file back into the table, copy it into the database directory, and then issue this statement:

```
ALTER TABLE tbl_name IMPORT TABLESPACE;
```

The tablespace file must have been created on the server into which it is imported later.

Note

The `ALTER TABLE ... IMPORT TABLESPACE` feature does not enforce foreign key constraints on imported data.

See Section 14.10.4, “InnoDB File-Per-Table Tablespaces”.

Row Order for MyISAM Tables

`ORDER BY` enables you to create the new table with the rows in a specific order. This option is useful primarily when you know that you query the rows in a certain order most of the time. By using this option after major changes to the table, you might be able to get higher performance. In some cases, it

might make sorting easier for MySQL if the table is in order by the column that you want to order it by later.

Note

The table does not remain in the specified order after inserts and deletes.

`ORDER BY` syntax permits one or more column names to be specified for sorting, each of which optionally can be followed by `ASC` or `DESC` to indicate ascending or descending sort order, respectively. The default is ascending order. Only column names are permitted as sort criteria; arbitrary expressions are not permitted. This clause should be given last after any other clauses.

`ORDER BY` does not make sense for `InnoDB` tables because `InnoDB` always orders table rows according to the clustered index.

When used on a partitioned table, `ALTER TABLE ... ORDER BY` orders rows within each partition only.

Partitioning Options

`partition_options` signifies options that can be used with partitioned tables for repartitioning, to add, drop, discard, merge, and split partitions, and to perform partitioning maintenance.

It is possible for an `ALTER TABLE` statement to contain a `PARTITION BY` or `REMOVE PARTITIONING` clause in an addition to other alter specifications, but the `PARTITION BY` or `REMOVE PARTITIONING` clause must be specified last after any other specifications. The `ADD PARTITION`, `DROP PARTITION`, `COALESCE PARTITION`, `REORGANIZE PARTITION`, `ANALYZE PARTITION`, `CHECK PARTITION`, and `REPAIR PARTITION` options cannot be combined with other alter specifications in a single `ALTER TABLE`, since the options just listed act on individual partitions.

For a list of partition options and a description of each, see Section 13.1.17, “CREATE TABLE Syntax”. For additional information, see Section 13.1.7.1, “ALTER TABLE Partition Operations”.

13.1.7.1 ALTER TABLE Partition Operations

Partitioning-related clauses for `ALTER TABLE` can be used with partitioned tables for repartitioning, to add, drop, discard, merge, and split partitions, and to perform partitioning maintenance.

- Simply using a *`partition_options`* clause with `ALTER TABLE` on a partitioned table repartitions the table according to the partitioning scheme defined by the *`partition_options`*. This clause always begins with `PARTITION BY`, and follows the same syntax and other rules as apply to the *`partition_options`* clause for `CREATE TABLE` (for more detailed information, see Section 13.1.17, “CREATE TABLE Syntax”), and can also be used to partition an existing table that is not already partitioned. For example, consider a (nonpartitioned) table defined as shown here:

```
CREATE TABLE t1 (
    id INT,
    year_col INT
);
```

This table can be partitioned by `HASH`, using the `id` column as the partitioning key, into 8 partitions by means of this statement:

```
ALTER TABLE t1
    PARTITION BY HASH(id)
    PARTITIONS 8;
```

MySQL 5.5.31 and later supports an `ALGORITHM` option with `[SUB]PARTITION BY [LINEAR] KEY`. `ALGORITHM=1` causes the server to use the same key-hashing functions as MySQL 5.1 when computing the placement of rows in partitions; `ALGORITHM=2` means that the server employs the key-hashing functions implemented and used by default for new `KEY` partitioned tables in MySQL

5.5 and later. (Partitioned tables created with the key-hashing functions employed in MySQL 5.5 and later cannot be used by a MySQL 5.1 server.) Not specifying the option has the same effect as using `ALGORITHM=2`. This option is intended for use chiefly when upgrading or downgrading `[LINEAR] KEY` partitioned tables between MySQL 5.1 and later MySQL versions, or for creating tables partitioned by `KEY` or `LINEAR KEY` on a MySQL 5.5 or later server which can be used on a MySQL 5.1 server.

To upgrade a `KEY` partitioned table that was created in MySQL 5.1, first execute `SHOW CREATE TABLE` and note the exact columns and number of partitions shown. Now execute an `ALTER TABLE` statement using exactly the same column list and number of partitions as in the `CREATE TABLE` statement, while adding `ALGORITHM=2` immediately following the `PARTITION BY` keywords. (You should also include the `LINEAR` keyword if it was used for the original table definition.) An example from a session in the `mysql` client is shown here:

```
mysql> SHOW CREATE TABLE p\G
*************************** 1. row ***************************
       Table: p
Create Table: CREATE TABLE `p` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `cd` datetime NOT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARSET=latin1
/*!50100 PARTITION BY LINEAR KEY (id)
PARTITIONS 32 */
1 row in set (0.00 sec)

mysql> ALTER TABLE p PARTITION BY LINEAR KEY ALGORITHM=2 (id) PARTITIONS 32;
Query OK, 0 rows affected (5.34 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW CREATE TABLE p\G
*************************** 1. row ***************************
       Table: p
Create Table: CREATE TABLE `p` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `cd` datetime NOT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARSET=latin1
/*!50100 PARTITION BY LINEAR KEY (id)
PARTITIONS 32 */
1 row in set (0.00 sec)
```

Downgrading a table created using the default key-hashing used in MySQL 5.5 and later to enable its use by a MySQL 5.1 server is similar, except in this case you should use `ALGORITHM=1` to force the table's partitions to be rebuilt using the MySQL 5.1 key-hashing functions. It is recommended that you not do this except when necessary for compatibility with a MySQL 5.1 server, as the improved `KEY` hashing functions used by default in MySQL 5.5 and later provide fixes for a number of issues found in the older implementation.

Note

A table upgraded by means of `ALTER TABLE ... PARTITION BY ALGORITHM=2 [LINEAR] KEY ...` can no longer be used by a MySQL 5.1 server. (Such a table would need to be downgraded with `ALTER TABLE ... PARTITION BY ALGORITHM=1 [LINEAR] KEY ...` before it could be used again by a MySQL 5.1 server.)

The table that results from using an `ALTER TABLE ... PARTITION BY` statement must follow the same rules as one created using `CREATE TABLE ... PARTITION BY`. This includes the rules governing the relationship between any unique keys (including any primary key) that the table might have, and the column or columns used in the partitioning expression, as discussed in Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”. The `CREATE TABLE ... PARTITION BY` rules for specifying the number of partitions also apply to `ALTER TABLE ... PARTITION BY`.

The *`partition_definition`* clause for `ALTER TABLE ADD PARTITION` supports the same options as the clause of the same name for the `CREATE TABLE` statement. (See Section 13.1.17, “CREATE TABLE Syntax”, for the syntax and description.) Suppose that you have the partitioned table created as shown here:

```
CREATE TABLE t1 (
    id INT,
    year_col INT
)
PARTITION BY RANGE (year_col) (
    PARTITION p0 VALUES LESS THAN (1991),
    PARTITION p1 VALUES LESS THAN (1995),
    PARTITION p2 VALUES LESS THAN (1999)
);
```

You can add a new partition `p3` to this table for storing values less than `2002` as follows:

```
ALTER TABLE t1 ADD PARTITION (PARTITION p3 VALUES LESS THAN (2002));
```

`DROP PARTITION` can be used to drop one or more `RANGE` or `LIST` partitions. This statement cannot be used with `HASH` or `KEY` partitions; instead, use `COALESCE PARTITION` (see below). Any data that was stored in the dropped partitions named in the *`partition_names`* list is discarded. For example, given the table `t1` defined previously, you can drop the partitions named `p0` and `p1` as shown here:

```
ALTER TABLE t1 DROP PARTITION p0, p1;
```

Note

`DROP PARTITION` does not work with tables that use the `NDBCLUSTER` storage engine. See Section 19.3.1, “Management of RANGE and LIST Partitions”, and Section 18.1.6, “Known Limitations of NDB Cluster”.

`ADD PARTITION` and `DROP PARTITION` do not currently support `IF [NOT] EXISTS`.

Renames of partitioned tables are supported. You can rename individual partitions indirectly using `ALTER TABLE ... REORGANIZE PARTITION`; however, this operation copies the partition's data.

To delete rows from selected partitions, use the `TRUNCATE PARTITION` option. This option takes a list of one or more comma-separated partition names. For example, consider the table `t1` as defined here:

```
CREATE TABLE t1 (
    id INT,
    year_col INT
)
PARTITION BY RANGE (year_col) (
    PARTITION p0 VALUES LESS THAN (1991),
    PARTITION p1 VALUES LESS THAN (1995),
    PARTITION p2 VALUES LESS THAN (1999),
    PARTITION p3 VALUES LESS THAN (2003),
    PARTITION p4 VALUES LESS THAN (2007)
);
```

To delete all rows from partition `p0`, use the following statement:

```
ALTER TABLE t1 TRUNCATE PARTITION p0;
```

The statement just shown has the same effect as the following `DELETE` statement:

```
DELETE FROM t1 WHERE year_col < 1991;
```

When truncating multiple partitions, the partitions do not have to be contiguous: This can greatly simplify delete operations on partitioned tables that would otherwise require very complex `WHERE` conditions if done with `DELETE` statements. For example, this statement deletes all rows from partitions `p1` and `p3`:

```
ALTER TABLE t1 TRUNCATE PARTITION p1, p3;
```

An equivalent `DELETE` statement is shown here:

```
DELETE FROM t1 WHERE
    (year_col >= 1991 AND year_col < 1995)
    OR
    (year_col >= 2003 AND year_col < 2007);
```

If you use the `ALL` keyword in place of the list of partition names, the statement acts on all table partitions.

`TRUNCATE PARTITION` merely deletes rows; it does not alter the definition of the table itself, or of any of its partitions.

Note

`TRUNCATE PARTITION` does not work with subpartitions.

To verify that the rows were dropped, check the `INFORMATION_SCHEMA.PARTITIONS` table, using a query such as this one:

```
SELECT PARTITION_NAME, TABLE_ROWS
    FROM INFORMATION_SCHEMA.PARTITIONS
    WHERE TABLE_NAME = 't1';
```

`TRUNCATE PARTITION` is supported only for partitioned tables that use the `MyISAM`, `InnoDB`, or `MEMORY` storage engine. It also works on `BLACKHOLE` tables (but has no effect). It is not supported for `ARCHIVE` tables.

`COALESCE PARTITION` can be used with a table that is partitioned by `HASH` or `KEY` to reduce the number of partitions by *`number`*. Suppose that you have created table `t2` as follows:

```
CREATE TABLE t2 (
    name VARCHAR (30),
    started DATE
)
PARTITION BY HASH( YEAR(started) )
PARTITIONS 6;
```

To reduce the number of partitions used by `t2` from 6 to 4, use the following statement:

```
ALTER TABLE t2 COALESCE PARTITION 2;
```

The data contained in the last *`number`* partitions will be merged into the remaining partitions. In this case, partitions 4 and 5 will be merged into the first 4 partitions (the partitions numbered 0, 1, 2, and 3).

To change some but not all the partitions used by a partitioned table, you can use `REORGANIZE PARTITION`. This statement can be used in several ways:

- To merge a set of partitions into a single partition. This is done by naming several partitions in the *`partition_names`* list and supplying a single definition for *`partition_definition`*.
- To split an existing partition into several partitions. Accomplish this by naming a single partition for *`partition_names`* and providing multiple *`partition_definitions`*.
- To change the ranges for a subset of partitions defined using `VALUES LESS THAN` or the value lists for a subset of partitions defined using `VALUES IN`.
- This statement may also be used without the *`partition_names`* `INTO (`*`partition_definitions`*`)` option on tables that are automatically partitioned using `HASH` partitioning to force redistribution of data. (Currently, only `NDB` tables are automatically partitioned in this way.) This is useful in NDB Cluster where, after you have added new NDB Cluster data nodes online to an existing NDB Cluster, you wish to redistribute existing NDB Cluster table data to the new data nodes. In such cases, you should invoke the statement with the `ONLINE` option; in other words, as shown here:

  ```
  ALTER ONLINE TABLE table REORGANIZE PARTITION;
  ```

  You cannot perform other DDL concurrently with online table reorganization—that is, no other DDL statements can be issued while an `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement is executing. For more information about adding NDB Cluster data nodes online, see Section 18.5.13, “Adding NDB Cluster Data Nodes Online”.

  `ALTER ONLINE TABLE ... REORGANIZE PARTITION` does not work with tables which were created using the `MAX_ROWS` option, because it uses the constant `MAX_ROWS` value specified in the original `CREATE TABLE` statement to determine the number of partitions required, so no new partitions are created. Beginning with MySQL NDB Cluster 7.2.6, you can use `ALTER ONLINE TABLE ... MAX_ROWS=`*`rows`* to increase the maximum number of rows for such a table; in this case, `ALTER ONLINE TABLE ... REORGANIZE PARTITION` is not needed (and causes an error if executed). The value of *`rows`* must be greater than the value specified for `MAX_ROWS` in the original `CREATE TABLE` statement for this to work.

  Attempting to use `REORGANIZE PARTITION` without the *`partition_names`* `INTO (`*`partition_definitions`*`)` option on explicitly partitioned tables results in the error `REORGANIZE PARTITION without parameters can only be used on auto-partitioned tables using HASH partitioning`.

  Note

  For partitions that have not been explicitly named, MySQL automatically provides the default names `p0`, `p1`, `p2`, and so on. The same is true with regard to subpartitions.

  For more detailed information about and examples of `ALTER TABLE ... REORGANIZE PARTITION` statements, see Section 19.3.1, “Management of RANGE and LIST Partitions”.

- Several options provide partition maintenance and repair functionality analogous to that implemented for nonpartitioned tables by statements such as `CHECK TABLE` and `REPAIR TABLE` (which are also supported for partitioned tables; for more information, see Section 13.7.2, “Table Maintenance Statements”). These include `ANALYZE PARTITION`, `CHECK PARTITION`, `OPTIMIZE PARTITION`, `REBUILD PARTITION`, and `REPAIR PARTITION`. Each of these options takes a *`partition_names`* clause consisting of one or more names of partitions, separated by commas. The partitions must already exist in the table to be altered. You can also use the `ALL` keyword in place of *`partition_names`*, in which case the statement acts on all table partitions. For more information and examples, see Section 19.3.3, “Maintenance of Partitions”.

Prior to MySQL 5.5.30, it was not safe to execute multiple concurrent `REBUILD TABLE` operations on partitioned tables, whether on the same or different tables. (Bug #14589559, Bug #66645)

Some MySQL storage engines, such as `InnoDB`, do not support per-partition optimization. For a partitioned table using such a storage engine, `ALTER TABLE ... OPTIMIZE PARTITION` rebuilds the entire table. This is a known issue. Beginning with MySQL 5.5.30, running this statement on such a table causes the entire table to rebuilt and analyzed, and an appropriate warning to be issued. (Bug #11751825, Bug #42822)

To work around this problem, use the statements `ALTER TABLE ... REBUILD PARTITION` and `ALTER TABLE ... ANALYZE PARTITION` instead.

The `ANALYZE PARTITION`, `CHECK PARTITION`, `OPTIMIZE PARTITION`, and `REPAIR PARTITION` options are not permitted for tables which are not partitioned.

- `REMOVE PARTITIONING` enables you to remove a table's partitioning without otherwise affecting the table or its data. This option can be combined with other `ALTER TABLE` options such as those used to add, drop, or rename columns or indexes.
- Using the `ENGINE` option with `ALTER TABLE` changes the storage engine used by the table without affecting the partitioning.

It is possible for an `ALTER TABLE` statement to contain a `PARTITION BY` or `REMOVE PARTITIONING` clause in an addition to other alter specifications, but the `PARTITION BY` or `REMOVE PARTITIONING` clause must be specified last after any other specifications.

The `ADD PARTITION`, `DROP PARTITION`, `COALESCE PARTITION`, `REORGANIZE PARTITION`, `ANALYZE PARTITION`, `CHECK PARTITION`, and `REPAIR PARTITION` options cannot be combined with other alter specifications in a single `ALTER TABLE`, since the options just listed act on individual partitions. For more information, see Section 13.1.7.1, “ALTER TABLE Partition Operations”.

Only a single instance of any one of the following options can be used in a given `ALTER TABLE` statement: `PARTITION BY`, `ADD PARTITION`, `DROP PARTITION`, `TRUNCATE PARTITION`, `REORGANIZE PARTITION`, or `COALESCE PARTITION`, `ANALYZE PARTITION`, `CHECK PARTITION`, `OPTIMIZE PARTITION`, `REBUILD PARTITION`, `REMOVE PARTITIONING`.

For example, the following two statements are invalid:

```
ALTER TABLE t1 ANALYZE PARTITION p1, ANALYZE PARTITION p2;

ALTER TABLE t1 ANALYZE PARTITION p1, CHECK PARTITION p2;
```

In the first case, you can analyze partitions `p1` and `p2` of table `t1` concurrently using a single statement with a single `ANALYZE PARTITION` option that lists both of the partitions to be analyzed, like this:

```
ALTER TABLE t1 ANALYZE PARTITION p1, p2;
```

In the second case, it is not possible to perform `ANALYZE` and `CHECK` operations on different partitions of the same table concurrently. Instead, you must issue two separate statements, like this:

```
ALTER TABLE t1 ANALYZE PARTITION p1;
ALTER TABLE t1 CHECK PARTITION p2;
```

`ANALYZE`, `CHECK`, `OPTIMIZE`, `REBUILD`, `REPAIR`, and `TRUNCATE` operations are not supported for subpartitions.

13.1.7.2 ALTER TABLE Online Operations in NDB Cluster 7.2

Operations that add and drop indexes on variable-width columns of `NDBCLUSTER` tables occur online. Online operations are noncopying; that is, they do not require that indexes be re-created.

They do not lock the table being altered from access by other API nodes in an NDB Cluster (but see *Limitations* later in this section). Such operations do not require single user mode for `NDBCLUSTER` table alterations made in a cluster with multiple API nodes; transactions can continue uninterrupted during online DDL operations.

The `ONLINE` keyword can be used to perform online `ADD COLUMN`, `ADD INDEX` (including `CREATE INDEX` statements), and `DROP INDEX` operations on `NDBCLUSTER` tables. Online renaming of `NDBCLUSTER` tables is also supported.

The `ONLINE` and `OFFLINE` keywords are supported only in NDB Cluster. For standard MySQL Server 5.5 releases:

- The server determines automatically whether an `ADD INDEX` or `DROP INDEX` operation can be (and is) performed online or offline; if the column is of a variable-width data type, the operation is performed online. It is not possible to override the server behavior in this regard.
- Attempting to use the `ONLINE` or `OFFLINE` keyword in an `ALTER TABLE`, `CREATE INDEX`, or `DROP INDEX` statement results in an error.

Currently you cannot add disk-based columns to `NDBCLUSTER` tables online. This means that, if you wish to add an in-memory column to an `NDBCLUSTER` table that uses a table-level `STORAGE DISK` option, you must declare the new column as using memory-based storage explicitly. For example—assuming that you have already created tablespace `ts1`—suppose that you create table `t1` as follows:

```
mysql> CREATE TABLE t1 (
    >     c1 INT NOT NULL PRIMARY KEY,
    >     c2 VARCHAR(30)
    >     )
    >     TABLESPACE ts1 STORAGE DISK
    >     ENGINE NDBCLUSTER;
Query OK, 0 rows affected (1.73 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

You can add a new in-memory column to this table online as shown here:

```
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c3 INT COLUMN_FORMAT DYNAMIC STORAGE MEMORY;
Query OK, 0 rows affected (1.25 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

This statement fails if the `STORAGE MEMORY` option is omitted:

```
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c3 INT COLUMN_FORMAT DYNAMIC;
ERROR 1235 (42000): This version of MySQL doesn't yet support
'ALTER ONLINE TABLE t1 ADD COLUMN c3 INT COLUMN_FORMAT DYNAMIC'
```

If you omit the `COLUMN_FORMAT DYNAMIC` option, the dynamic column format is employed automatically, but a warning is issued, as shown here:

```
mysql> ALTER ONLINE TABLE t1 ADD COLUMN c3 INT STORAGE MEMORY;
Query OK, 0 rows affected, 1 warning (1.17 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW WARNINGS;
+---------+------+-----------------------------------------------------------------+
| Level   | Code | Message                                                         |
+---------+------+-----------------------------------------------------------------+
| Warning | 1478 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
+---------+------+-----------------------------------------------------------------+
1 row in set (0.00 sec)

mysql> SHOW CREATE TABLE t1\G
*************************** 1. row ***************************
       Table: t1
```

```
Create Table: CREATE TABLE `t1` (
  `c1` int(11) NOT NULL,
  `c2` varchar(30) DEFAULT NULL,
  `c3` int(11) /*!50120 STORAGE MEMORY */ /*!50120 COLUMN_FORMAT DYNAMIC */ DEFAULT NULL,
  `t4` int(11) /*!50120 STORAGE MEMORY */ DEFAULT NULL,
  PRIMARY KEY (`c1`)
) /*!50100 TABLESPACE ts_1 STORAGE DISK */ ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.03 sec)
```

Note

The `STORAGE` and `COLUMN_FORMAT` keywords are supported only in NDB Cluster; in any other version of MySQL, attempting to use either of these keywords in a `CREATE TABLE` or `ALTER TABLE` statement results in an error.

It is also possible to use the statement `ALTER ONLINE TABLE ... REORGANIZE PARTITION` with no *`partition_names INTO (partition_definitions)`* option on `NDB` tables. This can be used to redistribute NDB Cluster data among new data nodes that have been added to the cluster online. This does *not* perform any defragmentation, which requires an `OPTIMIZE TABLE` or null `ALTER TABLE` statement. For more information, see Section 18.5.13, “Adding NDB Cluster Data Nodes Online”.

Limitations of NDBCLUSTER online operations

Online `DROP COLUMN` operations are not supported.

Online `ALTER TABLE`, `CREATE INDEX`, or `DROP INDEX` statements that add columns or add or drop indexes are subject to the following limitations:

- A given online `ALTER TABLE` can use only one of `ADD COLUMN`, `ADD INDEX`, or `DROP INDEX`. One or more columns can be added online in a single statement; only one index may be created or dropped online in a single statement.
- An `ALTER TABLE` statement that performs a rename while using the `ONLINE` or `OFFLINE` keyword cannot perform any other operations, including but not limited to `ADD COLUMN`, `ADD INDEX`, or `DROP INDEX`. Beginning with MySQL NDB Cluster 7.2.11, such statements are specifically disallowed, and fail with `ER_NOT_SUPPORTED_YET`. (Bug #16021021)
- The table being altered is not locked with respect to API nodes other than the one on which an online `ALTER TABLE ADD COLUMN`, `ADD INDEX`, or `DROP INDEX` operation (or `CREATE INDEX` or `DROP INDEX` statement) is run. However, the table is locked against any other operations originating on the *same* API node while the online operation is being executed.
- The table to be altered must have an explicit primary key; the hidden primary key created by the `NDB` storage engine is not sufficient for this purpose.
- The storage engine used by the table cannot be changed online.
- When used with NDB Cluster Disk Data tables, it is not possible to change the storage type (`DISK` or `MEMORY`) of a column online. This means, that when you add or drop an index in such a way that the operation would be performed online, and you want the storage type of the column or columns to be changed, you must use the `OFFLINE` keyword in the statement that adds or drops the index.

Columns to be added online cannot use the `BLOB` or `TEXT` type, and must meet the following criteria:

- The columns must be dynamic; that is, it must be possible to create them using `COLUMN_FORMAT DYNAMIC`. If you omit the `COLUMN_FORMAT DYNAMIC` option, the dynamic column format is employed automatically.
- The columns must permit `NULL` values and not have any explicit default value other than `NULL`. Columns added online are automatically created as `DEFAULT NULL`, as can be seen here:

```
mysql> CREATE TABLE t1 (
     >     c1 INT NOT NULL AUTO_INCREMENT PRIMARY KEY
     >     ) ENGINE=NDB;
Query OK, 0 rows affected (1.44 sec)

mysql> ALTER ONLINE TABLE t1
     >     ADD COLUMN c2 INT,
     >     ADD COLUMN c3 INT;
Query OK, 0 rows affected, 2 warnings (0.93 sec)

mysql> SHOW CREATE TABLE t1\G
*************************** 1. row ***************************
       Table: t1
Create Table: CREATE TABLE `t1` (
  `c1` int(11) NOT NULL AUTO_INCREMENT,
  `c2` int(11) DEFAULT NULL,
  `c3` int(11) DEFAULT NULL,
  PRIMARY KEY (`c1`)
) ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.00 sec)
```

- The columns must be added following any existing columns. If you attempt to add a column online before any existing columns or using the `FIRST` keyword, the statement fails with an error.
- Existing table columns cannot be reordered online.

For online `ALTER TABLE` operations on `NDB` tables, fixed-format columns are converted to dynamic when they are added online, or when indexes are created or dropped online, as shown here:

```
mysql> CREATE TABLE t1 (
     >     c1 INT NOT NULL AUTO_INCREMENT PRIMARY KEY
     >     ) ENGINE=NDB;
Query OK, 0 rows affected (1.44 sec)

mysql> ALTER ONLINE TABLE t1 ADD COLUMN c2 INT, ADD COLUMN c3 INT;
Query OK, 0 rows affected, 2 warnings (0.93 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW WARNINGS;
+---------+------+-----------------------------------------------------------------+
| Level   | Code | Message                                                         |
+---------+------+-----------------------------------------------------------------+
| Warning | 1475 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
| Warning | 1475 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
+---------+------+-----------------------------------------------------------------+
2 rows in set (0.00 sec)
```

Note

Existing columns, including the table's primary key, need not be dynamic; only the column or columns to be added online must be dynamic.

```
mysql> CREATE TABLE t2 (
     >     c1 INT NOT NULL AUTO_INCREMENT PRIMARY KEY COLUMN_FORMAT FIXED
     >     ) ENGINE=NDB;
Query OK, 0 rows affected (2.10 sec)

mysql> ALTER ONLINE TABLE t2 ADD COLUMN c2 INT;
Query OK, 0 rows affected, 1 warning (0.78 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW WARNINGS;
+---------+------+-----------------------------------------------------------------+
| Level   | Code | Message                                                         |
+---------+------+-----------------------------------------------------------------+
| Warning | 1475 | Converted FIXED field to DYNAMIC to enable on-line ADD COLUMN |
+---------+------+-----------------------------------------------------------------+
1 row in set (0.00 sec)
```

Columns are not converted from FIXED to DYNAMIC column format by renaming operations. For more information about COLUMN_FORMAT, see Section 13.1.17, “CREATE TABLE Syntax”.

The KEY, CONSTRAINT, and IGNORE keywords are supported in ALTER TABLE statements using the ONLINE keyword.

13.1.7.3 ALTER TABLE Examples

Begin with a table t1 created as shown here:

```
CREATE TABLE t1 (a INTEGER, b CHAR(10));
```

To rename the table from t1 to t2:

```
ALTER TABLE t1 RENAME t2;
```

To change column a from INTEGER to TINYINT NOT NULL (leaving the name the same), and to change column b from CHAR(10) to CHAR(20) as well as renaming it from b to c:

```
ALTER TABLE t2 MODIFY a TINYINT NOT NULL, CHANGE b c CHAR(20);
```

To add a new TIMESTAMP column named d:

```
ALTER TABLE t2 ADD d TIMESTAMP;
```

To add an index on column d and a UNIQUE index on column a:

```
ALTER TABLE t2 ADD INDEX (d), ADD UNIQUE (a);
```

To remove column c:

```
ALTER TABLE t2 DROP COLUMN c;
```

To add a new AUTO_INCREMENT integer column named c:

```
ALTER TABLE t2 ADD c INT UNSIGNED NOT NULL AUTO_INCREMENT,
  ADD PRIMARY KEY (c);
```

We indexed c (as a PRIMARY KEY) because AUTO_INCREMENT columns must be indexed, and we declare c as NOT NULL because primary key columns cannot be NULL.

For NDB tables, it is also possible to change the storage type used for a table or column. For example, consider an NDB table created as shown here:

```
mysql> CREATE TABLE t1 (c1 INT) TABLESPACE ts_1 ENGINE NDB;
Query OK, 0 rows affected (1.27 sec)
```

To convert this table to disk-based storage, you can use the following ALTER TABLE statement:

```
mysql> ALTER TABLE t1 TABLESPACE ts_1 STORAGE DISK;
Query OK, 0 rows affected (2.99 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW CREATE TABLE t1\G
*************************** 1. row ***************************
       Table: t1
Create Table: CREATE TABLE `t1` (
  `c1` int(11) DEFAULT NULL
) /*!50100 TABLESPACE ts_1 STORAGE DISK */
ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.01 sec)
```

It is not necessary that the tablespace was referenced when the table was originally created; however, the tablespace must be referenced by the `ALTER TABLE`:

```
mysql> CREATE TABLE t2 (c1 INT) ts_1 ENGINE NDB;
Query OK, 0 rows affected (1.00 sec)

mysql> ALTER TABLE t2 STORAGE DISK;
ERROR 1005 (HY000): Can't create table 'c.#sql-1750_3' (errno: 140)
mysql> ALTER TABLE t2 TABLESPACE ts_1 STORAGE DISK;
Query OK, 0 rows affected (3.42 sec)
Records: 0  Duplicates: 0  Warnings: 0
mysql> SHOW CREATE TABLE t2\G
*************************** 1. row ***************************
       Table: t1
Create Table: CREATE TABLE `t2` (
  `c1` int(11) DEFAULT NULL
) /*!50100 TABLESPACE ts_1 STORAGE DISK */
ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.01 sec)
```

To change the storage type of an individual column, you can use `ALTER TABLE ... MODIFY [COLUMN]`. For example, suppose you create an NDB Cluster Disk Data table with two columns, using this `CREATE TABLE` statement:

```
mysql> CREATE TABLE t3 (c1 INT, c2 INT)
    ->     TABLESPACE ts_1 STORAGE DISK ENGINE NDB;
Query OK, 0 rows affected (1.34 sec)
```

To change column `c2` from disk-based to in-memory storage, include a STORAGE MEMORY clause in the column definition used by the ALTER TABLE statement, as shown here:

```
mysql> ALTER TABLE t3 MODIFY c2 INT STORAGE MEMORY;
Query OK, 0 rows affected (3.14 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

You can make an in-memory column into a disk-based column by using `STORAGE DISK` in a similar fashion.

Column `c1` uses disk-based storage, since this is the default for the table (determined by the table-level `STORAGE DISK` clause in the `CREATE TABLE` statement). However, column `c2` uses in-memory storage, as can be seen here in the output of SHOW `CREATE TABLE`:

```
mysql> SHOW CREATE TABLE t3\G
*************************** 1. row ***************************
       Table: t3
Create Table: CREATE TABLE `t3` (
  `c1` int(11) DEFAULT NULL,
  `c2` int(11) /*!50120 STORAGE MEMORY */ DEFAULT NULL
) /*!50100 TABLESPACE ts_1 STORAGE DISK */ ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.02 sec)
```

When you add an `AUTO_INCREMENT` column, column values are filled in with sequence numbers automatically. For `MyISAM` tables, you can set the first sequence number by executing `SET INSERT_ID=value` before `ALTER TABLE` or by using the `AUTO_INCREMENT=value` table option.

With `MyISAM` tables, if you do not change the `AUTO_INCREMENT` column, the sequence number is not affected. If you drop an `AUTO_INCREMENT` column and then add another `AUTO_INCREMENT` column, the numbers are resequenced beginning with 1.

When replication is used, adding an `AUTO_INCREMENT` column to a table might not produce the same ordering of the rows on the slave and the master. This occurs because the order in which the rows are numbered depends on the specific storage engine used for the table and the order in which the rows were inserted. If it is important to have the same order on the master and slave, the rows must be ordered before assigning an `AUTO_INCREMENT` number. Assuming that you want to add an

AUTO_INCREMENT column to the table t1, the following statements produce a new table t2 identical to t1 but with an AUTO_INCREMENT column:

```
CREATE TABLE t2 (id INT AUTO_INCREMENT PRIMARY KEY)
SELECT * FROM t1 ORDER BY col1, col2;
```

This assumes that the table t1 has columns col1 and col2.

This set of statements will also produce a new table t2 identical to t1, with the addition of an AUTO_INCREMENT column:

```
CREATE TABLE t2 LIKE t1;
ALTER TABLE t2 ADD id INT AUTO_INCREMENT PRIMARY KEY;
INSERT INTO t2 SELECT * FROM t1 ORDER BY col1, col2;
```

Important

To guarantee the same ordering on both master and slave, *all* columns of t1 must be referenced in the ORDER BY clause.

Regardless of the method used to create and populate the copy having the AUTO_INCREMENT column, the final step is to drop the original table and then rename the copy:

```
DROP TABLE t1;
ALTER TABLE t2 RENAME t1;
```

13.1.8 ALTER TABLESPACE Syntax

```
ALTER TABLESPACE tablespace_name
    {ADD|DROP} DATAFILE 'file_name'
    [INITIAL_SIZE [=] size]
    [WAIT]
    ENGINE [=] engine_name
```

This statement can be used either to add a new data file, or to drop a data file from a tablespace.

The ADD DATAFILE variant enables you to specify an initial size using an INITIAL_SIZE clause, where *size* is measured in bytes; the default value is 134217728 (128 MB). Prior to MySQL NDB Cluster 7.2.14, this value was required to be specified using digits (Bug #13116514, Bug #16104705, Bug #62858); in MySQL NDB Cluster 7.2.14 and later, you may optionally follow *size* with a one-letter abbreviation for an order of magnitude, similar to those used in my.cnf. Generally, this is one of the letters M (megabytes) or G (gigabytes).

Note

All NDB Cluster Disk Data objects share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and an data file with the same name, or an undo log file and a tablespace with the same name.

On 32-bit systems, the maximum supported value for INITIAL_SIZE is 4294967296 (4 GB). (Bug #29186)

INITIAL_SIZE is rounded, explicitly, as for CREATE TABLESPACE.

Once a data file has been created, its size cannot be changed; however, you can add more data files to the tablespace using additional ALTER TABLESPACE ... ADD DATAFILE statements.

Using DROP DATAFILE with ALTER TABLESPACE drops the data file '*file_name*' from the tablespace. You cannot drop a data file from a tablespace which is in use by any table; in other

words, the data file must be empty (no extents used). See Section 18.5.12.1, “NDB Cluster Disk Data Objects”. In addition, any data file to be dropped must previously have been added to the tablespace with CREATE TABLESPACE or ALTER TABLESPACE.

Both ALTER TABLESPACE ... ADD DATAFILE and ALTER TABLESPACE ... DROP DATAFILE require an ENGINE clause which specifies the storage engine used by the tablespace. Currently, the only accepted values for *engine_name* are NDB and NDBCLUSTER.

WAIT is parsed but otherwise ignored, and so has no effect in MySQL 5.5. It is intended for future expansion.

When ALTER TABLESPACE ... ADD DATAFILE is used with ENGINE = NDB, a data file is created on each Cluster data node. You can verify that the data files were created and obtain information about them by querying the INFORMATION_SCHEMA.FILES table. For example, the following query shows all data files belonging to the tablespace named newts:

```
mysql> SELECT LOGFILE_GROUP_NAME, FILE_NAME, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE TABLESPACE_NAME = 'newts' AND FILE_TYPE = 'DATAFILE';
+--------------------+--------------+----------------+
| LOGFILE_GROUP_NAME | FILE_NAME    | EXTRA          |
+--------------------+--------------+----------------+
| lg_3               | newdata.dat  | CLUSTER_NODE=3 |
| lg_3               | newdata.dat  | CLUSTER_NODE=4 |
| lg_3               | newdata2.dat | CLUSTER_NODE=3 |
| lg_3               | newdata2.dat | CLUSTER_NODE=4 |
+--------------------+--------------+----------------+
2 rows in set (0.03 sec)
```

See Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”.

ALTER TABLESPACE is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, “NDB Cluster Disk Data Tables”.

13.1.9 ALTER VIEW Syntax

```
ALTER
    [ALGORITHM = {UNDEFINED | MERGE | TEMPTABLE}]
    [DEFINER = { user | CURRENT_USER }]
    [SQL SECURITY { DEFINER | INVOKER }]
    VIEW view_name [(column_list)]
    AS select_statement
    [WITH [CASCADED | LOCAL] CHECK OPTION]
```

This statement changes the definition of a view, which must exist. The syntax is similar to that for CREATE VIEW see Section 13.1.20, “CREATE VIEW Syntax”). This statement requires the CREATE VIEW and DROP privileges for the view, and some privilege for each column referred to in the SELECT statement. ALTER VIEW is permitted only to the definer or users with the SUPER privilege.

13.1.10 CREATE DATABASE Syntax

```
CREATE {DATABASE | SCHEMA} [IF NOT EXISTS] db_name
    [create_specification] ...

create_specification:
    [DEFAULT] CHARACTER SET [=] charset_name
  | [DEFAULT] COLLATE [=] collation_name
```

CREATE DATABASE creates a database with the given name. To use this statement, you need the CREATE privilege for the database. CREATE SCHEMA is a synonym for CREATE DATABASE.

An error occurs if the database exists and you did not specify IF NOT EXISTS.

`CREATE DATABASE` is not permitted within a session that has an active `LOCK TABLES` statement.

`create_specification` options specify database characteristics. Database characteristics are stored in the `db.opt` file in the database directory. The `CHARACTER SET` clause specifies the default database character set. The `COLLATE` clause specifies the default database collation. Section 10.1, “Character Set Support”, discusses character set and collation names.

A database in MySQL is implemented as a directory containing files that correspond to tables in the database. Because there are no tables in a database when it is initially created, the `CREATE DATABASE` statement creates only a directory under the MySQL data directory and the `db.opt` file. Rules for permissible database names are given in Section 9.2, “Schema Object Names”. If a database name contains special characters, the name for the database directory contains encoded versions of those characters as described in Section 9.2.3, “Mapping of Identifiers to File Names”.

If you manually create a directory under the data directory (for example, with `mkdir`), the server considers it a database directory and it shows up in the output of `SHOW DATABASES`.

You can also use the `mysqladmin` program to create databases. See Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”.

13.1.11 CREATE EVENT Syntax

```
CREATE
    [DEFINER = { user | CURRENT_USER }]
    EVENT
    [IF NOT EXISTS]
    event_name
    ON SCHEDULE schedule
    [ON COMPLETION [NOT] PRESERVE]
    [ENABLE | DISABLE | DISABLE ON SLAVE]
    [COMMENT 'string']
    DO event_body;

schedule:
    AT timestamp [+ INTERVAL interval] ...
  | EVERY interval
    [STARTS timestamp [+ INTERVAL interval] ...]
    [ENDS timestamp [+ INTERVAL interval] ...]

interval:
    quantity {YEAR | QUARTER | MONTH | DAY | HOUR | MINUTE |
              WEEK | SECOND | YEAR_MONTH | DAY_HOUR | DAY_MINUTE |
              DAY_SECOND | HOUR_MINUTE | HOUR_SECOND | MINUTE_SECOND}
```

This statement creates and schedules a new event. The event will not run unless the Event Scheduler is enabled. For information about checking Event Scheduler status and enabling it if necessary, see Section 20.4.2, “Event Scheduler Configuration”.

`CREATE EVENT` requires the `EVENT` privilege for the schema in which the event is to be created. It might also require the `SUPER` privilege, depending on the `DEFINER` value, as described later in this section.

The minimum requirements for a valid `CREATE EVENT` statement are as follows:

- The keywords `CREATE EVENT` plus an event name, which uniquely identifies the event in a database schema.
- An `ON SCHEDULE` clause, which determines when and how often the event executes.
- A `DO` clause, which contains the SQL statement to be executed by an event.

This is an example of a minimal `CREATE EVENT` statement:

```
CREATE EVENT myevent
```

```
  ON SCHEDULE AT CURRENT_TIMESTAMP + INTERVAL 1 HOUR
  DO
    UPDATE myschema.mytable SET mycol = mycol + 1;
```

The previous statement creates an event named `myevent`. This event executes once—one hour following its creation—by running an SQL statement that increments the value of the `myschema.mytable` table's `mycol` column by 1.

The *`event_name`* must be a valid MySQL identifier with a maximum length of 64 characters. Event names are not case sensitive, so you cannot have two events named `myevent` and `MyEvent` in the same schema. In general, the rules governing event names are the same as those for names of stored routines. See Section 9.2, “Schema Object Names”.

An event is associated with a schema. If no schema is indicated as part of *`event_name`*, the default (current) schema is assumed. To create an event in a specific schema, qualify the event name with a schema using *`schema_name.event_name`* syntax.

The `DEFINER` clause specifies the MySQL account to be used when checking access privileges at event execution time. If a *`user`* value is given, it should be a MySQL account specified as *`'user_name'@'host_name'`*, `CURRENT_USER`, or `CURRENT_USER()`. The default `DEFINER` value is the user who executes the `CREATE EVENT` statement. This is the same as specifying `DEFINER = CURRENT_USER` explicitly.

If you specify the `DEFINER` clause, these rules determine the valid `DEFINER` user values:

- If you do not have the `SUPER` privilege, the only permitted *`user`* value is your own account, either specified literally or by using `CURRENT_USER`. You cannot set the definer to some other account.
- If you have the `SUPER` privilege, you can specify any syntactically valid account name. If the account does not exist, a warning is generated.
- Although it is possible to create an event with a nonexistent `DEFINER` account, an error occurs at event execution time if the account does not exist.

For more information about event security, see Section 20.6, “Access Control for Stored Programs and Views”.

Within an event, the `CURRENT_USER()` function returns the account used to check privileges at event execution time, which is the `DEFINER` user. For information about user auditing within events, see Section 6.3.8, “SQL-Based MySQL Account Activity Auditing”.

`IF NOT EXISTS` has the same meaning for `CREATE EVENT` as for `CREATE TABLE`: If an event named *`event_name`* already exists in the same schema, no action is taken, and no error results. (However, a warning is generated in such cases.)

The `ON SCHEDULE` clause determines when, how often, and for how long the *`event_body`* defined for the event repeats. This clause takes one of two forms:

- `AT` *`timestamp`* is used for a one-time event. It specifies that the event executes one time only at the date and time given by *`timestamp`*, which must include both the date and time, or must be an expression that resolves to a datetime value. You may use a value of either the `DATETIME` or `TIMESTAMP` type for this purpose. If the date is in the past, a warning occurs, as shown here:

```
mysql> SELECT NOW();
+---------------------+
| NOW()               |
+---------------------+
| 2006-02-10 23:59:01 |
+---------------------+
1 row in set (0.04 sec)

mysql> CREATE EVENT e_totals
    ->     ON SCHEDULE AT '2006-02-10 23:59:00'
    ->     DO INSERT INTO test.totals VALUES (NOW());
```

```
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Note
   Code: 1588
Message: Event execution time is in the past and ON COMPLETION NOT
         PRESERVE is set. The event was dropped immediately after
         creation.
```

`CREATE EVENT` statements which are themselves invalid—for whatever reason—fail with an error.

You may use `CURRENT_TIMESTAMP` to specify the current date and time. In such a case, the event acts as soon as it is created.

To create an event which occurs at some point in the future relative to the current date and time—such as that expressed by the phrase “three weeks from now”—you can use the optional clause `+ INTERVAL` *`interval`*. The *`interval`* portion consists of two parts, a quantity and a unit of time, and follows the same syntax rules that govern intervals used in the `DATE_ADD()` function (see Section 12.7, “Date and Time Functions”. The units keywords are also the same, except that you cannot use any units involving microseconds when defining an event. With some interval types, complex time units may be used. For example, “two minutes and ten seconds” can be expressed as `+ INTERVAL '2:10' MINUTE_SECOND`.

You can also combine intervals. For example, `AT CURRENT_TIMESTAMP + INTERVAL 3 WEEK + INTERVAL 2 DAY` is equivalent to “three weeks and two days from now”. Each portion of such a clause must begin with `+ INTERVAL`.

- To repeat actions at a regular interval, use an `EVERY` clause. The `EVERY` keyword is followed by an *`interval`* as described in the previous discussion of the `AT` keyword. (`+ INTERVAL` is *not* used with `EVERY`.) For example, `EVERY 6 WEEK` means “every six weeks”.

  Although `+ INTERVAL` clauses are not permitted in an `EVERY` clause, you can use the same complex time units permitted in a `+ INTERVAL`.

  An `EVERY` clause may contain an optional `STARTS` clause. `STARTS` is followed by a *`timestamp`* value that indicates when the action should begin repeating, and may also use `+ INTERVAL` *`interval`* to specify an amount of time “from now”. For example, `EVERY 3 MONTH STARTS CURRENT_TIMESTAMP + INTERVAL 1 WEEK` means “every three months, beginning one week from now”. Similarly, you can express “every two weeks, beginning six hours and fifteen minutes from now” as `EVERY 2 WEEK STARTS CURRENT_TIMESTAMP + INTERVAL '6:15' HOUR_MINUTE`. Not specifying `STARTS` is the same as using `STARTS CURRENT_TIMESTAMP`—that is, the action specified for the event begins repeating immediately upon creation of the event.

  An `EVERY` clause may contain an optional `ENDS` clause. The `ENDS` keyword is followed by a *`timestamp`* value that tells MySQL when the event should stop repeating. You may also use `+ INTERVAL` *`interval`* with `ENDS`; for instance, `EVERY 12 HOUR STARTS CURRENT_TIMESTAMP + INTERVAL 30 MINUTE ENDS CURRENT_TIMESTAMP + INTERVAL 4 WEEK` is equivalent to “every twelve hours, beginning thirty minutes from now, and ending four weeks from now”. Not using `ENDS` means that the event continues executing indefinitely.

  `ENDS` supports the same syntax for complex time units as `STARTS` does.

  You may use `STARTS`, `ENDS`, both, or neither in an `EVERY` clause.

  If a repeating event does not terminate within its scheduling interval, the result may be multiple instances of the event executing simultaneously. If this is undesirable, you should institute a mechanism to prevent simultaneous instances. For example, you could use the `GET_LOCK()` function, or row or table locking.

The `ON SCHEDULE` clause may use expressions involving built-in MySQL functions and user variables to obtain any of the *`timestamp`* or *`interval`* values which it contains. You may not use stored

functions or user-defined functions in such expressions, nor may you use any table references; however, you may use `SELECT FROM DUAL`. This is true for both `CREATE EVENT` and `ALTER EVENT` statements. References to stored functions, user-defined functions, and tables in such cases are specifically not permitted, and fail with an error (see Bug #22830).

Times in the `ON SCHEDULE` clause are interpreted using the current session `time_zone` value. This becomes the event time zone; that is, the time zone that is used for event scheduling and is in effect within the event as it executes. These times are converted to UTC and stored along with the event time zone in the `mysql.event` table. This enables event execution to proceed as defined regardless of any subsequent changes to the server time zone or daylight saving time effects. For additional information about representation of event times, see Section 20.4.4, “Event Metadata”. See also Section 13.7.5.19, “SHOW EVENTS Syntax”, and Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”.

Normally, once an event has expired, it is immediately dropped. You can override this behavior by specifying `ON COMPLETION PRESERVE`. Using `ON COMPLETION NOT PRESERVE` merely makes the default nonpersistent behavior explicit.

You can create an event but prevent it from being active using the `DISABLE` keyword. Alternatively, you can use `ENABLE` to make explicit the default status, which is active. This is most useful in conjunction with `ALTER EVENT` (see Section 13.1.2, “ALTER EVENT Syntax”).

A third value may also appear in place of `ENABLE` or `DISABLE`; `DISABLE ON SLAVE` is set for the status of an event on a replication slave to indicate that the event was created on the master and replicated to the slave, but is not executed on the slave. See Section 17.4.1.15, “Replication of Invoked Features”.

You may supply a comment for an event using a `COMMENT` clause. *`comment`* may be any string of up to 64 characters that you wish to use for describing the event. The comment text, being a string literal, must be surrounded by quotation marks.

The `DO` clause specifies an action carried by the event, and consists of an SQL statement. Nearly any valid MySQL statement that can be used in a stored routine can also be used as the action statement for a scheduled event. (See Section C.1, “Restrictions on Stored Programs”.) For example, the following event `e_hourly` deletes all rows from the `sessions` table once per hour, where this table is part of the `site_activity` schema:

```
CREATE EVENT e_hourly
    ON SCHEDULE
      EVERY 1 HOUR
    COMMENT 'Clears out sessions table each hour.'
    DO
      DELETE FROM site_activity.sessions;
```

MySQL stores the `sql_mode` system variable setting in effect when an event is created or altered, and always executes the event with this setting in force, *regardless of the current server SQL mode when the event begins executing*.

A `CREATE EVENT` statement that contains an `ALTER EVENT` statement in its `DO` clause appears to succeed; however, when the server attempts to execute the resulting scheduled event, the execution fails with an error.

Note

Statements such as `SELECT` or `SHOW` that merely return a result set have no effect when used in an event; the output from these is not sent to the MySQL Monitor, nor is it stored anywhere. However, you can use statements such as `SELECT ... INTO` and `INSERT INTO ... SELECT` that store a result. (See the next example in this section for an instance of the latter.)

The schema to which an event belongs is the default schema for table references in the `DO` clause. Any references to tables in other schemas must be qualified with the proper schema name.

As with stored routines, you can use compound-statement syntax in the `DO` clause by using the `BEGIN` and `END` keywords, as shown here:

```
delimiter |

CREATE EVENT e_daily
    ON SCHEDULE
      EVERY 1 DAY
    COMMENT 'Saves total number of sessions then clears the table each day'
    DO
      BEGIN
        INSERT INTO site_activity.totals (time, total)
          SELECT CURRENT_TIMESTAMP, COUNT(*)
            FROM site_activity.sessions;
        DELETE FROM site_activity.sessions;
      END |

delimiter ;
```

This example uses the `delimiter` command to change the statement delimiter. See Section 20.1, “Defining Stored Programs”.

More complex compound statements, such as those used in stored routines, are possible in an event. This example uses local variables, an error handler, and a flow control construct:

```
delimiter |

CREATE EVENT e
    ON SCHEDULE
      EVERY 5 SECOND
    DO
      BEGIN
        DECLARE v INTEGER;
        DECLARE CONTINUE HANDLER FOR SQLEXCEPTION BEGIN END;

        SET v = 0;

        WHILE v < 5 DO
          INSERT INTO t1 VALUES (0);
          UPDATE t2 SET s1 = s1 + 1;
          SET v = v + 1;
        END WHILE;
    END |

delimiter ;
```

There is no way to pass parameters directly to or from events; however, it is possible to invoke a stored routine with parameters within an event:

```
CREATE EVENT e_call_myproc
    ON SCHEDULE
      AT CURRENT_TIMESTAMP + INTERVAL 1 DAY
    DO CALL myproc(5, 27);
```

If an event's definer has the `SUPER` privilege, the event can read and write global variables. As granting this privilege entails a potential for abuse, extreme care must be taken in doing so.

Generally, any statements that are valid in stored routines may be used for action statements executed by events. For more information about statements permitted within stored routines, see Section 20.2.1, “Stored Routine Syntax”. You can create an event as part of a stored routine, but an event cannot be created by another event.

13.1.12 CREATE FUNCTION Syntax

The `CREATE FUNCTION` statement is used to create stored functions and user-defined functions (UDFs):

- For information about creating stored functions, see Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”.
- For information about creating user-defined functions, see Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”.

13.1.13 CREATE INDEX Syntax

```
CREATE [ONLINE|OFFLINE] [UNIQUE|FULLTEXT|SPATIAL] INDEX index_name
    [index_type]
    ON tbl_name (index_col_name,...)
    [index_option] ...

index_col_name:
    col_name [(length)] [ASC | DESC]

index_option:
    KEY_BLOCK_SIZE [=] value
  | index_type
  | WITH PARSER parser_name
  | COMMENT 'string'

index_type:
    USING {BTREE | HASH}
```

`CREATE INDEX` is mapped to an `ALTER TABLE` statement to create indexes. See Section 13.1.7, “ALTER TABLE Syntax”. `CREATE INDEX` cannot be used to create a `PRIMARY KEY`; use `ALTER TABLE` instead. For more information about indexes, see Section 8.3.1, “How MySQL Uses Indexes”.

Normally, you create all indexes on a table at the time the table itself is created with `CREATE TABLE`. See Section 13.1.17, “CREATE TABLE Syntax”. This guideline is especially important for `InnoDB` tables, where the primary key determines the physical layout of rows in the data file. `CREATE INDEX` enables you to add indexes to existing tables.

A column list of the form `(col1, col2, ...)` creates a multiple-column index. Index key values are formed by concatenating the values of the given columns.

For string columns, indexes can be created that use only the leading part of column values, using *`col_name(length)`* syntax to specify an index prefix length:

- Prefixes can be specified for `CHAR`, `VARCHAR`, `BINARY`, and `VARBINARY` column indexes.
- Prefixes *must* be specified for `BLOB` and `TEXT` column indexes.
- Prefix limits are measured in bytes, whereas the prefix length in `CREATE TABLE`, `ALTER TABLE`, and `CREATE INDEX` statements is interpreted as number of characters for nonbinary string types (`CHAR`, `VARCHAR`, `TEXT`) and number of bytes for binary string types (`BINARY`, `VARBINARY`, `BLOB`). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.
- For spatial columns, prefix values cannot be given, as described later in this section.

The statement shown here creates an index using the first 10 characters of the `name` column (assuming that `name` has a nonbinary string type):

```
CREATE INDEX part_of_name ON customer (name(10));
```

If names in the column usually differ in the first 10 characters, this index should not be much slower than an index created from the entire `name` column. Also, using column prefixes for indexes can make the index file much smaller, which could save a lot of disk space and might also speed up `INSERT` operations.

Prefix support and lengths of prefixes (where supported) are storage engine dependent. For example, a prefix can be up to 767 bytes long for `InnoDB` tables or 3072 bytes if the `innodb_large_prefix`

option is enabled. For MyISAM tables, the prefix limit is 1000 bytes. The NDB storage engine does not support prefixes (see Section 18.1.6.6, “Unsupported or Missing Features in NDB Cluster”).

Indexes on variable-width columns of NDBCLUSTER tables are created online; that is, without any table copying. The table is not locked against access from other NDB Cluster API nodes, although it is locked against other operations on the *same* API node for the duration of the operation. This is done automatically by the server whenever it determines that it is possible to do so; you do not have to use any special SQL syntax or server options to cause it to happen.

In standard MySQL 5.5 releases, it is not possible to override the server when it determines that an index is to be created without table copying. In NDB Cluster, you can create indexes offline (which causes the table to be locked to all API nodes in the cluster) using the OFFLINE keyword. The rules and limitations governing CREATE OFFLINE INDEX and CREATE ONLINE INDEX are the same as for ALTER OFFLINE TABLE ... ADD INDEX and ALTER ONLINE TABLE ... ADD INDEX. You cannot cause the noncopying creation of an index that would normally be created offline by using the ONLINE keyword: If it is not possible to perform the CREATE INDEX operation without table copying, the server ignores the ONLINE keyword. For more information, see Section 13.1.7.2, “ALTER TABLE Online Operations in NDB Cluster 7.2”.

The ONLINE and OFFLINE keywords are available only in NDB Cluster; attempting to use these keywords in standard MySQL Server 5.5 releases results in a syntax error.

A UNIQUE index creates a constraint such that all values in the index must be distinct. An error occurs if you try to add a new row with a key value that matches an existing row. For all engines, a UNIQUE index permits multiple NULL values for columns that can contain NULL. If you specify a prefix value for a column in a UNIQUE index, the column values must be unique within the prefix.

If a UNIQUE index consists of only one column that has an integer type, you can also refer to the column as _rowid in SELECT statements.

FULLTEXT indexes are supported only for MyISAM tables and can include only CHAR, VARCHAR, and TEXT columns. Indexing always happens over the entire column; column prefix indexing is not supported and any prefix length is ignored if specified. See Section 12.9, “Full-Text Search Functions”, for details of operation.

The MyISAM, InnoDB, NDB, and ARCHIVE storage engines support spatial columns such as (POINT and GEOMETRY. (Section 11.5, “Spatial Data Types”, describes the spatial data types.) However, support for spatial column indexing varies among engines. Spatial and nonspatial indexes are available according to the following rules.

Spatial indexes (created using SPATIAL INDEX) have these characteristics:

- Available only for MyISAM tables. Specifying SPATIAL INDEX for other storage engines results in an error.
- Indexed columns must be NOT NULL.
- Column prefix lengths are prohibited. The full width of each column is indexed.

Characteristics of nonspatial indexes (created with INDEX, UNIQUE, or PRIMARY KEY):

- Permitted for any storage engine that supports spatial columns except ARCHIVE.
- Columns can be NULL unless the index is a primary key.
- For each spatial column in a non-SPATIAL index except POINT columns, a column prefix length must be specified. (This is the same requirement as for indexed BLOB columns.) The prefix length is given in bytes.
- The index type for a non-SPATIAL index depends on the storage engine. Currently, B-tree is used.
- You can add an index on a column that can have NULL values only for MyISAM, InnoDB, and MEMORY tables

- You can add an index on a BLOB or TEXT column only for MyISAM and InnoDB tables

An *index_col_name* specification can end with ASC or DESC. These keywords are permitted for future extensions for specifying ascending or descending index value storage. Currently, they are parsed but ignored; index values are always stored in ascending order.

Following the index column list, index options can be given. An *index_option* value can be any of the following:

- KEY_BLOCK_SIZE [=] *value*

  For MyISAM tables, KEY_BLOCK_SIZE optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A KEY_BLOCK_SIZE value specified for an individual index definition overrides a table-level KEY_BLOCK_SIZE value.

  KEY_BLOCK_SIZE is not supported at the index level for InnoDB tables. See Section 13.1.17, "CREATE TABLE Syntax".

- *index_type*

  Some storage engines permit you to specify an index type when creating an index. For example:

```
CREATE TABLE lookup (id INT) ENGINE = MEMORY;
CREATE INDEX id_index ON lookup (id) USING BTREE;
```

  Table 13.1, "Index Types Per Storage Engine" shows the permissible index type values supported by different storage engines. Where multiple index types are listed, the first one is the default when no index type specifier is given. Storage engines not listed in the table do not support an *index_type* clause in index definitions.

Table 13.1 Index Types Per Storage Engine

Storage Engine	Permissible Index Types
MyISAM	BTREE
InnoDB	BTREE
MEMORY/HEAP	HASH, BTREE
NDB	BTREE, HASH (see note in text)

  The *index_type* clause cannot be used for FULLTEXT INDEX or SPATIAL INDEX specifications. Full-text index implementation is storage engine dependent. Spatial indexes are implemented as R-tree indexes.

  BTREE indexes are implemented by the NDB storage engine as T-tree indexes.

Note

For indexes on NDB table columns, the USING option can be specified only for a unique index or primary key. USING HASH prevents the creation of an ordered index; otherwise, creating a unique index or primary key on an NDB table automatically results in the creation of both an ordered index and a hash index, each of which indexes the same set of columns.

For unique indexes that include one or more NULL columns of an NDB table, the hash index can be used only to look up literal values, which means that IS [NOT] NULL conditions require a full scan of the table. One workaround is to make sure that a unique index using one or more NULL columns on such a table is always created in such a way that it includes the ordered index; that is, avoid employing USING HASH when creating the index.

If you specify an index type that is not valid for a given storage engine, but another index type is available that the engine can use without affecting query results, the engine uses the available type. The parser recognizes `RTREE` as a type name, but currently this cannot be specified for any storage engine.

Note

Use of the *`index_type`* option before the `ON` *`tbl_name`* clause is deprecated; support for use of the option in this position will be removed in a future MySQL release. If an *`index_type`* option is given in both the earlier and later positions, the final option applies.

`TYPE` *`type_name`* is recognized as a synonym for `USING` *`type_name`*. However, `USING` is the preferred form.

For the storage engines that support an *`index_type`* option, Table 13.2, “Storage Engine Index Characteristics” shows some characteristics of index use.

Table 13.2 Storage Engine Index Characteristics

Storage Engine	Index Type	Index Class	Stores NULL Values	Permits Multiple NULL Values	IS NULL Scan Type	IS NOT NULL Scan Type
`InnoDB`	`BTREE`	Primary key	No	No	N/A	N/A
		Unique	Yes	Yes	Index	Index
		Key	Yes	Yes	Index	Index
`MyISAM`	`BTREE`	Primary key	No	No	N/A	N/A
		Unique	Yes	Yes	Index	Index
		Key	Yes	Yes	Index	Index
	Inapplicable	`FULLTEXT`	Yes	Yes	Table	Table
	Inapplicable	`SPATIAL`	No	No	N/A	N/A
`MEMORY`	`HASH`	Primary key	No	No	N/A	N/A
		Unique	Yes	Yes	Index	Index
		Key	Yes	Yes	Index	Index
	`BTREE`	Primary	No	No	N/A	N/A
		Unique	Yes	Yes	Index	Index
		Key	Yes	Yes	Index	Index
`NDB`	`BTREE`	Primary key	No	No	Index	Index
		Unique	Yes	Yes	Index	Index
		Key	Yes	Yes	Index	Index
	`HASH`	Primary	No	No	Table (see note 1)	Table (see note 1)
		Unique	Yes	Yes	Table (see note 1)	Table (see note 1)
		Key	Yes	Yes	Table (see note 1)	Table (see note 1)

Table note:

1. If `USING HASH` is specified that prevents creation of an implicit ordered index.

- `WITH PARSER parser_name`

  This option can be used only with `FULLTEXT` indexes. It associates a parser plugin with the index if full-text indexing and searching operations need special handling. See Section 24.2, “The MySQL Plugin API”, for details on creating plugins.

- `COMMENT 'string'`

  Index definitions can include an optional comment of up to 1024 characters.

13.1.14 CREATE LOGFILE GROUP Syntax

```
CREATE LOGFILE GROUP logfile_group
    ADD UNDOFILE 'undo_file'
    [INITIAL_SIZE [=] initial_size]
    [UNDO_BUFFER_SIZE [=] undo_buffer_size]
    [REDO_BUFFER_SIZE [=] redo_buffer_size]
    [NODEGROUP [=] nodegroup_id]
    [WAIT]
    [COMMENT [=] 'string']
    ENGINE [=] engine_name
```

This statement creates a new log file group named *`logfile_group`* having a single `UNDO` file named '*`undo_file`*'. A `CREATE LOGFILE GROUP` statement has one and only one `ADD UNDOFILE` clause. For rules covering the naming of log file groups, see Section 9.2, “Schema Object Names”.

Note

All NDB Cluster Disk Data objects share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a log file group with the same name, or a tablespace and a data file with the same name.

In MySQL NDB Cluster 7.2, you can have only one log file group per Cluster at any given time. (See Bug #16386)

The optional `INITIAL_SIZE` parameter sets the `UNDO` file's initial size; if not specified, it defaults to `128M` (128 megabytes). The optional `UNDO_BUFFER_SIZE` parameter sets the size used by the `UNDO` buffer for the log file group; The default value for `UNDO_BUFFER_SIZE` is `8M` (eight megabytes); this value cannot exceed the amount of system memory available. Both of these parameters are specified in bytes. In MySQL NDB Cluster 7.2.14 and later, you may optionally follow either or both of these with a one-letter abbreviation for an order of magnitude, similar to those used in `my.cnf`. Generally, this is one of the letters `M` (for megabytes) or `G` (for gigabytes). Prior to MySQL NDB Cluster 7.2.14, the values for these options could only be specified using digits. (Bug #13116514, Bug #16104705, Bug #62858)

Memory used for `UNDO_BUFFER_SIZE` comes from the global pool whose size is determined by the value of the `SharedGlobalMemory` data node configuration parameter. This includes any default value implied for this option by the setting of the `InitialLogFileGroup` data node configuration parameter.

The maximum permitted for `UNDO_BUFFER_SIZE` is 629145600 (600 MB).

On 32-bit systems, the maximum supported value for `INITIAL_SIZE` is 4294967296 (4 GB). (Bug #29186)

The minimum allowed value for `INITIAL_SIZE` is 1048576 (1 MB).

The `ENGINE` option determines the storage engine to be used by this log file group, with *`engine_name`* being the name of the storage engine. In MySQL 5.5, this must be `NDB` (or `NDBCLUSTER`). If `ENGINE` is not set, MySQL tries to use the engine specified by the `default_storage_engine` server system variable (formerly `storage_engine`). In any case, if the engine is not specified as `NDB` or `NDBCLUSTER`, the `CREATE LOGFILE GROUP` statement appears to succeed but actually fails to create the log file group, as shown here:

```
mysql> CREATE LOGFILE GROUP lg1
    ->     ADD UNDOFILE 'undo.dat' INITIAL_SIZE = 10M;
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+-------+------+--------------------------------------------------------------------------------------------
| Level | Code | Message
+-------+------+--------------------------------------------------------------------------------------------
| Error | 1478 | Table storage engine 'InnoDB' does not support the create option 'TABLESPACE or LOGFILE GR
+-------+------+--------------------------------------------------------------------------------------------
1 row in set (0.00 sec)

mysql> DROP LOGFILE GROUP lg1 ENGINE = NDB;
ERROR 1529 (HY000): Failed to drop LOGFILE GROUP

mysql> CREATE LOGFILE GROUP lg1
    ->     ADD UNDOFILE 'undo.dat' INITIAL_SIZE = 10M
    ->     ENGINE = NDB;
Query OK, 0 rows affected (2.97 sec)
```

The fact that the `CREATE LOGFILE GROUP` statement does not actually return an error when a non-`NDB` storage engine is named, but rather appears to succeed, is a known issue which we hope to address in a future release of NDB Cluster.

`REDO_BUFFER_SIZE`, `NODEGROUP`, `WAIT`, and `COMMENT` are parsed but ignored, and so have no effect in MySQL 5.5. These options are intended for future expansion.

When used with `ENGINE [=] NDB`, a log file group and associated `UNDO` log file are created on each Cluster data node. You can verify that the `UNDO` files were created and obtain information about them by querying the `INFORMATION_SCHEMA.FILES` table. For example:

```
mysql> SELECT LOGFILE_GROUP_NAME, LOGFILE_GROUP_NUMBER, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE FILE_NAME = 'undo_10.dat';
+--------------------+----------------------+----------------+
| LOGFILE_GROUP_NAME | LOGFILE_GROUP_NUMBER | EXTRA          |
+--------------------+----------------------+----------------+
| lg_3               |                   11 | CLUSTER_NODE=3 |
| lg_3               |                   11 | CLUSTER_NODE=4 |
+--------------------+----------------------+----------------+
2 rows in set (0.06 sec)
```

`CREATE LOGFILE GROUP` is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, “NDB Cluster Disk Data Tables”.

13.1.15 CREATE PROCEDURE and CREATE FUNCTION Syntax

```
CREATE
    [DEFINER = { user | CURRENT_USER }]
    PROCEDURE sp_name ([proc_parameter[,...]])
    [characteristic ...] routine_body

CREATE
    [DEFINER = { user | CURRENT_USER }]
    FUNCTION sp_name ([func_parameter[,...]])
    RETURNS type
    [characteristic ...] routine_body
```

```
proc_parameter:
    [ IN | OUT | INOUT ] param_name type

func_parameter:
    param_name type

type:
    Any valid MySQL data type

characteristic:
    COMMENT 'string'
  | LANGUAGE SQL
  | [NOT] DETERMINISTIC
  | { CONTAINS SQL | NO SQL | READS SQL DATA | MODIFIES SQL DATA }
  | SQL SECURITY { DEFINER | INVOKER }

routine_body:
    Valid SQL routine statement
```

These statements create stored routines. By default, a routine is associated with the default database. To associate the routine explicitly with a given database, specify the name as *`db_name.sp_name`* when you create it.

The `CREATE FUNCTION` statement is also used in MySQL to support UDFs (user-defined functions). See Section 24.4, “Adding New Functions to MySQL”. A UDF can be regarded as an external stored function. Stored functions share their namespace with UDFs. See Section 9.2.4, “Function Name Parsing and Resolution”, for the rules describing how the server interprets references to different kinds of functions.

To invoke a stored procedure, use the `CALL` statement (see Section 13.2.1, “CALL Syntax”). To invoke a stored function, refer to it in an expression. The function returns a value during expression evaluation.

`CREATE PROCEDURE` and `CREATE FUNCTION` require the `CREATE ROUTINE` privilege. They might also require the `SUPER` privilege, depending on the `DEFINER` value, as described later in this section. If binary logging is enabled, `CREATE FUNCTION` might require the `SUPER` privilege, as described in Section 20.7, “Binary Logging of Stored Programs”.

By default, MySQL automatically grants the `ALTER ROUTINE` and `EXECUTE` privileges to the routine creator. This behavior can be changed by disabling the `automatic_sp_privileges` system variable. See Section 20.2.2, “Stored Routines and MySQL Privileges”.

The `DEFINER` and `SQL SECURITY` clauses specify the security context to be used when checking access privileges at routine execution time, as described later in this section.

If the routine name is the same as the name of a built-in SQL function, a syntax error occurs unless you use a space between the name and the following parenthesis when defining the routine or invoking it later. For this reason, avoid using the names of existing SQL functions for your own stored routines.

The `IGNORE_SPACE` SQL mode applies to built-in functions, not to stored routines. It is always permissible to have spaces after a stored routine name, regardless of whether `IGNORE_SPACE` is enabled.

The parameter list enclosed within parentheses must always be present. If there are no parameters, an empty parameter list of `()` should be used. Parameter names are not case sensitive.

Each parameter is an `IN` parameter by default. To specify otherwise for a parameter, use the keyword `OUT` or `INOUT` before the parameter name.

Note

Specifying a parameter as `IN`, `OUT`, or `INOUT` is valid only for a `PROCEDURE`. For a `FUNCTION`, parameters are always regarded as `IN` parameters.

An `IN` parameter passes a value into a procedure. The procedure might modify the value, but the modification is not visible to the caller when the procedure returns. An `OUT` parameter passes a value from the procedure back to the caller. Its initial value is `NULL` within the procedure, and its value is visible to the caller when the procedure returns. An `INOUT` parameter is initialized by the caller, can be modified by the procedure, and any change made by the procedure is visible to the caller when the procedure returns.

For each `OUT` or `INOUT` parameter, pass a user-defined variable in the `CALL` statement that invokes the procedure so that you can obtain its value when the procedure returns. If you are calling the procedure from within another stored procedure or function, you can also pass a routine parameter or local routine variable as an `IN` or `INOUT` parameter.

Routine parameters cannot be referenced in statements prepared within the routine; see Section C.1, “Restrictions on Stored Programs”.

The following example shows a simple stored procedure that uses an `OUT` parameter:

```
mysql> delimiter //

mysql> CREATE PROCEDURE simpleproc (OUT param1 INT)
    -> BEGIN
    ->   SELECT COUNT(*) INTO param1 FROM t;
    -> END//
Query OK, 0 rows affected (0.00 sec)

mysql> delimiter ;

mysql> CALL simpleproc(@a);
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @a;
+------+
| @a   |
+------+
| 3    |
+------+
1 row in set (0.00 sec)
```

The example uses the `mysql` client `delimiter` command to change the statement delimiter from `;` to `//` while the procedure is being defined. This enables the `;` delimiter used in the procedure body to be passed through to the server rather than being interpreted by `mysql` itself. See Section 20.1, “Defining Stored Programs”.

The `RETURNS` clause may be specified only for a `FUNCTION`, for which it is mandatory. It indicates the return type of the function, and the function body must contain a `RETURN` *`value`* statement. If the `RETURN` statement returns a value of a different type, the value is coerced to the proper type. For example, if a function specifies an `ENUM` or `SET` value in the `RETURNS` clause, but the `RETURN` statement returns an integer, the value returned from the function is the string for the corresponding `ENUM` member of set of `SET` members.

The following example function takes a parameter, performs an operation using an SQL function, and returns the result. In this case, it is unnecessary to use `delimiter` because the function definition contains no internal `;` statement delimiters:

```
mysql> CREATE FUNCTION hello (s CHAR(20))
mysql> RETURNS CHAR(50) DETERMINISTIC
    -> RETURN CONCAT('Hello, ',s,'!');
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT hello('world');
+----------------+
| hello('world') |
+----------------+
```

```
| Hello, world!  |
+----------------+
1 row in set (0.00 sec)
```

Parameter types and function return types can be declared to use any valid data type, except that the `COLLATE` attribute cannot be used prior to MySQL 5.5.3. As of 5.5.3, `COLLATE` can be used if preceded by the `CHARACTER SET` attribute.

The *`routine_body`* consists of a valid SQL routine statement. This can be a simple statement such as `SELECT` or `INSERT`, or a compound statement written using `BEGIN` and `END`. Compound statements can contain declarations, loops, and other control structure statements. The syntax for these statements is described in Section 13.6, “Compound-Statement Syntax”.

MySQL permits routines to contain DDL statements, such as `CREATE` and `DROP`. MySQL also permits stored procedures (but not stored functions) to contain SQL transaction statements such as `COMMIT`. Stored functions may not contain statements that perform explicit or implicit commit or rollback. Support for these statements is not required by the SQL standard, which states that each DBMS vendor may decide whether to permit them.

Statements that return a result set can be used within a stored procedure but not within a stored function. This prohibition includes `SELECT` statements that do not have an `INTO` *`var_list`* clause and other statements such as `SHOW`, `EXPLAIN`, and `CHECK TABLE`. For statements that can be determined at function definition time to return a result set, a `Not allowed to return a result set from a function` error occurs (`ER_SP_NO_RETSET`). For statements that can be determined only at runtime to return a result set, a `PROCEDURE %s can't return a result set in the given context` error occurs (`ER_SP_BADSELECT`).

`USE` statements within stored routines are not permitted. When a routine is invoked, an implicit `USE` *`db_name`* is performed (and undone when the routine terminates). The causes the routine to have the given default database while it executes. References to objects in databases other than the routine default database should be qualified with the appropriate database name.

For additional information about statements that are not permitted in stored routines, see Section C.1, “Restrictions on Stored Programs”.

For information about invoking stored procedures from within programs written in a language that has a MySQL interface, see Section 13.2.1, “CALL Syntax”.

MySQL stores the `sql_mode` system variable setting in effect when a routine is created or altered, and always executes the routine with this setting in force, *regardless of the current server SQL mode when the routine begins executing*.

The switch from the SQL mode of the invoker to that of the routine occurs after evaluation of arguments and assignment of the resulting values to routine parameters. If you define a routine in strict SQL mode but invoke it in nonstrict mode, assignment of arguments to routine parameters does not take place in strict mode. If you require that expressions passed to a routine be assigned in strict SQL mode, you should invoke the routine with strict mode in effect.

The `COMMENT` characteristic is a MySQL extension, and may be used to describe the stored routine. This information is displayed by the `SHOW CREATE PROCEDURE` and `SHOW CREATE FUNCTION` statements.

The `LANGUAGE` characteristic indicates the language in which the routine is written. The server ignores this characteristic; only SQL routines are supported.

A routine is considered “deterministic” if it always produces the same result for the same input parameters, and “not deterministic” otherwise. If neither `DETERMINISTIC` nor `NOT DETERMINISTIC` is given in the routine definition, the default is `NOT DETERMINISTIC`. To declare that a function is deterministic, you must specify `DETERMINISTIC` explicitly.

Assessment of the nature of a routine is based on the “honesty” of the creator: MySQL does not check that a routine declared `DETERMINISTIC` is free of statements that produce nondeterministic results. However, misdeclaring a routine might affect results or affect performance. Declaring a nondeterministic routine as `DETERMINISTIC` might lead to unexpected results by causing the optimizer to make incorrect execution plan choices. Declaring a deterministic routine as `NONDETERMINISTIC` might diminish performance by causing available optimizations not to be used.

If binary logging is enabled, the `DETERMINISTIC` characteristic affects which routine definitions MySQL accepts. See Section 20.7, “Binary Logging of Stored Programs”.

A routine that contains the `NOW()` function (or its synonyms) or `RAND()` is nondeterministic, but it might still be replication-safe. For `NOW()`, the binary log includes the timestamp and replicates correctly. `RAND()` also replicates correctly as long as it is called only a single time during the execution of a routine. (You can consider the routine execution timestamp and random number seed as implicit inputs that are identical on the master and slave.)

Several characteristics provide information about the nature of data use by the routine. In MySQL, these characteristics are advisory only. The server does not use them to constrain what kinds of statements a routine will be permitted to execute.

- `CONTAINS SQL` indicates that the routine does not contain statements that read or write data. This is the default if none of these characteristics is given explicitly. Examples of such statements are `SET @x = 1` or `DO RELEASE_LOCK('abc')`, which execute but neither read nor write data.
- `NO SQL` indicates that the routine contains no SQL statements.
- `READS SQL DATA` indicates that the routine contains statements that read data (for example, `SELECT`), but not statements that write data.
- `MODIFIES SQL DATA` indicates that the routine contains statements that may write data (for example, `INSERT` or `DELETE`).

The `SQL SECURITY` characteristic can be `DEFINER` or `INVOKER` to specify the security context; that is, whether the routine executes using the privileges of the account named in the routine `DEFINER` clause or the user who invokes it. This account must have permission to access the database with which the routine is associated. The default value is `DEFINER`. The user who invokes the routine must have the `EXECUTE` privilege for it, as must the `DEFINER` account if the routine executes in definer security context.

The `DEFINER` clause specifies the MySQL account to be used when checking access privileges at routine execution time for routines that have the `SQL SECURITY DEFINER` characteristic.

If a *`user`* value is given for the `DEFINER` clause, it should be a MySQL account specified as *`'user_name'@'host_name'`*, `CURRENT_USER`, or `CURRENT_USER()`. The default `DEFINER` value is the user who executes the `CREATE PROCEDURE` or `CREATE FUNCTION` statement. This is the same as specifying `DEFINER = CURRENT_USER` explicitly.

If you specify the `DEFINER` clause, these rules determine the valid `DEFINER` user values:

- If you do not have the `SUPER` privilege, the only permitted *`user`* value is your own account, either specified literally or by using `CURRENT_USER`. You cannot set the definer to some other account.
- If you have the `SUPER` privilege, you can specify any syntactically valid account name. If the account does not exist, a warning is generated.
- Although it is possible to create a routine with a nonexistent `DEFINER` account, an error occurs at routine execution time if the `SQL SECURITY` value is `DEFINER` but the definer account does not exist.

For more information about stored routine security, see Section 20.6, “Access Control for Stored Programs and Views”.

Within a stored routine that is defined with the `SQL SECURITY DEFINER` characteristic, `CURRENT_USER` returns the routine's `DEFINER` value. For information about user auditing within stored routines, see Section 6.3.8, “SQL-Based MySQL Account Activity Auditing”.

Consider the following procedure, which displays a count of the number of MySQL accounts listed in the `mysql.user` table:

```
CREATE DEFINER = 'admin'@'localhost' PROCEDURE account_count()
BEGIN
  SELECT 'Number of accounts:', COUNT(*) FROM mysql.user;
END;
```

The procedure is assigned a `DEFINER` account of `'admin'@'localhost'` no matter which user defines it. It executes with the privileges of that account no matter which user invokes it (because the default security characteristic is `DEFINER`). The procedure succeeds or fails depending on whether invoker has the `EXECUTE` privilege for it and `'admin'@'localhost'` has the `SELECT` privilege for the `mysql.user` table.

Now suppose that the procedure is defined with the `SQL SECURITY INVOKER` characteristic:

```
CREATE DEFINER = 'admin'@'localhost' PROCEDURE account_count()
SQL SECURITY INVOKER
BEGIN
  SELECT 'Number of accounts:', COUNT(*) FROM mysql.user;
END;
```

The procedure still has a `DEFINER` of `'admin'@'localhost'`, but in this case, it executes with the privileges of the invoking user. Thus, the procedure succeeds or fails depending on whether the invoker has the `EXECUTE` privilege for it and the `SELECT` privilege for the `mysql.user` table.

The server handles the data type of a routine parameter, local routine variable created with `DECLARE`, or function return value as follows:

- Assignments are checked for data type mismatches and overflow. Conversion and overflow problems result in warnings, or errors in strict SQL mode.
- Only scalar values can be assigned. For example, a statement such as `SET x = (SELECT 1, 2)` is invalid.
- For character data types, if there is a `CHARACTER SET` attribute in the declaration, the specified character set and its default collation is used. If the `COLLATE` attribute is also present, that collation is used rather than the default collation.

  Prior to MySQL 5.5.3, if there is a `CHARACTER SET` attribute in the declaration, the `COLLATE` attribute is not supported, and the character set's default collation is used. (This includes use of `BINARY`, which in this context specifies the binary collation of the character set.) If there is no `CHARACTER SET` attribute, the database character set and its default collation (rather than the database collation) are used.

  If `CHARACTER SET` and `COLLATE` attributes are not present, the database character set and collation in effect at routine creation time are used. To avoid having the server use the database character set and collation, provide explicit `CHARACTER SET` and `COLLATE` attributes for character data parameters.

  If you change the database default character set or collation, stored routines that use the database defaults must be dropped and recreated so that they use the new defaults.

  The database character set and collation are given by the value of the `character_set_database` and `collation_database` system variables. For more information, see Section 10.1.3.3, “Database Character Set and Collation”.

13.1.16 CREATE SERVER Syntax

```
CREATE SERVER server_name
    FOREIGN DATA WRAPPER wrapper_name
    OPTIONS (option [, option] ...)

option:
  { HOST character-literal
  | DATABASE character-literal
  | USER character-literal
  | PASSWORD character-literal
  | SOCKET character-literal
  | OWNER character-literal
  | PORT numeric-literal }
```

This statement creates the definition of a server for use with the `FEDERATED` storage engine. The `CREATE SERVER` statement creates a new row in the `servers` table in the `mysql` database. This statement requires the `SUPER` privilege.

The *`server_name`* should be a unique reference to the server. Server definitions are global within the scope of the server, it is not possible to qualify the server definition to a specific database. *`server_name`* has a maximum length of 64 characters (names longer than 64 characters are silently truncated), and is case insensitive. You may specify the name as a quoted string.

The *`wrapper_name`* should be `mysql`, and may be quoted with single quotation marks. Other values for *`wrapper_name`* are not currently supported.

For each *`option`* you must specify either a character literal or numeric literal. Character literals are UTF-8, support a maximum length of 64 characters and default to a blank (empty) string. String literals are silently truncated to 64 characters. Numeric literals must be a number between 0 and 9999, default value is 0.

Note

The `OWNER` option is currently not applied, and has no effect on the ownership or operation of the server connection that is created.

The `CREATE SERVER` statement creates an entry in the `mysql.servers` table that can later be used with the `CREATE TABLE` statement when creating a `FEDERATED` table. The options that you specify will be used to populate the columns in the `mysql.servers` table. The table columns are `Server_name`, `Host`, `Db`, `Username`, `Password`, `Port` and `Socket`.

For example:

```
CREATE SERVER s
FOREIGN DATA WRAPPER mysql
OPTIONS (USER 'Remote', HOST '198.51.100.106', DATABASE 'test');
```

Be sure to specify all options necessary to establish a connection to the server. The user name, host name, and database name are mandatory. Other options might be required as well, such as password.

The data stored in the table can be used when creating a connection to a `FEDERATED` table:

```
CREATE TABLE t (s1 INT) ENGINE=FEDERATED CONNECTION='s';
```

For more information, see Section 15.9, “The FEDERATED Storage Engine”.

`CREATE SERVER` causes an implicit commit. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

`CREATE SERVER` is not written to the binary log, regardless of the logging format that is in use.

13.1.17 CREATE TABLE Syntax

```
CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
    (create_definition,...)
    [table_options]
    [partition_options]

CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
    [(create_definition,...)]
    [table_options]
    [partition_options]
    [IGNORE | REPLACE]
    [AS] query_expression

CREATE [TEMPORARY] TABLE [IF NOT EXISTS] tbl_name
    { LIKE old_tbl_name | (LIKE old_tbl_name) }

create_definition:
    col_name column_definition
  | [CONSTRAINT [symbol]] PRIMARY KEY [index_type] (index_col_name,...)
      [index_option] ...
  | {INDEX|KEY} [index_name] [index_type] (index_col_name,...)
      [index_option] ...
  | [CONSTRAINT [symbol]] UNIQUE [INDEX|KEY]
      [index_name] [index_type] (index_col_name,...)
      [index_option] ...
  | {FULLTEXT|SPATIAL} [INDEX|KEY] [index_name] (index_col_name,...)
      [index_option] ...
  | [CONSTRAINT [symbol]] FOREIGN KEY
      [index_name] (index_col_name,...) reference_definition
  | CHECK (expr)

column_definition:
    data_type [NOT NULL | NULL] [DEFAULT default_value]
      [AUTO_INCREMENT] [UNIQUE [KEY]] [[PRIMARY] KEY]
      [COMMENT 'string']
      [COLUMN_FORMAT {FIXED|DYNAMIC|DEFAULT}]
      [STORAGE {DISK|MEMORY|DEFAULT}]
      [reference_definition]

data_type:
    BIT[(length)]
  | TINYINT[(length)] [UNSIGNED] [ZEROFILL]
  | SMALLINT[(length)] [UNSIGNED] [ZEROFILL]
  | MEDIUMINT[(length)] [UNSIGNED] [ZEROFILL]
  | INT[(length)] [UNSIGNED] [ZEROFILL]
  | INTEGER[(length)] [UNSIGNED] [ZEROFILL]
  | BIGINT[(length)] [UNSIGNED] [ZEROFILL]
  | REAL[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | DOUBLE[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | FLOAT[(length,decimals)] [UNSIGNED] [ZEROFILL]
  | DECIMAL[(length[,decimals])] [UNSIGNED] [ZEROFILL]
  | NUMERIC[(length[,decimals])] [UNSIGNED] [ZEROFILL]
  | DATE
  | TIME
  | TIMESTAMP
  | DATETIME
  | YEAR
  | CHAR[(length)]
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | VARCHAR(length)
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | BINARY[(length)]
  | VARBINARY(length)
  | TINYBLOB
  | BLOB[(length)]
  | MEDIUMBLOB
  | LONGBLOB
  | TINYTEXT
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | TEXT[(length)]
```

```
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | MEDIUMTEXT
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | LONGTEXT
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | ENUM(value1,value2,value3,...)
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | SET(value1,value2,value3,...)
      [CHARACTER SET charset_name] [COLLATE collation_name]
  | spatial_type

index_col_name:
    col_name [(length)] [ASC | DESC]

index_type:
    USING {BTREE | HASH}

index_option:
    KEY_BLOCK_SIZE [=] value
  | index_type
  | WITH PARSER parser_name
  | COMMENT 'string'

reference_definition:
    REFERENCES tbl_name (index_col_name,...)
      [MATCH FULL | MATCH PARTIAL | MATCH SIMPLE]
      [ON DELETE reference_option]
      [ON UPDATE reference_option]

reference_option:
    RESTRICT | CASCADE | SET NULL | NO ACTION | SET DEFAULT

table_options:
    table_option [[,] table_option] ...

table_option:
    AUTO_INCREMENT [=] value
  | AVG_ROW_LENGTH [=] value
  | [DEFAULT] CHARACTER SET [=] charset_name
  | CHECKSUM [=] {0 | 1}
  | [DEFAULT] COLLATE [=] collation_name
  | COMMENT [=] 'string'
  | CONNECTION [=] 'connect_string'
  | {DATA|INDEX} DIRECTORY [=] 'absolute path to directory'
  | DELAY_KEY_WRITE [=] {0 | 1}
  | ENGINE [=] engine_name
  | INSERT_METHOD [=] { NO | FIRST | LAST }
  | KEY_BLOCK_SIZE [=] value
  | MAX_ROWS [=] value
  | MIN_ROWS [=] value
  | PACK_KEYS [=] {0 | 1 | DEFAULT}
  | PASSWORD [=] 'string'
  | ROW_FORMAT [=] {DEFAULT|DYNAMIC|FIXED|COMPRESSED|REDUNDANT|COMPACT}
  | TABLESPACE tablespace_name [STORAGE {DISK|MEMORY|DEFAULT}]
  | UNION [=] (tbl_name[,tbl_name]...)

partition_options:
    PARTITION BY
        { [LINEAR] HASH(expr)
        | [LINEAR] KEY [ALGORITHM={1|2}] (column_list)
        | RANGE{(expr) | COLUMNS(column_list)}
        | LIST{(expr) | COLUMNS(column_list)} }
    [PARTITIONS num]
    [SUBPARTITION BY
        { [LINEAR] HASH(expr)
        | [LINEAR] KEY [ALGORITHM={1|2}] (column_list) }
      [SUBPARTITIONS num]
    ]
    [(partition_definition [, partition_definition] ...)]

partition_definition:
    PARTITION partition_name
```

```
        [VALUES
            {LESS THAN {(expr | value_list) | MAXVALUE}
            |
            IN (value_list)}]
        [[STORAGE] ENGINE [=] engine_name]
        [COMMENT [=] 'string' ]
        [DATA DIRECTORY [=] 'data_dir']
        [INDEX DIRECTORY [=] 'index_dir']
        [MAX_ROWS [=] max_number_of_rows]
        [MIN_ROWS [=] min_number_of_rows]
        [TABLESPACE [=] tablespace_name]
        [NODEGROUP [=] node_group_id]
        [(subpartition_definition [, subpartition_definition] ...)]

subpartition_definition:
    SUBPARTITION logical_name
        [[STORAGE] ENGINE [=] engine_name]
        [COMMENT [=] 'string' ]
        [DATA DIRECTORY [=] 'data_dir']
        [INDEX DIRECTORY [=] 'index_dir']
        [MAX_ROWS [=] max_number_of_rows]
        [MIN_ROWS [=] min_number_of_rows]
        [TABLESPACE [=] tablespace_name]
        [NODEGROUP [=] node_group_id]

query_expression:
    SELECT ...   (Some valid select or union statement)
```

`CREATE TABLE` creates a table with the given name. You must have the `CREATE` privilege for the table.

By default, tables are created in the default database, using the `InnoDB` storage engine. An error occurs if the table exists, if there is no default database, or if the database does not exist.

For information about the physical representation of a table, see Section 13.1.17.2, “Files Created by CREATE TABLE”.

The original `CREATE TABLE` statement, including all specifications and table options are stored by MySQL when the table is created. For more information, see Section 13.1.17.1, “CREATE TABLE Statement Retention”.

There are several aspects to the `CREATE TABLE` statement, described under the following topics in this section:

- Table Name
- Temporary Tables
- Cloning or Copying a Table
- Column Data Types and Attributes
- Indexes and Foreign Keys
- Table Options
- Creating Partitioned Tables

Table Name

- *`tbl_name`*

  The table name can be specified as *`db_name.tbl_name`* to create the table in a specific database. This works regardless of whether there is a default database, assuming that the database exists. If you use quoted identifiers, quote the database and table names separately. For example, write `` `mydb`.`mytbl` ``, not `` `mydb.mytbl` ``.

Rules for permissible table names are given in Section 9.2, “Schema Object Names”.

- `IF NOT EXISTS`

  Prevents an error from occurring if the table exists. However, there is no verification that the existing table has a structure identical to that indicated by the `CREATE TABLE` statement.

Temporary Tables

You can use the `TEMPORARY` keyword when creating a table. A `TEMPORARY` table is visible only within the current session, and is dropped automatically when the session is closed. For more information, see Section 13.1.17.3, “CREATE TEMPORARY TABLE Syntax”.

Cloning or Copying a Table

- `LIKE`

  Use `CREATE TABLE ... LIKE` to create an empty table based on the definition of another table, including any column attributes and indexes defined in the original table:

```
CREATE TABLE new_tbl LIKE orig_tbl;
```

  For more information, see Section 13.1.17.4, “CREATE TABLE ... LIKE Syntax”.

- `[AS] query_expression`

  To create one table from another, add a `SELECT` statement at the end of the `CREATE TABLE` statement:

```
CREATE TABLE new_tbl AS SELECT * FROM orig_tbl;
```

  For more information, see Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”.

- `IGNORE|REPLACE`

  The `IGNORE` and `REPLACE` options indicate how to handle rows that duplicate unique key values when copying a table using a `SELECT` statement.

  For more information, see Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”.

Column Data Types and Attributes

There is a hard limit of 4096 columns per table, but the effective maximum may be less for a given table and depends on the factors discussed in Section C.10.4, “Limits on Table Column Count and Row Size”.

- *`data_type`*

  `data_type` represents the data type in a column definition. *`spatial_type`* represents a spatial data type. The data type syntax shown is representative only. For a full description of the syntax available for specifying column data types, as well as information about the properties of each type, see Chapter 11, *Data Types*, and Section 11.5, “Spatial Data Types”.

  - Some attributes do not apply to all data types. `AUTO_INCREMENT` applies only to integer and floating-point types. `DEFAULT` does not apply to the `BLOB` or `TEXT` types.
  - Character data types (`CHAR`, `VARCHAR`, `TEXT`) can include `CHARACTER SET` and `COLLATE` attributes to specify the character set and collation for the column. For details, see Section 10.1, “Character Set Support”. `CHARSET` is a synonym for `CHARACTER SET`. Example:

```
```

```
CREATE TABLE t (c CHAR(20) CHARACTER SET utf8 COLLATE utf8_bin);
```

MySQL 5.5 interprets length specifications in character column definitions in characters. Lengths for BINARY and VARBINARY are in bytes.

- For CHAR, VARCHAR, BINARY, and VARBINARY columns, indexes can be created that use only the leading part of column values, using *col_name(length)* syntax to specify an index prefix length. BLOB and TEXT columns also can be indexed, but a prefix length *must* be given. Prefix lengths are given in characters for nonbinary string types and in bytes for binary string types. That is, index entries consist of the first *length* characters of each column value for CHAR, VARCHAR, and TEXT columns, and the first *length* bytes of each column value for BINARY, VARBINARY, and BLOB columns. Indexing only a prefix of column values like this can make the index file much smaller. For additional information about index prefixes, see Section 13.1.13, "CREATE INDEX Syntax".

  Only the InnoDB and MyISAM storage engines support indexing on BLOB and TEXT columns. For example:

  ```
  CREATE TABLE test (blob_col BLOB, INDEX(blob_col(10)));
  ```

- NOT NULL | NULL

  If neither NULL nor NOT NULL is specified, the column is treated as though NULL had been specified.

  In MySQL 5.5, only the InnoDB, MyISAM, and MEMORY storage engines support indexes on columns that can have NULL values. In other cases, you must declare indexed columns as NOT NULL or an error results.

- DEFAULT

  Specifies a default value for a column. With one exception, the default value must be a constant; it cannot be a function or an expression. This means, for example, that you cannot set the default for a date column to be the value of a function such as NOW() or CURRENT_DATE. The exception is that you can specify CURRENT_TIMESTAMP as the default for a TIMESTAMP column. See Section 11.3.5, "Automatic Initialization and Updating for TIMESTAMP".

  If a column definition includes no explicit DEFAULT value, MySQL determines the default value as described in Section 11.6, "Data Type Default Values".

  BLOB and TEXT columns cannot be assigned a default value.

  CREATE TABLE fails if a date-valued default is not correct according to the NO_ZERO_IN_DATE SQL mode, even if strict SQL mode is not enabled. For example, c1 DATE DEFAULT '2010-00-00' causes CREATE TABLE to fail with Invalid default value for 'c1'.

- AUTO_INCREMENT

  An integer or floating-point column can have the additional attribute AUTO_INCREMENT. When you insert a value of NULL (recommended) or 0 into an indexed AUTO_INCREMENT column, the column is set to the next sequence value. Typically this is *value*+1, where *value* is the largest value for the column currently in the table. AUTO_INCREMENT sequences begin with 1.

  To retrieve an AUTO_INCREMENT value after inserting a row, use the LAST_INSERT_ID() SQL function or the mysql_insert_id() C API function. See Section 12.14, "Information Functions", and Section 23.8.7.37, "mysql_insert_id()".

  If the NO_AUTO_VALUE_ON_ZERO SQL mode is enabled, you can store 0 in AUTO_INCREMENT columns as 0 without generating a new sequence value. See Section 5.1.8, "Server SQL Modes".

  There can be only one AUTO_INCREMENT column per table, it must be indexed, and it cannot have a DEFAULT value. An AUTO_INCREMENT column works properly only if it contains only positive values.

Inserting a negative number is regarded as inserting a very large positive number. This is done to avoid precision problems when numbers “wrap” over from positive to negative and also to ensure that you do not accidentally get an AUTO_INCREMENT column that contains 0.

For MyISAM tables, you can specify an AUTO_INCREMENT secondary column in a multiple-column key. See Section 3.6.9, “Using AUTO_INCREMENT”.

To make MySQL compatible with some ODBC applications, you can find the AUTO_INCREMENT value for the last inserted row with the following query:

```
SELECT * FROM tbl_name WHERE auto_col IS NULL
```

This method requires that sql_auto_is_null variable is not set to 0. See Section 5.1.5, “Server System Variables”.

For information about InnoDB and AUTO_INCREMENT, see Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”. For information about AUTO_INCREMENT and MySQL Replication, see Section 17.4.1.1, “Replication and AUTO_INCREMENT”.

- COMMENT

  A comment for a column can be specified with the COMMENT option, up to 1024 characters long (255 characters before MySQL 5.5.3). The comment is displayed by the SHOW CREATE TABLE and SHOW FULL COLUMNS statements.

- COLUMN_FORMAT

  In NDB Cluster, it is also possible to specify a data storage format for individual columns of NDB tables using COLUMN_FORMAT. Permissible column formats are FIXED, DYNAMIC, and DEFAULT. FIXED is used to specify fixed-width storage, DYNAMIC permits the column to be variable-width, and DEFAULT causes the column to use fixed-width or variable-width storage as determined by the column's data type (possibly overridden by a ROW_FORMAT specifier).

  For NDB tables, the default value for COLUMN_FORMAT is DEFAULT.

  COLUMN_FORMAT currently has no effect on columns of tables using storage engines other than NDB. In MySQL 5.5 and later, COLUMN_FORMAT is silently ignored.

- STORAGE

  For NDB tables, it is possible to specify whether the column is stored on disk or in memory by using a STORAGE clause. STORAGE DISK causes the column to be stored on disk, and STORAGE MEMORY causes in-memory storage to be used. The CREATE TABLE statement used must still include a TABLESPACE clause:

```
mysql> CREATE TABLE t1 (
    ->     c1 INT STORAGE DISK,
    ->     c2 INT STORAGE MEMORY
    -> ) ENGINE NDB;
ERROR 1005 (HY000): Can't create table 'c.t1' (errno: 140)

mysql> CREATE TABLE t1 (
    ->     c1 INT STORAGE DISK,
    ->     c2 INT STORAGE MEMORY
    -> ) TABLESPACE ts_1 ENGINE NDB;
Query OK, 0 rows affected (1.06 sec)
```

  For NDB tables, STORAGE DEFAULT is equivalent to STORAGE MEMORY.

  The STORAGE clause has no effect on tables using storage engines other than NDB. The STORAGE keyword is supported only in the build of mysqld that is supplied with NDB Cluster; it is not

recognized in any other version of MySQL, where any attempt to use the STORAGE keyword causes a syntax error.

Indexes and Foreign Keys

- CONSTRAINT *symbol*

  If the CONSTRAINT *symbol* clause is given, the *symbol* value, if used, must be unique in the database. A duplicate *symbol* results in an error. If the clause is not given, or a *symbol* is not included following the CONSTRAINT keyword, a name for the constraint is created automatically.

- PRIMARY KEY

  A unique index where all key columns must be defined as NOT NULL. If they are not explicitly declared as NOT NULL, MySQL declares them so implicitly (and silently). A table can have only one PRIMARY KEY. The name of a PRIMARY KEY is always PRIMARY, which thus cannot be used as the name for any other kind of index.

  If you do not have a PRIMARY KEY and an application asks for the PRIMARY KEY in your tables, MySQL returns the first UNIQUE index that has no NULL columns as the PRIMARY KEY.

  In InnoDB tables, keep the PRIMARY KEY short to minimize storage overhead for secondary indexes. Each secondary index entry contains a copy of the primary key columns for the corresponding row. (See Section 14.11.2.1, “Clustered and Secondary Indexes”.)

  In the created table, a PRIMARY KEY is placed first, followed by all UNIQUE indexes, and then the nonunique indexes. This helps the MySQL optimizer to prioritize which index to use and also more quickly to detect duplicated UNIQUE keys.

  A PRIMARY KEY can be a multiple-column index. However, you cannot create a multiple-column index using the PRIMARY KEY key attribute in a column specification. Doing so only marks that single column as primary. You must use a separate PRIMARY KEY(*index_col_name, ...*) clause.

  If a PRIMARY KEY consists of only one column that has an integer type, you can also refer to the column as _rowid in SELECT statements.

  In MySQL, the name of a PRIMARY KEY is PRIMARY. For other indexes, if you do not assign a name, the index is assigned the same name as the first indexed column, with an optional suffix (_2, _3, ...) to make it unique. You can see index names for a table using SHOW INDEX FROM *tbl_name*. See Section 13.7.5.23, “SHOW INDEX Syntax”.

- KEY | INDEX

  KEY is normally a synonym for INDEX. The key attribute PRIMARY KEY can also be specified as just KEY when given in a column definition. This was implemented for compatibility with other database systems.

- UNIQUE

  A UNIQUE index creates a constraint such that all values in the index must be distinct. An error occurs if you try to add a new row with a key value that matches an existing row. For all engines, a UNIQUE index permits multiple NULL values for columns that can contain NULL. If you specify a prefix value for a column in a UNIQUE index, the column values must be unique within the prefix.

  If a UNIQUE index consists of only one column that has an integer type, you can also refer to the column as _rowid in SELECT statements.

- FULLTEXT

A FULLTEXT index is a special type of index used for full-text searches. Only the MyISAM storage engine supports FULLTEXT indexes. They can be created only from CHAR, VARCHAR, and TEXT columns. Indexing always happens over the entire column; column prefix indexing is not supported and any prefix length is ignored if specified. See Section 12.9, “Full-Text Search Functions”, for details of operation. A WITH PARSER clause can be specified as an *index_option* value to associate a parser plugin with the index if full-text indexing and searching operations need special handling. This clause is valid only for FULLTEXT indexes. See Section 24.2, “The MySQL Plugin API”, for details on creating plugins.

- SPATIAL

  You can create SPATIAL indexes on spatial data types. Spatial types are supported only for MyISAM tables and indexed columns must be declared as NOT NULL. See Section 11.5, “Spatial Data Types”.

- FOREIGN KEY

  MySQL supports foreign keys, which let you cross-reference related data across tables, and foreign key constraints, which help keep this spread-out data consistent. For definition and option information, see *reference_definition*, and *reference_option*.

  Partitioned tables employing the InnoDB storage engine do not support foreign keys. See Section 19.5, “Restrictions and Limitations on Partitioning”, for more information.

- CHECK

  The CHECK clause is parsed but ignored by all storage engines. See Section 1.7.2.3, “Foreign Key Differences”.

- *index_col_name*

  - An *index_col_name* specification can end with ASC or DESC. These keywords are permitted for future extensions for specifying ascending or descending index value storage. Currently, they are parsed but ignored; index values are always stored in ascending order.

  - Prefixes, defined by the *length* attribute, can be up to 767 bytes long for InnoDB tables or 3072 bytes if the innodb_large_prefix option is enabled.

    Prefix limits are measured in bytes, whereas the prefix length in CREATE TABLE, ALTER TABLE, and CREATE INDEX statements is interpreted as number of characters for nonbinary string types (CHAR, VARCHAR, TEXT) and number of bytes for binary string types (BINARY, VARBINARY, BLOB). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

- *index_type*

  Some storage engines permit you to specify an index type when creating an index. The syntax for the *index_type* specifier is USING *type_name*.

  Example:

```
CREATE TABLE lookup
  (id INT, INDEX USING BTREE (id))
  ENGINE = MEMORY;
```

  The preferred position for USING is after the index column list. It can be given before the column list, but support for use of the option in that position is deprecated and will be removed in a future MySQL release.

- *index_option*

index_option values specify additional options for an index.

- KEY_BLOCK_SIZE

  For MyISAM tables, KEY_BLOCK_SIZE optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A KEY_BLOCK_SIZE value specified for an individual index definition overrides the table-level KEY_BLOCK_SIZE value.

  For information about the table-level KEY_BLOCK_SIZE attribute, see Table Options.

- WITH PARSER

  A WITH PARSER clause can be specified as an *index_option* value to associate a parser plugin with the index if full-text indexing and searching operations need special handling. This clause is valid only for FULLTEXT indexes. See Section 24.2, “The MySQL Plugin API”, for details on creating plugins.

- COMMENT

  As of MySQL 5.5.3, index definitions can include an optional comment of up to 1024 characters.

For more information about permissible *index_option* values, see Section 13.1.13, “CREATE INDEX Syntax”. For more information about indexes, see Section 8.3.1, “How MySQL Uses Indexes”.

- *reference_definition*

  For *reference_definition* syntax details and examples, see Section 13.1.17.6, “Using FOREIGN KEY Constraints”. For information specific to foreign keys in InnoDB, see Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”.

  InnoDB tables support checking of foreign key constraints. The columns of the referenced table must always be explicitly named. Both ON DELETE and ON UPDATE actions on foreign keys. For more detailed information and examples, see Section 13.1.17.6, “Using FOREIGN KEY Constraints”. For information specific to foreign keys in InnoDB, see Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”.

  For other storage engines, MySQL Server parses and ignores the FOREIGN KEY and REFERENCES syntax in CREATE TABLE statements. See Section 1.7.2.3, “Foreign Key Differences”.

Important

For users familiar with the ANSI/ISO SQL Standard, please note that no storage engine, including InnoDB, recognizes or enforces the MATCH clause used in referential integrity constraint definitions. Use of an explicit MATCH clause will not have the specified effect, and also causes ON DELETE and ON UPDATE clauses to be ignored. For these reasons, specifying MATCH should be avoided.

The MATCH clause in the SQL standard controls how NULL values in a composite (multiple-column) foreign key are handled when comparing to a primary key. InnoDB essentially implements the semantics defined by MATCH SIMPLE, which permit a foreign key to be all or partially NULL. In that case, the (child table) row containing such a foreign key is permitted to be inserted, and does not match any row in the referenced (parent) table. It is possible to implement other semantics using triggers.

Additionally, MySQL requires that the referenced columns be indexed for performance. However, InnoDB does not enforce any requirement that the

> referenced columns be declared `UNIQUE` or `NOT NULL`. The handling of foreign key references to nonunique keys or keys that contain `NULL` values is not well defined for operations such as `UPDATE` or `DELETE CASCADE`. You are advised to use foreign keys that reference only keys that are both `UNIQUE` (or `PRIMARY`) and `NOT NULL`.
>
> MySQL parses but ignores "inline `REFERENCES` specifications" (as defined in the SQL standard) where the references are defined as part of the column specification. MySQL accepts `REFERENCES` clauses only when specified as part of a separate `FOREIGN KEY` specification.

- *`reference_option`*

  For information about the `RESTRICT`, `CASCADE`, `SET NULL`, `NO ACTION`, and `SET DEFAULT` options, see Section 13.1.17.6, "Using FOREIGN KEY Constraints".

Table Options

Table options are used to optimize the behavior of the table. In most cases, you do not have to specify any of them. These options apply to all storage engines unless otherwise indicated. Options that do not apply to a given storage engine may be accepted and remembered as part of the table definition. Such options then apply if you later use `ALTER TABLE` to convert the table to use a different storage engine.

- `ENGINE`

  Specifies the storage engine for the table, using one of the names shown in the following table. The engine name can be unquoted or quoted. The quoted name `'DEFAULT'` is equivalent to specifying the default storage engine name.

Storage Engine	Description
`InnoDB`	Transaction-safe tables with row locking and foreign keys. The default storage engine for new tables. See Chapter 14, *The InnoDB Storage Engine*, and in particular Section 14.1, "Introduction to InnoDB" if you have MySQL experience but are new to `InnoDB`.
`MyISAM`	The binary portable storage engine that is primarily used for read-only or read-mostly workloads. See Section 15.3, "The MyISAM Storage Engine".
`MEMORY`	The data for this storage engine is stored only in memory. See Section 15.4, "The MEMORY Storage Engine".
`CSV`	Tables that store rows in comma-separated values format. See Section 15.5, "The CSV Storage Engine".
`ARCHIVE`	The archiving storage engine. See Section 15.6, "The ARCHIVE Storage Engine".
`EXAMPLE`	An example engine. See Section 15.10, "The EXAMPLE Storage Engine".
`FEDERATED`	Storage engine that accesses remote tables. See Section 15.9, "The FEDERATED Storage Engine".
`HEAP`	This is a synonym for `MEMORY`.
`MERGE`	A collection of `MyISAM` tables used as one table. Also known as `MRG_MyISAM`. See Section 15.8, "The MERGE Storage Engine".
`NDBCLUSTER`	Clustered, fault-tolerant, memory-based tables. Also known as `NDB`. See Chapter 18, *MySQL NDB Cluster 7.2*.

If a storage engine is specified that is not available, MySQL uses the default engine instead. Normally, this is `MyISAM`. For example, if a table definition includes the `ENGINE=INNODB` option but

the MySQL server does not support INNODB tables, the table is created as a MyISAM table. This makes it possible to have a replication setup where you have transactional tables on the master but tables created on the slave are nontransactional (to get more speed). In MySQL 5.5, a warning occurs if the storage engine specification is not honored.

Engine substitution can be controlled by the setting of the NO_ENGINE_SUBSTITUTION SQL mode, as described in Section 5.1.8, “Server SQL Modes”.

Note

The older TYPE option was synonymous with ENGINE. TYPE was deprecated in MySQL 4.0 and removed in MySQL 5.5. *When upgrading to MySQL 5.5 or later, you must convert existing applications that rely on TYPE to use ENGINE instead*.

- AUTO_INCREMENT

  The initial AUTO_INCREMENT value for the table. In MySQL 5.5, this works for MyISAM, MEMORY, InnoDB, and ARCHIVE tables. To set the first auto-increment value for engines that do not support the AUTO_INCREMENT table option, insert a “dummy” row with a value one less than the desired value after creating the table, and then delete the dummy row.

  For engines that support the AUTO_INCREMENT table option in CREATE TABLE statements, you can also use ALTER TABLE *tbl_name* AUTO_INCREMENT = *N* to reset the AUTO_INCREMENT value. The value cannot be set lower than the maximum value currently in the column.

- AVG_ROW_LENGTH

  An approximation of the average row length for your table. You need to set this only for large tables with variable-size rows.

  When you create a MyISAM table, MySQL uses the product of the MAX_ROWS and AVG_ROW_LENGTH options to decide how big the resulting table is. If you don't specify either option, the maximum size for MyISAM data and index files is 256TB by default. (If your operating system does not support files that large, table sizes are constrained by the file size limit.) If you want to keep down the pointer sizes to make the index smaller and faster and you don't really need big files, you can decrease the default pointer size by setting the myisam_data_pointer_size system variable. (See Section 5.1.5, “Server System Variables”.) If you want all your tables to be able to grow above the default limit and are willing to have your tables slightly slower and larger than necessary, you can increase the default pointer size by setting this variable. Setting the value to 7 permits table sizes up to 65,536TB.

- [DEFAULT] CHARACTER SET

  Specifies a default character set for the table. CHARSET is a synonym for CHARACTER SET. If the character set name is DEFAULT, the database character set is used.

- CHECKSUM

  Set this to 1 if you want MySQL to maintain a live checksum for all rows (that is, a checksum that MySQL updates automatically as the table changes). This makes the table a little slower to update, but also makes it easier to find corrupted tables. The CHECKSUM TABLE statement reports the checksum. (MyISAM only.)

- [DEFAULT] COLLATE

  Specifies a default collation for the table.

- COMMENT

  A comment for the table, up to 2048 characters long (60 characters before MySQL 5.5.3).

- `CONNECTION`

  The connection string for a `FEDERATED` table.

  Note

  Older versions of MySQL used a `COMMENT` option for the connection string.

- `DATA DIRECTORY`, `INDEX DIRECTORY`

  By using `DATA DIRECTORY='directory'` or `INDEX DIRECTORY='directory'` you can specify where the `MyISAM` storage engine should put a table's data file and index file. The directory must be the full path name to the directory, not a relative path.

  As of MySQL 5.5.54, you must have the `FILE` privilege to use the `DATA DIRECTORY` or `INDEX DIRECTORY` table option.

  Important

  Table-level `DATA DIRECTORY` and `INDEX DIRECTORY` options are ignored for partitioned tables. (Bug #32091)

  These options work only when you are not using the `--skip-symbolic-links` option. Your operating system must also have a working, thread-safe `realpath()` call. See Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”, for more complete information.

  If a `MyISAM` table is created with no `DATA DIRECTORY` option, the `.MYD` file is created in the database directory. By default, if `MyISAM` finds an existing `.MYD` file in this case, it overwrites it. The same applies to `.MYI` files for tables created with no `INDEX DIRECTORY` option. To suppress this behavior, start the server with the `--keep_files_on_create` option, in which case `MyISAM` will not overwrite existing files and returns an error instead.

  If a `MyISAM` table is created with a `DATA DIRECTORY` or `INDEX DIRECTORY` option and an existing `.MYD` or `.MYI` file is found, MyISAM always returns an error. It will not overwrite a file in the specified directory.

  Important

  You cannot use path names that contain the MySQL data directory with `DATA DIRECTORY` or `INDEX DIRECTORY`. This includes partitioned tables and individual table partitions. (See Bug #32167.)

- `DELAY_KEY_WRITE`

  Set this to 1 if you want to delay key updates for the table until the table is closed. See the description of the `delay_key_write` system variable in Section 5.1.5, “Server System Variables”. (`MyISAM` only.)

- `INSERT_METHOD`

  If you want to insert data into a `MERGE` table, you must specify with `INSERT_METHOD` the table into which the row should be inserted. `INSERT_METHOD` is an option useful for `MERGE` tables only. Use a value of `FIRST` or `LAST` to have inserts go to the first or last table, or a value of `NO` to prevent inserts. See Section 15.8, “The MERGE Storage Engine”.

- `KEY_BLOCK_SIZE`

  For `MyISAM` tables, `KEY_BLOCK_SIZE` optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A `KEY_BLOCK_SIZE` value specified for an individual index definition overrides the table-level `KEY_BLOCK_SIZE` value.

For `InnoDB` tables, `KEY_BLOCK_SIZE` optionally specifies the page size (in kilobytes) to use for compressed `InnoDB` tables. The `KEY_BLOCK_SIZE` value is treated as a hint; a different size could be used by `InnoDB` if necessary. Valid `KEY_BLOCK_SIZE` values include 0, 1, 2, 4, 8, and 16. A value of 0 represents the default compressed page size, which is half of the `InnoDB` page size.

Oracle recommends enabling `innodb_strict_mode` when specifying `KEY_BLOCK_SIZE` for `InnoDB` tables. When `innodb_strict_mode` is enabled, specifying an invalid `KEY_BLOCK_SIZE` value returns an error. If `innodb_strict_mode` is disabled, an invalid `KEY_BLOCK_SIZE` value results in a warning, and the `KEY_BLOCK_SIZE` option is ignored.

The `Create_options` column in response to `SHOW TABLE STATUS` reports the originally specified `KEY_BLOCK_SIZE` option, as does `SHOW CREATE TABLE`.

`InnoDB` only supports `KEY_BLOCK_SIZE` at the table level.

- `MAX_ROWS`

  The maximum number of rows you plan to store in the table. This is not a hard limit, but rather a hint to the storage engine that the table must be able to store at least this many rows.

  The `NDB` storage engine treats this value as a maximum. If you plan to create very large NDB Cluster tables (containing millions of rows), you should use this option to insure that `NDB` allocates sufficient number of index slots in the hash table used for storing hashes of the table's primary keys by setting `MAX_ROWS = 2 * rows`, where *`rows`* is the number of rows that you expect to insert into the table.

  The maximum `MAX_ROWS` value is 4294967295; larger values are truncated to this limit.

- `MIN_ROWS`

  The minimum number of rows you plan to store in the table. The `MEMORY` storage engine uses this option as a hint about memory use.

- `PACK_KEYS`

  Takes effect only with `MyISAM` tables. Set this option to 1 if you want to have smaller indexes. This usually makes updates slower and reads faster. Setting the option to 0 disables all packing of keys. Setting it to `DEFAULT` tells the storage engine to pack only long `CHAR`, `VARCHAR`, `BINARY`, or `VARBINARY` columns.

  If you do not use `PACK_KEYS`, the default is to pack strings, but not numbers. If you use `PACK_KEYS=1`, numbers are packed as well.

  When packing binary number keys, MySQL uses prefix compression:

  - Every key needs one extra byte to indicate how many bytes of the previous key are the same for the next key.
  - The pointer to the row is stored in high-byte-first order directly after the key, to improve compression.

  This means that if you have many equal keys on two consecutive rows, all following “same” keys usually only take two bytes (including the pointer to the row). Compare this to the ordinary case where the following keys takes `storage_size_for_key + pointer_size` (where the pointer size is usually 4). Conversely, you get a significant benefit from prefix compression only if you have many numbers that are the same. If all keys are totally different, you use one byte more per key, if the key is not a key that can have `NULL` values. (In this case, the packed key length is stored in the same byte that is used to mark if a key is `NULL`.)

- `PASSWORD`

This option is unused. If you have a need to scramble your `.frm` files and make them unusable to any other MySQL server, please contact our sales department.

- `ROW_FORMAT`

  Defines the physical format in which the rows are stored.

  When executing a `CREATE TABLE` statement with strict mode disabled, if you specify a row format that is not supported by the storage engine that is used for the table, the table is created using that storage engine's default row format. The information reported in the `Row_format` column in response to `SHOW TABLE STATUS` is the actual row format used. This may differ from the value in the `Create_options` column because the original `CREATE TABLE` definition is retained during creation. `SHOW CREATE TABLE` also reports the row format used in the original `CREATE TABLE` statement.

  Row format choices differ depending on the storage engine used for the table.

  For `InnoDB` tables:

  - Rows are stored in compact format (`ROW_FORMAT=COMPACT`) by default.
  - The noncompact format used in older versions of MySQL can still be requested by specifying `ROW_FORMAT=REDUNDANT`.
  - To enable compression for `InnoDB` tables, specify `ROW_FORMAT=COMPRESSED` and follow the procedures in Section 14.12, “InnoDB Table Compression”.
  - For more efficient `InnoDB` storage of data types, especially `BLOB` types, specify `ROW_FORMAT=DYNAMIC` and follow the procedures in Section 14.14.3, “DYNAMIC and COMPRESSED Row Formats”. Both the `COMPRESSED` and `DYNAMIC` row formats require creating the table with the configuration settings `innodb_file_per_table=1` and `innodb_file_format=barracuda`.
  - When you specify a non-default `ROW_FORMAT` clause, consider also enabling the `innodb_strict_mode` configuration option.
  - `ROW_FORMAT=FIXED` is not supported. If `ROW_FORMAT=FIXED` is specified while `innodb_strict_mode` is disabled, `InnoDB` issues a warning and assumes `ROW_FORMAT=COMPACT`. If `ROW_FORMAT=FIXED` is specified while `innodb_strict_mode` is enabled, `InnoDB` returns an error.
  - For additional information about `InnoDB` row formats, see Section 14.14, “InnoDB Row Storage and Row Formats”.

  For `MyISAM` tables, the option value can be `FIXED` or `DYNAMIC` for static or variable-length row format. `myisampack` sets the type to `COMPRESSED`. See Section 15.3.3, “MyISAM Table Storage Formats”.

- `TABLESPACE`

  The `TABLESPACE` and `STORAGE` table options are employed only with `NDBCLUSTER` tables. The tablespace named *`tablespace_name`* must already have been created using `CREATE TABLESPACE`. `STORAGE` determines the type of storage used (disk or memory), and can be one of `DISK`, `MEMORY`, or `DEFAULT`.

  `TABLESPACE ... STORAGE DISK` assigns a table to an NDB Cluster Disk Data tablespace. See Section 18.5.12, “NDB Cluster Disk Data Tables”, for more information.

Important

A `STORAGE` clause cannot be used in a `CREATE TABLE` statement without a `TABLESPACE` clause.

- `UNION`

  Used to access a collection of identical `MyISAM` tables as one. This works only with `MERGE` tables. See Section 15.8, “The MERGE Storage Engine”.

  You must have `SELECT`, `UPDATE`, and `DELETE` privileges for the tables you map to a `MERGE` table.

Note

Formerly, all tables used had to be in the same database as the `MERGE` table itself. This restriction no longer applies.

Creating Partitioned Tables

`partition_options` can be used to control partitioning of the table created with `CREATE TABLE`.

Not all options shown in the syntax for *`partition_options`* at the beginning of this section are available for all partitioning types. Please see the listings for the following individual types for information specific to each type, and see Chapter 19, *Partitioning*, for more complete information about the workings of and uses for partitioning in MySQL, as well as additional examples of table creation and other statements relating to MySQL partitioning.

- `PARTITION BY`

  If used, a *`partition_options`* clause begins with `PARTITION BY`. This clause contains the function that is used to determine the partition; the function returns an integer value ranging from 1 to *`num`*, where *`num`* is the number of partitions. (The maximum number of user-defined partitions which a table may contain is 1024; the number of subpartitions—discussed later in this section—is included in this maximum.)

  Partitions can be modified, merged, added to tables, and dropped from tables. For basic information about the MySQL statements to accomplish these tasks, see Section 13.1.7, “ALTER TABLE Syntax”. For more detailed descriptions and examples, see Section 19.3, “Partition Management”.

Note

The expression (*`expr`*) used in a `PARTITION BY` clause cannot refer to any columns not in the table being created; such references are specifically not permitted and cause the statement to fail with an error. (Bug #29444)

- `HASH(`*`expr`*`)`

  Hashes one or more columns to create a key for placing and locating rows. *`expr`* is an expression using one or more table columns. This can be any valid MySQL expression (including MySQL functions) that yields a single integer value. For example, these are both valid `CREATE TABLE` statements using `PARTITION BY HASH`:

```
CREATE TABLE t1 (col1 INT, col2 CHAR(5))
    PARTITION BY HASH(col1);

CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATETIME)
    PARTITION BY HASH ( YEAR(col3) );
```

  You may not use either `VALUES LESS THAN` or `VALUES IN` clauses with `PARTITION BY HASH`.

`PARTITION BY HASH` uses the remainder of *`expr`* divided by the number of partitions (that is, the modulus). For examples and additional information, see Section 19.2.4, “HASH Partitioning”.

The `LINEAR` keyword entails a somewhat different algorithm. In this case, the number of the partition in which a row is stored is calculated as the result of one or more logical `AND` operations. For discussion and examples of linear hashing, see Section 19.2.4.1, “LINEAR HASH Partitioning”.

- `KEY [ALGORITHM={1|2}] (`*`column_list`*`)`: This is similar to `HASH`, except that MySQL supplies the hashing function so as to guarantee an even data distribution. The *`column_list`* argument is simply a list of 1 or more table columns (maximum: 16). This example shows a simple table partitioned by key, with 4 partitions:

```
CREATE TABLE tk (col1 INT, col2 CHAR(5), col3 DATE)
    PARTITION BY KEY(col3)
    PARTITIONS 4;
```

For tables that are partitioned by key, you can employ linear partitioning by using the `LINEAR` keyword. This has the same effect as with tables that are partitioned by `HASH`. That is, the partition number is found using the `&` operator rather than the modulus (see Section 19.2.4.1, “LINEAR HASH Partitioning”, and Section 19.2.5, “KEY Partitioning”, for details). This example uses linear partitioning by key to distribute data between 5 partitions:

```
CREATE TABLE tk (col1 INT, col2 CHAR(5), col3 DATE)
    PARTITION BY LINEAR KEY(col3)
    PARTITIONS 5;
```

The `ALGORITHM={1|2}` option is supported with `[SUB]PARTITION BY [LINEAR] KEY` beginning with MySQL 5.5.31. `ALGORITHM=1` causes the server to use the same key-hashing functions as MySQL 5.1; `ALGORITHM=2` means that the server employs the key-hashing functions implemented and used by default for new `KEY` partitioned tables in MySQL 5.5 and later. (Partitioned tables created with the key-hashing functions employed in MySQL 5.5 and later cannot be used by a MySQL 5.1 server.) Not specifying the option has the same effect as using `ALGORITHM=2`. This option is intended for use chiefly when upgrading or downgrading `[LINEAR] KEY` partitioned tables between MySQL 5.1 and later MySQL versions, or for creating tables partitioned by `KEY` or `LINEAR KEY` on a MySQL 5.5 or later server which can be used on a MySQL 5.1 server. For more information, see Section 13.1.7.1, “ALTER TABLE Partition Operations”.

`mysqldump` in MySQL 5.5.31 and later writes this option encased in versioned comments, like this:

```
CREATE TABLE t1 (a INT)
/*!50100 PARTITION BY KEY */ /*!50531 ALGORITHM = 1 */ /*!50100 ()
      PARTITIONS 3 */
```

This causes MySQL 5.5.30 and earlier servers to ignore the option, which would otherwise cause a syntax error in those versions. If you plan to load a dump made on a MySQL 5.5.31 or later MySQL 5.5 server where you use tables that are partitioned or subpartitioned by `KEY` into a MySQL 5.6 server previous to version 5.6.11, be sure to consult Changes Affecting Upgrades to MySQL 5.6, before proceeding. (The information found there also applies if you are loading a dump containing `KEY` partitioned or subpartitioned tables made from a MySQL 5.6.11 or later server into a MySQL 5.5.30 or earlier server.)

Also in MySQL 5.5.31 and later, `ALGORITHM=1` is shown when necessary in the output of `SHOW CREATE TABLE` using versioned comments in the same manner as `mysqldump`. `ALGORITHM=2` is always omitted from `SHOW CREATE TABLE` output, even if this option was specified when creating the original table.

You may not use either `VALUES LESS THAN` or `VALUES IN` clauses with `PARTITION BY KEY`.

- `RANGE(`*`expr`*`)`

In this case, *expr* shows a range of values using a set of VALUES LESS THAN operators. When using range partitioning, you must define at least one partition using VALUES LESS THAN. You cannot use VALUES IN with range partitioning.

Note

For tables partitioned by RANGE, VALUES LESS THAN must be used with either an integer literal value or an expression that evaluates to a single integer value. In MySQL 5.5, you can overcome this limitation in a table that is defined using PARTITION BY RANGE COLUMNS, as described later in this section.

Suppose that you have a table that you wish to partition on a column containing year values, according to the following scheme.

Partition Number:	Years Range:
0	1990 and earlier
1	1991 to 1994
2	1995 to 1998
3	1999 to 2002
4	2003 to 2005
5	2006 and later

A table implementing such a partitioning scheme can be realized by the CREATE TABLE statement shown here:

```
CREATE TABLE t1 (
    year_col  INT,
    some_data INT
)
PARTITION BY RANGE (year_col) (
    PARTITION p0 VALUES LESS THAN (1991),
    PARTITION p1 VALUES LESS THAN (1995),
    PARTITION p2 VALUES LESS THAN (1999),
    PARTITION p3 VALUES LESS THAN (2002),
    PARTITION p4 VALUES LESS THAN (2006),
    PARTITION p5 VALUES LESS THAN MAXVALUE
);
```

PARTITION ... VALUES LESS THAN ... statements work in a consecutive fashion. VALUES LESS THAN MAXVALUE works to specify “leftover” values that are greater than the maximum value otherwise specified.

VALUES LESS THAN clauses work sequentially in a manner similar to that of the case portions of a switch ... case block (as found in many programming languages such as C, Java, and PHP). That is, the clauses must be arranged in such a way that the upper limit specified in each successive VALUES LESS THAN is greater than that of the previous one, with the one referencing MAXVALUE coming last of all in the list.

- RANGE COLUMNS(*column_list*)

  This variant on RANGE was introduced in MySQL 5.5.0 to facilitate partition pruning for queries using range conditions on multiple columns (that is, having conditions such as WHERE a = 1 AND b < 10 or WHERE a = 1 AND b = 10 AND c < 10). It enables you to specify value ranges in multiple columns by using a list of columns in the COLUMNS clause and a set of column values in each PARTITION ... VALUES LESS THAN (*value_list*) partition definition clause. (In the simplest case, this set consists of a single column.) The maximum number of columns that can be referenced in the *column_list* and *value_list* is 16.

The *`column_list`* used in the `COLUMNS` clause may contain only names of columns; each column in the list must be one of the following MySQL data types: the integer types; the string types; and time or date column types. Columns using `BLOB`, `TEXT`, `SET`, `ENUM`, `BIT`, or spatial data types are not permitted; columns that use floating-point number types are also not permitted. You also may not use functions or arithmetic expressions in the `COLUMNS` clause.

The `VALUES LESS THAN` clause used in a partition definition must specify a literal value for each column that appears in the `COLUMNS()` clause; that is, the list of values used for each `VALUES LESS THAN` clause must contain the same number of values as there are columns listed in the `COLUMNS` clause. An attempt to use more or fewer values in a `VALUES LESS THAN` clause than there are in the `COLUMNS` clause causes the statement to fail with the error `Inconsistency in usage of column lists for partitioning...`. You cannot use `NULL` for any value appearing in `VALUES LESS THAN`. It is possible to use `MAXVALUE` more than once for a given column other than the first, as shown in this example:

```
CREATE TABLE rc (
    a INT NOT NULL,
    b INT NOT NULL
)
PARTITION BY RANGE COLUMNS(a,b) (
    PARTITION p0 VALUES LESS THAN (10,5),
    PARTITION p1 VALUES LESS THAN (20,10),
    PARTITION p2 VALUES LESS THAN (50,MAXVALUE),
    PARTITION p3 VALUES LESS THAN (65,MAXVALUE),
    PARTITION p4 VALUES LESS THAN (MAXVALUE,MAXVALUE)
);
```

Each value used in a `VALUES LESS THAN` value list must match the type of the corresponding column exactly; no conversion is made. For example, you cannot use the string `'1'` for a value that matches a column that uses an integer type (you must use the numeral `1` instead), nor can you use the numeral `1` for a value that matches a column that uses a string type (in such a case, you must use a quoted string: `'1'`).

For more information, see Section 19.2.1, “RANGE Partitioning”, and Section 19.4, “Partition Pruning”.

- `LIST(`*`expr`*`)`

  This is useful when assigning partitions based on a table column with a restricted set of possible values, such as a state or country code. In such a case, all rows pertaining to a certain state or country can be assigned to a single partition, or a partition can be reserved for a certain set of states or countries. It is similar to `RANGE`, except that only `VALUES IN` may be used to specify permissible values for each partition.

  `VALUES IN` is used with a list of values to be matched. For instance, you could create a partitioning scheme such as the following:

```
CREATE TABLE client_firms (
    id   INT,
    name VARCHAR(35)
)
PARTITION BY LIST (id) (
    PARTITION r0 VALUES IN (1, 5, 9, 13, 17, 21),
    PARTITION r1 VALUES IN (2, 6, 10, 14, 18, 22),
    PARTITION r2 VALUES IN (3, 7, 11, 15, 19, 23),
    PARTITION r3 VALUES IN (4, 8, 12, 16, 20, 24)
);
```

  When using list partitioning, you must define at least one partition using `VALUES IN`. You cannot use `VALUES LESS THAN` with `PARTITION BY LIST`.

Note

For tables partitioned by `LIST`, the value list used with `VALUES IN` must consist of integer values only. In MySQL 5.5, you can overcome this limitation using partitioning by `LIST COLUMNS`, which is described later in this section.

- `LIST COLUMNS(column_list)`

  This variant on `LIST` was introduced in MySQL 5.5.0 to facilitate partition pruning for queries using comparison conditions on multiple columns (that is, having conditions such as `WHERE a = 5 AND b = 5` or `WHERE a = 1 AND b = 10 AND c = 5`). It enables you to specify values in multiple columns by using a list of columns in the `COLUMNS` clause and a set of column values in each `PARTITION ... VALUES IN (value_list)` partition definition clause.

  The rules governing regarding data types for the column list used in `LIST COLUMNS(column_list)` and the value list used in `VALUES IN(value_list)` are the same as those for the column list used in `RANGE COLUMNS(column_list)` and the value list used in `VALUES LESS THAN(value_list)`, respectively, except that in the `VALUES IN` clause, `MAXVALUE` is not permitted, and you may use `NULL`.

  There is one important difference between the list of values used for `VALUES IN` with `PARTITION BY LIST COLUMNS` as opposed to when it is used with `PARTITION BY LIST`. When used with `PARTITION BY LIST COLUMNS`, each element in the `VALUES IN` clause must be a *set* of column values; the number of values in each set must be the same as the number of columns used in the `COLUMNS` clause, and the data types of these values must match those of the columns (and occur in the same order). In the simplest case, the set consists of a single column. The maximum number of columns that can be used in the *`column_list`* and in the elements making up the *`value_list`* is 16.

  The table defined by the following `CREATE TABLE` statement provides an example of a table using `LIST COLUMNS` partitioning:

```
CREATE TABLE lc (
    a INT NULL,
    b INT NULL
)
PARTITION BY LIST COLUMNS(a,b) (
    PARTITION p0 VALUES IN( (0,0), (NULL,NULL) ),
    PARTITION p1 VALUES IN( (0,1), (0,2), (0,3), (1,1), (1,2) ),
    PARTITION p2 VALUES IN( (1,0), (2,0), (2,1), (3,0), (3,1) ),
    PARTITION p3 VALUES IN( (1,3), (2,2), (2,3), (3,2), (3,3) )
);
```

- `PARTITIONS num`

  The number of partitions may optionally be specified with a `PARTITIONS num` clause, where *`num`* is the number of partitions. If both this clause *and* any `PARTITION` clauses are used, *`num`* must be equal to the total number of any partitions that are declared using `PARTITION` clauses.

Note

Whether or not you use a `PARTITIONS` clause in creating a table that is partitioned by `RANGE` or `LIST`, you must still include at least one `PARTITION VALUES` clause in the table definition (see below).

- `SUBPARTITION BY`

  A partition may optionally be divided into a number of subpartitions. This can be indicated by using the optional `SUBPARTITION BY` clause. Subpartitioning may be done by `HASH` or `KEY`. Either of these may be `LINEAR`. These work in the same way as previously described for the equivalent partitioning types. (It is not possible to subpartition by `LIST` or `RANGE`.)

The number of subpartitions can be indicated using the SUBPARTITIONS keyword followed by an integer value.

- Rigorous checking of the value used in PARTITIONS or SUBPARTITIONS clauses is applied and this value must adhere to the following rules:
  - The value must be a positive, nonzero integer.
  - No leading zeros are permitted.
  - The value must be an integer literal, and cannot not be an expression. For example, PARTITIONS 0.2E+01 is not permitted, even though 0.2E+01 evaluates to 2. (Bug #15890)
- *partition_definition*

  Each partition may be individually defined using a *partition_definition* clause. The individual parts making up this clause are as follows:
  - PARTITION *partition_name*

    Specifies a logical name for the partition.
  - VALUES

    For range partitioning, each partition must include a VALUES LESS THAN clause; for list partitioning, you must specify a VALUES IN clause for each partition. This is used to determine which rows are to be stored in this partition. See the discussions of partitioning types in Chapter 19, *Partitioning*, for syntax examples.
  - COMMENT

    An optional COMMENT clause may be used to specify a string that describes the partition. Example:

    ```
    COMMENT = 'Data for the years previous to 1999'
    ```
  - DATA DIRECTORY and INDEX DIRECTORY

    DATA DIRECTORY and INDEX DIRECTORY may be used to indicate the directory where, respectively, the data and indexes for this partition are to be stored. Both the *data_dir* and the *index_dir* must be absolute system path names.

    As of MySQL 5.5.54, you must have the FILE privilege to use the DATA DIRECTORY or INDEX DIRECTORY partition option.

    Example:

    ```
    CREATE TABLE th (id INT, name VARCHAR(30), adate DATE)
    PARTITION BY LIST(YEAR(adate))
    (
      PARTITION p1999 VALUES IN (1995, 1999, 2003)
        DATA DIRECTORY = '/var/appdata/95/data'
        INDEX DIRECTORY = '/var/appdata/95/idx',
      PARTITION p2000 VALUES IN (1996, 2000, 2004)
        DATA DIRECTORY = '/var/appdata/96/data'
        INDEX DIRECTORY = '/var/appdata/96/idx',
      PARTITION p2001 VALUES IN (1997, 2001, 2005)
        DATA DIRECTORY = '/var/appdata/97/data'
        INDEX DIRECTORY = '/var/appdata/97/idx',
      PARTITION p2002 VALUES IN (1998, 2002, 2006)
        DATA DIRECTORY = '/var/appdata/98/data'
        INDEX DIRECTORY = '/var/appdata/98/idx'
    );
    ```

`DATA DIRECTORY` and `INDEX DIRECTORY` behave in the same way as in the `CREATE TABLE` statement's *`table_option`* clause as used for `MyISAM` tables.

One data directory and one index directory may be specified per partition. If left unspecified, the data and indexes are stored by default in the table's database directory.

On Windows, the `DATA DIRECTORY` and `INDEX DIRECTORY` options are not supported for individual partitions or subpartitions. These options are ignored on Windows, except that a warning is generated. (Bug #30459)

Note

The `DATA DIRECTORY` and `INDEX DIRECTORY` options are ignored for creating partitioned tables if `NO_DIR_IN_CREATE` is in effect. (Bug #24633)

- `MAX_ROWS` and `MIN_ROWS`

  May be used to specify, respectively, the maximum and minimum number of rows to be stored in the partition. The values for *`max_number_of_rows`* and *`min_number_of_rows`* must be positive integers. As with the table-level options with the same names, these act only as “suggestions” to the server and are not hard limits.

- `TABLESPACE`

  The optional `TABLESPACE` clause may be used to designate a tablespace for the partition. Used for NDB Cluster only.

- `[STORAGE] ENGINE`

  The partitioning handler accepts a `[STORAGE] ENGINE` option for both `PARTITION` and `SUBPARTITION`. Currently, the only way in which this can be used is to set all partitions or all subpartitions to the same storage engine, and an attempt to set different storage engines for partitions or subpartitions in the same table will give rise to the error `ERROR 1469 (HY000): The mix of handlers in the partitions is not permitted in this version of MySQL`. We expect to lift this restriction on partitioning in a future MySQL release.

- `NODEGROUP`

  The `NODEGROUP` option can be used to make this partition act as part of the node group identified by *`node_group_id`*. This option is applicable only to NDB Cluster.

- *`subpartition_definition`*

  The partition definition may optionally contain one or more *`subpartition_definition`* clauses. Each of these consists at a minimum of the `SUBPARTITION` *`name`*, where *`name`* is an identifier for the subpartition. Except for the replacement of the `PARTITION` keyword with `SUBPARTITION`, the syntax for a subpartition definition is identical to that for a partition definition.

  Subpartitioning must be done by `HASH` or `KEY`, and can be done only on `RANGE` or `LIST` partitions. See Section 19.2.6, “Subpartitioning”.

13.1.17.1 CREATE TABLE Statement Retention

The original `CREATE TABLE` statement, including all specifications and table options are stored by MySQL when the table is created. The information is retained so that if you change storage engines, collations or other settings using an `ALTER TABLE` statement, the original table options specified are retained. This enables you to change between `InnoDB` and `MyISAM` table types even though the row formats supported by the two engines are different.

Because the text of the original statement is retained, but due to the way that certain values and options may be silently reconfigured (such as the `ROW_FORMAT`), the active table definition (accessible through `DESCRIBE` or with `SHOW TABLE STATUS`) and the table creation string (accessible through `SHOW CREATE TABLE`) will report different values.

13.1.17.2 Files Created by CREATE TABLE

MySQL represents each table by an `.frm` table format (definition) file in the database directory. The storage engine for the table might create other files as well.

For `InnoDB` tables, the file storage is controlled by the `innodb_file_per_table` configuration option. For each `InnoDB` table created when this option is turned on, the table data and all associated indexes are stored in a .ibd file located inside the database directory. When this option is turned off, all `InnoDB` tables and indexes are stored in the system tablespace, represented by one or more ibdata* files.

For `MyISAM` tables, the storage engine creates data and index files. Thus, for each `MyISAM` table *`tbl_name`*, there are three disk files.

File	Purpose
`tbl_name``.frm`	Table format (definition) file
`tbl_name``.MYD`	Data file
`tbl_name``.MYI`	Index file

Chapter 15, *Alternative Storage Engines*, describes what files each storage engine creates to represent tables. If a table name contains special characters, the names for the table files contain encoded versions of those characters as described in Section 9.2.3, “Mapping of Identifiers to File Names”.

13.1.17.3 CREATE TEMPORARY TABLE Syntax

You can use the `TEMPORARY` keyword when creating a table. A `TEMPORARY` table is visible only within the current session, and is dropped automatically when the session is closed. This means that two different sessions can use the same temporary table name without conflicting with each other or with an existing non-`TEMPORARY` table of the same name. (The existing table is hidden until the temporary table is dropped.)

`CREATE TABLE` causes an implicit commit, except when used with the `TEMPORARY` keyword. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

`TEMPORARY` tables have a very loose relationship with databases (schemas). Dropping a database does not automatically drop any `TEMPORARY` tables created within that database. Also, you can create a `TEMPORARY` table in a nonexistent database if you qualify the table name with the database name in the `CREATE TABLE` statement. In this case, all subsequent references to the table must be qualified with the database name.

To create a temporary table, you must have the `CREATE TEMPORARY TABLES` privilege. However, other operations on a temporary table, such as `INSERT`, `UPDATE`, or `SELECT`, require additional privileges for those operations for the database containing the temporary table, or for the nontemporary table of the same name.

To keep privileges for temporary and nontemporary tables separate, a common workaround for this situation is to create a database dedicated to the use of temporary tables. Then for that database, a user can be granted the `CREATE TEMPORARY TABLES` privilege, along with any other privileges required for temporary table operations done by that user.

13.1.17.4 CREATE TABLE ... LIKE Syntax

Use `CREATE TABLE ... LIKE` to create an empty table based on the definition of another table, including any column attributes and indexes defined in the original table:

```
CREATE TABLE new_tbl LIKE orig_tbl;
```

The copy is created using the same version of the table storage format as the original table. The `SELECT` privilege is required on the original table.

`LIKE` works only for base tables, not for views.

Important

Beginning with MySQL 5.5.3, you cannot execute `CREATE TABLE` or `CREATE TABLE ... LIKE` while a `LOCK TABLES` statement is in effect.

Also as of MySQL 5.5.3, `CREATE TABLE ... LIKE` makes the same checks as `CREATE TABLE` and does not just copy the `.frm` file. This means that if the current SQL mode is different from the mode in effect when the original table was created, the table definition might be considered invalid for the new mode and the statement will fail.

`CREATE TABLE ... LIKE` does not preserve any `DATA DIRECTORY` or `INDEX DIRECTORY` table options that were specified for the original table, or any foreign key definitions.

If the original table is a `TEMPORARY` table, `CREATE TABLE ... LIKE` does not preserve `TEMPORARY`. To create a `TEMPORARY` destination table, use `CREATE TEMPORARY TABLE ... LIKE`.

13.1.17.5 CREATE TABLE ... SELECT Syntax

You can create one table from another by adding a `SELECT` statement at the end of the `CREATE TABLE` statement:

```
CREATE TABLE new_tbl [AS] SELECT * FROM orig_tbl;
```

MySQL creates new columns for all elements in the `SELECT`. For example:

```
mysql> CREATE TABLE test (a INT NOT NULL AUTO_INCREMENT,
    ->        PRIMARY KEY (a), KEY(b))
    ->        ENGINE=MyISAM SELECT b,c FROM test2;
```

This creates a `MyISAM` table with three columns, `a`, `b`, and `c`. The `ENGINE` option is part of the `CREATE TABLE` statement, and should not be used following the `SELECT`; this would result in a syntax error. The same is true for other `CREATE TABLE` options such as `CHARSET`.

Notice that the columns from the `SELECT` statement are appended to the right side of the table, not overlapped onto it. Take the following example:

```
mysql> SELECT * FROM foo;
+---+
| n |
+---+
| 1 |
+---+

mysql> CREATE TABLE bar (m INT) SELECT n FROM foo;
Query OK, 1 row affected (0.02 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM bar;
+------+---+
```

```
| m    | n |
+------+---+
| NULL | 1 |
+------+---+
1 row in set (0.00 sec)
```

For each row in table `foo`, a row is inserted in `bar` with the values from `foo` and default values for the new columns.

In a table resulting from `CREATE TABLE ... SELECT`, columns named only in the `CREATE TABLE` part come first. Columns named in both parts or only in the `SELECT` part come after that. The data type of `SELECT` columns can be overridden by also specifying the column in the `CREATE TABLE` part.

If any errors occur while copying the data to the table, it is automatically dropped and not created.

You can precede the `SELECT` by `IGNORE` or `REPLACE` to indicate how to handle rows that duplicate unique key values. With `IGNORE`, rows that duplicate an existing row on a unique key value are discarded. With `REPLACE`, new rows replace rows that have the same unique key value. If neither `IGNORE` nor `REPLACE` is specified, duplicate unique key values result in an error.

Because the ordering of the rows in the underlying `SELECT` statements cannot always be determined, `CREATE TABLE ... IGNORE SELECT` and `CREATE TABLE ... REPLACE SELECT` statements in MySQL 5.5.18 and later are flagged as unsafe for statement-based replication. With this change, such statements produce a warning in the error log when using statement-based mode and are written to the binary log using the row-based format when using `MIXED` mode. See also Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

`CREATE TABLE ... SELECT` does not automatically create any indexes for you. This is done intentionally to make the statement as flexible as possible. If you want to have indexes in the created table, you should specify these before the `SELECT` statement:

```
mysql> CREATE TABLE bar (UNIQUE (n)) SELECT n FROM foo;
```

Some conversion of data types might occur. For example, the `AUTO_INCREMENT` attribute is not preserved, and `VARCHAR` columns can become `CHAR` columns. Retrained attributes are `NULL` (or `NOT NULL`) and, for those columns that have them, `CHARACTER SET`, `COLLATION`, `COMMENT`, and the `DEFAULT` clause.

When creating a table with `CREATE TABLE ... SELECT`, make sure to alias any function calls or expressions in the query. If you do not, the `CREATE` statement might fail or result in undesirable column names.

```
CREATE TABLE artists_and_works
  SELECT artist.name, COUNT(work.artist_id) AS number_of_works
  FROM artist LEFT JOIN work ON artist.id = work.artist_id
  GROUP BY artist.id;
```

You can also explicitly specify the data type for a column in the created table:

```
CREATE TABLE foo (a TINYINT NOT NULL) SELECT b+1 AS a FROM bar;
```

For `CREATE TABLE ... SELECT`, if `IF NOT EXISTS` is given and the destination table already exists, the result is version dependent. Before MySQL 5.5.6, MySQL handles the statement as follows:

- The table definition given in the `CREATE TABLE` part is ignored. No error occurs, even if the definition does not match that of the existing table. MySQL attempts to insert the rows from the `SELECT` part anyway.
- If there is a mismatch between the number of columns in the table and the number of columns produced by the `SELECT` part, the selected values are assigned to the rightmost columns. For

example, if the table contains *n* columns and the SELECT produces *m* columns, where *m* < *n*, the selected values are assigned to the *m* rightmost columns in the table. Each of the initial *n* − *m* columns is assigned its default value, either that specified explicitly in the column definition or the implicit column data type default if the definition contains no default. If the SELECT part produces too many columns (*m* > *n*), an error occurs.

- If strict SQL mode is enabled and any of these initial columns do not have an explicit default value, the statement fails with an error.

The following example illustrates IF NOT EXISTS handling:

```
mysql> CREATE TABLE t1 (i1 INT DEFAULT 0, i2 INT, i3 INT, i4 INT);
Query OK, 0 rows affected (0.05 sec)

mysql> CREATE TABLE IF NOT EXISTS t1 (c1 CHAR(10)) SELECT 1, 2;
Query OK, 1 row affected, 1 warning (0.01 sec)
Records: 1  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM t1;
+------+------+------+------+
| i1   | i2   | i3   | i4   |
+------+------+------+------+
|    0 | NULL |    1 |    2 |
+------+------+------+------+
1 row in set (0.00 sec)
```

As of MySQL 5.5.6, handling of CREATE TABLE IF NOT EXISTS ... SELECT statements was changed for the case that the destination table already exists. This change also involves a change in MySQL 5.1 beginning with 5.1.51.

- Previously, for CREATE TABLE IF NOT EXISTS ... SELECT, MySQL produced a warning that the table exists, but inserted the rows and wrote the statement to the binary log anyway. By contrast, CREATE TABLE ... SELECT (without IF NOT EXISTS) failed with an error, but MySQL inserted no rows and did not write the statement to the binary log.
- MySQL now handles both statements the same way when the destination table exists, in that neither statement inserts rows or is written to the binary log. The difference between them is that MySQL produces a warning when IF NOT EXISTS is present and an error when it is not.

This change means that, for the preceding example, the CREATE TABLE IF NOT EXISTS ... SELECT statement inserts nothing into the destination table as of MySQL 5.5.6.

This change in handling of IF NOT EXISTS results in an incompatibility for statement-based replication from a MySQL 5.1 master with the original behavior and a MySQL 5.5 slave with the new behavior. Suppose that CREATE TABLE IF NOT EXISTS ... SELECT is executed on the master and the destination table exists. The result is that rows are inserted on the master but not on the slave. (Row-based replication does not have this problem.)

To address this issue, statement-based binary logging for CREATE TABLE IF NOT EXISTS ... SELECT is changed in MySQL 5.1 as of 5.1.51:

- If the destination table does not exist, there is no change: The statement is logged as is.
- If the destination table does exist, the statement is logged as the equivalent pair of CREATE TABLE IF NOT EXISTS and INSERT ... SELECT statements. (If the SELECT in the original statement is preceded by IGNORE or REPLACE, the INSERT becomes INSERT IGNORE or REPLACE, respectively.)

This change provides forward compatibility for statement-based replication from MySQL 5.1 to 5.5 because when the destination table exists, the rows will be inserted on both the master and slave. To take advantage of this compatibility measure, the 5.1 server must be at least 5.1.51 and the 5.5 server must be at least 5.5.6.

To upgrade an existing 5.1-to-5.5 replication scenario, upgrade the master first to 5.1.51 or higher. Note that this differs from the usual replication upgrade advice of upgrading the slave first.

A workaround for applications that wish to achieve the original effect (rows inserted regardless of whether the destination table exists) is to use `CREATE TABLE IF NOT EXISTS` and `INSERT ... SELECT` statements rather than `CREATE TABLE IF NOT EXISTS ... SELECT` statements.

Along with the change just described, the following related change was made: Previously, if an existing view was named as the destination table for `CREATE TABLE IF NOT EXISTS ... SELECT`, rows were inserted into the underlying base table and the statement was written to the binary log. As of MySQL 5.1.51 and 5.5.6, nothing is inserted or logged.

To ensure that the binary log can be used to re-create the original tables, MySQL does not permit concurrent inserts during `CREATE TABLE ... SELECT`.

13.1.17.6 Using FOREIGN KEY Constraints

MySQL supports foreign keys, which let you cross-reference related data across tables, and foreign key constraints, which help keep this spread-out data consistent. The essential syntax for a foreign key constraint definition in a `CREATE TABLE` or `ALTER TABLE` statement looks like this:

```
[CONSTRAINT [symbol]] FOREIGN KEY
    [index_name] (index_col_name, ...)
    REFERENCES tbl_name (index_col_name,...)
    [ON DELETE reference_option]
    [ON UPDATE reference_option]

reference_option:
    RESTRICT | CASCADE | SET NULL | NO ACTION | SET DEFAULT
```

`index_name` represents a foreign key ID. The *`index_name`* value is ignored if there is already an explicitly defined index on the child table that can support the foreign key. Otherwise, MySQL implicitly creates a foreign key index that is named according to the following rules:

- If defined, the `CONSTRAINT` *`symbol`* value is used. Otherwise, the `FOREIGN KEY` *`index_name`* value is used.
- If neither a `CONSTRAINT` *`symbol`* or `FOREIGN KEY` *`index_name`* is defined, the foreign key index name is generated using the name of the referencing foreign key column.

Foreign keys definitions are subject to the following conditions:

- Foreign key relationships involve a parent table that holds the central data values, and a child table with identical values pointing back to its parent. The `FOREIGN KEY` clause is specified in the child table. The parent and child tables must use the same storage engine. They must not be `TEMPORARY` tables.

  In MySQL 5.5, creation of a foreign key constraint requires at least one of the `SELECT`, `INSERT`, `UPDATE`, `DELETE`, or `REFERENCES` privileges for the parent table as of 5.5.41.

- Corresponding columns in the foreign key and the referenced key must have similar data types. *The size and sign of integer types must be the same*. The length of string types need not be the same. For nonbinary (character) string columns, the character set and collation must be the same.

- When `foreign_key_checks` is enabled, which is the default setting, character set conversion is not permitted on tables that include a character string column used in a foreign key constraint. The workaround is described in Section 13.1.7, “ALTER TABLE Syntax”.

- MySQL requires indexes on foreign keys and referenced keys so that foreign key checks can be fast and not require a table scan. In the referencing table, there must be an index where the foreign key columns are listed as the *first* columns in the same order. Such an index is created on the referencing table automatically if it does not exist. This index might be silently dropped later, if you

create another index that can be used to enforce the foreign key constraint. *`index_name`*, if given, is used as described previously.

- `InnoDB` permits a foreign key to reference any column or group of columns. However, in the referenced table, there must be an index where the referenced columns are listed as the *first* columns in the same order.
- Index prefixes on foreign key columns are not supported. One consequence of this is that `BLOB` and `TEXT` columns cannot be included in a foreign key because indexes on those columns must always include a prefix length.
- If the `CONSTRAINT` *`symbol`* clause is given, the *`symbol`* value, if used, must be unique in the database. A duplicate *`symbol`* will result in an error similar to: `ERROR 1005 (HY000): Can't create table 'test.#sql-211d_3' (errno: 121)`. If the clause is not given, or a *`symbol`* is not included following the `CONSTRAINT` keyword, a name for the constraint is created automatically.
- `InnoDB` does not currently support foreign keys for tables with user-defined partitioning. This includes both parent and child tables.

Referential Actions

This section describes how foreign keys help guarantee referential integrity.

For storage engines supporting foreign keys, MySQL rejects any `INSERT` or `UPDATE` operation that attempts to create a foreign key value in a child table if there is no a matching candidate key value in the parent table.

When an `UPDATE` or `DELETE` operation affects a key value in the parent table that has matching rows in the child table, the result depends on the *referential action* specified using `ON UPDATE` and `ON DELETE` subclauses of the `FOREIGN KEY` clause. MySQL supports five options regarding the action to be taken, listed here:

- `CASCADE`: Delete or update the row from the parent table, and automatically delete or update the matching rows in the child table. Both `ON DELETE CASCADE` and `ON UPDATE CASCADE` are supported. Between two tables, do not define several `ON UPDATE CASCADE` clauses that act on the same column in the parent table or in the child table.

  Note

  Cascaded foreign key actions do not activate triggers.

- `SET NULL`: Delete or update the row from the parent table, and set the foreign key column or columns in the child table to `NULL`. Both `ON DELETE SET NULL` and `ON UPDATE SET NULL` clauses are supported.

  If you specify a `SET NULL` action, *make sure that you have not declared the columns in the child table as* *`NOT NULL`*.

- `RESTRICT`: Rejects the delete or update operation for the parent table. Specifying `RESTRICT` (or `NO ACTION`) is the same as omitting the `ON DELETE` or `ON UPDATE` clause.
- `NO ACTION`: A keyword from standard SQL. In MySQL, equivalent to `RESTRICT`. The MySQL Server rejects the delete or update operation for the parent table if there is a related foreign key value in the referenced table. Some database systems have deferred checks, and `NO ACTION` is a deferred check. In MySQL, foreign key constraints are checked immediately, so `NO ACTION` is the same as `RESTRICT`.
- `SET DEFAULT`: This action is recognized by the MySQL parser, but `InnoDB` rejects table definitions containing `ON DELETE SET DEFAULT` or `ON UPDATE SET DEFAULT` clauses.

For an `ON DELETE` or `ON UPDATE` that is not specified, the default action is always `RESTRICT`.

MySQL supports foreign key references between one column and another within a table. (A column cannot have a foreign key reference to itself.) In these cases, “child table records” really refers to dependent records within the same table.

Examples of Foreign Key Clauses

Here is a simple example that relates `parent` and `child` tables through a single-column foreign key:

```
CREATE TABLE parent (
    id INT NOT NULL,
    PRIMARY KEY (id)
) ENGINE=INNODB;

CREATE TABLE child (
    id INT,
    parent_id INT,
    INDEX par_ind (parent_id),
    FOREIGN KEY (parent_id)
        REFERENCES parent(id)
        ON DELETE CASCADE
) ENGINE=INNODB;
```

A more complex example in which a `product_order` table has foreign keys for two other tables. One foreign key references a two-column index in the `product` table. The other references a single-column index in the `customer` table:

```
CREATE TABLE product (
    category INT NOT NULL, id INT NOT NULL,
    price DECIMAL,
    PRIMARY KEY(category, id)
)   ENGINE=INNODB;

CREATE TABLE customer (
    id INT NOT NULL,
    PRIMARY KEY (id)
)   ENGINE=INNODB;

CREATE TABLE product_order (
    no INT NOT NULL AUTO_INCREMENT,
    product_category INT NOT NULL,
    product_id INT NOT NULL,
    customer_id INT NOT NULL,

    PRIMARY KEY(no),
    INDEX (product_category, product_id),
    INDEX (customer_id),

    FOREIGN KEY (product_category, product_id)
      REFERENCES product(category, id)
      ON UPDATE CASCADE ON DELETE RESTRICT,

    FOREIGN KEY (customer_id)
      REFERENCES customer(id)
)   ENGINE=INNODB;
```

Adding foreign keys

You can add a new foreign key constraint to an existing table by using `ALTER TABLE`. The syntax relating to foreign keys for this statement is shown here:

```
ALTER TABLE tbl_name
    ADD [CONSTRAINT [symbol]] FOREIGN KEY
    [index_name] (index_col_name, ...)
    REFERENCES tbl_name (index_col_name,...)
    [ON DELETE reference_option]
```

```
    [ON UPDATE reference_option]
```

The foreign key can be self referential (referring to the same table). When you add a foreign key constraint to a table using `ALTER TABLE`, *remember to create the required indexes first.*

Dropping Foreign Keys

You can also use `ALTER TABLE` to drop foreign keys, using the syntax shown here:

```
ALTER TABLE tbl_name DROP FOREIGN KEY fk_symbol;
```

If the `FOREIGN KEY` clause included a `CONSTRAINT` name when you created the foreign key, you can refer to that name to drop the foreign key. Otherwise, the *`fk_symbol`* value is generated internally when the foreign key is created. To find out the symbol value when you want to drop a foreign key, use a `SHOW CREATE TABLE` statement, as shown here:

```
mysql> SHOW CREATE TABLE ibtest11c\G
*************************** 1. row ***************************
       Table: ibtest11c
Create Table: CREATE TABLE `ibtest11c` (
  `A` int(11) NOT NULL auto_increment,
  `D` int(11) NOT NULL default '0',
  `B` varchar(200) NOT NULL default '',
  `C` varchar(175) default NULL,
  PRIMARY KEY  (`A`,`D`,`B`),
  KEY `B` (`B`,`C`),
  KEY `C` (`C`),
  CONSTRAINT `0_38775` FOREIGN KEY (`A`, `D`)
REFERENCES `ibtest11a` (`A`, `D`)
ON DELETE CASCADE ON UPDATE CASCADE,
  CONSTRAINT `0_38776` FOREIGN KEY (`B`, `C`)
REFERENCES `ibtest11a` (`B`, `C`)
ON DELETE CASCADE ON UPDATE CASCADE
) ENGINE=INNODB CHARSET=latin1
1 row in set (0.01 sec)

mysql> ALTER TABLE ibtest11c DROP FOREIGN KEY `0_38775`;
```

Adding and dropping a foreign key in separate clauses of a single `ALTER TABLE` statement may be problematic in some cases and is therefore unsupported. Use separate statements for each operation.

If an `ALTER TABLE` statement results in changes to column values (for example, because a column is truncated), MySQL's foreign key constraint checks do not notice possible violations caused by changing the values.

Foreign Keys and Other MySQL Statements

Table and column identifiers in a `FOREIGN KEY ... REFERENCES ...` clause can be quoted within backticks (`` ` ``). Alternatively, double quotation marks (`"`) can be used if the `ANSI_QUOTES` SQL mode is enabled. The setting of the `lower_case_table_names` system variable is also taken into account.

You can view a child table's foreign key definitions as part of the output of the `SHOW CREATE TABLE` statement:

```
SHOW CREATE TABLE tbl_name;
```

You can also obtain information about foreign keys by querying the `INFORMATION_SCHEMA.KEY_COLUMN_USAGE` table.

`mysqldump` produces correct definitions of tables in the dump file, including the foreign keys for child tables.

To make it easier to reload dump files for tables that have foreign key relationships, `mysqldump` automatically includes a statement in the dump output to set `foreign_key_checks` to 0. This avoids

problems with tables having to be reloaded in a particular order when the dump is reloaded. It is also possible to set this variable manually:

```
mysql> SET foreign_key_checks = 0;
mysql> SOURCE dump_file_name;
mysql> SET foreign_key_checks = 1;
```

This enables you to import the tables in any order if the dump file contains tables that are not correctly ordered for foreign keys. It also speeds up the import operation. Setting `foreign_key_checks` to 0 can also be useful for ignoring foreign key constraints during `LOAD DATA` and `ALTER TABLE` operations. However, even if `foreign_key_checks = 0`, MySQL does not permit the creation of a foreign key constraint where a column references a nonmatching column type. Also, if a table has foreign key constraints, `ALTER TABLE` cannot be used to alter the table to use another storage engine. To change the storage engine, you must drop any foreign key constraints first.

You cannot issue `DROP TABLE` for a table that is referenced by a `FOREIGN KEY` constraint, unless you do `SET foreign_key_checks = 0`. When you drop a table, any constraints that were defined in the statement used to create that table are also dropped.

If you re-create a table that was dropped, it must have a definition that conforms to the foreign key constraints referencing it. It must have the correct column names and types, and it must have indexes on the referenced keys, as stated earlier. If these are not satisfied, MySQL returns Error 1005 and refers to Error 150 in the error message, which means that a foreign key constraint was not correctly formed. Similarly, if an `ALTER TABLE` fails due to Error 150, this means that a foreign key definition would be incorrectly formed for the altered table.

For `InnoDB` tables, you can obtain a detailed explanation of the most recent `InnoDB` foreign key error in the MySQL Server, by checking the output of `SHOW ENGINE INNODB STATUS`.

Important

For users familiar with the ANSI/ISO SQL Standard, please note that no storage engine, including `InnoDB`, recognizes or enforces the `MATCH` clause used in referential-integrity constraint definitions. Use of an explicit `MATCH` clause will not have the specified effect, and also causes `ON DELETE` and `ON UPDATE` clauses to be ignored. For these reasons, specifying `MATCH` should be avoided.

The `MATCH` clause in the SQL standard controls how `NULL` values in a composite (multiple-column) foreign key are handled when comparing to a primary key. MySQL essentially implements the semantics defined by `MATCH SIMPLE`, which permit a foreign key to be all or partially `NULL`. In that case, the (child table) row containing such a foreign key is permitted to be inserted, and does not match any row in the referenced (parent) table. It is possible to implement other semantics using triggers.

Additionally, MySQL requires that the referenced columns be indexed for performance reasons. However, the system does not enforce a requirement that the referenced columns be `UNIQUE` or be declared `NOT NULL`. The handling of foreign key references to nonunique keys or keys that contain `NULL` values is not well defined for operations such as `UPDATE` or `DELETE CASCADE`. You are advised to use foreign keys that reference only `UNIQUE` (including `PRIMARY`) and `NOT NULL` keys.

Furthermore, MySQL parses but ignores “inline `REFERENCES` specifications” (as defined in the SQL standard) where the references are defined as part of the column specification. MySQL accepts `REFERENCES` clauses only when specified as part of a separate `FOREIGN KEY` specification. For storage engines that do not support foreign keys (such as `MyISAM`), MySQL Server parses and ignores foreign key specifications.

13.1.17.7 Silent Column Specification Changes

In some cases, MySQL silently changes column specifications from those given in a `CREATE TABLE` or `ALTER TABLE` statement. These might be changes to a data type, to attributes associated with a data type, or to an index specification.

All changes are subject to the internal row-size limit of 65,535 bytes, which may cause some attempts at data type changes to fail. See Section C.10.4, “Limits on Table Column Count and Row Size”.

- `TIMESTAMP` display sizes are discarded.

  Also note that `TIMESTAMP` columns are `NOT NULL` by default.

- Columns that are part of a `PRIMARY KEY` are made `NOT NULL` even if not declared that way.

- Trailing spaces are automatically deleted from `ENUM` and `SET` member values when the table is created.

- MySQL maps certain data types used by other SQL database vendors to MySQL types. See Section 11.9, “Using Data Types from Other Database Engines”.

- If you include a `USING` clause to specify an index type that is not permitted for a given storage engine, but there is another index type available that the engine can use without affecting query results, the engine uses the available type.

- If strict SQL mode is not enabled, a `VARCHAR` column with a length specification greater than 65535 is converted to `TEXT`, and a `VARBINARY` column with a length specification greater than 65535 is converted to `BLOB`. Otherwise, an error occurs in either of these cases.

- Specifying the `CHARACTER SET binary` attribute for a character data type causes the column to be created as the corresponding binary data type: `CHAR` becomes `BINARY`, `VARCHAR` becomes `VARBINARY`, and `TEXT` becomes `BLOB`. For the `ENUM` and `SET` data types, this does not occur; they are created as declared. Suppose that you specify a table using this definition:

  ```
  CREATE TABLE t
  (
    c1 VARCHAR(10) CHARACTER SET binary,
    c2 TEXT CHARACTER SET binary,
    c3 ENUM('a','b','c') CHARACTER SET binary
  );
  ```

  The resulting table has this definition:

  ```
  CREATE TABLE t
  (
    c1 VARBINARY(10),
    c2 BLOB,
    c3 ENUM('a','b','c') CHARACTER SET binary
  );
  ```

To see whether MySQL used a data type other than the one you specified, issue a `DESCRIBE` or `SHOW CREATE TABLE` statement after creating or altering the table.

Certain other data type changes can occur if you compress a table using `myisampack`. See Section 15.3.3.3, “Compressed Table Characteristics”.

13.1.18 CREATE TABLESPACE Syntax

```
CREATE TABLESPACE tablespace_name
    ADD DATAFILE 'file_name'
    USE LOGFILE GROUP logfile_group
    [EXTENT_SIZE [=] extent_size]
```

```
    [INITIAL_SIZE [=] initial_size]
    [AUTOEXTEND_SIZE [=] autoextend_size]
    [MAX_SIZE [=] max_size]
    [NODEGROUP [=] nodegroup_id]
    [WAIT]
    [COMMENT [=] comment_text]
    ENGINE [=] engine_name
```

This statement is used to create a tablespace, which can contain one or more data files, providing storage space for tables. One data file is created and added to the tablespace using this statement. Additional data files may be added to the tablespace by using the `ALTER TABLESPACE` statement (see Section 13.1.8, “ALTER TABLESPACE Syntax”). For rules covering the naming of tablespaces, see Section 9.2, “Schema Object Names”.

Note

All NDB Cluster Disk Data objects share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a log file group with the same name, or a tablespace and a data file with the same name.

A log file group of one or more `UNDO` log files must be assigned to the tablespace to be created with the `USE LOGFILE GROUP` clause. *`logfile_group`* must be an existing log file group created with `CREATE LOGFILE GROUP` (see Section 13.1.14, “CREATE LOGFILE GROUP Syntax”). Multiple tablespaces may use the same log file group for `UNDO` logging.

The `EXTENT_SIZE` sets the size, in bytes, of the extents used by any files belonging to the tablespace. The default value is 1M. The minimum size is 32K, and theoretical maximum is 2G, although the practical maximum size depends on a number of factors. In most cases, changing the extent size does not have any measurable effect on performance, and the default value is recommended for all but the most unusual situations.

An *extent* is a unit of disk space allocation. One extent is filled with as much data as that extent can contain before another extent is used. In theory, up to 65,535 (64K) extents may used per data file; however, the recommended maximum is 32,768 (32K). The recommended maximum size for a single data file is 32G—that is, 32K extents × 1 MB per extent. In addition, once an extent is allocated to a given partition, it cannot be used to store data from a different partition; an extent cannot store data from more than one partition. This means, for example that a tablespace having a single datafile whose `INITIAL_SIZE` is 256 MB and whose `EXTENT_SIZE` is 128M has just two extents, and so can be used to store data from at most two different disk data table partitions.

You can see how many extents remain free in a given data file by querying the `INFORMATION_SCHEMA.FILES` table, and so derive an estimate for how much space remains free in the file. For further discussion and examples, see Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”.

The `INITIAL_SIZE` parameter sets the data file's total size in bytes. Once the file has been created, its size cannot be changed; however, you can add more data files to the tablespace using `ALTER TABLESPACE ... ADD DATAFILE`. See Section 13.1.8, “ALTER TABLESPACE Syntax”.

`INITIAL_SIZE` is optional; its default value is 134217728 (128 MB).

On 32-bit systems, the maximum supported value for `INITIAL_SIZE` is 4294967296 (4 GB). (Bug #29186)

When setting `EXTENT_SIZE`, you may optionally follow the number with a one-letter abbreviation for an order of magnitude, similar to those used in `my.cnf`. Generally, this is one of the letters `M` (for megabytes) or `G` (for gigabytes). In MySQL NDB Cluster 7.2.14 and later, these abbreviations are also supported when specifying `INITIAL_SIZE` as well. (Bug #13116514, Bug #16104705, Bug #62858)

`INITIAL_SIZE`, `EXTENT_SIZE`, and `UNDO_BUFFER_SIZE` are subject to rounding as follows:

- `EXTENT_SIZE` and `UNDO_BUFFER_SIZE` are each rounded up to the nearest whole multiple of 32K.
- `INITIAL_SIZE` is rounded *down* to the nearest whole multiple of 32K.

  For data files, *INITIAL_SIZE* is subject to further rounding; the result just obtained is rounded up to the nearest whole multiple of `EXTENT_SIZE` (after any rounding).

The rounding just described is done explicitly, and a warning is issued by the MySQL Server when any such rounding is performed. The rounded values are also used by the NDB kernel for calculating `INFORMATION_SCHEMA.FILES` column values and other purposes. However, to avoid an unexpected result, we suggest that you always use whole multiples of 32K in specifying these options.

`AUTOEXTEND_SIZE`, `MAX_SIZE`, `NODEGROUP`, `WAIT`, and `COMMENT` are parsed but ignored, and so currently have no effect. These options are intended for future expansion.

The `ENGINE` parameter determines the storage engine which uses this tablespace, with *`engine_name`* being the name of the storage engine. Currently, *`engine_name`* must be one of the values `NDB` or `NDBCLUSTER`.

When `CREATE TABLESPACE` is used with `ENGINE = NDB`, a tablespace and associated data file are created on each Cluster data node. You can verify that the data files were created and obtain information about them by querying the `INFORMATION_SCHEMA.FILES` table. For example:

```
mysql> SELECT LOGFILE_GROUP_NAME, FILE_NAME, EXTRA
    -> FROM INFORMATION_SCHEMA.FILES
    -> WHERE TABLESPACE_NAME = 'newts' AND FILE_TYPE = 'DATAFILE';
+--------------------+-------------+----------------+
| LOGFILE_GROUP_NAME | FILE_NAME   | EXTRA          |
+--------------------+-------------+----------------+
| lg_3               | newdata.dat | CLUSTER_NODE=3 |
| lg_3               | newdata.dat | CLUSTER_NODE=4 |
+--------------------+-------------+----------------+
2 rows in set (0.01 sec)
```

(See Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”.)

`CREATE TABLESPACE` is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, “NDB Cluster Disk Data Tables”.

13.1.19 CREATE TRIGGER Syntax

```
CREATE
    [DEFINER = { user | CURRENT_USER }]
    TRIGGER trigger_name
    trigger_time trigger_event
    ON tbl_name FOR EACH ROW
    trigger_body

trigger_time: { BEFORE | AFTER }

trigger_event: { INSERT | UPDATE | DELETE }
```

This statement creates a new trigger. A trigger is a named database object that is associated with a table, and that activates when a particular event occurs for the table. The trigger becomes associated with the table named *`tbl_name`*, which must refer to a permanent table. You cannot associate a trigger with a `TEMPORARY` table or a view.

Trigger names exist in the schema namespace, meaning that all triggers must have unique names within a schema. Triggers in different schemas can have the same name.

This section describes `CREATE TRIGGER` syntax. For additional discussion, see Section 20.3.1, “Trigger Syntax and Examples”.

`CREATE TRIGGER` requires the `TRIGGER` privilege for the table associated with the trigger. The statement might also require the `SUPER` privilege, depending on the `DEFINER` value, as described later in this section. If binary logging is enabled, `CREATE TRIGGER` might require the `SUPER` privilege, as described in Section 20.7, “Binary Logging of Stored Programs”.

The `DEFINER` clause determines the security context to be used when checking access privileges at trigger activation time, as described later in this section.

`trigger_time` is the trigger action time. It can be `BEFORE` or `AFTER` to indicate that the trigger activates before or after each row to be modified.

Basic column value checks occur prior to trigger activation, so you cannot use `BEFORE` triggers to convert values inappropriate for the column type to valid values.

`trigger_event` indicates the kind of operation that activates the trigger. These *`trigger_event`* values are permitted:

- `INSERT`: The trigger activates whenever a new row is inserted into the table; for example, through `INSERT`, `LOAD DATA`, and `REPLACE` statements.
- `UPDATE`: The trigger activates whenever a row is modified; for example, through `UPDATE` statements.
- `DELETE`: The trigger activates whenever a row is deleted from the table; for example, through `DELETE` and `REPLACE` statements. `DROP TABLE` and `TRUNCATE TABLE` statements on the table do *not* activate this trigger, because they do not use `DELETE`. Dropping a partition does not activate `DELETE` triggers, either.

The *`trigger_event`* does not represent a literal type of SQL statement that activates the trigger so much as it represents a type of table operation. For example, an `INSERT` trigger activates not only for `INSERT` statements but also `LOAD DATA` statements because both statements insert rows into a table.

A potentially confusing example of this is the `INSERT INTO ... ON DUPLICATE KEY UPDATE ...` syntax: a `BEFORE INSERT` trigger activates for every row, followed by either an `AFTER INSERT` trigger or both the `BEFORE UPDATE` and `AFTER UPDATE` triggers, depending on whether there was a duplicate key for the row.

Note

Cascaded foreign key actions do not activate triggers.

There cannot be multiple triggers for a given table that have the same trigger event and action time. For example, you cannot have two `BEFORE UPDATE` triggers for a table. But you can have a `BEFORE UPDATE` and a `BEFORE INSERT` trigger, or a `BEFORE UPDATE` and an `AFTER UPDATE` trigger.

`trigger_body` is the statement to execute when the trigger activates. To execute multiple statements, use the `BEGIN ... END` compound statement construct. This also enables you to use the same statements that are permissible within stored routines. See Section 13.6.1, “BEGIN ... END Compound-Statement Syntax”. Some statements are not permitted in triggers; see Section C.1, “Restrictions on Stored Programs”.

Within the trigger body, you can refer to columns in the subject table (the table associated with the trigger) by using the aliases `OLD` and `NEW`. `OLD.`*`col_name`* refers to a column of an existing row before it is updated or deleted. `NEW.`*`col_name`* refers to the column of a new row to be inserted or an existing row after it is updated.

MySQL stores the `sql_mode` system variable setting in effect when a trigger is created, and always executes the trigger body with this setting in force, *regardless of the current server SQL mode when the trigger begins executing*.

The `DEFINER` clause specifies the MySQL account to be used when checking access privileges at trigger activation time. If a *`user`* value is given, it should be a MySQL account specified as

'user_name'@'host_name', CURRENT_USER, or CURRENT_USER(). The default DEFINER value is the user who executes the CREATE TRIGGER statement. This is the same as specifying DEFINER = CURRENT_USER explicitly.

If you specify the DEFINER clause, these rules determine the valid DEFINER user values:

- If you do not have the SUPER privilege, the only permitted *user* value is your own account, either specified literally or by using CURRENT_USER. You cannot set the definer to some other account.
- If you have the SUPER privilege, you can specify any syntactically valid account name. If the account does not exist, a warning is generated.
- Although it is possible to create a trigger with a nonexistent DEFINER account, it is not a good idea for such triggers to be activated until the account actually does exist. Otherwise, the behavior with respect to privilege checking is undefined.

MySQL takes the DEFINER user into account when checking trigger privileges as follows:

- At CREATE TRIGGER time, the user who issues the statement must have the TRIGGER privilege.
- At trigger activation time, privileges are checked against the DEFINER user. This user must have these privileges:
  - The TRIGGER privilege for the subject table.
  - The SELECT privilege for the subject table if references to table columns occur using OLD.*col_name* or NEW.*col_name* in the trigger body.
  - The UPDATE privilege for the subject table if table columns are targets of SET NEW.*col_name* = *value* assignments in the trigger body.
  - Whatever other privileges normally are required for the statements executed by the trigger.

For more information about trigger security, see Section 20.6, “Access Control for Stored Programs and Views”.

Within a trigger body, the CURRENT_USER() function returns the account used to check privileges at trigger activation time. This is the DEFINER user, not the user whose actions caused the trigger to be activated. For information about user auditing within triggers, see Section 6.3.8, “SQL-Based MySQL Account Activity Auditing”.

If you use LOCK TABLES to lock a table that has triggers, the tables used within the trigger are also locked, as described in Section 13.3.5.2, “LOCK TABLES and Triggers”.

For additional discussion of trigger use, see Section 20.3.1, “Trigger Syntax and Examples”.

13.1.20 CREATE VIEW Syntax

```
CREATE
    [OR REPLACE]
    [ALGORITHM = {UNDEFINED | MERGE | TEMPTABLE}]
    [DEFINER = { user | CURRENT_USER }]
    [SQL SECURITY { DEFINER | INVOKER }]
    VIEW view_name [(column_list)]
    AS select_statement
    [WITH [CASCADED | LOCAL] CHECK OPTION]
```

The CREATE VIEW statement creates a new view, or replaces an existing view if the OR REPLACE clause is given. If the view does not exist, CREATE OR REPLACE VIEW is the same as CREATE VIEW. If the view does exist, CREATE OR REPLACE VIEW replaces it.

For information about restrictions on view use, see Section C.5, “Restrictions on Views”.

The *`select_statement`* is a `SELECT` statement that provides the definition of the view. (Selecting from the view selects, in effect, using the `SELECT` statement.) The *`select_statement`* can select from base tables or other views.

The view definition is “frozen” at creation time and is not affected by subsequent changes to the definitions of the underlying tables. For example, if a view is defined as `SELECT *` on a table, new columns added to the table later do not become part of the view, and columns dropped from the table will result in an error when selecting from the view.

The `ALGORITHM` clause affects how MySQL processes the view. The `DEFINER` and `SQL SECURITY` clauses specify the security context to be used when checking access privileges at view invocation time. The `WITH CHECK OPTION` clause can be given to constrain inserts or updates to rows in tables referenced by the view. These clauses are described later in this section.

The `CREATE VIEW` statement requires the `CREATE VIEW` privilege for the view, and some privilege for each column selected by the `SELECT` statement. For columns used elsewhere in the `SELECT` statement, you must have the `SELECT` privilege. If the `OR REPLACE` clause is present, you must also have the `DROP` privilege for the view. `CREATE VIEW` might also require the `SUPER` privilege, depending on the `DEFINER` value, as described later in this section.

When a view is referenced, privilege checking occurs as described later in this section.

A view belongs to a database. By default, a new view is created in the default database. To create the view explicitly in a given database, use *`db_name.view_name`* syntax to qualify the view name with the database name:

```
CREATE VIEW test.v AS SELECT * FROM t;
```

Unqualified table or view names in the `SELECT` statement are also interpreted with respect to the default database. A view can refer to tables or views in other databases by qualifying the table or view name with the appropriate database name.

Within a database, base tables and views share the same namespace, so a base table and a view cannot have the same name.

Columns retrieved by the `SELECT` statement can be simple references to table columns, or expressions that use functions, constant values, operators, and so forth.

A view must have unique column names with no duplicates, just like a base table. By default, the names of the columns retrieved by the `SELECT` statement are used for the view column names. To define explicit names for the view columns, specify the optional *`column_list`* clause as a list of comma-separated identifiers. The number of names in *`column_list`* must be the same as the number of columns retrieved by the `SELECT` statement.

A view can be created from many kinds of `SELECT` statements. It can refer to base tables or other views. It can use joins, `UNION`, and subqueries. The `SELECT` need not even refer to any tables:

```
CREATE VIEW v_today (today) AS SELECT CURRENT_DATE;
```

The following example defines a view that selects two columns from another table as well as an expression calculated from those columns:

```
mysql> CREATE TABLE t (qty INT, price INT);
mysql> INSERT INTO t VALUES(3, 50);
mysql> CREATE VIEW v AS SELECT qty, price, qty*price AS value FROM t;
mysql> SELECT * FROM v;
+------+-------+-------+
| qty  | price | value |
+------+-------+-------+
|    3 |    50 |   150 |
+------+-------+-------+
```

A view definition is subject to the following restrictions:

- The `SELECT` statement cannot contain a subquery in the `FROM` clause.
- The `SELECT` statement cannot refer to system variables or user-defined variables.
- Within a stored program, the `SELECT` statement cannot refer to program parameters or local variables.
- The `SELECT` statement cannot refer to prepared statement parameters.
- Any table or view referred to in the definition must exist. If, after the view has been created, a table or view that the definition refers to is dropped, use of the view results in an error. To check a view definition for problems of this kind, use the `CHECK TABLE` statement.
- The definition cannot refer to a `TEMPORARY` table, and you cannot create a `TEMPORARY` view.
- You cannot associate a trigger with a view.
- Aliases for column names in the `SELECT` statement are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters).

`ORDER BY` is permitted in a view definition, but it is ignored if you select from a view using a statement that has its own `ORDER BY` or filtering or grouping. When `ORDER BY` is combined with `LIMIT` or `OFFSET` in a view definition, the ordering is always enforced before the query result is used by the outer query, but it does not guarantee that the same ordering is used in the end result. As a workaround, add an `ORDER BY` clause to the outer query.

For other options or clauses in the definition, they are added to the options or clauses of the statement that references the view, but the effect is undefined. For example, if a view definition includes a `LIMIT` clause, and you select from the view using a statement that has its own `LIMIT` clause, it is undefined which limit applies. This same principle applies to options such as `ALL`, `DISTINCT`, or `SQL_SMALL_RESULT` that follow the `SELECT` keyword, and to clauses such as `INTO`, `FOR UPDATE`, `LOCK IN SHARE MODE`, and `PROCEDURE`.

The results obtained from a view may be affected if you change the query processing environment by changing system variables:

```
mysql> CREATE VIEW v (mycol) AS SELECT 'abc';
Query OK, 0 rows affected (0.01 sec)

mysql> SET sql_mode = '';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT "mycol" FROM v;
+-------+
| mycol |
+-------+
| mycol |
+-------+
1 row in set (0.01 sec)

mysql> SET sql_mode = 'ANSI_QUOTES';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT "mycol" FROM v;
+-------+
| mycol |
+-------+
| abc   |
+-------+
1 row in set (0.00 sec)
```

The `DEFINER` and `SQL SECURITY` clauses determine which MySQL account to use when checking access privileges for the view when a statement is executed that references the view. The valid `SQL`

SECURITY characteristic values are DEFINER (the default) and INVOKER. These indicate that the required privileges must be held by the user who defined or invoked the view, respectively.

If a *user* value is given for the DEFINER clause, it should be a MySQL account specified as *'user_name'@'host_name'*, CURRENT_USER, or CURRENT_USER(). The default DEFINER value is the user who executes the CREATE VIEW statement. This is the same as specifying DEFINER = CURRENT_USER explicitly.

If the DEFINER clause is present, these rules determine the valid DEFINER user values:

- If you do not have the SUPER privilege, the only valid *user* value is your own account, either specified literally or by using CURRENT_USER. You cannot set the definer to some other account.
- If you have the SUPER privilege, you can specify any syntactically valid account name. If the account does not exist, a warning is generated.
- Although it is possible to create a view with a nonexistent DEFINER account, an error occurs when the view is referenced if the SQL SECURITY value is DEFINER but the definer account does not exist.

For more information about view security, see Section 20.6, “Access Control for Stored Programs and Views”.

Within a view definition, CURRENT_USER returns the view's DEFINER value by default. For views defined with the SQL SECURITY INVOKER characteristic, CURRENT_USER returns the account for the view's invoker. For information about user auditing within views, see Section 6.3.8, “SQL-Based MySQL Account Activity Auditing”.

Within a stored routine that is defined with the SQL SECURITY DEFINER characteristic, CURRENT_USER returns the routine's DEFINER value. This also affects a view defined within such a routine, if the view definition contains a DEFINER value of CURRENT_USER.

MySQL checks view privileges like this:

- At view definition time, the view creator must have the privileges needed to use the top-level objects accessed by the view. For example, if the view definition refers to table columns, the creator must have some privilege for each column in the select list of the definition, and the SELECT privilege for each column used elsewhere in the definition. If the definition refers to a stored function, only the privileges needed to invoke the function can be checked. The privileges required at function invocation time can be checked only as it executes: For different invocations, different execution paths within the function might be taken.
- The user who references a view must have appropriate privileges to access it (SELECT to select from it, INSERT to insert into it, and so forth.)
- When a view has been referenced, privileges for objects accessed by the view are checked against the privileges held by the view DEFINER account or invoker, depending on whether the SQL SECURITY characteristic is DEFINER or INVOKER, respectively.
- If reference to a view causes execution of a stored function, privilege checking for statements executed within the function depend on whether the function SQL SECURITY characteristic is DEFINER or INVOKER. If the security characteristic is DEFINER, the function runs with the privileges of the DEFINER account. If the characteristic is INVOKER, the function runs with the privileges determined by the view's SQL SECURITY characteristic.

Example: A view might depend on a stored function, and that function might invoke other stored routines. For example, the following view invokes a stored function f():

```
CREATE VIEW v AS SELECT * FROM t WHERE t.id = f(t.name);
```

Suppose that f() contains a statement such as this:

```
IF name IS NULL then
  CALL p1();
ELSE
  CALL p2();
END IF;
```

The privileges required for executing statements within `f()` need to be checked when `f()` executes. This might mean that privileges are needed for `p1()` or `p2()`, depending on the execution path within `f()`. Those privileges must be checked at runtime, and the user who must possess the privileges is determined by the `SQL SECURITY` values of the view `v` and the function `f()`.

The `DEFINER` and `SQL SECURITY` clauses for views are extensions to standard SQL. In standard SQL, views are handled using the rules for `SQL SECURITY DEFINER`. The standard says that the definer of the view, which is the same as the owner of the view's schema, gets applicable privileges on the view (for example, `SELECT`) and may grant them. MySQL has no concept of a schema “owner”, so MySQL adds a clause to identify the definer. The `DEFINER` clause is an extension where the intent is to have what the standard has; that is, a permanent record of who defined the view. This is why the default `DEFINER` value is the account of the view creator.

The optional `ALGORITHM` clause is a MySQL extension to standard SQL. It affects how MySQL processes the view. `ALGORITHM` takes three values: `MERGE`, `TEMPTABLE`, or `UNDEFINED`. The default algorithm is `UNDEFINED` if no `ALGORITHM` clause is present. For more information, see Section 20.5.2, “View Processing Algorithms”, as well as Optimizing Derived Tables.

Some views are updatable. That is, you can use them in statements such as `UPDATE`, `DELETE`, or `INSERT` to update the contents of the underlying table. For a view to be updatable, there must be a one-to-one relationship between the rows in the view and the rows in the underlying table. There are also certain other constructs that make a view nonupdatable.

The `WITH CHECK OPTION` clause can be given for an updatable view to prevent inserts or updates to rows except those for which the `WHERE` clause in the *`select_statement`* is true.

In a `WITH CHECK OPTION` clause for an updatable view, the `LOCAL` and `CASCADED` keywords determine the scope of check testing when the view is defined in terms of another view. The `LOCAL` keyword restricts the `CHECK OPTION` only to the view being defined. `CASCADED` causes the checks for underlying views to be evaluated as well. When neither keyword is given, the default is `CASCADED`.

For more information about updatable views and the `WITH CHECK OPTION` clause, see Section 20.5.3, “Updatable and Insertable Views”, and Section 20.5.4, “The View WITH CHECK OPTION Clause”.

13.1.21 DROP DATABASE Syntax

```
DROP {DATABASE | SCHEMA} [IF EXISTS] db_name
```

`DROP DATABASE` drops all tables in the database and deletes the database. Be *very* careful with this statement! To use `DROP DATABASE`, you need the `DROP` privilege on the database. `DROP SCHEMA` is a synonym for `DROP DATABASE`.

Important

When a database is dropped, privileges granted specifically for the database are *not* automatically dropped. They must be dropped manually. See Section 13.7.1.3, “GRANT Syntax”.

`IF EXISTS` is used to prevent an error from occurring if the database does not exist.

If the default database is dropped, the default database is unset (the `DATABASE()` function returns `NULL`).

If you use `DROP DATABASE` on a symbolically linked database, both the link and the original database are deleted.

`DROP DATABASE` returns the number of tables that were removed. This corresponds to the number of `.frm` files removed.

The `DROP DATABASE` statement removes from the given database directory those files and directories that MySQL itself may create during normal operation:

- All files with the following extensions.

`.BAK`	`.DAT`	`.HSH`	`.MRG`
`.MYD`	`.MYI`	`.TRG`	`.TRN`
`.db`	`.frm`	`.ibd`	`.ndb`
`.par`			

- The `db.opt` file, if it exists.

If other files or directories remain in the database directory after MySQL removes those just listed, the database directory cannot be removed. In this case, you must remove any remaining files or directories manually and issue the `DROP DATABASE` statement again.

Dropping a database does not remove any `TEMPORARY` tables that were created in that database. `TEMPORARY` tables are automatically removed when the session that created them ends. See Section 13.1.17.3, “CREATE TEMPORARY TABLE Syntax”.

You can also drop databases with `mysqladmin`. See Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”.

13.1.22 DROP EVENT Syntax

```
DROP EVENT [IF EXISTS] event_name
```

This statement drops the event named *`event_name`*. The event immediately ceases being active, and is deleted completely from the server.

If the event does not exist, the error `ERROR 1517 (HY000): Unknown event 'event_name'` results. You can override this and cause the statement to generate a warning for nonexistent events instead using `IF EXISTS`.

This statement requires the `EVENT` privilege for the schema to which the event to be dropped belongs.

13.1.23 DROP FUNCTION Syntax

The `DROP FUNCTION` statement is used to drop stored functions and user-defined functions (UDFs):

- For information about dropping stored functions, see Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Syntax”.
- For information about dropping user-defined functions, see Section 13.7.3.2, “DROP FUNCTION Syntax”.

13.1.24 DROP INDEX Syntax

```
DROP [ONLINE|OFFLINE] INDEX index_name ON tbl_name
```

`DROP INDEX` drops the index named *`index_name`* from the table *`tbl_name`*. This statement is mapped to an `ALTER TABLE` statement to drop the index. See Section 13.1.7, “ALTER TABLE Syntax”.

To drop a primary key, the index name is always `PRIMARY`, which must be specified as a quoted identifier because `PRIMARY` is a reserved word:

```
DROP INDEX `PRIMARY` ON t;
```

Indexes on variable-width columns of `NDB` tables are dropped online; that is, without any table copying. The table is not locked against access from other NDB Cluster API nodes, although it is locked against other operations on the *same* API node for the duration of the operation. This is done automatically by the server whenever it determines that it is possible to do so; you do not have to use any special SQL syntax or server options to cause it to happen.

In standard MySQL 5.5 releases, it is not possible to override the server when it determines that an index is to be dropped without table copying. In NDB Cluster, you can drop indexes offline (which causes the table to be locked for all API nodes in the cluster) using the `OFFLINE` keyword. The rules and limitations governing `DROP OFFLINE INDEX` and `DROP ONLINE INDEX` are the same as for `ALTER OFFLINE TABLE ... DROP INDEX` and `ALTER ONLINE TABLE ... DROP INDEX`. You cannot cause the noncopying dropping of an index that would normally be dropped offline by using the `ONLINE` keyword: If it is not possible to perform the `DROP` operation without table copying, the server ignores the `ONLINE` keyword. For more information, see Section 13.1.7.2, “ALTER TABLE Online Operations in NDB Cluster 7.2”.

The `ONLINE` and `OFFLINE` keywords are available only in NDB Cluster; attempting to use these keywords in standard MySQL Server 5.5 releases results in a syntax error.

13.1.25 DROP LOGFILE GROUP Syntax

```
DROP LOGFILE GROUP logfile_group
    ENGINE [=] engine_name
```

This statement drops the log file group named *`logfile_group`*. The log file group must already exist or an error results. (For information on creating log file groups, see Section 13.1.14, “CREATE LOGFILE GROUP Syntax”.)

Important

Before dropping a log file group, you must drop all tablespaces that use that log file group for `UNDO` logging.

The required `ENGINE` clause provides the name of the storage engine used by the log file group to be dropped. Currently, the only permitted values for *`engine_name`* are `NDB` and `NDBCLUSTER`.

`DROP LOGFILE GROUP` is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, “NDB Cluster Disk Data Tables”.

13.1.26 DROP PROCEDURE and DROP FUNCTION Syntax

```
DROP {PROCEDURE | FUNCTION} [IF EXISTS] sp_name
```

This statement is used to drop a stored procedure or function. That is, the specified routine is removed from the server. You must have the `ALTER ROUTINE` privilege for the routine. (If the `automatic_sp_privileges` system variable is enabled, that privilege and `EXECUTE` are granted automatically to the routine creator when the routine is created and dropped from the creator when the routine is dropped. See Section 20.2.2, “Stored Routines and MySQL Privileges”.)

The `IF EXISTS` clause is a MySQL extension. It prevents an error from occurring if the procedure or function does not exist. A warning is produced that can be viewed with `SHOW WARNINGS`.

`DROP FUNCTION` is also used to drop user-defined functions (see Section 13.7.3.2, “DROP FUNCTION Syntax”).

13.1.27 DROP SERVER Syntax

```
DROP SERVER [ IF EXISTS ] server_name
```

Drops the server definition for the server named *`server_name`*. The corresponding row in the `mysql.servers` table is deleted. This statement requires the `SUPER` privilege.

Dropping a server for a table does not affect any `FEDERATED` tables that used this connection information when they were created. See Section 13.1.16, “CREATE SERVER Syntax”.

`DROP SERVER` causes an implicit commit. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

`DROP SERVER` is not written to the binary log, regardless of the logging format that is in use.

13.1.28 DROP TABLE Syntax

```
DROP [TEMPORARY] TABLE [IF EXISTS]
    tbl_name [, tbl_name] ...
    [RESTRICT | CASCADE]
```

`DROP TABLE` removes one or more tables. You must have the `DROP` privilege for each table.

Be careful with this statement! It removes the table definition and all table data. For a partitioned table, it permanently removes the table definition, all its partitions, and all data stored in those partitions. It also removes the partitioning definition (`.par`) file associated with the dropped table.

`DROP TABLE` causes an implicit commit, except when used with the `TEMPORARY` keyword. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

Important

When a table is dropped, privileges granted specifically for the table are *not* automatically dropped. They must be dropped manually. See Section 13.7.1.3, “GRANT Syntax”.

If any tables named in the argument list do not exist, the statement returns an error indicating by name which nonexisting tables it was unable to drop, but also drops all tables in the list that do exist.

Use `IF EXISTS` to prevent an error from occurring for tables that do not exist. Instead of an error, a `NOTE` is generated for each nonexistent table; these notes can be displayed with `SHOW WARNINGS`. See Section 13.7.5.41, “SHOW WARNINGS Syntax”.

`IF EXISTS` can also be useful for dropping tables in unusual circumstances under which there is an `.frm` file but no table managed by the storage engine. (For example, if an abnormal server exit occurs after removal of the table from the storage engine but before `.frm` file removal.)

The `TEMPORARY` keyword has the following effects:

- The statement drops only `TEMPORARY` tables.
- The statement does not cause an implicit commit.
- No access rights are checked. A `TEMPORARY` table is visible only with the session that created it, so no check is necessary.

Using `TEMPORARY` is a good way to ensure that you do not accidentally drop a non-`TEMPORARY` table.

The `RESTRICT` and `CASCADE` keywords do nothing. They are permitted to make porting easier from other database systems.

13.1.29 DROP TABLESPACE Syntax

```
DROP TABLESPACE tablespace_name
    ENGINE [=] engine_name
```

This statement drops a tablespace that was previously created using `CREATE TABLESPACE` (see Section 13.1.18, “CREATE TABLESPACE Syntax”).

Important

The tablespace to be dropped must not contain any data files; in other words, before you can drop a tablespace, you must first drop each of its data files using `ALTER TABLESPACE ... DROP DATAFILE` (see Section 13.1.8, “ALTER TABLESPACE Syntax”).

The `ENGINE` clause (required) specifies the storage engine used by the tablespace. Currently, the only accepted values for *`engine_name`* are `NDB` and `NDBCLUSTER`.

`DROP TABLESPACE` is useful only with Disk Data storage for NDB Cluster. See Section 18.5.12, “NDB Cluster Disk Data Tables”.

13.1.30 DROP TRIGGER Syntax

```
DROP TRIGGER [IF EXISTS] [schema_name.]trigger_name
```

This statement drops a trigger. The schema (database) name is optional. If the schema is omitted, the trigger is dropped from the default schema. `DROP TRIGGER` requires the `TRIGGER` privilege for the table associated with the trigger.

Use `IF EXISTS` to prevent an error from occurring for a trigger that does not exist. A `NOTE` is generated for a nonexistent trigger when using `IF EXISTS`. See Section 13.7.5.41, “SHOW WARNINGS Syntax”.

Triggers for a table are also dropped if you drop the table.

Note

When upgrading from a version of MySQL older than MySQL 5.0.10 to 5.0.10 or higher—including all MySQL 5.5 releases—you must drop all triggers and re-create them. Otherwise, `DROP TRIGGER` does not work for older triggers after the upgrade. See Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”, for a suggested upgrade procedure.

13.1.31 DROP VIEW Syntax

```
DROP VIEW [IF EXISTS]
    view_name [, view_name] ...
    [RESTRICT | CASCADE]
```

`DROP VIEW` removes one or more views. You must have the `DROP` privilege for each view.

If any views named in the argument list do not exist, the statement returns an error indicating by name which nonexisting views it was unable to drop, but also drops all views in the list that do exist.

The `IF EXISTS` clause prevents an error from occurring for views that don't exist. When this clause is given, a `NOTE` is generated for each nonexistent view. See Section 13.7.5.41, “SHOW WARNINGS Syntax”.

`RESTRICT` and `CASCADE`, if given, are parsed and ignored.

13.1.32 RENAME TABLE Syntax

```
RENAME TABLE
    tbl_name TO new_tbl_name
    [, tbl_name2 TO new_tbl_name2] ...
```

`RENAME TABLE` renames one or more tables. You must have `ALTER` and `DROP` privileges for the original table, and `CREATE` and `INSERT` privileges for the new table.

For example, to rename a table named `old_table` to to `new_table`, use this statement:

```
RENAME TABLE old_table TO new_table;
```

That statement is equivalent to the following `ALTER TABLE` statement:

```
ALTER TABLE old_table RENAME new_table;
```

`RENAME TABLE`, unlike `ALTER TABLE`, can rename multiple tables within a single statement:

```
RENAME TABLE old_table1 TO new_table1,
             old_table2 TO new_table2,
             old_table3 TO new_table3;
```

Renaming operations are performed left to right. Thus, to swap two table names, do this (assuming that a table with the intermediary name `tmp_table` does not already exist):

```
RENAME TABLE old_table TO tmp_table,
             new_table TO old_table,
             tmp_table TO new_table;
```

When you execute `RENAME TABLE`, you cannot have any locked tables or active transactions. With that condition satisfied, the rename operation is done atomically; no other session can access any of the tables while the rename is in progress.

If any errors occur during a `RENAME TABLE`, the statement fails and no changes are made.

You can use `RENAME TABLE` to move a table from one database to another:

```
RENAME TABLE current_db.tbl_name TO other_db.tbl_name;
```

Using this method to move all tables from one database to a different one in effect renames the database (an operation for which MySQL has no single statement), except that the original database continues to exist, albeit with no tables.

Like `RENAME TABLE`, `ALTER TABLE ... RENAME` can also be used to move a table to a different database. Regardless of the statement used, if the rename operation would move the table to a database located on a different file system, the success of the outcome is platform specific and depends on the underlying operating system calls used to move the table files.

If a table has triggers, attempts to rename the table into a different database fail with a `Trigger in wrong schema` error.

`RENAME TABLE` does not work for `TEMPORARY` tables. However, you can use `ALTER TABLE` to rename `TEMPORARY` tables.

`RENAME TABLE` works for views, except that views cannot be renamed into a different database.

Any privileges granted specifically for a renamed table or view are not migrated to the new name. They must be changed manually.

`RENAME TABLE` changes internally generated foreign key constraint names and user-defined foreign key constraint names that contain the string "*`tbl_name`*_ibfk_" to reflect the new table name. `InnoDB` interprets foreign key constraint names that contain the string "*`tbl_name`*_ibfk_" as internally generated names.

Foreign key constraint names that point to the renamed table are automatically updated unless there is a conflict, in which case, the statement fails with an error. A conflict occurs if the renamed constraint name already exists. In such cases, you must drop and re-create the foreign keys in order for them to function properly.

13.1.33 TRUNCATE TABLE Syntax

```
TRUNCATE [TABLE] tbl_name
```

`TRUNCATE TABLE` empties a table completely. It requires the `DROP` privilege.

Logically, `TRUNCATE TABLE` is similar to a `DELETE` statement that deletes all rows, or a sequence of `DROP TABLE` and `CREATE TABLE` statements. To achieve high performance, it bypasses the DML method of deleting data. Thus, it cannot be rolled back, it does not cause `ON DELETE` triggers to fire, and it cannot be performed for `InnoDB` tables with parent-child foreign key relationships.

Although `TRUNCATE TABLE` is similar to `DELETE`, it is classified as a DDL statement rather than a DML statement. It differs from `DELETE` in the following ways:

- Truncate operations drop and re-create the table, which is much faster than deleting rows one by one, particularly for large tables.
- Truncate operations cause an implicit commit, and so cannot be rolled back. See Section 13.3.3, "Statements That Cause an Implicit Commit".
- Truncation operations cannot be performed if the session holds an active table lock.
- `TRUNCATE TABLE` fails for an `InnoDB` table if there are any `FOREIGN KEY` constraints from other tables that reference the table. Foreign key constraints between columns of the same table are permitted.
- Truncation operations do not return a meaningful value for the number of deleted rows. The usual result is "0 rows affected," which should be interpreted as "no information."
- As long as the table format file *`tbl_name`*`.frm` is valid, the table can be re-created as an empty table with `TRUNCATE TABLE`, even if the data or index files have become corrupted.
- Any `AUTO_INCREMENT` value is reset to its start value. This is true even for `MyISAM` and `InnoDB`, which normally do not reuse sequence values.
- When used with partitioned tables, `TRUNCATE TABLE` preserves the partitioning; that is, the data and index files are dropped and re-created, while the partition definitions (`.par`) file is unaffected.
- The `TRUNCATE TABLE` statement does not invoke `ON DELETE` triggers.

`TRUNCATE TABLE` for a table closes all handlers for the table that were opened with `HANDLER OPEN`.

`TRUNCATE TABLE` is treated for purposes of binary logging and replication as `DROP TABLE` followed by `CREATE TABLE`—that is, as DDL rather than DML. This is due to the fact that, when using `InnoDB` and other transactional storage engines where the transaction isolation level does not permit statement-based logging (`READ COMMITTED` or `READ UNCOMMITTED`), the statement was not logged and replicated when using `STATEMENT` or `MIXED` logging mode. (Bug #36763) However, it is still applied on replication slaves using `InnoDB` in the manner described previously.

On a system with a large `InnoDB` buffer pool and `innodb_adaptive_hash_index` enabled, `TRUNCATE TABLE` operations may cause a temporary drop in system performance due to an LRU

scan that occurs when removing an InnoDB table's adaptive hash index entries. The problem was addressed for DROP TABLE in MySQL 5.5.23 (Bug #13704145, Bug #64284) but remains a known issue for TRUNCATE TABLE (Bug #68184).

TRUNCATE TABLE can be used with Performance Schema summary tables, but the effect is to reset the summary columns to 0 or NULL, not to remove rows. See Section 22.9.5, "Performance Schema Summary Tables".

13.2 Data Manipulation Statements

13.2.1 CALL Syntax

```
CALL sp_name([parameter[,...]])
CALL sp_name[()]
```

The CALL statement invokes a stored procedure that was defined previously with CREATE PROCEDURE.

Stored procedures that take no arguments can be invoked without parentheses. That is, CALL p() and CALL p are equivalent.

CALL can pass back values to its caller using parameters that are declared as OUT or INOUT parameters. When the procedure returns, a client program can also obtain the number of rows affected for the final statement executed within the routine: At the SQL level, call the ROW_COUNT() function; from the C API, call the mysql_affected_rows() function.

To get back a value from a procedure using an OUT or INOUT parameter, pass the parameter by means of a user variable, and then check the value of the variable after the procedure returns. (If you are calling the procedure from within another stored procedure or function, you can also pass a routine parameter or local routine variable as an IN or INOUT parameter.) For an INOUT parameter, initialize its value before passing it to the procedure. The following procedure has an OUT parameter that the procedure sets to the current server version, and an INOUT value that the procedure increments by one from its current value:

```
CREATE PROCEDURE p (OUT ver_param VARCHAR(25), INOUT incr_param INT)
BEGIN
  # Set value of OUT parameter
  SELECT VERSION() INTO ver_param;
  # Increment value of INOUT parameter
  SET incr_param = incr_param + 1;
END;
```

Before calling the procedure, initialize the variable to be passed as the INOUT parameter. After calling the procedure, the values of the two variables will have been set or modified:

```
mysql> SET @increment = 10;
mysql> CALL p(@version, @increment);
mysql> SELECT @version, @increment;
+------------------+------------+
| @version         | @increment |
+------------------+------------+
| 5.5.58-debug-log |         11 |
+------------------+------------+
```

In prepared CALL statements used with PREPARE and EXECUTE, placeholders can be used for IN parameters, OUT, and INOUT parameters. These types of parameters can be used as follows:

```
mysql> SET @increment = 10;
mysql> PREPARE s FROM 'CALL p(?, ?)';
mysql> EXECUTE s USING @version, @increment;
```

```
mysql> SELECT @version, @increment;
+-----------------+------------+
| @version        | @increment |
+-----------------+------------+
| 5.5.58-debug-log |         11 |
+-----------------+------------+
```

To write C programs that use the `CALL` SQL statement to execute stored procedures that produce result sets, the `CLIENT_MULTI_RESULTS` flag must be enabled. This is because each `CALL` returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure. `CLIENT_MULTI_RESULTS` must also be enabled if `CALL` is used to execute any stored procedure that contains prepared statements. It cannot be determined when such a procedure is loaded whether those statements will produce result sets, so it is necessary to assume that they will.

`CLIENT_MULTI_RESULTS` can be enabled when you call `mysql_real_connect()`, either explicitly by passing the `CLIENT_MULTI_RESULTS` flag itself, or implicitly by passing `CLIENT_MULTI_STATEMENTS` (which also enables `CLIENT_MULTI_RESULTS`). `CLIENT_MULTI_RESULTS` is enabled by default.

To process the result of a `CALL` statement executed using `mysql_query()` or `mysql_real_query()`, use a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 23.8.16, “C API Multiple Statement Execution Support”.

C programs can use the prepared-statement interface to execute `CALL` statements and access `OUT` and `INOUT` parameters. This is done by processing the result of a `CALL` statement using a loop that calls `mysql_stmt_next_result()` to determine whether there are more results. For an example, see Section 23.8.18, “C API Prepared CALL Statement Support”. Languages that provide a MySQL interface can use prepared `CALL` statements to directly retrieve `OUT` and `INOUT` procedure parameters.

13.2.2 DELETE Syntax

`DELETE` is a DML statement that removes rows from a table.

Single-table syntax:

```
DELETE [LOW_PRIORITY] [QUICK] [IGNORE] FROM tbl_name
    [WHERE where_condition]
    [ORDER BY ...]
    [LIMIT row_count]
```

Multiple-table syntax:

```
DELETE [LOW_PRIORITY] [QUICK] [IGNORE]
    tbl_name[.*] [, tbl_name[.*]] ...
    FROM table_references
    [WHERE where_condition]

DELETE [LOW_PRIORITY] [QUICK] [IGNORE]
    FROM tbl_name[.*] [, tbl_name[.*]] ...
    USING table_references
    [WHERE where_condition]
```

For the single-table syntax, the `DELETE` statement deletes rows from *`tbl_name`* and returns a count of the number of deleted rows. This count can be obtained by calling the `ROW_COUNT()` function (see Section 12.14, “Information Functions”). The `WHERE` clause, if given, specifies the conditions that identify which rows to delete. With no `WHERE` clause, all rows are deleted. If the `ORDER BY` clause is specified, the rows are deleted in the order that is specified. The `LIMIT` clause places a limit on the number of rows that can be deleted.

For the multiple-table syntax, `DELETE` deletes from each *`tbl_name`* the rows that satisfy the conditions. In this case, `ORDER BY` and `LIMIT` cannot be used.

where_condition is an expression that evaluates to true for each row to be deleted. It is specified as described in Section 13.2.9, “SELECT Syntax”.

You cannot delete from a table and select from the same table in a subquery.

You need the DELETE privilege on a table to delete rows from it. You need only the SELECT privilege for any columns that are only read, such as those named in the WHERE clause.

As stated, a DELETE statement with no WHERE clause deletes all rows. A faster way to do this, when you do not need to know the number of deleted rows, is to use TRUNCATE TABLE. However, within a transaction or if you have a lock on the table, TRUNCATE TABLE cannot be used whereas DELETE can. See Section 13.1.33, “TRUNCATE TABLE Syntax”, and Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”.

If you delete the row containing the maximum value for an AUTO_INCREMENT column, the value is not reused for a MyISAM or InnoDB table. If you delete all rows in the table with DELETE FROM *tbl_name* (without a WHERE clause) in autocommit mode, the sequence starts over for all storage engines except InnoDB and MyISAM. There are some exceptions to this behavior for InnoDB tables, as discussed in Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”.

For MyISAM tables, you can specify an AUTO_INCREMENT secondary column in a multiple-column key. In this case, reuse of values deleted from the top of the sequence occurs even for MyISAM tables. See Section 3.6.9, “Using AUTO_INCREMENT”.

The DELETE statement supports the following modifiers:

- If you specify LOW_PRIORITY, the server delays execution of the DELETE until no other clients are reading from the table. This affects only storage engines that use only table-level locking (such as MyISAM, MEMORY, and MERGE).
- For MyISAM tables, if you use the QUICK modifier, the storage engine does not merge index leaves during delete, which may speed up some kinds of delete operations.
- The IGNORE modifier causes MySQL to ignore errors during the process of deleting rows. (Errors encountered during the parsing stage are processed in the usual manner.) Errors that are ignored due to the use of IGNORE are returned as warnings.

The speed of delete operations may also be affected by factors discussed in Section 8.2.4.3, “Optimizing DELETE Statements”.

In MyISAM tables, deleted rows are maintained in a linked list and subsequent INSERT operations reuse old row positions. To reclaim unused space and reduce file sizes, use the OPTIMIZE TABLE statement or the myisamchk utility to reorganize tables. OPTIMIZE TABLE is easier to use, but myisamchk is faster. See Section 13.7.2.4, “OPTIMIZE TABLE Syntax”, and Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”.

The QUICK modifier affects whether index leaves are merged for delete operations. DELETE QUICK is most useful for applications where index values for deleted rows are replaced by similar index values from rows inserted later. In this case, the holes left by deleted values are reused.

DELETE QUICK is not useful when deleted values lead to underfilled index blocks spanning a range of index values for which new inserts occur again. In this case, use of QUICK can lead to wasted space in the index that remains unreclaimed. Here is an example of such a scenario:

1. Create a table that contains an indexed AUTO_INCREMENT column.
2. Insert many rows into the table. Each insert results in an index value that is added to the high end of the index.
3. Delete a block of rows at the low end of the column range using DELETE QUICK.

In this scenario, the index blocks associated with the deleted index values become underfilled but are not merged with other index blocks due to the use of `QUICK`. They remain underfilled when new inserts occur, because new rows do not have index values in the deleted range. Furthermore, they remain underfilled even if you later use `DELETE` without `QUICK`, unless some of the deleted index values happen to lie in index blocks within or adjacent to the underfilled blocks. To reclaim unused index space under these circumstances, use `OPTIMIZE TABLE`.

If you are going to delete many rows from a table, it might be faster to use `DELETE QUICK` followed by `OPTIMIZE TABLE`. This rebuilds the index rather than performing many index block merge operations.

The MySQL-specific `LIMIT row_count` option to `DELETE` tells the server the maximum number of rows to be deleted before control is returned to the client. This can be used to ensure that a given `DELETE` statement does not take too much time. You can simply repeat the `DELETE` statement until the number of affected rows is less than the `LIMIT` value.

If the `DELETE` statement includes an `ORDER BY` clause, rows are deleted in the order specified by the clause. This is useful primarily in conjunction with `LIMIT`. For example, the following statement finds rows matching the `WHERE` clause, sorts them by `timestamp_column`, and deletes the first (oldest) one:

```
DELETE FROM somelog WHERE user = 'jcole'
ORDER BY timestamp_column LIMIT 1;
```

`ORDER BY` may also be useful in some cases to delete rows in an order required to avoid referential integrity violations.

If you are deleting many rows from a large table, you may exceed the lock table size for an `InnoDB` table. To avoid this problem, or simply to minimize the time that the table remains locked, the following strategy (which does not use `DELETE` at all) might be helpful:

1. Select the rows *not* to be deleted into an empty table that has the same structure as the original table:

   ```
   INSERT INTO t_copy SELECT * FROM t WHERE ... ;
   ```

2. Use `RENAME TABLE` to atomically move the original table out of the way and rename the copy to the original name:

   ```
   RENAME TABLE t TO t_old, t_copy TO t;
   ```

3. Drop the original table:

   ```
   DROP TABLE t_old;
   ```

No other sessions can access the tables involved while `RENAME TABLE` executes, so the rename operation is not subject to concurrency problems. See Section 13.1.32, “RENAME TABLE Syntax”.

You can specify multiple tables in a `DELETE` statement to delete rows from one or more tables depending on the condition in the `WHERE` clause. You cannot use `ORDER BY` or `LIMIT` in a multiple-table `DELETE`. The `table_references` clause lists the tables involved in the join, as described in Section 13.2.9.2, “JOIN Syntax”.

For the first multiple-table syntax, only matching rows from the tables listed before the `FROM` clause are deleted. For the second multiple-table syntax, only matching rows from the tables listed in the `FROM` clause (before the `USING` clause) are deleted. The effect is that you can delete rows from many tables at the same time and have additional tables that are used only for searching:

```
DELETE t1, t2 FROM t1 INNER JOIN t2 INNER JOIN t3
WHERE t1.id=t2.id AND t2.id=t3.id;
```

Or:

```
DELETE FROM t1, t2 USING t1 INNER JOIN t2 INNER JOIN t3
WHERE t1.id=t2.id AND t2.id=t3.id;
```

These statements use all three tables when searching for rows to delete, but delete matching rows only from tables `t1` and `t2`.

The preceding examples use `INNER JOIN`, but multiple-table `DELETE` statements can use other types of join permitted in `SELECT` statements, such as `LEFT JOIN`. For example, to delete rows that exist in `t1` that have no match in `t2`, use a `LEFT JOIN`:

```
DELETE t1 FROM t1 LEFT JOIN t2 ON t1.id=t2.id WHERE t2.id IS NULL;
```

The syntax permits `.*` after each *`tbl_name`* for compatibility with `Access`.

If you use a multiple-table `DELETE` statement involving `InnoDB` tables for which there are foreign key constraints, the MySQL optimizer might process tables in an order that differs from that of their parent/child relationship. In this case, the statement fails and rolls back. Instead, you should delete from a single table and rely on the `ON DELETE` capabilities that `InnoDB` provides to cause the other tables to be modified accordingly.

Note

If you declare an alias for a table, you must use the alias when referring to the table:

```
DELETE t1 FROM test AS t1, test2 WHERE ...
```

Table aliases in a multiple-table `DELETE` should be declared only in the *`table_references`* part of the statement. Elsewhere, alias references are permitted but not alias declarations.

Correct:

```
DELETE a1, a2 FROM t1 AS a1 INNER JOIN t2 AS a2
WHERE a1.id=a2.id;

DELETE FROM a1, a2 USING t1 AS a1 INNER JOIN t2 AS a2
WHERE a1.id=a2.id;
```

Incorrect:

```
DELETE t1 AS a1, t2 AS a2 FROM t1 INNER JOIN t2
WHERE a1.id=a2.id;

DELETE FROM t1 AS a1, t2 AS a2 USING t1 INNER JOIN t2
WHERE a1.id=a2.id;
```

13.2.3 DO Syntax

```
DO expr [, expr] ...
```

`DO` executes the expressions but does not return any results. In most respects, `DO` is shorthand for `SELECT expr, ...`, but has the advantage that it is slightly faster when you do not care about the result.

`DO` is useful primarily with functions that have side effects, such as `RELEASE_LOCK()`.

Example: This `SELECT` statement pauses, but also produces a result set:

```
mysql> SELECT SLEEP(5);
+----------+
| SLEEP(5) |
+----------+
|        0 |
+----------+
1 row in set (5.02 sec)
```

`DO`, on the other hand, pauses without producing a result set.:

```
mysql> DO SLEEP(5);
Query OK, 0 rows affected (4.99 sec)
```

This could be useful, for example in a stored function or trigger, which prohibit statements that produce result sets.

`DO` only executes expressions. It cannot be used in all cases where `SELECT` can be used. For example, `DO id FROM t1` is invalid because it references a table.

13.2.4 HANDLER Syntax

```
HANDLER tbl_name OPEN [ [AS] alias]

HANDLER tbl_name READ index_name { = | <= | >= | < | > } (value1,value2,...)
    [ WHERE where_condition ] [LIMIT ... ]
HANDLER tbl_name READ index_name { FIRST | NEXT | PREV | LAST }
    [ WHERE where_condition ] [LIMIT ... ]
HANDLER tbl_name READ { FIRST | NEXT }
    [ WHERE where_condition ] [LIMIT ... ]

HANDLER tbl_name CLOSE
```

The `HANDLER` statement provides direct access to table storage engine interfaces. It is available for `InnoDB` and `MyISAM` tables.

The `HANDLER ... OPEN` statement opens a table, making it accessible using subsequent `HANDLER ... READ` statements. This table object is not shared by other sessions and is not closed until the session calls `HANDLER ... CLOSE` or the session terminates.

If you open the table using an alias, further references to the open table with other `HANDLER` statements must use the alias rather than the table name. If you do not use an alias, but open the table using a table name qualified by the database name, further references must use the unqualified table name. For example, for a table opened using `mydb.mytable`, further references must use `mytable`.

The first `HANDLER ... READ` syntax fetches a row where the index specified satisfies the given values and the `WHERE` condition is met. If you have a multiple-column index, specify the index column values as a comma-separated list. Either specify values for all the columns in the index, or specify values for a leftmost prefix of the index columns. Suppose that an index `my_idx` includes three columns named `col_a`, `col_b`, and `col_c`, in that order. The `HANDLER` statement can specify values for all three columns in the index, or for the columns in a leftmost prefix. For example:

```
HANDLER ... READ my_idx = (col_a_val,col_b_val,col_c_val) ...
HANDLER ... READ my_idx = (col_a_val,col_b_val) ...
HANDLER ... READ my_idx = (col_a_val) ...
```

To employ the `HANDLER` interface to refer to a table's `PRIMARY KEY`, use the quoted identifier `` `PRIMARY` ``:

```
HANDLER tbl_name READ `PRIMARY` ...
```

The second `HANDLER ... READ` syntax fetches a row from the table in index order that matches the `WHERE` condition.

The third `HANDLER ... READ` syntax fetches a row from the table in natural row order that matches the `WHERE` condition. It is faster than `HANDLER tbl_name READ index_name` when a full table scan is desired. Natural row order is the order in which rows are stored in a `MyISAM` table data file. This statement works for `InnoDB` tables as well, but there is no such concept because there is no separate data file.

Without a `LIMIT` clause, all forms of `HANDLER ... READ` fetch a single row if one is available. To return a specific number of rows, include a `LIMIT` clause. It has the same syntax as for the `SELECT` statement. See Section 13.2.9, “SELECT Syntax”.

`HANDLER ... CLOSE` closes a table that was opened with `HANDLER ... OPEN`.

There are several reasons to use the `HANDLER` interface instead of normal `SELECT` statements:

- `HANDLER` is faster than `SELECT`:
  - A designated storage engine handler object is allocated for the `HANDLER ... OPEN`. The object is reused for subsequent `HANDLER` statements for that table; it need not be reinitialized for each one.
  - There is less parsing involved.
  - There is no optimizer or query-checking overhead.
  - The handler interface does not have to provide a consistent look of the data (for example, dirty reads are permitted), so the storage engine can use optimizations that `SELECT` does not normally permit.
- `HANDLER` makes it easier to port to MySQL applications that use a low-level `ISAM`-like interface.
- `HANDLER` enables you to traverse a database in a manner that is difficult (or even impossible) to accomplish with `SELECT`. The `HANDLER` interface is a more natural way to look at data when working with applications that provide an interactive user interface to the database.

`HANDLER` is a somewhat low-level statement. For example, it does not provide consistency. That is, `HANDLER ... OPEN` does *not* take a snapshot of the table, and does *not* lock the table. This means that after a `HANDLER ... OPEN` statement is issued, table data can be modified (by the current session or other sessions) and these modifications might be only partially visible to `HANDLER ... NEXT` or `HANDLER ... PREV` scans.

An open handler can be closed and marked for reopen, in which case the handler loses its position in the table. This occurs when both of the following circumstances are true:

- Any session executes `FLUSH TABLES` or DDL statements on the handler's table.
- The session in which the handler is open executes non-`HANDLER` statements that use tables.

`TRUNCATE TABLE` for a table closes all handlers for the table that were opened with `HANDLER OPEN`.

If a table is flushed with `FLUSH TABLES tbl_name WITH READ LOCK` was opened with `HANDLER`, the handler is implicitly flushed and loses its position.

`HANDLER` is not supported with partitioned tables.

13.2.5 INSERT Syntax

```
INSERT [LOW_PRIORITY | DELAYED | HIGH_PRIORITY] [IGNORE]
    [INTO] tbl_name
    [(col_name [, col_name] ...)]
    {VALUES | VALUE} (value_list) [, (value_list)] ...
    [ON DUPLICATE KEY UPDATE assignment_list]
```

```
INSERT [LOW_PRIORITY | DELAYED | HIGH_PRIORITY] [IGNORE]
    [INTO] tbl_name
    SET assignment_list
    [ON DUPLICATE KEY UPDATE assignment_list]

INSERT [LOW_PRIORITY | HIGH_PRIORITY] [IGNORE]
    [INTO] tbl_name
    [(col_name [, col_name] ...)]
    SELECT ...
    [ON DUPLICATE KEY UPDATE assignment_list]

value:
    {expr | DEFAULT}

value_list:
    value [, value] ...

assignment:
    col_name = value

assignment_list:
    assignment [, assignment] ...
```

`INSERT` inserts new rows into an existing table. The `INSERT ... VALUES` and `INSERT ... SET` forms of the statement insert rows based on explicitly specified values. The `INSERT ... SELECT` form inserts rows selected from another table or tables. `INSERT` with an `ON DUPLICATE KEY UPDATE` clause enables existing rows to be updated if a row to be inserted would cause a duplicate value in a `UNIQUE` index or `PRIMARY KEY`.

For additional information about `INSERT ... SELECT` and `INSERT ... ON DUPLICATE KEY UPDATE`, see Section 13.2.5.1, “INSERT ... SELECT Syntax”, and Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”.

Inserting into a table requires the `INSERT` privilege for the table. If the `ON DUPLICATE KEY UPDATE` clause is used and a duplicate key causes an `UPDATE` to be performed instead, the statement requires the `UPDATE` privilege for the columns to be updated. For columns that are read but not modified you need only the `SELECT` privilege (such as for a column referenced only on the right hand side of an *`col_name`*=*`expr`* assignment in an `ON DUPLICATE KEY UPDATE` clause).

You can use `REPLACE` instead of `INSERT` to overwrite old rows. `REPLACE` is the counterpart to `INSERT IGNORE` in the treatment of new rows that contain unique key values that duplicate old rows: The new rows replace the old rows rather than being discarded. See Section 13.2.8, “REPLACE Syntax”.

`tbl_name` is the table into which rows should be inserted. Specify the columns for which the statement provides values as follows:

- Provide a parenthesized list of comma-separated column names following the table name. In this case, a value for each named column must be provided by the `VALUES` list or the `SELECT` statement.
- If you do not specify a list of column names for `INSERT ... VALUES` or `INSERT ... SELECT`, values for every column in the table must be provided by the `VALUES` list or the `SELECT` statement. If you do not know the order of the columns in the table, use `DESCRIBE tbl_name` to find out.
- A `SET` clause indicates columns explicitly by name, together with the value to assign each one.

Column values can be given in several ways:

- If strict SQL mode is not enabled, any column not explicitly given a value is set to its default (explicit or implicit) value. For example, if you specify a column list that does not name all the columns in the table, unnamed columns are set to their default values. Default value assignment is described in Section 11.6, “Data Type Default Values”. See also Section 1.7.3.3, “Constraints on Invalid Data”.

  If strict SQL mode is enabled, an `INSERT` statement generates an error if it does not specify an explicit value for every column that has no default value. See Section 5.1.8, “Server SQL Modes”.

- If both the column list and the `VALUES` list are empty, `INSERT` creates a row with each column set to its default value:

```
INSERT INTO tbl_name () VALUES();
```

  If strict mode is not enabled, MySQL uses the implicit default value for any column that has no explicitly defined default. If strict mode is enabled, an error occurs if any column has no default value.

- Use the keyword `DEFAULT` to set a column explicitly to its default value. This makes it easier to write `INSERT` statements that assign values to all but a few columns, because it enables you to avoid writing an incomplete `VALUES` list that does not include a value for each column in the table. Otherwise, you must provide the list of column names corresponding to each value in the `VALUES` list.

- In expressions, you can use `DEFAULT(col_name)` to produce the default value for column *`col_name`*.

- Type conversion of an expression *`expr`* that provides a column value might occur if the expression data type does not match the column data type. Conversion of a given value can result in different inserted values depending on the column type. For example, inserting the string `'1999.0e-2'` into an `INT`, `FLOAT`, `DECIMAL(10,6)`, or `YEAR` column inserts the value `1999`, `19.9921`, `19.992100`, or `1999`, respectively. The value stored in the `INT` and `YEAR` columns is `1999` because the string-to-number conversion looks only at as much of the initial part of the string as may be considered a valid integer or year. For the `FLOAT` and `DECIMAL` columns, the string-to-number conversion considers the entire string a valid numeric value.

- An expression *`expr`* can refer to any column that was set earlier in a value list. For example, you can do this because the value for `col2` refers to `col1`, which has previously been assigned:

```
INSERT INTO tbl_name (col1,col2) VALUES(15,col1*2);
```

  But the following is not legal, because the value for `col1` refers to `col2`, which is assigned after `col1`:

```
INSERT INTO tbl_name (col1,col2) VALUES(col2*2,15);
```

  An exception occurs for columns that contain `AUTO_INCREMENT` values. Because `AUTO_INCREMENT` values are generated after other value assignments, any reference to an `AUTO_INCREMENT` column in the assignment returns a `0`.

`INSERT` statements that use `VALUES` syntax can insert multiple rows. To do this, include multiple lists of comma-separated column values, with lists enclosed within parentheses and separated by commas. Example:

```
INSERT INTO tbl_name (a,b,c) VALUES(1,2,3),(4,5,6),(7,8,9);
```

Each values list must contain exactly as many values as are to be inserted per row. The following statement is invalid because it contains one list of nine values, rather than three lists of three values each:

```
INSERT INTO tbl_name (a,b,c) VALUES(1,2,3,4,5,6,7,8,9);
```

`VALUE` is a synonym for `VALUES` in this context. Neither implies anything about the number of values lists, nor about the number of values per list. Either may be used whether there is a single values list or multiple lists, and regardless of the number of values per list.

The affected-rows value for an `INSERT` can be obtained using the `ROW_COUNT()` SQL function or the `mysql_affected_rows()` C API function. See Section 12.14, “Information Functions”, and Section 23.8.7.1, “mysql_affected_rows()”.

If you use an `INSERT ... VALUES` statement with multiple value lists or `INSERT ... SELECT`, the statement returns an information string in this format:

```
Records: N1 Duplicates: N2 Warnings: N3
```

If you are using the C API, the information string can be obtained by invoking the `mysql_info()` function. See Section 23.8.7.35, “mysql_info()”.

`Records` indicates the number of rows processed by the statement. (This is not necessarily the number of rows actually inserted because `Duplicates` can be nonzero.) `Duplicates` indicates the number of rows that could not be inserted because they would duplicate some existing unique index value. `Warnings` indicates the number of attempts to insert column values that were problematic in some way. Warnings can occur under any of the following conditions:

- Inserting `NULL` into a column that has been declared `NOT NULL`. For multiple-row `INSERT` statements or `INSERT INTO ... SELECT` statements, the column is set to the implicit default value for the column data type. This is `0` for numeric types, the empty string (`''`) for string types, and the “zero” value for date and time types. `INSERT INTO ... SELECT` statements are handled the same way as multiple-row inserts because the server does not examine the result set from the `SELECT` to see whether it returns a single row. (For a single-row `INSERT`, no warning occurs when `NULL` is inserted into a `NOT NULL` column. Instead, the statement fails with an error.)
- Setting a numeric column to a value that lies outside the column's range. The value is clipped to the closest endpoint of the range.
- Assigning a value such as `'10.34 a'` to a numeric column. The trailing nonnumeric text is stripped off and the remaining numeric part is inserted. If the string value has no leading numeric part, the column is set to `0`.
- Inserting a string into a string column (`CHAR`, `VARCHAR`, `TEXT`, or `BLOB`) that exceeds the column's maximum length. The value is truncated to the column's maximum length.
- Inserting a value into a date or time column that is illegal for the data type. The column is set to the appropriate zero value for the type.

If `INSERT` inserts a row into a table that has an `AUTO_INCREMENT` column, you can find the value used for that column by using the `LAST_INSERT_ID()` SQL function or the `mysql_insert_id()` C API function.

Note

These two functions do not always behave identically. The behavior of `INSERT` statements with respect to `AUTO_INCREMENT` columns is discussed further in Section 12.14, “Information Functions”, and Section 23.8.7.37, “mysql_insert_id()”.

The `INSERT` statement supports the following modifiers:

- If you use the `DELAYED` modifier, the server puts the row or rows to be inserted into a buffer, and the client issuing the `INSERT DELAYED` statement can then continue immediately. If the table is in use, the server holds the rows. When the table is free, the server begins inserting rows, checking periodically to see whether there are any new read requests for the table. If there are, the delayed row queue is suspended until the table becomes free again. See Section 13.2.5.3, “INSERT DELAYED Syntax”.

  `DELAYED` is ignored with `INSERT ... SELECT` or `INSERT ... ON DUPLICATE KEY UPDATE`.

  `DELAYED` is also disregarded for an `INSERT` that uses functions accessing tables or triggers, or that is called from a function or a trigger.

- If you use the `LOW_PRIORITY` modifier, execution of the `INSERT` is delayed until no other clients are reading from the table. This includes other clients that began reading while existing clients are reading, and while the `INSERT LOW_PRIORITY` statement is waiting. It is possible, therefore, for a client that issues an `INSERT LOW_PRIORITY` statement to wait for a very long time (or even forever) in a read-heavy environment. (This is in contrast to `INSERT DELAYED`, which lets the client continue at once.)

  `LOW_PRIORITY` affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

  Note

  `LOW_PRIORITY` should normally not be used with `MyISAM` tables because doing so disables concurrent inserts. See Section 8.11.3, “Concurrent Inserts”.

- If you specify `HIGH_PRIORITY`, it overrides the effect of the `--low-priority-updates` option if the server was started with that option. It also causes concurrent inserts not to be used. See Section 8.11.3, “Concurrent Inserts”.

  `HIGH_PRIORITY` affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

- If you use the `IGNORE` modifier, errors that occur while executing the `INSERT` statement are ignored. For example, without `IGNORE`, a row that duplicates an existing `UNIQUE` index or `PRIMARY KEY` value in the table causes a duplicate-key error and the statement is aborted. With `IGNORE`, the row is discarded and no error occurs. Ignored errors may generate warnings instead, although duplicate-key errors do not.

  `IGNORE` has a similar effect on inserts into partitioned tables where no partition matching a given value is found. Without `IGNORE`, such `INSERT` statements are aborted with an error. When `INSERT IGNORE` is used, the insert operation fails silently for rows containing the unmatched value, but inserts rows that are matched. For an example, see Section 19.2.2, “LIST Partitioning”.

  Data conversions that would trigger errors abort the statement if `IGNORE` is not specified. With `IGNORE`, invalid values are adjusted to the closest values and inserted; warnings are produced but the statement does not abort. You can determine with the `mysql_info()` C API function how many rows were actually inserted into the table.

- If you specify `ON DUPLICATE KEY UPDATE`, and a row is inserted that would cause a duplicate value in a `UNIQUE` index or `PRIMARY KEY`, an `UPDATE` of the old row occurs. The affected-rows value per row is 1 if the row is inserted as a new row, 2 if an existing row is updated, and 0 if an existing row is set to its current values. If you specify the `CLIENT_FOUND_ROWS` flag to the `mysql_real_connect()` C API function when connecting to `mysqld`, the affected-rows value is 1 (not 0) if an existing row is set to its current values. See Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”.

An `INSERT` statement affecting a partitioned table using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as `InnoDB` that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.2.5.1 INSERT ... SELECT Syntax

```
INSERT [LOW_PRIORITY | HIGH_PRIORITY] [IGNORE]
    [INTO] tbl_name
    [(col_name [, col_name] ...)]
    SELECT ...
    [ON DUPLICATE KEY UPDATE assignment_list]

value:
```

```
    {expr | DEFAULT}

assignment:
    col_name = value

assignment_list:
    assignment [, assignment] ...
```

With `INSERT ... SELECT`, you can quickly insert many rows into a table from the result of a `SELECT` statement, which can select from one or many tables. For example:

```
INSERT INTO tbl_temp2 (fld_id)
  SELECT tbl_temp1.fld_order_id
  FROM tbl_temp1 WHERE tbl_temp1.fld_order_id > 100;
```

The following conditions hold for `INSERT ... SELECT` statements:

- Specify `IGNORE` to ignore rows that would cause duplicate-key violations.
- `DELAYED` is ignored with `INSERT ... SELECT`.
- The target table of the `INSERT` statement may appear in the `FROM` clause of the `SELECT` part of the query. However, you cannot insert into a table and select from the same table in a subquery.

  When selecting from and inserting into the same table, MySQL creates an internal temporary table to hold the rows from the `SELECT` and then inserts those rows into the target table. However, you cannot use `INSERT INTO t ... SELECT ... FROM t` when `t` is a `TEMPORARY` table, because `TEMPORARY` tables cannot be referred to twice in the same statement. See Section 8.4.4, “Internal Temporary Table Use in MySQL”, and Section B.5.6.2, “TEMPORARY Table Problems”.
- `AUTO_INCREMENT` columns work as usual.
- To ensure that the binary log can be used to re-create the original tables, MySQL does not permit concurrent inserts for `INSERT ... SELECT` statements (see Section 8.11.3, “Concurrent Inserts”).
- To avoid ambiguous column reference problems when the `SELECT` and the `INSERT` refer to the same table, provide a unique alias for each table used in the `SELECT` part, and qualify column names in that part with the appropriate alias.

For `INSERT ... SELECT` statements, see Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax” for conditions under which the `SELECT` columns can be referred to in an `ON DUPLICATE KEY UPDATE` clause.

The order in which a `SELECT` statement with no `ORDER BY` clause returns rows is indeterminate. This means that, when using replication, there is no guarantee that such a `SELECT` returns rows in the same order on the master and the slave, which can lead to inconsistencies between them. To prevent this from occurring, always write `INSERT ... SELECT` statements that are to be replicated using an `ORDER BY` clause that produces the same row order on the master and the slave. See also Section 17.4.1.16, “Replication and LIMIT”.

Due to this issue, beginning with MySQL 5.5.18, `INSERT ... SELECT ON DUPLICATE KEY UPDATE` and `INSERT IGNORE ... SELECT` statements are flagged as unsafe for statement-based replication. Such statements produce a warning in the error log when using statement-based mode and are written to the binary log using the row-based format when using `MIXED` mode. (Bug #11758262, Bug #50439)

See also Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

An `INSERT ... SELECT` statement affecting partitioned tables using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the source and target tables. This does not occur with tables using storage engines such as `InnoDB` that employ row-level locking. This issue

is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.2.5.2 INSERT ... ON DUPLICATE KEY UPDATE Syntax

If you specify an `ON DUPLICATE KEY UPDATE` clause and a row to be inserted would cause a duplicate value in a `UNIQUE` index or `PRIMARY KEY`, an `UPDATE` of the old row occurs. For example, if column `a` is declared as `UNIQUE` and contains the value `1`, the following two statements have similar effect:

```
INSERT INTO t1 (a,b,c) VALUES (1,2,3)
  ON DUPLICATE KEY UPDATE c=c+1;

UPDATE t1 SET c=c+1 WHERE a=1;
```

(The effects are not identical for an `InnoDB` table where `a` is an auto-increment column. With an auto-increment column, an `INSERT` statement increases the auto-increment value but `UPDATE` does not.)

If column `b` is also unique, the `INSERT` is equivalent to this `UPDATE` statement instead:

```
UPDATE t1 SET c=c+1 WHERE a=1 OR b=2 LIMIT 1;
```

If `a=1 OR b=2` matches several rows, only *one* row is updated. In general, you should try to avoid using an `ON DUPLICATE KEY UPDATE` clause on tables with multiple unique indexes.

With `ON DUPLICATE KEY UPDATE`, the affected-rows value per row is 1 if the row is inserted as a new row, 2 if an existing row is updated, and 0 if an existing row is set to its current values. If you specify the `CLIENT_FOUND_ROWS` flag to the `mysql_real_connect()` C API function when connecting to `mysqld`, the affected-rows value is 1 (not 0) if an existing row is set to its current values.

If a table contains an `AUTO_INCREMENT` column and `INSERT ... ON DUPLICATE KEY UPDATE` inserts or updates a row, the `LAST_INSERT_ID()` function returns the `AUTO_INCREMENT` value.

The `ON DUPLICATE KEY UPDATE` clause can contain multiple column assignments, separated by commas.

In assignment value expressions in the `ON DUPLICATE KEY UPDATE` clause, you can use the `VALUES(col_name)` function to refer to column values from the `INSERT` portion of the `INSERT ... ON DUPLICATE KEY UPDATE` statement. In other words, `VALUES(col_name)` in the `ON DUPLICATE KEY UPDATE` clause refers to the value of *`col_name`* that would be inserted, had no duplicate-key conflict occurred. This function is especially useful in multiple-row inserts. The `VALUES()` function is meaningful only in the `ON DUPLICATE KEY UPDATE` clause or `INSERT` statements and returns `NULL` otherwise. Example:

```
INSERT INTO t1 (a,b,c) VALUES (1,2,3),(4,5,6)
  ON DUPLICATE KEY UPDATE c=VALUES(a)+VALUES(b);
```

That statement is identical to the following two statements:

```
INSERT INTO t1 (a,b,c) VALUES (1,2,3)
  ON DUPLICATE KEY UPDATE c=3;
INSERT INTO t1 (a,b,c) VALUES (4,5,6)
  ON DUPLICATE KEY UPDATE c=9;
```

The `DELAYED` option is ignored when you use `ON DUPLICATE KEY UPDATE`.

For `INSERT ... SELECT` statements, these rules apply regarding acceptable forms of `SELECT` query expressions that you can refer to in an `ON DUPLICATE KEY UPDATE` clause:

- References to columns from queries on a single table, which may be a derived table.

- References to columns from queries on a join over multiple tables.
- References to columns from `DISTINCT` queries.
- References to columns in other tables, as long as the `SELECT` does not use `GROUP BY`. One side effect is that you must qualify references to nonunique column names.

References to columns from a `UNION` do not work reliably. To work around this restriction, rewrite the `UNION` as a derived table so that its rows can be treated as a single-table result set. For example, this statement is problematic:

```
INSERT INTO t1 (a, b)
  SELECT c, d FROM t2
  UNION
  SELECT e, f FROM t3
ON DUPLICATE KEY UPDATE b = b + c;
```

Instead, use an equivalent statement that rewrites the `UNION` as a derived table:

```
INSERT INTO t1 (a, b)
SELECT * FROM
  (SELECT c, d FROM t2
   UNION
   SELECT e, f FROM t3) AS dt
ON DUPLICATE KEY UPDATE b = b + c;
```

The technique of rewriting a query as a derived table also enables references to columns from `GROUP BY` queries.

Because the results of `INSERT ... SELECT` statements depend on the ordering of rows from the `SELECT` and this order cannot always be guaranteed, it is possible when logging `INSERT ... SELECT ON DUPLICATE KEY UPDATE` statements for the master and the slave to diverge. Thus, in MySQL 5.5.18 and later, `INSERT ... SELECT ON DUPLICATE KEY UPDATE` statements are flagged as unsafe for statement-based replication. With this change, such statements produce a warning in the error log when using statement-based mode and are written to the binary using the row-based format when using `MIXED` mode. In addition, beginning with MySQL 5.5.24, an `INSERT ... ON DUPLICATE KEY UPDATE` statement against a table having more than one unique or primary key is also marked as unsafe. (Bug #11765650, Bug #58637)

See also Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

An `INSERT ... ON DUPLICATE KEY UPDATE` on a partitioned table using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as `InnoDB` that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.2.5.3 INSERT DELAYED Syntax

```
INSERT DELAYED ...
```

The `DELAYED` option for the `INSERT` statement is a MySQL extension to standard SQL that is very useful if you have clients that cannot or need not wait for the `INSERT` to complete. This is a common situation when you use MySQL for logging and you also periodically run `SELECT` and `UPDATE` statements that take a long time to complete.

When a client uses `INSERT DELAYED`, it gets an okay from the server at once, and the row is queued to be inserted when the table is not in use by any other thread.

Another major benefit of using `INSERT DELAYED` is that inserts from many clients are bundled together and written in one block. This is much faster than performing many separate inserts.

Note

`INSERT DELAYED` is slower than a normal `INSERT` if the table is not otherwise in use. There is also the additional overhead for the server to handle a separate thread for each table for which there are delayed rows. This means that you should use `INSERT DELAYED` only when you are really sure that you need it.

The queued rows are held only in memory until they are inserted into the table. This means that if you terminate `mysqld` forcibly (for example, with `kill -9`) or if `mysqld` dies unexpectedly, *any queued rows that have not been written to disk are lost*.

There are some constraints on the use of `DELAYED`:

- `INSERT DELAYED` works only with `MyISAM`, `MEMORY`, `ARCHIVE`, and `BLACKHOLE` tables. For engines that do not support `DELAYED`, an error occurs.
- An error occurs for `INSERT DELAYED` if used with a table that has been locked with `LOCK TABLES` because the insert must be handled by a separate thread, not by the session that holds the lock.
- For `MyISAM` tables, if there are no free blocks in the middle of the data file, concurrent `SELECT` and `INSERT` statements are supported. Under these circumstances, you very seldom need to use `INSERT DELAYED` with `MyISAM`.
- `INSERT DELAYED` should be used only for `INSERT` statements that specify value lists. The server ignores `DELAYED` for `INSERT ... SELECT` or `INSERT ... ON DUPLICATE KEY UPDATE` statements.
- Because the `INSERT DELAYED` statement returns immediately, before the rows are inserted, you cannot use `LAST_INSERT_ID()` to get the `AUTO_INCREMENT` value that the statement might generate.
- `DELAYED` rows are not visible to `SELECT` statements until they actually have been inserted.
- `INSERT DELAYED` is handled as a simple `INSERT` (that is, without the `DELAYED` option) whenever the value of `binlog_format` is `STATEMENT` or `MIXED`. (In the latter case, the statement does not trigger a switch to row-based logging, and so is logged using the statement-based format.)

  This does not apply when using row-based binary logging mode (`binlog_format` set to `ROW`), in which `INSERT DELAYED` statements are always executed using the `DELAYED` option as specified, and logged as row-update events.
- `DELAYED` is ignored on slave replication servers, so that `INSERT DELAYED` is treated as a normal `INSERT` on slaves. This is because `DELAYED` could cause the slave to have different data than the master.
- Pending `INSERT DELAYED` statements are lost if a table is write locked and `ALTER TABLE` is used to modify the table structure.
- `INSERT DELAYED` is not supported for views.
- `INSERT DELAYED` is not supported for partitioned tables.

The following describes in detail what happens when you use the `DELAYED` option to `INSERT` or `REPLACE`. In this description, the “thread” is the thread that received an `INSERT DELAYED` statement and “handler” is the thread that handles all `INSERT DELAYED` statements for a particular table.

- When a thread executes a `DELAYED` statement for a table, a handler thread is created to process all `DELAYED` statements for the table, if no such handler already exists.
- The thread checks whether the handler has previously acquired a `DELAYED` lock; if not, it tells the handler thread to do so. The `DELAYED` lock can be obtained even if other threads have a `READ` or

`WRITE` lock on the table. However, the handler waits for all `ALTER TABLE` locks or `FLUSH TABLES` statements to finish, to ensure that the table structure is up to date.

- The thread executes the `INSERT` statement, but instead of writing the row to the table, it puts a copy of the final row into a queue that is managed by the handler thread. Any syntax errors are noticed by the thread and reported to the client program.
- The client cannot obtain from the server the number of duplicate rows or the `AUTO_INCREMENT` value for the resulting row, because the `INSERT` returns before the insert operation has been completed. (If you use the C API, the `mysql_info()` function does not return anything meaningful, for the same reason.)
- The binary log is updated by the handler thread when the row is inserted into the table. In case of multiple-row inserts, the binary log is updated when the first row is inserted.
- Each time that `delayed_insert_limit` rows are written, the handler checks whether any `SELECT` statements are still pending. If so, it permits these to execute before continuing.
- When the handler has no more rows in its queue, the table is unlocked. If no new `INSERT DELAYED` statements are received within `delayed_insert_timeout` seconds, the handler terminates.
- If more than `delayed_queue_size` rows are pending in a specific handler queue, the thread requesting `INSERT DELAYED` waits until there is room in the queue. This is done to ensure that `mysqld` does not use all memory for the delayed memory queue.
- The handler thread shows up in the MySQL process list with `delayed_insert` in the `Command` column. It is killed if you execute a `FLUSH TABLES` statement or kill it with `KILL *thread_id*`. However, before exiting, it first stores all queued rows into the table. During this time it does not accept any new `INSERT` statements from other threads. If you execute an `INSERT DELAYED` statement after this, a new handler thread is created.

  This means that `INSERT DELAYED` statements have higher priority than normal `INSERT` statements if there is an `INSERT DELAYED` handler running. Other update statements have to wait until the `INSERT DELAYED` queue is empty, someone terminates the handler thread (with `KILL *thread_id*`), or someone executes a `FLUSH TABLES`.
- The following status variables provide information about `INSERT DELAYED` statements.

Status Variable	Meaning
`Delayed_insert_threads`	Number of handler threads
`Delayed_writes`	Number of rows written with `INSERT DELAYED`
`Not_flushed_delayed_rows`	Number of rows waiting to be written

You can view these variables by issuing a `SHOW STATUS` statement or by executing a `mysqladmin extended-status` command.

13.2.6 LOAD DATA INFILE Syntax

```
LOAD DATA [LOW_PRIORITY | CONCURRENT] [LOCAL] INFILE 'file_name'
    [REPLACE | IGNORE]
    INTO TABLE tbl_name
    [CHARACTER SET charset_name]
    [{FIELDS | COLUMNS}
        [TERMINATED BY 'string']
        [[OPTIONALLY] ENCLOSED BY 'char']
        [ESCAPED BY 'char']
    ]
    [LINES
        [STARTING BY 'string']
```

```
        [TERMINATED BY 'string']
    ]
    [IGNORE number {LINES | ROWS}]
    [(col_name_or_user_var
        [, col_name_or_user_var] ...)]
    [SET col_name={expr | DEFAULT},
        [, col_name={expr | DEFAULT}] ...]
```

The `LOAD DATA INFILE` statement reads rows from a text file into a table at a very high speed. `LOAD DATA INFILE` is the complement of `SELECT ... INTO OUTFILE`. (See Section 13.2.9.1, "SELECT ... INTO Syntax".) To write data from a table to a file, use `SELECT ... INTO OUTFILE`. To read the file back into a table, use `LOAD DATA INFILE`. The syntax of the `FIELDS` and `LINES` clauses is the same for both statements. Both clauses are optional, but `FIELDS` must precede `LINES` if both are specified.

You can also load data files by using the `mysqlimport` utility; it operates by sending a `LOAD DATA INFILE` statement to the server. The `--local` option causes `mysqlimport` to read data files from the client host. You can specify the `--compress` option to get better performance over slow networks if the client and server support the compressed protocol. See Section 4.5.5, "`mysqlimport` — A Data Import Program".

For more information about the efficiency of `INSERT` versus `LOAD DATA INFILE` and speeding up `LOAD DATA INFILE`, see Section 8.2.4.1, "Optimizing INSERT Statements".

The file name must be given as a literal string. On Windows, specify backslashes in path names as forward slashes or doubled backslashes. The `character_set_filesystem` system variable controls the interpretation of the file name.

The server uses the character set indicated by the `character_set_database` system variable to interpret the information in the file. `SET NAMES` and the setting of `character_set_client` do not affect interpretation of input. If the contents of the input file use a character set that differs from the default, it is usually preferable to specify the character set of the file by using the `CHARACTER SET` clause. A character set of `binary` specifies "no conversion."

`LOAD DATA INFILE` interprets all fields in the file as having the same character set, regardless of the data types of the columns into which field values are loaded. For proper interpretation of file contents, you must ensure that it was written with the correct character set. For example, if you write a data file with `mysqldump -T` or by issuing a `SELECT ... INTO OUTFILE` statement in `mysql`, be sure to use a `--default-character-set` option so that output is written in the character set to be used when the file is loaded with `LOAD DATA INFILE`.

Note

It is not possible to load data files that use the `ucs2`, `utf16`, or `utf32` character set.

If you use `LOW_PRIORITY`, execution of the `LOAD DATA` statement is delayed until no other clients are reading from the table. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

If you specify `CONCURRENT` with a `MyISAM` table that satisfies the condition for concurrent inserts (that is, it contains no free blocks in the middle), other threads can retrieve data from the table while `LOAD DATA` is executing. This option affects the performance of `LOAD DATA` a bit, even if no other thread is using the table at the same time.

With row-based replication, `CONCURRENT` is replicated regardless of MySQL version. With statement-based replication `CONCURRENT` is not replicated prior to MySQL 5.5.1 (see Bug #34628). For more information, see Section 17.4.1.17, "Replication and LOAD DATA INFILE".

The `LOCAL` keyword affects expected location of the file and error handling, as described later. `LOCAL` works only if your server and your client both have been configured to permit it. For example, if

`mysqld` was started with the `local_infile` system variable disabled, `LOCAL` does not work. See Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.

The `LOCAL` keyword affects where the file is expected to be found:

- If `LOCAL` is specified, the file is read by the client program on the client host and sent to the server. The file can be given as a full path name to specify its exact location. If given as a relative path name, the name is interpreted relative to the directory in which the client program was started.

  When using `LOCAL` with `LOAD DATA`, a copy of the file is created in the server's temporary directory. This is *not* the directory determined by the value of `tmpdir` or `slave_load_tmpdir`, but rather the operating system's temporary directory, and is not configurable in the MySQL Server. (Typically the system temporary directory is `/tmp` on Linux systems and `C:\WINDOWS\TEMP` on Windows.) Lack of sufficient space for the copy in this directory can cause the `LOAD DATA LOCAL` statement to fail.

- If `LOCAL` is not specified, the file must be located on the server host and is read directly by the server. The server uses the following rules to locate the file:

  - If the file name is an absolute path name, the server uses it as given.
  - If the file name is a relative path name with one or more leading components, the server searches for the file relative to the server's data directory.
  - If a file name with no leading components is given, the server looks for the file in the database directory of the default database.

In the non-`LOCAL` case, these rules mean that a file named as `./myfile.txt` is read from the server's data directory, whereas the file named as `myfile.txt` is read from the database directory of the default database. For example, if `db1` is the default database, the following `LOAD DATA` statement reads the file `data.txt` from the database directory for `db1`, even though the statement explicitly loads the file into a table in the `db2` database:

```
LOAD DATA INFILE 'data.txt' INTO TABLE db2.my_table;
```

Non-`LOCAL` load operations read text files located on the server. For security reasons, such operations require that you have the `FILE` privilege. See Section 6.2.1, “Privileges Provided by MySQL”. Also, non-`LOCAL` load operations are subject to the `secure_file_priv` system variable setting. If the variable value is a nonempty directory name, the file to be loaded must be located in that directory. If the variable value is empty (which is insecure), the file need only be readable by the server.

Using `LOCAL` is a bit slower than letting the server access the files directly, because the contents of the file must be sent over the connection by the client to the server. On the other hand, you do not need the `FILE` privilege to load local files.

`LOCAL` also affects error handling:

- With `LOAD DATA INFILE`, data-interpretation and duplicate-key errors terminate the operation.
- With `LOAD DATA LOCAL INFILE`, data-interpretation and duplicate-key errors become warnings and the operation continues because the server has no way to stop transmission of the file in the middle of the operation. For duplicate-key errors, this is the same as if `IGNORE` is specified. `IGNORE` is explained further later in this section.

The `REPLACE` and `IGNORE` keywords control handling of input rows that duplicate existing rows on unique key values:

- If you specify `REPLACE`, input rows replace existing rows. In other words, rows that have the same value for a primary key or unique index as an existing row. See Section 13.2.8, “REPLACE Syntax”.
- If you specify `IGNORE`, rows that duplicate an existing row on a unique key value are discarded.

- If you do not specify either option, the behavior depends on whether the `LOCAL` keyword is specified. Without `LOCAL`, an error occurs when a duplicate key value is found, and the rest of the text file is ignored. With `LOCAL`, the default behavior is the same as if `IGNORE` is specified; this is because the server has no way to stop transmission of the file in the middle of the operation.

To ignore foreign key constraints during the load operation, issue a `SET foreign_key_checks = 0` statement before executing `LOAD DATA`.

If you use `LOAD DATA INFILE` on an empty `MyISAM` table, all nonunique indexes are created in a separate batch (as for `REPAIR TABLE`). Normally, this makes `LOAD DATA INFILE` much faster when you have many indexes. In some extreme cases, you can create the indexes even faster by turning them off with `ALTER TABLE ... DISABLE KEYS` before loading the file into the table and using `ALTER TABLE ... ENABLE KEYS` to re-create the indexes after loading the file. See Section 8.2.4.1, “Optimizing INSERT Statements”.

For both the `LOAD DATA INFILE` and `SELECT ... INTO OUTFILE` statements, the syntax of the `FIELDS` and `LINES` clauses is the same. Both clauses are optional, but `FIELDS` must precede `LINES` if both are specified.

If you specify a `FIELDS` clause, each of its subclauses (`TERMINATED BY`, `[OPTIONALLY] ENCLOSED BY`, and `ESCAPED BY`) is also optional, except that you must specify at least one of them.

If you specify no `FIELDS` or `LINES` clause, the defaults are the same as if you had written this:

```
FIELDS TERMINATED BY '\t' ENCLOSED BY '' ESCAPED BY '\\'
LINES TERMINATED BY '\n' STARTING BY ''
```

(Backslash is the MySQL escape character within strings in SQL statements, so to specify a literal backslash, you must specify two backslashes for the value to be interpreted as a single backslash. The escape sequences `'\t'` and `'\n'` specify tab and newline characters, respectively.)

In other words, the defaults cause `LOAD DATA INFILE` to act as follows when reading input:

- Look for line boundaries at newlines.
- Do not skip over any line prefix.
- Break lines into fields at tabs.
- Do not expect fields to be enclosed within any quoting characters.
- Interpret characters preceded by the escape character `\` as escape sequences. For example, `\t`, `\n`, and `\\` signify tab, newline, and backslash, respectively. See the discussion of `FIELDS ESCAPED BY` later for the full list of escape sequences.

Conversely, the defaults cause `SELECT ... INTO OUTFILE` to act as follows when writing output:

- Write tabs between fields.
- Do not enclose fields within any quoting characters.
- Use `\` to escape instances of tab, newline, or `\` that occur within field values.
- Write newlines at the ends of lines.

Note

If you have generated the text file on a Windows system, you might have to use `LINES TERMINATED BY '\r\n'` to read the file properly, because Windows programs typically use two characters as a line terminator. Some programs, such as `WordPad`, might use `\r` as a line terminator when writing files. To read such files, use `LINES TERMINATED BY '\r'`.

If all the lines you want to read in have a common prefix that you want to ignore, you can use `LINES STARTING BY 'prefix_string'` to skip over the prefix, *and anything before it*. If a line does not include the prefix, the entire line is skipped. Suppose that you issue the following statement:

```
LOAD DATA INFILE '/tmp/test.txt' INTO TABLE test
  FIELDS TERMINATED BY ','  LINES STARTING BY 'xxx';
```

If the data file looks like this:

```
xxx"abc",1
something xxx"def",2
"ghi",3
```

The resulting rows will be `("abc",1)` and `("def",2)`. The third row in the file is skipped because it does not contain the prefix.

The `IGNORE number LINES` option can be used to ignore lines at the start of the file. For example, you can use `IGNORE 1 LINES` to skip over an initial header line containing column names:

```
LOAD DATA INFILE '/tmp/test.txt' INTO TABLE test IGNORE 1 LINES;
```

When you use `SELECT ... INTO OUTFILE` in tandem with `LOAD DATA INFILE` to write data from a database into a file and then read the file back into the database later, the field- and line-handling options for both statements must match. Otherwise, `LOAD DATA INFILE` will not interpret the contents of the file properly. Suppose that you use `SELECT ... INTO OUTFILE` to write a file with fields delimited by commas:

```
SELECT * INTO OUTFILE 'data.txt'
  FIELDS TERMINATED BY ','
  FROM table2;
```

To read the comma-delimited file back in, the correct statement would be:

```
LOAD DATA INFILE 'data.txt' INTO TABLE table2
  FIELDS TERMINATED BY ',';
```

If instead you tried to read in the file with the statement shown following, it wouldn't work because it instructs `LOAD DATA INFILE` to look for tabs between fields:

```
LOAD DATA INFILE 'data.txt' INTO TABLE table2
  FIELDS TERMINATED BY '\t';
```

The likely result is that each input line would be interpreted as a single field.

`LOAD DATA INFILE` can be used to read files obtained from external sources. For example, many programs can export data in comma-separated values (CSV) format, such that lines have fields separated by commas and enclosed within double quotation marks, with an initial line of column names. If the lines in such a file are terminated by carriage return/newline pairs, the statement shown here illustrates the field- and line-handling options you would use to load the file:

```
LOAD DATA INFILE 'data.txt' INTO TABLE tbl_name
  FIELDS TERMINATED BY ',' ENCLOSED BY '"'
  LINES TERMINATED BY '\r\n'
  IGNORE 1 LINES;
```

If the input values are not necessarily enclosed within quotation marks, use `OPTIONALLY` before the `ENCLOSED BY` keywords.

Any of the field- or line-handling options can specify an empty string (`''`). If not empty, the `FIELDS [OPTIONALLY] ENCLOSED BY` and `FIELDS ESCAPED BY` values must be a single character. The

`FIELDS TERMINATED BY`, `LINES STARTING BY`, and `LINES TERMINATED BY` values can be more than one character. For example, to write lines that are terminated by carriage return/linefeed pairs, or to read a file containing such lines, specify a `LINES TERMINATED BY '\r\n'` clause.

To read a file containing jokes that are separated by lines consisting of `%%`, you can do this

```
CREATE TABLE jokes
  (a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
  joke TEXT NOT NULL);
LOAD DATA INFILE '/tmp/jokes.txt' INTO TABLE jokes
  FIELDS TERMINATED BY ''
  LINES TERMINATED BY '\n%%\n' (joke);
```

`FIELDS [OPTIONALLY] ENCLOSED BY` controls quoting of fields. For output (`SELECT ... INTO OUTFILE`), if you omit the word `OPTIONALLY`, all fields are enclosed by the `ENCLOSED BY` character. An example of such output (using a comma as the field delimiter) is shown here:

```
"1","a string","100.20"
"2","a string containing a , comma","102.20"
"3","a string containing a \" quote","102.20"
"4","a string containing a \", quote and comma","102.20"
```

If you specify `OPTIONALLY`, the `ENCLOSED BY` character is used only to enclose values from columns that have a string data type (such as `CHAR`, `BINARY`, `TEXT`, or `ENUM`):

```
1,"a string",100.20
2,"a string containing a , comma",102.20
3,"a string containing a \" quote",102.20
4,"a string containing a \", quote and comma",102.20
```

Occurrences of the `ENCLOSED BY` character within a field value are escaped by prefixing them with the `ESCAPED BY` character. Also, if you specify an empty `ESCAPED BY` value, it is possible to inadvertently generate output that cannot be read properly by `LOAD DATA INFILE`. For example, the preceding output just shown would appear as follows if the escape character is empty. Observe that the second field in the fourth line contains a comma following the quote, which (erroneously) appears to terminate the field:

```
1,"a string",100.20
2,"a string containing a , comma",102.20
3,"a string containing a " quote",102.20
4,"a string containing a ", quote and comma",102.20
```

For input, the `ENCLOSED BY` character, if present, is stripped from the ends of field values. (This is true regardless of whether `OPTIONALLY` is specified; `OPTIONALLY` has no effect on input interpretation.) Occurrences of the `ENCLOSED BY` character preceded by the `ESCAPED BY` character are interpreted as part of the current field value.

If the field begins with the `ENCLOSED BY` character, instances of that character are recognized as terminating a field value only if followed by the field or line `TERMINATED BY` sequence. To avoid ambiguity, occurrences of the `ENCLOSED BY` character within a field value can be doubled and are interpreted as a single instance of the character. For example, if `ENCLOSED BY '"'` is specified, quotation marks are handled as shown here:

```
"The ""BIG"" boss"  -> The "BIG" boss
The "BIG" boss      -> The "BIG" boss
The ""BIG"" boss    -> The ""BIG"" boss
```

`FIELDS ESCAPED BY` controls how to read or write special characters:

- For input, if the `FIELDS ESCAPED BY` character is not empty, occurrences of that character are stripped and the following character is taken literally as part of a field value. Some two-character

sequences that are exceptions, where the first character is the escape character. These sequences are shown in the following table (using `\` for the escape character). The rules for `NULL` handling are described later in this section.

Character	Escape Sequence
`\0`	An ASCII NUL (`X'00'`) character
`\b`	A backspace character
`\n`	A newline (linefeed) character
`\r`	A carriage return character
`\t`	A tab character.
`\Z`	ASCII 26 (Control+Z)
`\N`	NULL

For more information about `\`-escape syntax, see Section 9.1.1, “String Literals”.

If the `FIELDS ESCAPED BY` character is empty, escape-sequence interpretation does not occur.

- For output, if the `FIELDS ESCAPED BY` character is not empty, it is used to prefix the following characters on output:
  - The `FIELDS ESCAPED BY` character
  - The `FIELDS [OPTIONALLY] ENCLOSED BY` character
  - The first character of the `FIELDS TERMINATED BY` and `LINES TERMINATED BY` values
  - ASCII `0` (what is actually written following the escape character is ASCII `0`, not a zero-valued byte)

  If the `FIELDS ESCAPED BY` character is empty, no characters are escaped and `NULL` is output as `NULL`, not `\N`. It is probably not a good idea to specify an empty escape character, particularly if field values in your data contain any of the characters in the list just given.

In certain cases, field- and line-handling options interact:

- If `LINES TERMINATED BY` is an empty string and `FIELDS TERMINATED BY` is nonempty, lines are also terminated with `FIELDS TERMINATED BY`.
- If the `FIELDS TERMINATED BY` and `FIELDS ENCLOSED BY` values are both empty (`''`), a fixed-row (nondelimited) format is used. With fixed-row format, no delimiters are used between fields (but you can still have a line terminator). Instead, column values are read and written using a field width wide enough to hold all values in the field. For `TINYINT`, `SMALLINT`, `MEDIUMINT`, `INT`, and `BIGINT`, the field widths are 4, 6, 8, 11, and 20, respectively, no matter what the declared display width is.

  `LINES TERMINATED BY` is still used to separate lines. If a line does not contain all fields, the rest of the columns are set to their default values. If you do not have a line terminator, you should set this to `''`. In this case, the text file must contain all fields for each row.

  Fixed-row format also affects handling of `NULL` values, as described later.

  Note

  Fixed-size format does not work if you are using a multibyte character set.

Handling of `NULL` values varies according to the `FIELDS` and `LINES` options in use:

- For the default `FIELDS` and `LINES` values, `NULL` is written as a field value of `\N` for output, and a field value of `\N` is read as `NULL` for input (assuming that the `ESCAPED BY` character is `\`).

- If `FIELDS ENCLOSED BY` is not empty, a field containing the literal word `NULL` as its value is read as a `NULL` value. This differs from the word `NULL` enclosed within `FIELDS ENCLOSED BY` characters, which is read as the string `'NULL'`.
- If `FIELDS ESCAPED BY` is empty, `NULL` is written as the word `NULL`.
- With fixed-row format (which is used when `FIELDS TERMINATED BY` and `FIELDS ENCLOSED BY` are both empty), `NULL` is written as an empty string. This causes both `NULL` values and empty strings in the table to be indistinguishable when written to the file because both are written as empty strings. If you need to be able to tell the two apart when reading the file back in, you should not use fixed-row format.

An attempt to load `NULL` into a `NOT NULL` column causes assignment of the implicit default value for the column's data type and a warning, or an error in strict SQL mode. Implicit default values are discussed in Section 11.6, “Data Type Default Values”.

Some cases are not supported by `LOAD DATA INFILE`:

- Fixed-size rows (`FIELDS TERMINATED BY` and `FIELDS ENCLOSED BY` both empty) and `BLOB` or `TEXT` columns.
- If you specify one separator that is the same as or a prefix of another, `LOAD DATA INFILE` cannot interpret the input properly. For example, the following `FIELDS` clause would cause problems:

```
FIELDS TERMINATED BY '"' ENCLOSED BY '"'
```

- If `FIELDS ESCAPED BY` is empty, a field value that contains an occurrence of `FIELDS ENCLOSED BY` or `LINES TERMINATED BY` followed by the `FIELDS TERMINATED BY` value causes `LOAD DATA INFILE` to stop reading a field or line too early. This happens because `LOAD DATA INFILE` cannot properly determine where the field or line value ends.

The following example loads all columns of the `persondata` table:

```
LOAD DATA INFILE 'persondata.txt' INTO TABLE persondata;
```

By default, when no column list is provided at the end of the `LOAD DATA INFILE` statement, input lines are expected to contain a field for each table column. If you want to load only some of a table's columns, specify a column list:

```
LOAD DATA INFILE 'persondata.txt' INTO TABLE persondata (col1,col2,...);
```

You must also specify a column list if the order of the fields in the input file differs from the order of the columns in the table. Otherwise, MySQL cannot tell how to match input fields with table columns.

The column list can contain either column names or user variables. With user variables, the `SET` clause enables you to perform transformations on their values before assigning the result to columns.

User variables in the `SET` clause can be used in several ways. The following example uses the first input column directly for the value of `t1.column1`, and assigns the second input column to a user variable that is subjected to a division operation before being used for the value of `t1.column2`:

```
LOAD DATA INFILE 'file.txt'
  INTO TABLE t1
  (column1, @var1)
  SET column2 = @var1/100;
```

The `SET` clause can be used to supply values not derived from the input file. The following statement sets `column3` to the current date and time:

```
LOAD DATA INFILE 'file.txt'
```

```
  INTO TABLE t1
  (column1, column2)
  SET column3 = CURRENT_TIMESTAMP;
```

You can also discard an input value by assigning it to a user variable and not assigning the variable to a table column:

```
LOAD DATA INFILE 'file.txt'
  INTO TABLE t1
  (column1, @dummy, column2, @dummy, column3);
```

Use of the column/variable list and `SET` clause is subject to the following restrictions:

- Assignments in the `SET` clause should have only column names on the left hand side of assignment operators.
- You can use subqueries in the right hand side of `SET` assignments. A subquery that returns a value to be assigned to a column may be a scalar subquery only. Also, you cannot use a subquery to select from the table that is being loaded.
- Lines ignored by an `IGNORE` clause are not processed for the column/variable list or `SET` clause.
- User variables cannot be used when loading data with fixed-row format because user variables do not have a display width.

When processing an input line, `LOAD DATA` splits it into fields and uses the values according to the column/variable list and the `SET` clause, if they are present. Then the resulting row is inserted into the table. If there are `BEFORE INSERT` or `AFTER INSERT` triggers for the table, they are activated before or after inserting the row, respectively.

If an input line has too many fields, the extra fields are ignored and the number of warnings is incremented.

If an input line has too few fields, the table columns for which input fields are missing are set to their default values. Default value assignment is described in Section 11.6, “Data Type Default Values”.

An empty field value is interpreted different from a missing field:

- For string types, the column is set to the empty string.
- For numeric types, the column is set to `0`.
- For date and time types, the column is set to the appropriate “zero” value for the type. See Section 11.3, “Date and Time Types”.

These are the same values that result if you assign an empty string explicitly to a string, numeric, or date or time type explicitly in an `INSERT` or `UPDATE` statement.

Treatment of empty or incorrect field values differs from that just described if the SQL mode is set to a restrictive value. For example, if `sql_mode` is set to `TRADITIONAL`, conversion of an empty value or a value such as `'x'` for a numeric column results in an error, not conversion to 0. (With `LOCAL` or `IGNORE`, warnings occur rather than errors, even with a restrictive `sql_mode` value, and the row is inserted using the same closest-value behavior used for nonrestrictive SQL modes. This occurs because the server has no way to stop transmission of the file in the middle of the operation.)

`TIMESTAMP` columns are set to the current date and time only if there is a `NULL` value for the column (that is, `\N`) and the column is not declared to permit `NULL` values, or if the `TIMESTAMP` column's default value is the current timestamp and it is omitted from the field list when a field list is specified.

`LOAD DATA INFILE` regards all input as strings, so you cannot use numeric values for `ENUM` or `SET` columns the way you can with `INSERT` statements. All `ENUM` and `SET` values must be specified as strings.

`BIT` values cannot be loaded directly using binary notation (for example, `b'011010'`). To work around this, use the `SET` clause to strip off the leading `b'` and trailing `'` and perform a base-2 to base-10 conversion so that MySQL loads the values into the `BIT` column properly:

```
shell> cat /tmp/bit_test.txt
b'10'
b'1111111'
shell> mysql test
mysql> LOAD DATA INFILE '/tmp/bit_test.txt'
       INTO TABLE bit_test (@var1)
       SET b = CAST(CONV(MID(@var1, 3, LENGTH(@var1)-3), 2, 10) AS UNSIGNED);
Query OK, 2 rows affected (0.00 sec)
Records: 2  Deleted: 0  Skipped: 0  Warnings: 0

mysql> SELECT BIN(b+0) FROM bit_test;
+----------+
| BIN(b+0) |
+----------+
| 10       |
| 1111111  |
+----------+
2 rows in set (0.00 sec)
```

For `BIT` values in `0b` binary notation (for example, `0b011010`), use this `SET` clause instead to strip off the leading `0b`:

```
SET b = CAST(CONV(MID(@var1, 3, LENGTH(@var1)-2), 2, 10) AS UNSIGNED)
```

On Unix, if you need `LOAD DATA` to read from a pipe, you can use the following technique (the example loads a listing of the `/` directory into the table `db1.t1`):

```
mkfifo /mysql/data/db1/ls.dat
chmod 666 /mysql/data/db1/ls.dat
find / -ls > /mysql/data/db1/ls.dat &
mysql -e "LOAD DATA INFILE 'ls.dat' INTO TABLE t1" db1
```

Here you must run the command that generates the data to be loaded and the `mysql` commands either on separate terminals, or run the data generation process in the background (as shown in the preceding example). If you do not do this, the pipe will block until data is read by the `mysql` process.

When the `LOAD DATA INFILE` statement finishes, it returns an information string in the following format:

```
Records: 1  Deleted: 0  Skipped: 0  Warnings: 0
```

Warnings occur under the same circumstances as when values are inserted using the `INSERT` statement (see Section 13.2.5, “INSERT Syntax”), except that `LOAD DATA INFILE` also generates warnings when there are too few or too many fields in the input row.

You can use `SHOW WARNINGS` to get a list of the first `max_error_count` warnings as information about what went wrong. See Section 13.7.5.41, “SHOW WARNINGS Syntax”.

If you are using the C API, you can get information about the statement by calling the `mysql_info()` function. See Section 23.8.7.35, “mysql_info()”.

For partitioned tables using storage engines that employ table locks, such as `MyISAM`, any locks caused by `LOAD DATA` perform locks on all partitions of the table. This does not apply to tables using storage engines which employ row-level locking, such as `InnoDB`. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.2.7 LOAD XML Syntax

```
LOAD XML [LOW_PRIORITY | CONCURRENT] [LOCAL] INFILE 'file_name'
    [REPLACE | IGNORE]
    INTO TABLE [db_name.]tbl_name
    [CHARACTER SET charset_name]
    [ROWS IDENTIFIED BY '<tagname>']
    [IGNORE number {LINES | ROWS}]
    [(field_name_or_user_var
        [, field_name_or_user_var] ...)]
    [SET col_name={expr | DEFAULT},
        [, col_name={expr | DEFAULT}] ...]
```

The `LOAD XML` statement reads data from an XML file into a table. The *`file_name`* must be given as a literal string. The *`tagname`* in the optional `ROWS IDENTIFIED BY` clause must also be given as a literal string, and must be surrounded by angle brackets (`<` and `>`).

`LOAD XML` acts as the complement of running the `mysql` client in XML output mode (that is, starting the client with the `--xml` option). To write data from a table to an XML file, you can invoke the `mysql` client with the `--xml` and `-e` options from the system shell, as shown here:

```
shell> mysql --xml -e 'SELECT * FROM mydb.mytable' > file.xml
```

To read the file back into a table, use `LOAD XML INFILE`. By default, the `<row>` element is considered to be the equivalent of a database table row; this can be changed using the `ROWS IDENTIFIED BY` clause.

This statement supports three different XML formats:

- Column names as attributes and column values as attribute values:

  ```
  <row column1="value1" column2="value2" .../>
  ```

- Column names as tags and column values as the content of these tags:

  ```
  <row>
    <column1>value1</column1>
    <column2>value2</column2>
  </row>
  ```

- Column names are the `name` attributes of `<field>` tags, and values are the contents of these tags:

  ```
  <row>
    <field name='column1'>value1</field>
    <field name='column2'>value2</field>
  </row>
  ```

  This is the format used by other MySQL tools, such as `mysqldump`.

All three formats can be used in the same XML file; the import routine automatically detects the format for each row and interprets it correctly. Tags are matched based on the tag or attribute name and the column name.

Prior to MySQL 5.5.46, `LOAD XML` did not handle empty XML elements in the form `<element/>` correctly. (Bug #67542, Bug #16171518)

The following clauses work essentially the same way for `LOAD XML` as they do for `LOAD DATA`:

- `LOW_PRIORITY` or `CONCURRENT`
- `LOCAL`
- `REPLACE` or `IGNORE`

- `CHARACTER SET`
- `SET`

See Section 13.2.6, “LOAD DATA INFILE Syntax”, for more information about these clauses.

`(field_name_or_user_var, ...)` is a list of one or more comma-separated XML fields or user variables. The name of a user variable used for this purpose must match the name of a field from the XML file, prefixed with `@`. You can use field names to select only desired fields. User variables can be employed to store the corresponding field values for subsequent re-use.

The `IGNORE` *`number`* `LINES` or `IGNORE` *`number`* `ROWS` clause causes the first *`number`* rows in the XML file to be skipped. It is analogous to the `LOAD DATA` statement's `IGNORE ... LINES` clause.

Suppose that we have a table named `person`, created as shown here:

```
USE test;

CREATE TABLE person (
    person_id INT NOT NULL PRIMARY KEY,
    fname VARCHAR(40) NULL,
    lname VARCHAR(40) NULL,
    created TIMESTAMP
);
```

Suppose further that this table is initially empty.

Now suppose that we have a simple XML file `person.xml`, whose contents are as shown here:

```
<list>
  <person person_id="1" fname="Kapek" lname="Sainnouine"/>
  <person person_id="2" fname="Sajon" lname="Rondela"/>
  <person person_id="3"><fname>Likame</fname><lname>Örrtmons</lname></person>
  <person person_id="4"><fname>Slar</fname><lname>Manlanth</lname></person>
  <person><field name="person_id">5</field><field name="fname">Stoma</field>
    <field name="lname">Milu</field></person>
  <person><field name="person_id">6</field><field name="fname">Nirtam</field>
    <field name="lname">Sklöd</field></person>
  <person person_id="7"><fname>Sungam</fname><lname>Dulbåd</lname></person>
  <person person_id="8" fname="Sraref" lname="Encmelt"/>
</list>
```

Each of the permissible XML formats discussed previously is represented in this example file.

To import the data in `person.xml` into the `person` table, you can use this statement:

```
mysql> LOAD XML LOCAL INFILE 'person.xml'
    ->   INTO TABLE person
    ->   ROWS IDENTIFIED BY '<person>';

Query OK, 8 rows affected (0.00 sec)
Records: 8  Deleted: 0  Skipped: 0  Warnings: 0
```

Here, we assume that `person.xml` is located in the MySQL data directory. If the file cannot be found, the following error results:

```
ERROR 2 (HY000): File '/person.xml' not found (Errcode: 2)
```

The `ROWS IDENTIFIED BY '<person>'` clause means that each `<person>` element in the XML file is considered equivalent to a row in the table into which the data is to be imported. In this case, this is the `person` table in the `test` database.

As can be seen by the response from the server, 8 rows were imported into the `test.person` table. This can be verified by a simple `SELECT` statement:

```
mysql> SELECT * FROM person;
+-----------+--------+------------+---------------------+
| person_id | fname  | lname      | created             |
+-----------+--------+------------+---------------------+
|         1 | Kapek  | Sainnouine | 2007-07-13 16:18:47 |
|         2 | Sajon  | Rondela    | 2007-07-13 16:18:47 |
|         3 | Likame | Örrtmons   | 2007-07-13 16:18:47 |
|         4 | Slar   | Manlanth   | 2007-07-13 16:18:47 |
|         5 | Stoma  | Nilu       | 2007-07-13 16:18:47 |
|         6 | Nirtam | Sklöd      | 2007-07-13 16:18:47 |
|         7 | Sungam | Dulbåd     | 2007-07-13 16:18:47 |
|         8 | Sreraf | Encmelt    | 2007-07-13 16:18:47 |
+-----------+--------+------------+---------------------+
8 rows in set (0.00 sec)
```

This shows, as stated earlier in this section, that any or all of the 3 permitted XML formats may appear in a single file and be read in using `LOAD XML`.

The inverse of the import operation just shown—that is, dumping MySQL table data into an XML file—can be accomplished using the `mysql` client from the system shell, as shown here:

```
shell> mysql --xml -e "SELECT * FROM test.person" > person-dump.xml
shell> cat person-dump.xml
<?xml version="1.0"?>

<resultset statement="SELECT * FROM test.person" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <row>
 <field name="person_id">1</field>
 <field name="fname">Kapek</field>
 <field name="lname">Sainnouine</field>
  </row>

  <row>
 <field name="person_id">2</field>
 <field name="fname">Sajon</field>
 <field name="lname">Rondela</field>
  </row>

  <row>
 <field name="person_id">3</field>
 <field name="fname">Likema</field>
 <field name="lname">Örrtmons</field>
  </row>

  <row>
 <field name="person_id">4</field>
 <field name="fname">Slar</field>
 <field name="lname">Manlanth</field>
  </row>

  <row>
 <field name="person_id">5</field>
 <field name="fname">Stoma</field>
 <field name="lname">Nilu</field>
  </row>

  <row>
 <field name="person_id">6</field>
 <field name="fname">Nirtam</field>
 <field name="lname">Sklöd</field>
  </row>

  <row>
 <field name="person_id">7</field>
 <field name="fname">Sungam</field>
 <field name="lname">Dulbåd</field>
  </row>

  <row>
```

```
 <field name="person_id">8</field>
 <field name="fname">Sreraf</field>
 <field name="lname">Encmelt</field>
  </row>
</resultset>
```

Note

The `--xml` option causes the `mysql` client to use XML formatting for its output; the `-e` option causes the client to execute the SQL statement immediately following the option. See Section 4.5.1, “`mysql` — The MySQL Command-Line Tool”.

You can verify that the dump is valid by creating a copy of the `person` table and importing the dump file into the new table, like this:

```
mysql> USE test;
mysql> CREATE TABLE person2 LIKE person;
Query OK, 0 rows affected (0.00 sec)

mysql> LOAD XML LOCAL INFILE 'person-dump.xml'
    ->   INTO TABLE person2;
Query OK, 8 rows affected (0.01 sec)
Records: 8  Deleted: 0  Skipped: 0  Warnings: 0

mysql> SELECT * FROM person2;
+-----------+--------+------------+---------------------+
| person_id | fname  | lname      | created             |
+-----------+--------+------------+---------------------+
|         1 | Kapek  | Sainnouine | 2007-07-13 16:18:47 |
|         2 | Sajon  | Rondela    | 2007-07-13 16:18:47 |
|         3 | Likema | Örrtmons   | 2007-07-13 16:18:47 |
|         4 | Slar   | Manlanth   | 2007-07-13 16:18:47 |
|         5 | Stoma  | Nilu       | 2007-07-13 16:18:47 |
|         6 | Nirtam | Sklöd      | 2007-07-13 16:18:47 |
|         7 | Sungam | Dulbåd     | 2007-07-13 16:18:47 |
|         8 | Sreraf | Encmelt    | 2007-07-13 16:18:47 |
+-----------+--------+------------+---------------------+
8 rows in set (0.00 sec)
```

There is no requirement that every field in the XML file be matched with a column in the corresponding table. Fields which have no corresponding columns are skipped. You can see this by first emptying the `person2` table and dropping the `created` column, then using the same `LOAD XML` statement we just employed previously, like this:

```
mysql> TRUNCATE person2;
Query OK, 8 rows affected (0.26 sec)

mysql> ALTER TABLE person2 DROP COLUMN created;
Query OK, 0 rows affected (0.52 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> SHOW CREATE TABLE person2\G
*************************** 1. row ***************************
       Table: person2
Create Table: CREATE TABLE `person2` (
  `person_id` int(11) NOT NULL,
  `fname` varchar(40) DEFAULT NULL,
  `lname` varchar(40) DEFAULT NULL,
  PRIMARY KEY (`person_id`)
) ENGINE=InnoDB DEFAULT CHARSET=utf8
1 row in set (0.00 sec)

mysql> LOAD XML LOCAL INFILE 'person-dump.xml'
    ->   INTO TABLE person2;
Query OK, 8 rows affected (0.01 sec)
Records: 8  Deleted: 0  Skipped: 0  Warnings: 0
```

```
mysql> SELECT * FROM person2;
+-----------+--------+------------+
| person_id | fname  | lname      |
+-----------+--------+------------+
|         1 | Kapek  | Sainnouine |
|         2 | Sajon  | Rondela    |
|         3 | Likema | Örrtmons   |
|         4 | Slar   | Manlanth   |
|         5 | Stoma  | Nilu       |
|         6 | Nirtam | Sklöd      |
|         7 | Sungam | Dulbåd     |
|         8 | Sreraf | Encmelt    |
+-----------+--------+------------+
8 rows in set (0.00 sec)
```

The order in which the fields are given within each row of the XML file does not affect the operation of `LOAD XML`; the field order can vary from row to row, and is not required to be in the same order as the corresponding columns in the table.

As mentioned previously, you can use a `(field_name_or_user_var, ...)` list of one or more XML fields (to select desired fields only) or user variables (to store the corresponding field values for later use). User variables can be especially useful when you want to insert data from an XML file into table columns whose names do not match those of the XML fields. To see how this works, we first create a table named `individual` whose structure matches that of the `person` table, but whose columns are named differently:

```
mysql> CREATE TABLE individual (
    ->     individual_id INT NOT NULL PRIMARY KEY,
    ->     name1 VARCHAR(40) NULL,
    ->     name2 VARCHAR(40) NULL,
    ->     made TIMESTAMP
    -> );
Query OK, 0 rows affected (0.42 sec)
```

In this case, you cannot simply load the XML file directly into the table, because the field and column names do not match:

```
mysql> LOAD XML INFILE '../bin/person-dump.xml' INTO TABLE test.individual;
ERROR 1263 (22004): Column set to default value; NULL supplied to NOT NULL column 'individual_id' at ro
```

This happens because the MySQL server looks for field names matching the column names of the target table. You can work around this problem by selecting the field values into user variables, then setting the target table's columns equal to the values of those variables using `SET`. You can perform both of these operations in a single statement, as shown here:

```
mysql> LOAD XML INFILE '../bin/person-dump.xml'
    ->     INTO TABLE test.individual (@person_id, @fname, @lname, @created)
    ->     SET individual_id=@person_id, name1=@fname, name2=@lname, made=@created;
Query OK, 8 rows affected (0.05 sec)
Records: 8  Deleted: 0  Skipped: 0  Warnings: 0

mysql> SELECT * FROM individual;
+---------------+--------+------------+---------------------+
| individual_id | name1  | name2      | made                |
+---------------+--------+------------+---------------------+
|             1 | Kapek  | Sainnouine | 2007-07-13 16:18:47 |
|             2 | Sajon  | Rondela    | 2007-07-13 16:18:47 |
|             3 | Likema | Örrtmons   | 2007-07-13 16:18:47 |
|             4 | Slar   | Manlanth   | 2007-07-13 16:18:47 |
|             5 | Stoma  | Nilu       | 2007-07-13 16:18:47 |
|             6 | Nirtam | Sklöd      | 2007-07-13 16:18:47 |
|             7 | Sungam | Dulbåd     | 2007-07-13 16:18:47 |
|             8 | Srraf  | Encmelt    | 2007-07-13 16:18:47 |
+---------------+--------+------------+---------------------+
8 rows in set (0.00 sec)
```

The names of the user variables *must* match those of the corresponding fields from the XML file, with the addition of the required `@` prefix to indicate that they are variables. The user variables need not be listed or assigned in the same order as the corresponding fields.

Using a `ROWS IDENTIFIED BY '<tagname>'` clause, it is possible to import data from the same XML file into database tables with different definitions. For this example, suppose that you have a file named `address.xml` which contains the following XML:

```
<?xml version="1.0"?>

<list>
  <person person_id="1">
    <fname>Robert</fname>
    <lname>Jones</lname>
    <address address_id="1" street="Mill Creek Road" zip="45365" city="Sidney"/>
    <address address_id="2" street="Main Street" zip="28681" city="Taylorsville"/>
  </person>

  <person person_id="2">
    <fname>Mary</fname>
    <lname>Smith</lname>
    <address address_id="3" street="River Road" zip="80239" city="Denver"/>
    <!-- <address address_id="4" street="North Street" zip="37920" city="Knoxville"/> -->
  </person>

</list>
```

You can again use the `test.person` table as defined previously in this section, after clearing all the existing records from the table and then showing its structure as shown here:

```
mysql< TRUNCATE person;
Query OK, 0 rows affected (0.04 sec)

mysql< SHOW CREATE TABLE person\G
*************************** 1. row ***************************
       Table: person
Create Table: CREATE TABLE `person` (
  `person_id` int(11) NOT NULL,
  `fname` varchar(40) DEFAULT NULL,
  `lname` varchar(40) DEFAULT NULL,
  `created` timestamp NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
  PRIMARY KEY (`person_id`)
) ENGINE=MyISAM DEFAULT CHARSET=latin1
1 row in set (0.00 sec)
```

Now create an `address` table in the `test` database using the following `CREATE TABLE` statement:

```
CREATE TABLE address (
    address_id INT NOT NULL PRIMARY KEY,
    person_id INT NULL,
    street VARCHAR(40) NULL,
    zip INT NULL,
    city VARCHAR(40) NULL,
    created TIMESTAMP
);
```

To import the data from the XML file into the `person` table, execute the following `LOAD XML` statement, which specifies that rows are to be specified by the `<person>` element, as shown here;

```
mysql> LOAD XML LOCAL INFILE 'address.xml'
    ->   INTO TABLE person
    ->   ROWS IDENTIFIED BY '<person>';
Query OK, 2 rows affected (0.00 sec)
Records: 2  Deleted: 0  Skipped: 0  Warnings: 0
```

You can verify that the records were imported using a `SELECT` statement:

```
mysql> SELECT * FROM person;
+-----------+--------+-------+---------------------+
| person_id | fname  | lname | created             |
+-----------+--------+-------+---------------------+
|         1 | Robert | Jones | 2007-07-24 17:37:06 |
|         2 | Mary   | Smith | 2007-07-24 17:37:06 |
+-----------+--------+-------+---------------------+
2 rows in set (0.00 sec)
```

Since the `<address>` elements in the XML file have no corresponding columns in the `person` table, they are skipped.

To import the data from the `<address>` elements into the `address` table, use the `LOAD XML` statement shown here:

```
mysql> LOAD XML LOCAL INFILE 'address.xml'
    ->   INTO TABLE address
    ->   ROWS IDENTIFIED BY '<address>';
Query OK, 3 rows affected (0.00 sec)
Records: 3  Deleted: 0  Skipped: 0  Warnings: 0
```

You can see that the data was imported using a `SELECT` statement such as this one:

```
mysql> SELECT * FROM address;
+------------+-----------+-----------------+-------+-------------+---------------------+
| address_id | person_id | street          | zip   | city        | created             |
+------------+-----------+-----------------+-------+-------------+---------------------+
|          1 |         1 | Mill Creek Road | 45365 | Sidney      | 2007-07-24 17:37:37 |
|          2 |         1 | Main Street     | 28681 | Taylorsville | 2007-07-24 17:37:37 |
|          3 |         2 | River Road      | 80239 | Denver      | 2007-07-24 17:37:37 |
+------------+-----------+-----------------+-------+-------------+---------------------+
3 rows in set (0.00 sec)
```

The data from the `<address>` element that is enclosed in XML comments is not imported. However, since there is a `person_id` column in the `address` table, the value of the `person_id` attribute from the parent `<person>` element for each `<address>` *is* imported into the `address` table.

Security Considerations. As with the `LOAD DATA` statement, the transfer of the XML file from the client host to the server host is initiated by the MySQL server. In theory, a patched server could be built that would tell the client program to transfer a file of the server's choosing rather than the file named by the client in the `LOAD XML` statement. Such a server could access any file on the client host to which the client user has read access.

In a Web environment, clients usually connect to MySQL from a Web server. A user that can run any command against the MySQL server can use `LOAD XML LOCAL` to read any files to which the Web server process has read access. In this environment, the client with respect to the MySQL server is actually the Web server, not the remote program being run by the user who connects to the Web server.

You can disable loading of XML files from clients by starting the server with `--local-infile=0` or `--local-infile=OFF`. This option can also be used when starting the `mysql` client to disable `LOAD XML` for the duration of the client session.

To prevent a client from loading XML files from the server, do not grant the `FILE` privilege to the corresponding MySQL user account, or revoke this privilege if the client user account already has it.

Important

Revoking the `FILE` privilege (or not granting it in the first place) keeps the user only from executing the `LOAD XML INFILE` statement (as well as the `LOAD_FILE()` function; it does *not* prevent the user from executing `LOAD XML LOCAL INFILE`. To disallow this statement, you must start the server or the client with `--local-infile=OFF`.

> In other words, the FILE privilege affects only whether the client can read files on the server; it has no bearing on whether the client can read files on the local file system.

For partitioned tables using storage engines that employ table locks, such as MyISAM, any locks caused by LOAD XML perform locks on all partitions of the table. This does not apply to tables using storage engines which employ row-level locking, such as InnoDB. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.2.8 REPLACE Syntax

```
REPLACE [LOW_PRIORITY | DELAYED]
    [INTO] tbl_name
    [(col_name [, col_name] ...)]
    {VALUES | VALUE} (value_list) [, (value_list)] ...

REPLACE [LOW_PRIORITY | DELAYED]
    [INTO] tbl_name
    SET assignment_list

REPLACE [LOW_PRIORITY | DELAYED]
    [INTO] tbl_name
    [(col_name [, col_name] ...)]
    SELECT ...

value:
    {expr | DEFAULT}

value_list:
    value [, value] ...

assignment:
    col_name = value

assignment_list:
    assignment [, assignment] ...
```

REPLACE works exactly like INSERT, except that if an old row in the table has the same value as a new row for a PRIMARY KEY or a UNIQUE index, the old row is deleted before the new row is inserted. See Section 13.2.5, “INSERT Syntax”.

REPLACE is a MySQL extension to the SQL standard. It either inserts, or *deletes* and inserts. For another MySQL extension to standard SQL—that either inserts or *updates*—see Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”.

Note

REPLACE makes sense only if a table has a PRIMARY KEY or UNIQUE index. Otherwise, it becomes equivalent to INSERT, because there is no index to be used to determine whether a new row duplicates another.

Values for all columns are taken from the values specified in the REPLACE statement. Any missing columns are set to their default values, just as happens for INSERT. You cannot refer to values from the current row and use them in the new row. If you use an assignment such as SET *col_name* = *col_name* + 1, the reference to the column name on the right hand side is treated as DEFAULT(*col_name*), so the assignment is equivalent to SET *col_name* = DEFAULT(*col_name*) + 1.

To use REPLACE, you must have both the INSERT and DELETE privileges for the table.

The REPLACE statement returns a count to indicate the number of rows affected. This is the sum of the rows deleted and inserted. If the count is 1 for a single-row REPLACE, a row was inserted and no rows were deleted. If the count is greater than 1, one or more old rows were deleted before the new row was

inserted. It is possible for a single row to replace more than one old row if the table contains multiple unique indexes and the new row duplicates values for different old rows in different unique indexes.

The affected-rows count makes it easy to determine whether `REPLACE` only added a row or whether it also replaced any rows: Check whether the count is 1 (added) or greater (replaced).

If you are using the C API, the affected-rows count can be obtained using the `mysql_affected_rows()` function.

You cannot replace into a table and select from the same table in a subquery.

MySQL uses the following algorithm for `REPLACE` (and `LOAD DATA ... REPLACE`):

1. Try to insert the new row into the table
2. While the insertion fails because a duplicate-key error occurs for a primary key or unique index:
   a. Delete from the table the conflicting row that has the duplicate key value
   b. Try again to insert the new row into the table

It is possible that in the case of a duplicate-key error, a storage engine may perform the `REPLACE` as an update rather than a delete plus insert, but the semantics are the same. There are no user-visible effects other than a possible difference in how the storage engine increments `Handler_xxx` status variables.

Because the results of `REPLACE ... SELECT` statements depend on the ordering of rows from the `SELECT` and this order cannot always be guaranteed, it is possible when logging these statements for the master and the slave to diverge. For this reason, in MySQL 5.5.18 and later, `REPLACE ... SELECT` statements are flagged as unsafe for statement-based replication. With this change, such statements produce a warning in the error log when using statement-based mode, and are written to the binary log using the row-based format when using `MIXED` mode. See also Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

When modifying an existing table that is not partitioned to accommodate partitioning, or, when modifying the partitioning of an already partitioned table, you may consider altering the table's primary key (see Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”). You should be aware that, if you do this, the results of `REPLACE` statements may be affected, just as they would be if you modified the primary key of a nonpartitioned table. Consider the table created by the following `CREATE TABLE` statement:

```
CREATE TABLE test (
  id INT UNSIGNED NOT NULL AUTO_INCREMENT,
  data VARCHAR(64) DEFAULT NULL,
  ts TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
  PRIMARY KEY (id)
);
```

When we create this table and run the statements shown in the mysql client, the result is as follows:

```
mysql> REPLACE INTO test VALUES (1, 'Old', '2014-08-20 18:47:00');
Query OK, 1 row affected (0.04 sec)

mysql> REPLACE INTO test VALUES (1, 'New', '2014-08-20 18:47:42');
Query OK, 2 rows affected (0.04 sec)

mysql> SELECT * FROM test;
+----+------+---------------------+
| id | data | ts                  |
+----+------+---------------------+
|  1 | New  | 2014-08-20 18:47:42 |
+----+------+---------------------+
1 row in set (0.00 sec)
```

Now we create a second table almost identical to the first, except that the primary key now covers 2 columns, as shown here (emphasized text):

```
CREATE TABLE test2 (
  id INT UNSIGNED NOT NULL AUTO_INCREMENT,
  data VARCHAR(64) DEFAULT NULL,
  ts TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
  PRIMARY KEY (id, ts)
);
```

When we run on `test2` the same two `REPLACE` statements as we did on the original `test` table, we obtain a different result:

```
mysql> REPLACE INTO test2 VALUES (1, 'Old', '2014-08-20 18:47:00');
Query OK, 1 row affected (0.05 sec)

mysql> REPLACE INTO test2 VALUES (1, 'New', '2014-08-20 18:47:42');
Query OK, 1 row affected (0.06 sec)

mysql> SELECT * FROM test2;
+----+------+---------------------+
| id | data | ts                  |
+----+------+---------------------+
|  1 | Old  | 2014-08-20 18:47:00 |
|  1 | New  | 2014-08-20 18:47:42 |
+----+------+---------------------+
2 rows in set (0.00 sec)
```

This is due to the fact that, when run on `test2`, both the `id` and `ts` column values must match those of an existing row for the row to be replaced; otherwise, a row is inserted.

A `REPLACE` statement affecting a partitioned table using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as `InnoDB` that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.2.9 SELECT Syntax

```
SELECT
    [ALL | DISTINCT | DISTINCTROW ]
      [HIGH_PRIORITY]
      [STRAIGHT_JOIN]
      [SQL_SMALL_RESULT] [SQL_BIG_RESULT] [SQL_BUFFER_RESULT]
      [SQL_CACHE | SQL_NO_CACHE] [SQL_CALC_FOUND_ROWS]
    select_expr [, select_expr ...]
    [FROM table_references
    [WHERE where_condition]
    [GROUP BY {col_name | expr | position}
      [ASC | DESC], ... [WITH ROLLUP]]
    [HAVING where_condition]
    [ORDER BY {col_name | expr | position}
      [ASC | DESC], ...]
    [LIMIT {[offset,] row_count | row_count OFFSET offset}]
    [PROCEDURE procedure_name(argument_list)]
    [INTO OUTFILE 'file_name'
        [CHARACTER SET charset_name]
        export_options
      | INTO DUMPFILE 'file_name'
      | INTO var_name [, var_name]]
    [FOR UPDATE | LOCK IN SHARE MODE]]
```

`SELECT` is used to retrieve rows selected from one or more tables, and can include `UNION` statements and subqueries. See Section 13.2.9.3, “UNION Syntax”, and Section 13.2.10, “Subquery Syntax”.

The most commonly used clauses of `SELECT` statements are these:

- Each *`select_expr`* indicates a column that you want to retrieve. There must be at least one *`select_expr`*.
- *`table_references`* indicates the table or tables from which to retrieve rows. Its syntax is described in Section 13.2.9.2, “JOIN Syntax”.
- The `WHERE` clause, if given, indicates the condition or conditions that rows must satisfy to be selected. *`where_condition`* is an expression that evaluates to true for each row to be selected. The statement selects all rows if there is no `WHERE` clause.

  In the `WHERE` expression, you can use any of the functions and operators that MySQL supports, except for aggregate (summary) functions. See Section 9.5, “Expression Syntax”, and Chapter 12, *Functions and Operators*.

`SELECT` can also be used to retrieve rows computed without reference to any table.

For example:

```
mysql> SELECT 1 + 1;
        -> 2
```

You are permitted to specify `DUAL` as a dummy table name in situations where no tables are referenced:

```
mysql> SELECT 1 + 1 FROM DUAL;
        -> 2
```

`DUAL` is purely for the convenience of people who require that all `SELECT` statements should have `FROM` and possibly other clauses. MySQL may ignore the clauses. MySQL does not require `FROM DUAL` if no tables are referenced.

In general, clauses used must be given in exactly the order shown in the syntax description. For example, a `HAVING` clause must come after any `GROUP BY` clause and before any `ORDER BY` clause. The exception is that the `INTO` clause can appear either as shown in the syntax description or immediately following the *`select_expr`* list. For more information about `INTO`, see Section 13.2.9.1, “SELECT ... INTO Syntax”.

The list of *`select_expr`* terms comprises the select list that indicates which columns to retrieve. Terms specify a column or expression or can use `*`-shorthand:

- A select list consisting only of a single unqualified `*` can be used as shorthand to select all columns from all tables:

  ```
  SELECT * FROM t1 INNER JOIN t2 ...
  ```

- *`tbl_name`*`.*` can be used as a qualified shorthand to select all columns from the named table:

  ```
  SELECT t1.*, t2.* FROM t1 INNER JOIN t2 ...
  ```

- Use of an unqualified `*` with other items in the select list may produce a parse error. To avoid this problem, use a qualified *`tbl_name`*`.*` reference

  ```
  SELECT AVG(score), t1.* FROM t1 ...
  ```

The following list provides additional information about other `SELECT` clauses:

- A *`select_expr`* can be given an alias using `AS` *`alias_name`*. The alias is used as the expression's column name and can be used in `GROUP BY`, `ORDER BY`, or `HAVING` clauses. For example:

```
SELECT CONCAT(last_name,', ',first_name) AS full_name
  FROM mytable ORDER BY full_name;
```

The AS keyword is optional when aliasing a *select_expr* with an identifier. The preceding example could have been written like this:

```
SELECT CONCAT(last_name,', ',first_name) full_name
  FROM mytable ORDER BY full_name;
```

However, because the AS is optional, a subtle problem can occur if you forget the comma between two *select_expr* expressions: MySQL interprets the second as an alias name. For example, in the following statement, columnb is treated as an alias name:

```
SELECT columna columnb FROM mytable;
```

For this reason, it is good practice to be in the habit of using AS explicitly when specifying column aliases.

It is not permissible to refer to a column alias in a WHERE clause, because the column value might not yet be determined when the WHERE clause is executed. See Section B.5.4.4, “Problems with Column Aliases”.

- The FROM *table_references* clause indicates the table or tables from which to retrieve rows. If you name more than one table, you are performing a join. For information on join syntax, see Section 13.2.9.2, “JOIN Syntax”. For each table specified, you can optionally specify an alias.

```
tbl_name [[AS] alias] [index_hint]
```

The use of index hints provides the optimizer with information about how to choose indexes during query processing. For a description of the syntax for specifying these hints, see Section 8.9.3, “Index Hints”.

You can use SET max_seeks_for_key=*value* as an alternative way to force MySQL to prefer key scans instead of table scans. See Section 5.1.5, “Server System Variables”.

- You can refer to a table within the default database as *tbl_name*, or as *db_name*.*tbl_name* to specify a database explicitly. You can refer to a column as *col_name*, *tbl_name*.*col_name*, or *db_name*.*tbl_name*.*col_name*. You need not specify a *tbl_name* or *db_name*.*tbl_name* prefix for a column reference unless the reference would be ambiguous. See Section 9.2.1, “Identifier Qualifiers”, for examples of ambiguity that require the more explicit column reference forms.

- A table reference can be aliased using *tbl_name* AS *alias_name* or *tbl_name* *alias_name*:

```
SELECT t1.name, t2.salary FROM employee AS t1, info AS t2
  WHERE t1.name = t2.name;

SELECT t1.name, t2.salary FROM employee t1, info t2
  WHERE t1.name = t2.name;
```

- Columns selected for output can be referred to in ORDER BY and GROUP BY clauses using column names, column aliases, or column positions. Column positions are integers and begin with 1:

```
SELECT college, region, seed FROM tournament
  ORDER BY region, seed;

SELECT college, region AS r, seed AS s FROM tournament
  ORDER BY r, s;
```

```
SELECT college, region, seed FROM tournament
  ORDER BY 2, 3;
```

To sort in reverse order, add the `DESC` (descending) keyword to the name of the column in the `ORDER BY` clause that you are sorting by. The default is ascending order; this can be specified explicitly using the `ASC` keyword.

If `ORDER BY` occurs within a subquery and also is applied in the outer query, the outermost `ORDER BY` takes precedence. For example, results for the following statement are sorted in descending order, not ascending order:

```
(SELECT ... ORDER BY a) ORDER BY a DESC;
```

Use of column positions is deprecated because the syntax has been removed from the SQL standard.

- If you use `GROUP BY`, output rows are sorted according to the `GROUP BY` columns as if you had an `ORDER BY` for the same columns. To avoid the overhead of sorting that `GROUP BY` produces, add `ORDER BY NULL`:

```
SELECT a, COUNT(b) FROM test_table GROUP BY a ORDER BY NULL;
```

Relying on implicit `GROUP BY` sorting (that is, sorting in the absence of `ASC` or `DESC` designators) is deprecated. To produce a given sort order, use explicit `ASC` or `DESC` designators for `GROUP BY` columns or provide an `ORDER BY` clause.

- When you use `ORDER BY` or `GROUP BY` to sort a column in a `SELECT`, the server sorts values using only the initial number of bytes indicated by the `max_sort_length` system variable.

- MySQL extends the `GROUP BY` clause so that you can also specify `ASC` and `DESC` after columns named in the clause:

```
SELECT a, COUNT(b) FROM test_table GROUP BY a DESC;
```

- MySQL extends the use of `GROUP BY` to permit selecting fields that are not mentioned in the `GROUP BY` clause. If you are not getting the results that you expect from your query, please read the description of `GROUP BY` found in Section 12.16, “Aggregate (GROUP BY) Functions”.

- `GROUP BY` permits a `WITH ROLLUP` modifier. See Section 12.16.2, “GROUP BY Modifiers”.

- The `HAVING` clause is applied nearly last, just before items are sent to the client, with no optimization. (`LIMIT` is applied after `HAVING`.)

  The SQL standard requires that `HAVING` must reference only columns in the `GROUP BY` clause or columns used in aggregate functions. However, MySQL supports an extension to this behavior, and permits `HAVING` to refer to columns in the `SELECT` list and columns in outer subqueries as well.

  If the `HAVING` clause refers to a column that is ambiguous, a warning occurs. In the following statement, `col2` is ambiguous because it is used as both an alias and a column name:

```
SELECT COUNT(col1) AS col2 FROM t GROUP BY col2 HAVING col2 = 2;
```

  Preference is given to standard SQL behavior, so if a `HAVING` column name is used both in `GROUP BY` and as an aliased column in the output column list, preference is given to the column in the `GROUP BY` column.

- Do not use `HAVING` for items that should be in the `WHERE` clause. For example, do not write the following:

```
```

```
SELECT col_name FROM tbl_name HAVING col_name > 0;
```

Write this instead:

```
SELECT col_name FROM tbl_name WHERE col_name > 0;
```

- The `HAVING` clause can refer to aggregate functions, which the `WHERE` clause cannot:

```
SELECT user, MAX(salary) FROM users
  GROUP BY user HAVING MAX(salary) > 10;
```

(This did not work in some older versions of MySQL.)

- MySQL permits duplicate column names. That is, there can be more than one *`select_expr`* with the same name. This is an extension to standard SQL. Because MySQL also permits `GROUP BY` and `HAVING` to refer to *`select_expr`* values, this can result in an ambiguity:

```
SELECT 12 AS a, a FROM t GROUP BY a;
```

In that statement, both columns have the name `a`. To ensure that the correct column is used for grouping, use different names for each *`select_expr`*.

- MySQL resolves unqualified column or alias references in `ORDER BY` clauses by searching in the *`select_expr`* values, then in the columns of the tables in the `FROM` clause. For `GROUP BY` or `HAVING` clauses, it searches the `FROM` clause before searching in the *`select_expr`* values. (For `GROUP BY` and `HAVING`, this differs from the pre-MySQL 5.0 behavior that used the same rules as for `ORDER BY`.)

- The `LIMIT` clause can be used to constrain the number of rows returned by the `SELECT` statement. `LIMIT` takes one or two numeric arguments, which must both be nonnegative integer constants, with these exceptions:

  - Within prepared statements, `LIMIT` parameters can be specified using `?` placeholder markers.

  - Within stored programs, `LIMIT` parameters can be specified using integer-valued routine parameters or local variables as of MySQL 5.5.6.

With two arguments, the first argument specifies the offset of the first row to return, and the second specifies the maximum number of rows to return. The offset of the initial row is 0 (not 1):

```
SELECT * FROM tbl LIMIT 5,10;  # Retrieve rows 6-15
```

To retrieve all rows from a certain offset up to the end of the result set, you can use some large number for the second parameter. This statement retrieves all rows from the 96th row to the last:

```
SELECT * FROM tbl LIMIT 95,18446744073709551615;
```

With one argument, the value specifies the number of rows to return from the beginning of the result set:

```
SELECT * FROM tbl LIMIT 5;     # Retrieve first 5 rows
```

In other words, `LIMIT` *`row_count`* is equivalent to `LIMIT 0,` *`row_count`*.

For prepared statements, you can use placeholders. The following statements will return one row from the `tbl` table:

```
SET @a=1;
```

```
PREPARE STMT FROM 'SELECT * FROM tbl LIMIT ?';
EXECUTE STMT USING @a;
```

The following statements will return the second to sixth row from the `tbl` table:

```
SET @skip=1; SET @numrows=5;
PREPARE STMT FROM 'SELECT * FROM tbl LIMIT ?, ?';
EXECUTE STMT USING @skip, @numrows;
```

For compatibility with PostgreSQL, MySQL also supports the `LIMIT row_count OFFSET offset` syntax.

If `LIMIT` occurs within a subquery and also is applied in the outer query, the outermost `LIMIT` takes precedence. For example, the following statement produces two rows, not one:

```
(SELECT ... LIMIT 1) LIMIT 2;
```

- A `PROCEDURE` clause names a procedure that should process the data in the result set. For an example, see Section 8.4.2.4, “Using PROCEDURE ANALYSE”, which describes `ANALYSE`, a procedure that can be used to obtain suggestions for optimal column data types that may help reduce table sizes.

  A `PROCEDURE` clause is not permitted in a `UNION` statement.

- The `SELECT ... INTO` form of `SELECT` enables the query result to be written to a file or stored in variables. For more information, see Section 13.2.9.1, “SELECT ... INTO Syntax”.

- If you use `FOR UPDATE` with a storage engine that uses page or row locks, rows examined by the query are write-locked until the end of the current transaction. Using `LOCK IN SHARE MODE` sets a shared lock that permits other transactions to read the examined rows but not to update or delete them. See Section 14.8.2.4, “Locking Reads”.

Following the `SELECT` keyword, you can use a number of modifiers that affect the operation of the statement. `HIGH_PRIORITY`, `STRAIGHT_JOIN`, and modifiers beginning with `SQL_` are MySQL extensions to standard SQL.

- The `ALL` and `DISTINCT` modifiers specify whether duplicate rows should be returned. `ALL` (the default) specifies that all matching rows should be returned, including duplicates. `DISTINCT` specifies removal of duplicate rows from the result set. It is an error to specify both modifiers. `DISTINCTROW` is a synonym for `DISTINCT`.

- `HIGH_PRIORITY` gives the `SELECT` higher priority than a statement that updates a table. You should use this only for queries that are very fast and must be done at once. A `SELECT HIGH_PRIORITY` query that is issued while the table is locked for reading runs even if there is an update statement waiting for the table to be free. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).

  `HIGH_PRIORITY` cannot be used with `SELECT` statements that are part of a `UNION`.

- `STRAIGHT_JOIN` forces the optimizer to join the tables in the order in which they are listed in the `FROM` clause. You can use this to speed up a query if the optimizer joins the tables in nonoptimal order. `STRAIGHT_JOIN` also can be used in the *`table_references`* list. See Section 13.2.9.2, “JOIN Syntax”.

  `STRAIGHT_JOIN` does not apply to any table that the optimizer treats as a `const` or `system` table. Such a table produces a single row, is read during the optimization phase of query execution, and references to its columns are replaced with the appropriate column values before query execution proceeds. These tables will appear first in the query plan displayed by `EXPLAIN`. See Section 8.8.1, “Optimizing Queries with EXPLAIN”. This exception may not apply to `const` or `system` tables that are used on the `NULL`-complemented side of an outer join (that is, the right-side table of a `LEFT JOIN` or the left-side table of a `RIGHT JOIN`.

- SQL_BIG_RESULT or SQL_SMALL_RESULT can be used with GROUP BY or DISTINCT to tell the optimizer that the result set has many rows or is small, respectively. For SQL_BIG_RESULT, MySQL directly uses disk-based temporary tables if needed, and prefers sorting to using a temporary table with a key on the GROUP BY elements. For SQL_SMALL_RESULT, MySQL uses fast temporary tables to store the resulting table instead of using sorting. This should not normally be needed.

- SQL_BUFFER_RESULT forces the result to be put into a temporary table. This helps MySQL free the table locks early and helps in cases where it takes a long time to send the result set to the client. This modifier can be used only for top-level SELECT statements, not for subqueries or following UNION.

- SQL_CALC_FOUND_ROWS tells MySQL to calculate how many rows there would be in the result set, disregarding any LIMIT clause. The number of rows can then be retrieved with SELECT FOUND_ROWS(). See Section 12.14, “Information Functions”.

- The SQL_CACHE and SQL_NO_CACHE modifiers affect caching of query results in the query cache (see Section 8.10.3, “The MySQL Query Cache”). SQL_CACHE tells MySQL to store the result in the query cache if it is cacheable and the value of the query_cache_type system variable is 2 or DEMAND. With SQL_NO_CACHE, the server does not use the query cache. It neither checks the query cache to see whether the result is already cached, nor does it cache the query result. (Due to a limitation in the parser, a space character must precede and follow the SQL_NO_CACHE keyword; a nonspace such as a newline causes the server to check the query cache to see whether the result is already cached.)

  For views, SQL_NO_CACHE applies if it appears in any SELECT in the query. For a cacheable query, SQL_CACHE applies if it appears in the first SELECT of a view referred to by the query.

  As of MySQL 5.5.3, these two modifiers are mutually exclusive and an error occurs if they are both specified. Also, these modifiers are not permitted in subqueries (including subqueries in the FROM clause), and SELECT statements in unions other than the first SELECT.

  Before MySQL 5.5.3, for a query that uses UNION or subqueries, the following rules apply:

  - SQL_NO_CACHE applies if it appears in any SELECT in the query.
  - For a cacheable query, SQL_CACHE applies if it appears in the first SELECT of the query.

A SELECT from a partitioned table using a storage engine such as MyISAM that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as InnoDB that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.2.9.1 SELECT ... INTO Syntax

The SELECT ... INTO form of SELECT enables a query result to be stored in variables or written to a file:

- SELECT ... INTO *var_list* selects column values and stores them into variables.
- SELECT ... INTO OUTFILE writes the selected rows to a file. Column and line terminators can be specified to produce a specific output format.
- SELECT ... INTO DUMPFILE writes a single row to a file without any formatting.

The SELECT syntax description (see Section 13.2.9, “SELECT Syntax”) shows the INTO clause near the end of the statement. It is also possible to use INTO immediately following the *select_expr* list.

An INTO clause should not be used in a nested SELECT because such a SELECT must return its result to the outer context.

The INTO clause can name a list of one or more variables, which can be user-defined variables, stored procedure or function parameters, or stored program local variables. (Within a prepared SELECT ...

`INTO OUTFILE` statement, only user-defined variables are permitted;see Section 13.6.4.2, “Local Variable Scope and Resolution”.)

The selected values are assigned to the variables. The number of variables must match the number of columns. The query should return a single row. If the query returns no rows, a warning with error code 1329 occurs (`No data`), and the variable values remain unchanged. If the query returns multiple rows, error 1172 occurs (`Result consisted of more than one row`). If it is possible that the statement may retrieve multiple rows, you can use `LIMIT 1` to limit the result set to a single row.

```
SELECT id, data INTO @x, @y FROM test.t1 LIMIT 1;
```

User variable names are not case sensitive. See Section 9.4, “User-Defined Variables”.

The `SELECT ... INTO OUTFILE 'file_name'` form of `SELECT` writes the selected rows to a file. The file is created on the server host, so you must have the `FILE` privilege to use this syntax. *`file_name`* cannot be an existing file, which among other things prevents files such as `/etc/passwd` and database tables from being destroyed. The `character_set_filesystem` system variable controls the interpretation of the file name.

The `SELECT ... INTO OUTFILE` statement is intended primarily to let you very quickly dump a table to a text file on the server machine. If you want to create the resulting file on some other host than the server host, you normally cannot use `SELECT ... INTO OUTFILE` since there is no way to write a path to the file relative to the server host's file system.

However, if the MySQL client software is installed on the remote machine, you can instead use a client command such as `mysql -e "SELECT ..." > file_name` to generate the file on the client host.

It is also possible to create the resulting file on a different host other than the server host, if the location of the file on the remote host can be accessed using a network-mapped path on the server's file system. In this case, the presence of `mysql` (or some other MySQL client program) is not required on the target host.

`SELECT ... INTO OUTFILE` is the complement of `LOAD DATA INFILE`. Column values are written converted to the character set specified in the `CHARACTER SET` clause. If no such clause is present, values are dumped using the `binary` character set. In effect, there is no character set conversion. If a result set contains columns in several character sets, the output data file will as well and you may not be able to reload the file correctly.

The syntax for the *`export_options`* part of the statement consists of the same `FIELDS` and `LINES` clauses that are used with the `LOAD DATA INFILE` statement. See Section 13.2.6, “LOAD DATA INFILE Syntax”, for information about the `FIELDS` and `LINES` clauses, including their default values and permissible values.

`FIELDS ESCAPED BY` controls how to write special characters. If the `FIELDS ESCAPED BY` character is not empty, it is used when necessary to avoid ambiguity as a prefix that precedes following characters on output:

- The `FIELDS ESCAPED BY` character
- The `FIELDS [OPTIONALLY] ENCLOSED BY` character
- The first character of the `FIELDS TERMINATED BY` and `LINES TERMINATED BY` values
- ASCII `NUL` (the zero-valued byte; what is actually written following the escape character is ASCII `0`, not a zero-valued byte)

The `FIELDS TERMINATED BY`, `ENCLOSED BY`, `ESCAPED BY`, or `LINES TERMINATED BY` characters *must* be escaped so that you can read the file back in reliably. ASCII `NUL` is escaped to make it easier to view with some pagers.

The resulting file does not have to conform to SQL syntax, so nothing else need be escaped.

If the FIELDS ESCAPED BY character is empty, no characters are escaped and NULL is output as NULL, not \N. It is probably not a good idea to specify an empty escape character, particularly if field values in your data contain any of the characters in the list just given.

Here is an example that produces a file in the comma-separated values (CSV) format used by many programs:

```
SELECT a,b,a+b INTO OUTFILE '/tmp/result.txt'
  FIELDS TERMINATED BY ',' OPTIONALLY ENCLOSED BY '"'
  LINES TERMINATED BY '\n'
  FROM test_table;
```

If you use INTO DUMPFILE instead of INTO OUTFILE, MySQL writes only one row into the file, without any column or line termination and without performing any escape processing. This is useful if you want to store a BLOB value in a file.

Note

Any file created by INTO OUTFILE or INTO DUMPFILE is writable by all users on the server host. The reason for this is that the MySQL server cannot create a file that is owned by anyone other than the user under whose account it is running. (You should *never* run mysqld as root for this and other reasons.) The file thus must be world-writable so that you can manipulate its contents.

If the secure_file_priv system variable is set to a nonempty directory name, the file to be written must be located in that directory.

In the context of SELECT ... INTO statements that occur as part of events executed by the Event Scheduler, diagnostics messages (not only errors, but also warnings) are written to the error log, and, on Windows, to the application event log. For additional information, see Section 20.4.5, “Event Scheduler Status”.

13.2.9.2 JOIN Syntax

MySQL supports the following JOIN syntax for the *table_references* part of SELECT statements and multiple-table DELETE and UPDATE statements:

```
table_references:
    escaped_table_reference [, escaped_table_reference] ...

escaped_table_reference:
    table_reference
  | { OJ table_reference }

table_reference:
    table_factor
  | join_table

table_factor:
    tbl_name [[AS] alias] [index_hint_list]
  | table_subquery [AS] alias
  | ( table_references )

join_table:
    table_reference [INNER | CROSS] JOIN table_factor [join_condition]
  | table_reference STRAIGHT_JOIN table_factor
  | table_reference STRAIGHT_JOIN table_factor ON conditional_expr
  | table_reference {LEFT|RIGHT} [OUTER] JOIN table_reference join_condition
  | table_reference NATURAL [{LEFT|RIGHT} [OUTER]] JOIN table_factor

join_condition:
    ON conditional_expr
  | USING (column_list)
```

```
index_hint_list:
    index_hint [, index_hint] ...

index_hint:
    USE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] ([index_list])
  | IGNORE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] (index_list)
  | FORCE {INDEX|KEY}
      [FOR {JOIN|ORDER BY|GROUP BY}] (index_list)

index_list:
    index_name [, index_name] ...
```

A table reference is also known as a join expression.

The syntax of *`table_factor`* is extended in MySQL in comparison with standard SQL. The standard accepts only *`table_reference`*, not a list of them inside a pair of parentheses.

This is a conservative extension if each comma in a list of *`table_reference`* items is considered as equivalent to an inner join. For example:

```
SELECT * FROM t1 LEFT JOIN (t2, t3, t4)
                 ON (t2.a = t1.a AND t3.b = t1.b AND t4.c = t1.c)
```

is equivalent to:

```
SELECT * FROM t1 LEFT JOIN (t2 CROSS JOIN t3 CROSS JOIN t4)
                 ON (t2.a = t1.a AND t3.b = t1.b AND t4.c = t1.c)
```

In MySQL, `JOIN`, `CROSS JOIN`, and `INNER JOIN` are syntactic equivalents (they can replace each other). In standard SQL, they are not equivalent. `INNER JOIN` is used with an `ON` clause, `CROSS JOIN` is used otherwise.

In general, parentheses can be ignored in join expressions containing only inner join operations. MySQL also supports nested joins. See Section 8.2.1.6, “Nested Join Optimization”.

Index hints can be specified to affect how the MySQL optimizer makes use of indexes. For more information, see Section 8.9.3, “Index Hints”. The `optimizer_switch` system variable is another way to influence optimizer use of indexes. See Section 8.9.2, “Switchable Optimizations”.

The following list describes general factors to take into account when writing joins:

- A table reference can be aliased using *`tbl_name AS alias_name`* or *`tbl_name alias_name`*:

  ```
  SELECT t1.name, t2.salary
    FROM employee AS t1 INNER JOIN info AS t2 ON t1.name = t2.name;

  SELECT t1.name, t2.salary
    FROM employee t1 INNER JOIN info t2 ON t1.name = t2.name;
  ```

- A *`table_subquery`* is also known as a derived table or subquery in the `FROM` clause. See Section 13.2.10.8, “Derived Tables (Subqueries in the FROM Clause)”. Such subqueries *must* include an alias to give the subquery result a table name. A trivial example follows:

  ```
  SELECT * FROM (SELECT 1, 2, 3) AS t1;
  ```

- `INNER JOIN` and `,` (comma) are semantically equivalent in the absence of a join condition: both produce a Cartesian product between the specified tables (that is, each and every row in the first table is joined to each and every row in the second table).

  However, the precedence of the comma operator is less than that of `INNER JOIN`, `CROSS JOIN`, `LEFT JOIN`, and so on. If you mix comma joins with the other join types when there is a join

condition, an error of the form `Unknown column 'col_name' in 'on clause'` may occur. Information about dealing with this problem is given later in this section.

- The *`conditional_expr`* used with `ON` is any conditional expression of the form that can be used in a `WHERE` clause. Generally, the `ON` clause serves for conditions that specify how to join tables, and the `WHERE` clause restricts which rows to include in the result set.
- If there is no matching row for the right table in the `ON` or `USING` part in a `LEFT JOIN`, a row with all columns set to `NULL` is used for the right table. You can use this fact to find rows in a table that have no counterpart in another table:

```
SELECT left_tbl.*
  FROM left_tbl LEFT JOIN right_tbl ON left_tbl.id = right_tbl.id
  WHERE right_tbl.id IS NULL;
```

  This example finds all rows in `left_tbl` with an `id` value that is not present in `right_tbl` (that is, all rows in `left_tbl` with no corresponding row in `right_tbl`). See Section 8.2.1.7, “Left Join and Right Join Optimization”.
- The `USING(column_list)` clause names a list of columns that must exist in both tables. If tables `a` and `b` both contain columns `c1`, `c2`, and `c3`, the following join compares corresponding columns from the two tables:

```
a LEFT JOIN b USING (c1, c2, c3)
```

- The `NATURAL [LEFT] JOIN` of two tables is defined to be semantically equivalent to an `INNER JOIN` or a `LEFT JOIN` with a `USING` clause that names all columns that exist in both tables.
- `RIGHT JOIN` works analogously to `LEFT JOIN`. To keep code portable across databases, it is recommended that you use `LEFT JOIN` instead of `RIGHT JOIN`.
- The `{ OJ ... }` syntax shown in the join syntax description exists only for compatibility with ODBC. The curly braces in the syntax should be written literally; they are not metasyntax as used elsewhere in syntax descriptions.

```
SELECT left_tbl.*
    FROM { OJ left_tbl LEFT OUTER JOIN right_tbl ON left_tbl.id = right_tbl.id }
    WHERE right_tbl.id IS NULL;
```

  You can use other types of joins within `{ OJ ... }`, such as `INNER JOIN` or `RIGHT OUTER JOIN`. This helps with compatibility with some third-party applications, but is not official ODBC syntax.

  The parser does not permit nested `{ OJ ... }` constructs (which are not legal ODBC syntax, anyway). Queries that use such constructs should be rewritten.
- `STRAIGHT_JOIN` is similar to `JOIN`, except that the left table is always read before the right table. This can be used for those (few) cases for which the join optimizer processes the tables in a suboptimal order.

Some join examples:

```
SELECT * FROM table1, table2;

SELECT * FROM table1 INNER JOIN table2 ON table1.id = table2.id;

SELECT * FROM table1 LEFT JOIN table2 ON table1.id = table2.id;

SELECT * FROM table1 LEFT JOIN table2 USING (id);

SELECT * FROM table1 LEFT JOIN table2 ON table1.id = table2.id
```

```
  LEFT JOIN table3 ON table2.id = table3.id;
```

Natural joins and joins with `USING`, including outer join variants, are processed according to the SQL:2003 standard:

- Redundant columns of a `NATURAL` join do not appear. Consider this set of statements:

```
CREATE TABLE t1 (i INT, j INT);
CREATE TABLE t2 (k INT, j INT);
INSERT INTO t1 VALUES(1, 1);
INSERT INTO t2 VALUES(1, 1);
SELECT * FROM t1 NATURAL JOIN t2;
SELECT * FROM t1 JOIN t2 USING (j);
```

  In the first `SELECT` statement, column `j` appears in both tables and thus becomes a join column, so, according to standard SQL, it should appear only once in the output, not twice. Similarly, in the second SELECT statement, column `j` is named in the `USING` clause and should appear only once in the output, not twice.

  Thus, the statements produce this output:

```
+------+------+------+
| j    | i    | k    |
+------+------+------+
|    1 |    1 |    1 |
+------+------+------+
+------+------+------+
| j    | i    | k    |
+------+------+------+
|    1 |    1 |    1 |
+------+------+------+
```

  Redundant column elimination and column ordering occurs according to standard SQL, producing this display order:

  - First, coalesced common columns of the two joined tables, in the order in which they occur in the first table
  - Second, columns unique to the first table, in order in which they occur in that table
  - Third, columns unique to the second table, in order in which they occur in that table

  The single result column that replaces two common columns is defined using the coalesce operation. That is, for two `t1.a` and `t2.a` the resulting single join column `a` is defined as `a = COALESCE(t1.a, t2.a)`, where:

```
COALESCE(x, y) = (CASE WHEN x IS NOT NULL THEN x ELSE y END)
```

  If the join operation is any other join, the result columns of the join consist of the concatenation of all columns of the joined tables.

  A consequence of the definition of coalesced columns is that, for outer joins, the coalesced column contains the value of the non-`NULL` column if one of the two columns is always `NULL`. If neither or both columns are `NULL`, both common columns have the same value, so it doesn't matter which one is chosen as the value of the coalesced column. A simple way to interpret this is to consider that a coalesced column of an outer join is represented by the common column of the inner table of a `JOIN`. Suppose that the tables `t1(a, b)` and `t2(a, c)` have the following contents:

```
t1    t2
----  ----
1 x   2 z
2 y   3 w
```

Then, for this join, column `a` contains the values of `t1.a`:

```
mysql> SELECT * FROM t1 NATURAL LEFT JOIN t2;
+------+------+------+
| a    | b    | c    |
+------+------+------+
|    1 | x    | NULL |
|    2 | y    | z    |
+------+------+------+
```

By contrast, for this join, column `a` contains the values of `t2.a`.

```
mysql> SELECT * FROM t1 NATURAL RIGHT JOIN t2;
+------+------+------+
| a    | c    | b    |
+------+------+------+
|    2 | z    | y    |
|    3 | w    | NULL |
+------+------+------+
```

Compare those results to the otherwise equivalent queries with `JOIN ... ON`:

```
mysql> SELECT * FROM t1 LEFT JOIN t2 ON (t1.a = t2.a);
+------+------+------+------+
| a    | b    | a    | c    |
+------+------+------+------+
|    1 | x    | NULL | NULL |
|    2 | y    |    2 | z    |
+------+------+------+------+
```

```
mysql> SELECT * FROM t1 RIGHT JOIN t2 ON (t1.a = t2.a);
+------+------+------+------+
| a    | b    | a    | c    |
+------+------+------+------+
|    2 | y    |    2 | z    |
| NULL | NULL |    3 | w    |
+------+------+------+------+
```

- A `USING` clause can be rewritten as an `ON` clause that compares corresponding columns. However, although `USING` and `ON` are similar, they are not quite the same. Consider the following two queries:

  ```
  a LEFT JOIN b USING (c1, c2, c3)
  a LEFT JOIN b ON a.c1 = b.c1 AND a.c2 = b.c2 AND a.c3 = b.c3
  ```

  With respect to determining which rows satisfy the join condition, both joins are semantically identical.

  With respect to determining which columns to display for `SELECT *` expansion, the two joins are not semantically identical. The `USING` join selects the coalesced value of corresponding columns, whereas the `ON` join selects all columns from all tables. For the `USING` join, `SELECT *` selects these values:

  ```
  COALESCE(a.c1, b.c1), COALESCE(a.c2, b.c2), COALESCE(a.c3, b.c3)
  ```

  For the `ON` join, `SELECT *` selects these values:

  ```
  a.c1, a.c2, a.c3, b.c1, b.c2, b.c3
  ```

With an inner join, `COALESCE(a.c1, b.c1)` is the same as either `a.c1` or `b.c1` because both columns will have the same value. With an outer join (such as `LEFT JOIN`), one of the two columns can be `NULL`. That column is omitted from the result.

- An `ON` clause can refer only to its operands.

  Example:

```
CREATE TABLE t1 (i1 INT);
CREATE TABLE t2 (i2 INT);
CREATE TABLE t3 (i3 INT);
SELECT * FROM t1 JOIN t2 ON (i1 = i3) JOIN t3;
```

  The statement fails with an `Unknown column 'i3' in 'on clause'` error because `i3` is a column in `t3`, which is not an operand of the `ON` clause. To enable the join to be processed, rewrite the statement as follows:

```
SELECT * FROM t1 JOIN t2 JOIN t3 ON (i1 = i3);
```

- `JOIN` has higher precedence than the comma operator (`,`), so the join expression `t1, t2 JOIN t3` is interpreted as `(t1, (t2 JOIN t3))`, not as `((t1, t2) JOIN t3)`. This affects statements that use an `ON` clause because that clause can refer only to columns in the operands of the join, and the precedence affects interpretation of what those operands are.

  Example:

```
CREATE TABLE t1 (i1 INT, j1 INT);
CREATE TABLE t2 (i2 INT, j2 INT);
CREATE TABLE t3 (i3 INT, j3 INT);
INSERT INTO t1 VALUES(1, 1);
INSERT INTO t2 VALUES(1, 1);
INSERT INTO t3 VALUES(1, 1);
SELECT * FROM t1, t2 JOIN t3 ON (t1.i1 = t3.i3);
```

  The `JOIN` takes precedence over the comma operator, so the operands for the `ON` clause are `t2` and `t3`. Because `t1.i1` is not a column in either of the operands, the result is an `Unknown column 't1.i1' in 'on clause'` error.

  To enable the join to be processed, use either of these strategies:

  - Group the first two tables explicitly with parentheses so that the operands for the `ON` clause are `(t1, t2)` and `t3`:

```
SELECT * FROM (t1, t2) JOIN t3 ON (t1.i1 = t3.i3);
```

  - Avoid the use of the comma operator and use `JOIN` instead:

```
SELECT * FROM t1 JOIN t2 JOIN t3 ON (t1.i1 = t3.i3);
```

  The same precedence interpretation also applies to statements that mix the comma operator with `INNER JOIN`, `CROSS JOIN`, `LEFT JOIN`, and `RIGHT JOIN`, all of which have higher precedence than the comma operator.

- A MySQL extension compared to the SQL:2003 standard is that MySQL permits you to qualify the common (coalesced) columns of `NATURAL` or `USING` joins, whereas the standard disallows that.

13.2.9.3 UNION Syntax

```
```

```
SELECT ...
UNION [ALL | DISTINCT] SELECT ...
[UNION [ALL | DISTINCT] SELECT ...]
```

`UNION` is used to combine the result from multiple `SELECT` statements into a single result set.

The column names from the first `SELECT` statement are used as the column names for the results returned. Selected columns listed in corresponding positions of each `SELECT` statement should have the same data type. (For example, the first column selected by the first statement should have the same type as the first column selected by the other statements.)

If the data types of corresponding `SELECT` columns do not match, the types and lengths of the columns in the `UNION` result take into account the values retrieved by all of the `SELECT` statements. For example, consider the following:

```
mysql> SELECT REPEAT('a',1) UNION SELECT REPEAT('b',10);
+---------------+
| REPEAT('a',1) |
+---------------+
| a             |
| bbbbbbbbbb    |
+---------------+
```

The `SELECT` statements are normal select statements, but with the following restrictions:

- Only the last `SELECT` statement can use `INTO OUTFILE`. (However, the entire `UNION` result is written to the file.)
- `HIGH_PRIORITY` cannot be used with `SELECT` statements that are part of a `UNION`. If you specify it for the first `SELECT`, it has no effect. If you specify it for any subsequent `SELECT` statements, a syntax error results.

The default behavior for `UNION` is that duplicate rows are removed from the result. The optional `DISTINCT` keyword has no effect other than the default because it also specifies duplicate-row removal. With the optional `ALL` keyword, duplicate-row removal does not occur and the result includes all matching rows from all the `SELECT` statements.

You can mix `UNION ALL` and `UNION DISTINCT` in the same query. Mixed `UNION` types are treated such that a `DISTINCT` union overrides any `ALL` union to its left. A `DISTINCT` union can be produced explicitly by using `UNION DISTINCT` or implicitly by using `UNION` with no following `DISTINCT` or `ALL` keyword.

To apply `ORDER BY` or `LIMIT` to an individual `SELECT`, place the clause inside the parentheses that enclose the `SELECT`:

```
(SELECT a FROM t1 WHERE a=10 AND B=1 ORDER BY a LIMIT 10)
UNION
(SELECT a FROM t2 WHERE a=11 AND B=2 ORDER BY a LIMIT 10);
```

However, use of `ORDER BY` for individual `SELECT` statements implies nothing about the order in which the rows appear in the final result because `UNION` by default produces an unordered set of rows. Therefore, the use of `ORDER BY` in this context is typically in conjunction with `LIMIT`, so that it is used to determine the subset of the selected rows to retrieve for the `SELECT`, even though it does not necessarily affect the order of those rows in the final `UNION` result. If `ORDER BY` appears without `LIMIT` in a `SELECT`, it is optimized away because it will have no effect anyway.

To use an `ORDER BY` or `LIMIT` clause to sort or limit the entire `UNION` result, parenthesize the individual `SELECT` statements and place the `ORDER BY` or `LIMIT` after the last one. The following example uses both clauses:

```
(SELECT a FROM t1 WHERE a=10 AND B=1)
UNION
(SELECT a FROM t2 WHERE a=11 AND B=2)
ORDER BY a LIMIT 10;
```

A statement without parentheses is equivalent to one parenthesized as just shown.

This kind of `ORDER BY` cannot use column references that include a table name (that is, names in *`tbl_name.col_name`* format). Instead, provide a column alias in the first `SELECT` statement and refer to the alias in the `ORDER BY`. (Alternatively, refer to the column in the `ORDER BY` using its column position. However, use of column positions is deprecated.)

Also, if a column to be sorted is aliased, the `ORDER BY` clause *must* refer to the alias, not the column name. The first of the following statements will work, but the second will fail with an `Unknown column 'a' in 'order clause'` error:

```
(SELECT a AS b FROM t) UNION (SELECT ...) ORDER BY b;
(SELECT a AS b FROM t) UNION (SELECT ...) ORDER BY a;
```

To cause rows in a `UNION` result to consist of the sets of rows retrieved by each `SELECT` one after the other, select an additional column in each `SELECT` to use as a sort column and add an `ORDER BY` following the last `SELECT`:

```
(SELECT 1 AS sort_col, col1a, col1b, ... FROM t1)
UNION
(SELECT 2, col2a, col2b, ... FROM t2) ORDER BY sort_col;
```

To additionally maintain sort order within individual `SELECT` results, add a secondary column to the `ORDER BY` clause:

```
(SELECT 1 AS sort_col, col1a, col1b, ... FROM t1)
UNION
(SELECT 2, col2a, col2b, ... FROM t2) ORDER BY sort_col, col1a;
```

Use of an additional column also enables you to determine which `SELECT` each row comes from. Extra columns can provide other identifying information as well, such as a string that indicates a table name.

13.2.10 Subquery Syntax

A subquery is a `SELECT` statement within another statement.

All subquery forms and operations that the SQL standard requires are supported, as well as a few features that are MySQL-specific.

Here is an example of a subquery:

```
SELECT * FROM t1 WHERE column1 = (SELECT column1 FROM t2);
```

In this example, `SELECT * FROM t1 ...` is the *outer query* (or *outer statement*), and `(SELECT column1 FROM t2)` is the *subquery*. We say that the subquery is *nested* within the outer query, and in fact it is possible to nest subqueries within other subqueries, to a considerable depth. A subquery must always appear within parentheses.

The main advantages of subqueries are:

- They allow queries that are *structured* so that it is possible to isolate each part of a statement.
- They provide alternative ways to perform operations that would otherwise require complex joins and unions.

- Many people find subqueries more readable than complex joins or unions. Indeed, it was the innovation of subqueries that gave people the original idea of calling the early SQL “Structured Query Language.”

Here is an example statement that shows the major points about subquery syntax as specified by the SQL standard and supported in MySQL:

```
DELETE FROM t1
WHERE s11 > ANY
 (SELECT COUNT(*) /* no hint */ FROM t2
  WHERE NOT EXISTS
   (SELECT * FROM t3
    WHERE ROW(5*t2.s1,77)=
     (SELECT 50,11*s1 FROM t4 UNION SELECT 50,77 FROM
      (SELECT * FROM t5) AS t5)));
```

A subquery can return a scalar (a single value), a single row, a single column, or a table (one or more rows of one or more columns). These are called scalar, column, row, and table subqueries. Subqueries that return a particular kind of result often can be used only in certain contexts, as described in the following sections.

There are few restrictions on the type of statements in which subqueries can be used. A subquery can contain many of the keywords or clauses that an ordinary `SELECT` can contain: `DISTINCT`, `GROUP BY`, `ORDER BY`, `LIMIT`, joins, index hints, `UNION` constructs, comments, functions, and so on.

A subquery's outer statement can be any one of: `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `SET`, or `DO`.

In MySQL, you cannot modify a table and select from the same table in a subquery. This applies to statements such as `DELETE`, `INSERT`, `REPLACE`, `UPDATE`, and (because subqueries can be used in the `SET` clause) `LOAD DATA INFILE`.

For information about how the optimizer handles subqueries, see Section 8.2.2, “Subquery Optimization”. For a discussion of restrictions on subquery use, including performance issues for certain forms of subquery syntax, see Section C.4, “Restrictions on Subqueries”.

13.2.10.1 The Subquery as Scalar Operand

In its simplest form, a subquery is a scalar subquery that returns a single value. A scalar subquery is a simple operand, and you can use it almost anywhere a single column value or literal is legal, and you can expect it to have those characteristics that all operands have: a data type, a length, an indication that it can be `NULL`, and so on. For example:

```
CREATE TABLE t1 (s1 INT, s2 CHAR(5) NOT NULL);
INSERT INTO t1 VALUES(100, 'abcde');
SELECT (SELECT s2 FROM t1);
```

The subquery in this `SELECT` returns a single value (`'abcde'`) that has a data type of `CHAR`, a length of 5, a character set and collation equal to the defaults in effect at `CREATE TABLE` time, and an indication that the value in the column can be `NULL`. Nullability of the value selected by a scalar subquery is not copied because if the subquery result is empty, the result is `NULL`. For the subquery just shown, if `t1` were empty, the result would be `NULL` even though `s2` is `NOT NULL`.

There are a few contexts in which a scalar subquery cannot be used. If a statement permits only a literal value, you cannot use a subquery. For example, `LIMIT` requires literal integer arguments, and `LOAD DATA INFILE` requires a literal string file name. You cannot use subqueries to supply these values.

When you see examples in the following sections that contain the rather spartan construct `(SELECT column1 FROM t1)`, imagine that your own code contains much more diverse and complex constructions.

Suppose that we make two tables:

```
CREATE TABLE t1 (s1 INT);
INSERT INTO t1 VALUES (1);
CREATE TABLE t2 (s1 INT);
INSERT INTO t2 VALUES (2);
```

Then perform a `SELECT`:

```
SELECT (SELECT s1 FROM t2) FROM t1;
```

The result is `2` because there is a row in `t2` containing a column `s1` that has a value of `2`.

A scalar subquery can be part of an expression, but remember the parentheses, even if the subquery is an operand that provides an argument for a function. For example:

```
SELECT UPPER((SELECT s1 FROM t1)) FROM t2;
```

13.2.10.2 Comparisons Using Subqueries

The most common use of a subquery is in the form:

```
non_subquery_operand comparison_operator (subquery)
```

Where *`comparison_operator`* is one of these operators:

```
=  >  <  >=  <=  <>  !=  <=>
```

For example:

```
... WHERE 'a' = (SELECT column1 FROM t1)
```

MySQL also permits this construct:

```
non_subquery_operand LIKE (subquery)
```

At one time the only legal place for a subquery was on the right side of a comparison, and you might still find some old DBMSs that insist on this.

Here is an example of a common-form subquery comparison that you cannot do with a join. It finds all the rows in table `t1` for which the `column1` value is equal to a maximum value in table `t2`:

```
SELECT * FROM t1
  WHERE column1 = (SELECT MAX(column2) FROM t2);
```

Here is another example, which again is impossible with a join because it involves aggregating for one of the tables. It finds all rows in table `t1` containing a value that occurs twice in a given column:

```
SELECT * FROM t1 AS t
  WHERE 2 = (SELECT COUNT(*) FROM t1 WHERE t1.id = t.id);
```

For a comparison of the subquery to a scalar, the subquery must return a scalar. For a comparison of the subquery to a row constructor, the subquery must be a row subquery that returns a row with the same number of values as the row constructor. See Section 13.2.10.5, “Row Subqueries”.

13.2.10.3 Subqueries with ANY, IN, or SOME

Syntax:

```
operand comparison_operator ANY (subquery)
operand IN (subquery)
operand comparison_operator SOME (subquery)
```

Where *comparison_operator* is one of these operators:

```
=  >  <  >=  <=  <>  !=
```

The ANY keyword, which must follow a comparison operator, means “return TRUE if the comparison is TRUE for ANY of the values in the column that the subquery returns.” For example:

```
SELECT s1 FROM t1 WHERE s1 > ANY (SELECT s1 FROM t2);
```

Suppose that there is a row in table t1 containing (10). The expression is TRUE if table t2 contains (21,14,7) because there is a value 7 in t2 that is less than 10. The expression is FALSE if table t2 contains (20,10), or if table t2 is empty. The expression is *unknown* (that is, NULL) if table t2 contains (NULL,NULL,NULL).

When used with a subquery, the word IN is an alias for = ANY. Thus, these two statements are the same:

```
SELECT s1 FROM t1 WHERE s1 = ANY (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 IN    (SELECT s1 FROM t2);
```

IN and = ANY are not synonyms when used with an expression list. IN can take an expression list, but = ANY cannot. See Section 12.3.2, “Comparison Functions and Operators”.

NOT IN is not an alias for <> ANY, but for <> ALL. See Section 13.2.10.4, “Subqueries with ALL”.

The word SOME is an alias for ANY. Thus, these two statements are the same:

```
SELECT s1 FROM t1 WHERE s1 <> ANY  (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 <> SOME (SELECT s1 FROM t2);
```

Use of the word SOME is rare, but this example shows why it might be useful. To most people, the English phrase “a is not equal to any b” means “there is no b which is equal to a,” but that is not what is meant by the SQL syntax. The syntax means “there is some b to which a is not equal.” Using <> SOME instead helps ensure that everyone understands the true meaning of the query.

13.2.10.4 Subqueries with ALL

Syntax:

```
operand comparison_operator ALL (subquery)
```

The word ALL, which must follow a comparison operator, means “return TRUE if the comparison is TRUE for ALL of the values in the column that the subquery returns.” For example:

```
SELECT s1 FROM t1 WHERE s1 > ALL (SELECT s1 FROM t2);
```

Suppose that there is a row in table t1 containing (10). The expression is TRUE if table t2 contains (-5,0,+5) because 10 is greater than all three values in t2. The expression is FALSE if table t2 contains (12,6,NULL,-100) because there is a single value 12 in table t2 that is greater than 10. The expression is *unknown* (that is, NULL) if table t2 contains (0,NULL,1).

Finally, the expression is `TRUE` if table `t2` is empty. So, the following expression is `TRUE` when table `t2` is empty:

```
SELECT * FROM t1 WHERE 1 > ALL (SELECT s1 FROM t2);
```

But this expression is `NULL` when table `t2` is empty:

```
SELECT * FROM t1 WHERE 1 > (SELECT s1 FROM t2);
```

In addition, the following expression is `NULL` when table `t2` is empty:

```
SELECT * FROM t1 WHERE 1 > ALL (SELECT MAX(s1) FROM t2);
```

In general, *tables containing `NULL` values* and *empty tables* are “edge cases.” When writing subqueries, always consider whether you have taken those two possibilities into account.

`NOT IN` is an alias for `<> ALL`. Thus, these two statements are the same:

```
SELECT s1 FROM t1 WHERE s1 <> ALL (SELECT s1 FROM t2);
SELECT s1 FROM t1 WHERE s1 NOT IN (SELECT s1 FROM t2);
```

13.2.10.5 Row Subqueries

Scalar or column subqueries return a single value or a column of values. A *row subquery* is a subquery variant that returns a single row and can thus return more than one column value. Legal operators for row subquery comparisons are:

```
=  >  <  >=  <=  <>  !=  <=>
```

Here are two examples:

```
SELECT * FROM t1
  WHERE (col1,col2) = (SELECT col3, col4 FROM t2 WHERE id = 10);
SELECT * FROM t1
  WHERE ROW(col1,col2) = (SELECT col3, col4 FROM t2 WHERE id = 10);
```

For both queries, if the table `t2` contains a single row with `id = 10`, the subquery returns a single row. If this row has `col3` and `col4` values equal to the `col1` and `col2` values of any rows in `t1`, the `WHERE` expression is `TRUE` and each query returns those `t1` rows. If the `t2` row `col3` and `col4` values are not equal the `col1` and `col2` values of any `t1` row, the expression is `FALSE` and the query returns an empty result set. The expression is *unknown* (that is, `NULL`) if the subquery produces no rows. An error occurs if the subquery produces multiple rows because a row subquery can return at most one row.

For information about how each operator works for row comparisons, see Section 12.3.2, “Comparison Functions and Operators”.

The expressions `(1,2)` and `ROW(1,2)` are sometimes called *row constructors*. The two are equivalent. The row constructor and the row returned by the subquery must contain the same number of values.

A row constructor is used for comparisons with subqueries that return two or more columns. When a subquery returns a single column, this is regarded as a scalar value and not as a row, so a row constructor cannot be used with a subquery that does not return at least two columns. Thus, the following query fails with a syntax error:

```
```

```
SELECT * FROM t1 WHERE ROW(1) = (SELECT column1 FROM t2)
```

Row constructors are legal in other contexts. For example, the following two statements are semantically equivalent (and are handled in the same way by the optimizer):

```
SELECT * FROM t1 WHERE (column1,column2) = (1,1);
SELECT * FROM t1 WHERE column1 = 1 AND column2 = 1;
```

The following query answers the request, “find all rows in table `t1` that also exist in table `t2`”:

```
SELECT column1,column2,column3
  FROM t1
  WHERE (column1,column2,column3) IN
         (SELECT column1,column2,column3 FROM t2);
```

For more information about the optimizer and row constructors, see Section 8.2.1.15, “Row Constructor Expression Optimization”

13.2.10.6 Subqueries with EXISTS or NOT EXISTS

If a subquery returns any rows at all, `EXISTS subquery` is `TRUE`, and `NOT EXISTS subquery` is `FALSE`. For example:

```
SELECT column1 FROM t1 WHERE EXISTS (SELECT * FROM t2);
```

Traditionally, an `EXISTS` subquery starts with `SELECT *`, but it could begin with `SELECT 5` or `SELECT column1` or anything at all. MySQL ignores the `SELECT` list in such a subquery, so it makes no difference.

For the preceding example, if `t2` contains any rows, even rows with nothing but `NULL` values, the `EXISTS` condition is `TRUE`. This is actually an unlikely example because a `[NOT] EXISTS` subquery almost always contains correlations. Here are some more realistic examples:

- What kind of store is present in one or more cities?

  ```
  SELECT DISTINCT store_type FROM stores
    WHERE EXISTS (SELECT * FROM cities_stores
                  WHERE cities_stores.store_type = stores.store_type);
  ```

- What kind of store is present in no cities?

  ```
  SELECT DISTINCT store_type FROM stores
    WHERE NOT EXISTS (SELECT * FROM cities_stores
                      WHERE cities_stores.store_type = stores.store_type);
  ```

- What kind of store is present in all cities?

  ```
  SELECT DISTINCT store_type FROM stores s1
    WHERE NOT EXISTS (
      SELECT * FROM cities WHERE NOT EXISTS (
        SELECT * FROM cities_stores
        WHERE cities_stores.city = cities.city
        AND cities_stores.store_type = stores.store_type));
  ```

The last example is a double-nested `NOT EXISTS` query. That is, it has a `NOT EXISTS` clause within a `NOT EXISTS` clause. Formally, it answers the question “does a city exist with a store that is not in `Stores`”? But it is easier to say that a nested `NOT EXISTS` answers the question “is *x* `TRUE` for all *y*?”

13.2.10.7 Correlated Subqueries

A *correlated subquery* is a subquery that contains a reference to a table that also appears in the outer query. For example:

```
SELECT * FROM t1
  WHERE column1 = ANY (SELECT column1 FROM t2
                       WHERE t2.column2 = t1.column2);
```

Notice that the subquery contains a reference to a column of `t1`, even though the subquery's `FROM` clause does not mention a table `t1`. So, MySQL looks outside the subquery, and finds `t1` in the outer query.

Suppose that table `t1` contains a row where `column1 = 5` and `column2 = 6`; meanwhile, table `t2` contains a row where `column1 = 5` and `column2 = 7`. The simple expression `... WHERE column1 = ANY (SELECT column1 FROM t2)` would be `TRUE`, but in this example, the `WHERE` clause within the subquery is `FALSE` (because `(5,6)` is not equal to `(5,7)`), so the expression as a whole is `FALSE`.

Scoping rule: MySQL evaluates from inside to outside. For example:

```
SELECT column1 FROM t1 AS x
  WHERE x.column1 = (SELECT column1 FROM t2 AS x
    WHERE x.column1 = (SELECT column1 FROM t3
      WHERE x.column2 = t3.column1));
```

In this statement, `x.column2` must be a column in table `t2` because `SELECT column1 FROM t2 AS x ...` renames `t2`. It is not a column in table `t1` because `SELECT column1 FROM t1 ...` is an outer query that is *farther out*.

For subqueries in `HAVING` or `ORDER BY` clauses, MySQL also looks for column names in the outer select list.

For certain cases, a correlated subquery is optimized. For example:

```
val IN (SELECT key_val FROM tbl_name WHERE correlated_condition)
```

Otherwise, they are inefficient and likely to be slow. Rewriting the query as a join might improve performance.

Aggregate functions in correlated subqueries may contain outer references, provided the function contains nothing but outer references, and provided the function is not contained in another function or expression.

13.2.10.8 Derived Tables (Subqueries in the FROM Clause)

A derived table is a subquery in a `SELECT` statement `FROM` clause:

```
SELECT ... FROM (subquery) [AS] tbl_name ...
```

The `[AS] tbl_name` clause is mandatory because every table in a `FROM` clause must have a name. Any columns in the *`subquery`* select list must have unique names.

For the sake of illustration, assume that you have this table:

```
CREATE TABLE t1 (s1 INT, s2 CHAR(5), s3 FLOAT);
```

Here is how to use a subquery in the `FROM` clause, using the example table:

```
INSERT INTO t1 VALUES (1,'1',1.0);
INSERT INTO t1 VALUES (2,'2',2.0);
SELECT sb1,sb2,sb3
  FROM (SELECT s1 AS sb1, s2 AS sb2, s3*2 AS sb3 FROM t1) AS sb
  WHERE sb1 > 1;
```

Result: `2, '2', 4.0`.

Here is another example: Suppose that you want to know the average of a set of sums for a grouped table. This does not work:

```
SELECT AVG(SUM(column1)) FROM t1 GROUP BY column1;
```

However, this query provides the desired information:

```
SELECT AVG(sum_column1)
  FROM (SELECT SUM(column1) AS sum_column1
        FROM t1 GROUP BY column1) AS t1;
```

Notice that the column name used within the subquery (`sum_column1`) is recognized in the outer query.

Derived tables can return a scalar, column, row, or table.

Derived tables cannot be correlated subqueries, or contain outer references or references to other tables of the same `SELECT`.

Subqueries in the `FROM` clause are executed even for the `EXPLAIN` statement (that is, derived temporary tables are materialized). This occurs because upper-level queries need information about all tables during the optimization phase, and the table represented by a subquery in the `FROM` clause is unavailable unless the subquery is executed.

It is possible under certain circumstances that using `EXPLAIN SELECT` will modify table data. This can occur if the outer query accesses any tables and an inner query invokes a stored function that changes one or more rows of a table. Suppose that there are two tables `t1` and `t2` in database `d1`, and a stored function `f1` that modifies `t2`, created as shown here:

```
CREATE DATABASE d1;
USE d1;
CREATE TABLE t1 (c1 INT);
CREATE TABLE t2 (c1 INT);
CREATE FUNCTION f1(p1 INT) RETURNS INT
  BEGIN
    INSERT INTO t2 VALUES (p1);
    RETURN p1;
  END;
```

Referencing the function directly in an `EXPLAIN SELECT` has no effect on `t2`, as shown here:

```
mysql> SELECT * FROM t2;
Empty set (0.02 sec)

mysql> EXPLAIN SELECT f1(5)\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: NULL
         type: NULL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: NULL
```

```
       Extra: No tables used
1 row in set (0.01 sec)

mysql> SELECT * FROM t2;
Empty set (0.01 sec)
```

This is because the `SELECT` statement did not reference any tables, as can be seen in the `table` and `Extra` columns of the output. This is also true of the following nested `SELECT`:

```
mysql> EXPLAIN SELECT NOW() AS a1, (SELECT f1(5)) AS a2\G
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: NULL
         type: NULL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: NULL
     filtered: NULL
        Extra: No tables used
1 row in set, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+-------+------+-----------------------------------------+
| Level | Code | Message                                 |
+-------+------+-----------------------------------------+
| Note  | 1249 | Select 2 was reduced during optimization |
+-------+------+-----------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT * FROM t2;
Empty set (0.00 sec)
```

However, if the outer `SELECT` references any tables, the optimizer executes the statement in the subquery as well:

```
mysql> EXPLAIN SELECT * FROM t1 AS a1, (SELECT f1(5)) AS a2\G
*************************** 1. row ***************************
           id: 1
  select_type: PRIMARY
        table: <derived2>
         type: system
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 1
        Extra:
*************************** 2. row ***************************
           id: 1
  select_type: PRIMARY
        table: a1
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 1
        Extra:
*************************** 3. row ***************************
           id: 2
  select_type: DERIVED
        table: NULL
         type: NULL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
```

```
         rows: NULL
        Extra: No tables used
3 rows in set (0.00 sec)

mysql> SELECT * FROM t2;
+------+
| c1   |
+------+
|    5 |
+------+
1 row in set (0.00 sec)
```

This also means that an `EXPLAIN SELECT` statement such as the one shown here may take a long time to execute because the `BENCHMARK()` function is executed once for each row in `t1`:

```
EXPLAIN SELECT * FROM t1 AS a1, (SELECT BENCHMARK(1000000, MD5(NOW())));
```

13.2.10.9 Subquery Errors

There are some errors that apply only to subqueries. This section describes them.

- Unsupported subquery syntax:

  ```
  ERROR 1235 (ER_NOT_SUPPORTED_YET)
  SQLSTATE = 42000
  Message = "This version of MySQL doesn't yet support
  'LIMIT & IN/ALL/ANY/SOME subquery'"
  ```

  This means that MySQL does not support statements of the following form:

  ```
  SELECT * FROM t1 WHERE s1 IN (SELECT s2 FROM t2 ORDER BY s1 LIMIT 1)
  ```

- Incorrect number of columns from subquery:

  ```
  ERROR 1241 (ER_OPERAND_COL)
  SQLSTATE = 21000
  Message = "Operand should contain 1 column(s)"
  ```

  This error occurs in cases like this:

  ```
  SELECT (SELECT column1, column2 FROM t2) FROM t1;
  ```

  You may use a subquery that returns multiple columns, if the purpose is row comparison. In other contexts, the subquery must be a scalar operand. See Section 13.2.10.5, “Row Subqueries”.

- Incorrect number of rows from subquery:

  ```
  ERROR 1242 (ER_SUBSELECT_NO_1_ROW)
  SQLSTATE = 21000
  Message = "Subquery returns more than 1 row"
  ```

  This error occurs for statements where the subquery must return at most one row but returns multiple rows. Consider the following example:

  ```
  SELECT * FROM t1 WHERE column1 = (SELECT column1 FROM t2);
  ```

  If `SELECT column1 FROM t2` returns just one row, the previous query will work. If the subquery returns more than one row, error 1242 will occur. In that case, the query should be rewritten as:

  ```
  SELECT * FROM t1 WHERE column1 = ANY (SELECT column1 FROM t2);
  ```

- Incorrectly used table in subquery:

```
Error 1093 (ER_UPDATE_TABLE_USED)
SQLSTATE = HY000
Message = "You can't specify target table 'x'
for update in FROM clause"
```

  This error occurs in cases such as the following, which attempts to modify a table and select from the same table in the subquery:

```
UPDATE t1 SET column2 = (SELECT MAX(column1) FROM t1);
```

  You can use a subquery for assignment within an `UPDATE` statement because subqueries are legal in `UPDATE` and `DELETE` statements as well as in `SELECT` statements. However, you cannot use the same table (in this case, table `t1`) for both the subquery `FROM` clause and the update target.

For transactional storage engines, the failure of a subquery causes the entire statement to fail. For nontransactional storage engines, data modifications made before the error was encountered are preserved.

13.2.10.10 Optimizing Subqueries

Development is ongoing, so no optimization tip is reliable for the long term. The following list provides some interesting tricks that you might want to play with. See also Section 8.2.2, “Subquery Optimization”.

- Use subquery clauses that affect the number or order of the rows in the subquery. For example:

```
SELECT * FROM t1 WHERE t1.column1 IN
  (SELECT column1 FROM t2 ORDER BY column1);
SELECT * FROM t1 WHERE t1.column1 IN
  (SELECT DISTINCT column1 FROM t2);
SELECT * FROM t1 WHERE EXISTS
  (SELECT * FROM t2 LIMIT 1);
```

- Replace a join with a subquery. For example, try this:

```
SELECT DISTINCT column1 FROM t1 WHERE t1.column1 IN (
  SELECT column1 FROM t2);
```

  Instead of this:

```
SELECT DISTINCT t1.column1 FROM t1, t2
  WHERE t1.column1 = t2.column1;
```

- Some subqueries can be transformed to joins for compatibility with older versions of MySQL that do not support subqueries. However, in some cases, converting a subquery to a join may improve performance. See Section 13.2.10.11, “Rewriting Subqueries as Joins”.

- Move clauses from outside to inside the subquery. For example, use this query:

```
SELECT * FROM t1
  WHERE s1 IN (SELECT s1 FROM t1 UNION ALL SELECT s1 FROM t2);
```

  Instead of this query:

```
SELECT * FROM t1
  WHERE s1 IN (SELECT s1 FROM t1) OR s1 IN (SELECT s1 FROM t2);
```

  For another example, use this query:

```
SELECT (SELECT column1 + 5 FROM t1) FROM t2;
```

Instead of this query:

```
SELECT (SELECT column1 FROM t1) + 5 FROM t2;
```

- Use a row subquery instead of a correlated subquery. For example, use this query:

```
SELECT * FROM t1
  WHERE (column1,column2) IN (SELECT column1,column2 FROM t2);
```

Instead of this query:

```
SELECT * FROM t1
  WHERE EXISTS (SELECT * FROM t2 WHERE t2.column1=t1.column1
                AND t2.column2=t1.column2);
```

- Use `NOT (a = ANY (...))` rather than `a <> ALL (...)`.
- Use `x = ANY (table containing (1,2))` rather than `x=1 OR x=2`.
- Use `= ANY` rather than `EXISTS`.
- For uncorrelated subqueries that always return one row, `IN` is always slower than `=`. For example, use this query:

```
SELECT * FROM t1
  WHERE t1.col_name = (SELECT a FROM t2 WHERE b = some_const);
```

Instead of this query:

```
SELECT * FROM t1
  WHERE t1.col_name IN (SELECT a FROM t2 WHERE b = some_const);
```

These tricks might cause programs to go faster or slower. Using MySQL facilities like the `BENCHMARK()` function, you can get an idea about what helps in your own situation. See Section 12.14, “Information Functions”.

Some optimizations that MySQL itself makes are:

- MySQL executes uncorrelated subqueries only once. Use `EXPLAIN` to make sure that a given subquery really is uncorrelated.
- MySQL rewrites `IN`, `ALL`, `ANY`, and `SOME` subqueries in an attempt to take advantage of the possibility that the select-list columns in the subquery are indexed.
- MySQL replaces subqueries of the following form with an index-lookup function, which `EXPLAIN` describes as a special join type (`unique_subquery` or `index_subquery`):

```
... IN (SELECT indexed_column FROM single_table ...)
```

- MySQL enhances expressions of the following form with an expression involving `MIN()` or `MAX()`, unless `NULL` values or empty sets are involved:

```
value {ALL|ANY|SOME} {> | < | >= | <=} (uncorrelated subquery)
```

For example, this `WHERE` clause:

```
WHERE 5 > ALL (SELECT x FROM t)
```

might be treated by the optimizer like this:

```
WHERE 5 > (SELECT MAX(x) FROM t)
```

See also MySQL Internals: How MySQL Transforms Subqueries.

13.2.10.11 Rewriting Subqueries as Joins

Sometimes there are other ways to test membership in a set of values than by using a subquery. Also, on some occasions, it is not only possible to rewrite a query without a subquery, but it can be more efficient to make use of some of these techniques rather than to use subqueries. One of these is the `IN()` construct:

For example, this query:

```
SELECT * FROM t1 WHERE id IN (SELECT id FROM t2);
```

Can be rewritten as:

```
SELECT DISTINCT t1.* FROM t1, t2 WHERE t1.id=t2.id;
```

The queries:

```
SELECT * FROM t1 WHERE id NOT IN (SELECT id FROM t2);
SELECT * FROM t1 WHERE NOT EXISTS (SELECT id FROM t2 WHERE t1.id=t2.id);
```

Can be rewritten as:

```
SELECT table1.*
  FROM table1 LEFT JOIN table2 ON table1.id=table2.id
  WHERE table2.id IS NULL;
```

A `LEFT [OUTER] JOIN` can be faster than an equivalent subquery because the server might be able to optimize it better—a fact that is not specific to MySQL Server alone. Prior to SQL-92, outer joins did not exist, so subqueries were the only way to do certain things. Today, MySQL Server and many other modern database systems offer a wide range of outer join types.

MySQL Server supports multiple-table `DELETE` statements that can be used to efficiently delete rows based on information from one table or even from many tables at the same time. Multiple-table `UPDATE` statements are also supported. See Section 13.2.2, “DELETE Syntax”, and Section 13.2.11, “UPDATE Syntax”.

13.2.11 UPDATE Syntax

`UPDATE` is a DML statement that modifies rows in a table.

Single-table syntax:

```
UPDATE [LOW_PRIORITY] [IGNORE] table_reference
    SET assignment_list
    [WHERE where_condition]
    [ORDER BY ...]
    [LIMIT row_count]

value:
```

```
    {expr | DEFAULT}

assignment:
    col_name = value

assignment_list:
    assignment [, assignment] ...
```

Multiple-table syntax:

```
UPDATE [LOW_PRIORITY] [IGNORE] table_references
    SET assignment_list
    [WHERE where_condition]
```

For the single-table syntax, the `UPDATE` statement updates columns of existing rows in the named table with new values. The `SET` clause indicates which columns to modify and the values they should be given. Each value can be given as an expression, or the keyword `DEFAULT` to set a column explicitly to its default value. The `WHERE` clause, if given, specifies the conditions that identify which rows to update. With no `WHERE` clause, all rows are updated. If the `ORDER BY` clause is specified, the rows are updated in the order that is specified. The `LIMIT` clause places a limit on the number of rows that can be updated.

For the multiple-table syntax, `UPDATE` updates rows in each table named in *`table_references`* that satisfy the conditions. Each matching row is updated once, even if it matches the conditions multiple times. For multiple-table syntax, `ORDER BY` and `LIMIT` cannot be used.

`where_condition` is an expression that evaluates to true for each row to be updated. For expression syntax, see Section 9.5, “Expression Syntax”.

`table_references` and *`where_condition`* are specified as described in Section 13.2.9, “SELECT Syntax”.

You need the `UPDATE` privilege only for columns referenced in an `UPDATE` that are actually updated. You need only the `SELECT` privilege for any columns that are read but not modified.

The `UPDATE` statement supports the following modifiers:

- With the `LOW_PRIORITY` modifier, execution of the `UPDATE` is delayed until no other clients are reading from the table. This affects only storage engines that use only table-level locking (such as `MyISAM`, `MEMORY`, and `MERGE`).
- With the `IGNORE` modifier, the update statement does not abort even if errors occur during the update. Rows for which duplicate-key conflicts occur on a unique key value are not updated. Rows updated to values that would cause data conversion errors are updated to the closest valid values instead.

In MySQL 5.5.18 and later, `UPDATE IGNORE` statements, including those having an `ORDER BY` clause, are flagged as unsafe for statement-based replication. (This is because the order in which the rows are updated determines which rows are ignored.) Such statements produce a warning in the error log when using statement-based mode and are written to the binary log using the row-based format when using `MIXED` mode. (Bug #11758262, Bug #50439) See Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”, for more information.

If you access a column from the table to be updated in an expression, `UPDATE` uses the current value of the column. For example, the following statement sets `col1` to one more than its current value:

```
UPDATE t1 SET col1 = col1 + 1;
```

The second assignment in the following statement sets `col2` to the current (updated) `col1` value, not the original `col1` value. The result is that `col1` and `col2` have the same value. This behavior differs from standard SQL.

```
UPDATE t1 SET col1 = col1 + 1, col2 = col1;
```

Single-table `UPDATE` assignments are generally evaluated from left to right. For multiple-table updates, there is no guarantee that assignments are carried out in any particular order.

If you set a column to the value it currently has, MySQL notices this and does not update it.

If you update a column that has been declared `NOT NULL` by setting to `NULL`, an error occurs if strict SQL mode is enabled; otherwise, the column is set to the implicit default value for the column data type and the warning count is incremented. The implicit default value is `0` for numeric types, the empty string (`''`) for string types, and the "zero" value for date and time types. See Section 11.6, "Data Type Default Values".

`UPDATE` returns the number of rows that were actually changed. The `mysql_info()` C API function returns the number of rows that were matched and updated and the number of warnings that occurred during the `UPDATE`.

You can use `LIMIT` *`row_count`* to restrict the scope of the `UPDATE`. A `LIMIT` clause is a rows-matched restriction. The statement stops as soon as it has found *`row_count`* rows that satisfy the `WHERE` clause, whether or not they actually were changed.

If an `UPDATE` statement includes an `ORDER BY` clause, the rows are updated in the order specified by the clause. This can be useful in certain situations that might otherwise result in an error. Suppose that a table `t` contains a column `id` that has a unique index. The following statement could fail with a duplicate-key error, depending on the order in which rows are updated:

```
UPDATE t SET id = id + 1;
```

For example, if the table contains 1 and 2 in the `id` column and 1 is updated to 2 before 2 is updated to 3, an error occurs. To avoid this problem, add an `ORDER BY` clause to cause the rows with larger `id` values to be updated before those with smaller values:

```
UPDATE t SET id = id + 1 ORDER BY id DESC;
```

You can also perform `UPDATE` operations covering multiple tables. However, you cannot use `ORDER BY` or `LIMIT` with a multiple-table `UPDATE`. The *`table_references`* clause lists the tables involved in the join. Its syntax is described in Section 13.2.9.2, "JOIN Syntax". Here is an example:

```
UPDATE items,month SET items.price=month.price
WHERE items.id=month.id;
```

The preceding example shows an inner join that uses the comma operator, but multiple-table `UPDATE` statements can use any type of join permitted in `SELECT` statements, such as `LEFT JOIN`.

If you use a multiple-table `UPDATE` statement involving `InnoDB` tables for which there are foreign key constraints, the MySQL optimizer might process tables in an order that differs from that of their parent/child relationship. In this case, the statement fails and rolls back. Instead, update a single table and rely on the `ON UPDATE` capabilities that `InnoDB` provides to cause the other tables to be modified accordingly. See Section 14.11.1.6, "InnoDB and FOREIGN KEY Constraints".

You cannot update a table and select from the same table in a subquery.

Index hints (see Section 8.9.3, "Index Hints") are accepted for `UPDATE` statements, but are ignored prior to MySQL 5.5.6.

An `UPDATE` on a partitioned table using a storage engine such as `MyISAM` that employs table-level locks locks all partitions of the table. This does not occur with tables using storage engines such as

InnoDB that employ row-level locking. This issue is resolved in MySQL 5.6. For more information, see Section 19.5.4, “Partitioning and Table-Level Locking”.

13.3 Transactional and Locking Statements

MySQL supports local transactions (within a given client session) through statements such as SET autocommit, START TRANSACTION, COMMIT, and ROLLBACK. See Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”. XA transaction support enables MySQL to participate in distributed transactions as well. See Section 13.3.7, “XA Transactions”.

13.3.1 START TRANSACTION, COMMIT, and ROLLBACK Syntax

```
START TRANSACTION [WITH CONSISTENT SNAPSHOT]
BEGIN [WORK]
COMMIT [WORK] [AND [NO] CHAIN] [[NO] RELEASE]
ROLLBACK [WORK] [AND [NO] CHAIN] [[NO] RELEASE]
SET autocommit = {0 | 1}
```

These statements provide control over use of transactions:

- START TRANSACTION or BEGIN start a new transaction.
- COMMIT commits the current transaction, making its changes permanent.
- ROLLBACK rolls back the current transaction, canceling its changes.
- SET autocommit disables or enables the default autocommit mode for the current session.

By default, MySQL runs with autocommit mode enabled. This means that as soon as you execute a statement that updates (modifies) a table, MySQL stores the update on disk to make it permanent. The change cannot be rolled back.

To disable autocommit mode implicitly for a single series of statements, use the START TRANSACTION statement:

```
START TRANSACTION;
SELECT @A:=SUM(salary) FROM table1 WHERE type=1;
UPDATE table2 SET summary=@A WHERE type=1;
COMMIT;
```

With START TRANSACTION, autocommit remains disabled until you end the transaction with COMMIT or ROLLBACK. The autocommit mode then reverts to its previous state.

You can also begin a transaction like this:

```
START TRANSACTION WITH CONSISTENT SNAPSHOT;
```

The WITH CONSISTENT SNAPSHOT option starts a consistent read for storage engines that are capable of it. This applies only to InnoDB. The effect is the same as issuing a START TRANSACTION followed by a SELECT from any InnoDB table. See Section 14.8.2.3, “Consistent Nonlocking Reads”. The WITH CONSISTENT SNAPSHOT option does not change the current transaction isolation level, so it provides a consistent snapshot only if the current isolation level is one that permits a consistent read. The only isolation level that permits a consistent read is REPEATABLE READ. For all other isolation levels, the WITH CONSISTENT SNAPSHOT clause is ignored. As of MySQL 5.5.34, a warning is generated when the WITH CONSISTENT SNAPSHOT is ignored.

Important

Many APIs used for writing MySQL client applications (such as JDBC) provide their own methods for starting transactions that can (and sometimes should) be

used instead of sending a START TRANSACTION statement from the client. See Chapter 23, *Connectors and APIs*, or the documentation for your API, for more information.

To disable autocommit mode explicitly, use the following statement:

```
SET autocommit=0;
```

After disabling autocommit mode by setting the autocommit variable to zero, changes to transaction-safe tables (such as those for InnoDB or NDBCLUSTER) are not made permanent immediately. You must use COMMIT to store your changes to disk or ROLLBACK to ignore the changes.

autocommit is a session variable and must be set for each session. To disable autocommit mode for each new connection, see the description of the autocommit system variable at Section 5.1.5, "Server System Variables".

BEGIN and BEGIN WORK are supported as aliases of START TRANSACTION for initiating a transaction. START TRANSACTION is standard SQL syntax and is the recommended way to start an ad-hoc transaction.

The BEGIN statement differs from the use of the BEGIN keyword that starts a BEGIN ... END compound statement. The latter does not begin a transaction. See Section 13.6.1, "BEGIN ... END Compound-Statement Syntax".

Note

Within all stored programs (stored procedures and functions, triggers, and events), the parser treats BEGIN [WORK] as the beginning of a BEGIN ... END block. Begin a transaction in this context with START TRANSACTION instead.

The optional WORK keyword is supported for COMMIT and ROLLBACK, as are the CHAIN and RELEASE clauses. CHAIN and RELEASE can be used for additional control over transaction completion. The value of the completion_type system variable determines the default completion behavior. See Section 5.1.5, "Server System Variables".

The AND CHAIN clause causes a new transaction to begin as soon as the current one ends, and the new transaction has the same isolation level as the just-terminated transaction. The new transaction also uses the same access mode (READ WRITE or READ ONLY) as the just-terminated transaction. The RELEASE clause causes the server to disconnect the current client session after terminating the current transaction. Including the NO keyword suppresses CHAIN or RELEASE completion, which can be useful if the completion_type system variable is set to cause chaining or release completion by default.

Beginning a transaction causes any pending transaction to be committed. See Section 13.3.3, "Statements That Cause an Implicit Commit", for more information.

Beginning a transaction also causes table locks acquired with LOCK TABLES to be released, as though you had executed UNLOCK TABLES. Beginning a transaction does not release a global read lock acquired with FLUSH TABLES WITH READ LOCK.

For best results, transactions should be performed using only tables managed by a single transaction-safe storage engine. Otherwise, the following problems can occur:

- If you use tables from more than one transaction-safe storage engine (such as InnoDB), and the transaction isolation level is not SERIALIZABLE, it is possible that when one transaction commits, another ongoing transaction that uses the same tables will see only some of the changes made by the first transaction. That is, the atomicity of transactions is not guaranteed with mixed engines and inconsistencies can result. (If mixed-engine transactions are infrequent, you can use SET

`TRANSACTION ISOLATION LEVEL` to set the isolation level to `SERIALIZABLE` on a per-transaction basis as necessary.)

- If you use tables that are not transaction-safe within a transaction, changes to those tables are stored at once, regardless of the status of autocommit mode.
- If you issue a `ROLLBACK` statement after updating a nontransactional table within a transaction, an `ER_WARNING_NOT_COMPLETE_ROLLBACK` warning occurs. Changes to transaction-safe tables are rolled back, but not changes to nontransaction-safe tables.

Each transaction is stored in the binary log in one chunk, upon `COMMIT`. Transactions that are rolled back are not logged. (**Exception**: Modifications to nontransactional tables cannot be rolled back. If a transaction that is rolled back includes modifications to nontransactional tables, the entire transaction is logged with a `ROLLBACK` statement at the end to ensure that modifications to the nontransactional tables are replicated.) See Section 5.4.4, “The Binary Log”.

You can change the isolation level for transactions with the `SET TRANSACTION` statement. See Section 13.3.6, “SET TRANSACTION Syntax”.

Rolling back can be a slow operation that may occur implicitly without the user having explicitly asked for it (for example, when an error occurs). Because of this, `SHOW PROCESSLIST` displays `Rolling back` in the `State` column for the session, not only for explicit rollbacks performed with the `ROLLBACK` statement but also for implicit rollbacks.

Note

In MySQL 5.5, `BEGIN`, `COMMIT`, and `ROLLBACK` are not affected by `--replicate-do-db` or `--replicate-ignore-db` rules.

13.3.2 Statements That Cannot Be Rolled Back

Some statements cannot be rolled back. In general, these include data definition language (DDL) statements, such as those that create or drop databases, those that create, drop, or alter tables or stored routines.

You should design your transactions not to include such statements. If you issue a statement early in a transaction that cannot be rolled back, and then another statement later fails, the full effect of the transaction cannot be rolled back in such cases by issuing a `ROLLBACK` statement.

13.3.3 Statements That Cause an Implicit Commit

The statements listed in this section (and any synonyms for them) implicitly end any transaction active in the current session, as if you had done a `COMMIT` before executing the statement. As of MySQL 5.5.3, most of these statements also cause an implicit commit after executing; for additional details, see the end of this section.

- **Data definition language (DDL) statements that define or modify database objects.** `ALTER DATABASE ... UPGRADE DATA DIRECTORY NAME`, `ALTER EVENT`, `ALTER PROCEDURE`, `ALTER SERVER`, `ALTER TABLE`, `ALTER VIEW`, `CREATE DATABASE`, `CREATE EVENT`, `CREATE INDEX`, `CREATE PROCEDURE`, `CREATE SERVER`, `CREATE TABLE`, `CREATE TRIGGER`, `CREATE VIEW`, `DROP DATABASE`, `DROP EVENT`, `DROP INDEX`, `DROP PROCEDURE`, `DROP SERVER`, `DROP TABLE`, `DROP TRIGGER`, `DROP VIEW`, `RENAME TABLE`, `TRUNCATE TABLE`.

  `ALTER FUNCTION`, `CREATE FUNCTION` and `DROP FUNCTION` also cause an implicit commit when used with stored functions, but not with user-defined functions. (`ALTER FUNCTION` can only be used with stored functions.)

  `CREATE TABLE` and `DROP TABLE` statements do not commit a transaction if the `TEMPORARY` keyword is used. (This does not apply to other operations on temporary tables such as `ALTER`

TABLE and CREATE INDEX, which do cause a commit.) However, although no implicit commit occurs, neither can the statement be rolled back, which means that the use of such statements causes transactional atomicity to be violated. For example, if you use CREATE TEMPORARY TABLE and then roll back the transaction, the table remains in existence.

The CREATE TABLE statement in InnoDB is processed as a single transaction. This means that a ROLLBACK from the user does not undo CREATE TABLE statements the user made during that transaction.

CREATE TABLE ... SELECT causes an implicit commit before and after the statement is executed when you are creating nontemporary tables. (No commit occurs for CREATE TEMPORARY TABLE ... SELECT.)

- **Statements that implicitly use or modify tables in the mysql database.** CREATE USER, DROP USER, GRANT, RENAME USER, REVOKE, SET PASSWORD.
- **Transaction-control and locking statements.** BEGIN, LOCK TABLES, SET autocommit = 1 (if the value is not already 1), START TRANSACTION, UNLOCK TABLES.

  UNLOCK TABLES commits a transaction only if any tables currently have been locked with LOCK TABLES to acquire nontransactional table locks. A commit does not occur for UNLOCK TABLES following FLUSH TABLES WITH READ LOCK because the latter statement does not acquire table-level locks.

  Transactions cannot be nested. This is a consequence of the implicit commit performed for any current transaction when you issue a START TRANSACTION statement or one of its synonyms.

  Statements that cause an implicit commit cannot be used in an XA transaction while the transaction is in an ACTIVE state.

  The BEGIN statement differs from the use of the BEGIN keyword that starts a BEGIN ... END compound statement. The latter does not cause an implicit commit. See Section 13.6.1, “BEGIN ... END Compound-Statement Syntax”.
- **Data loading statements.** LOAD DATA INFILE. LOAD DATA INFILE causes an implicit commit only for tables using the NDB storage engine. For more information, see Bug #11151.
- **Administrative statements.** ANALYZE TABLE, CACHE INDEX, CHECK TABLE, LOAD INDEX INTO CACHE, OPTIMIZE TABLE, REPAIR TABLE.

As of MySQL 5.5.3, most statements that previously caused an implicit commit before executing also do so after executing. The intent is to handle each such statement in its own special transaction because it cannot be rolled back anyway. The following list provides additional details pertaining to this change:

- The CREATE TABLE variants (CREATE TABLE for InnoDB tables and CREATE TABLE ... SELECT) that previously were special cases no longer are so because CREATE TABLE uniformly causes an implicit commit before and after executing.
- The FLUSH and RESET statements cause an implicit commit.
- Transaction-control and locking statements behave as before. If an implicit commit occurs before execution, another does not occur after.

13.3.4 SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Syntax

```
SAVEPOINT identifier
ROLLBACK [WORK] TO [SAVEPOINT] identifier
RELEASE SAVEPOINT identifier
```

`InnoDB` supports the SQL statements `SAVEPOINT`, `ROLLBACK TO SAVEPOINT`, `RELEASE SAVEPOINT` and the optional `WORK` keyword for `ROLLBACK`.

The `SAVEPOINT` statement sets a named transaction savepoint with a name of *`identifier`*. If the current transaction has a savepoint with the same name, the old savepoint is deleted and a new one is set.

The `ROLLBACK TO SAVEPOINT` statement rolls back a transaction to the named savepoint without terminating the transaction. Modifications that the current transaction made to rows after the savepoint was set are undone in the rollback, but `InnoDB` does *not* release the row locks that were stored in memory after the savepoint. (For a new inserted row, the lock information is carried by the transaction ID stored in the row; the lock is not separately stored in memory. In this case, the row lock is released in the undo.) Savepoints that were set at a later time than the named savepoint are deleted.

If the `ROLLBACK TO SAVEPOINT` statement returns the following error, it means that no savepoint with the specified name exists:

```
ERROR 1305 (42000): SAVEPOINT identifier does not exist
```

The `RELEASE SAVEPOINT` statement removes the named savepoint from the set of savepoints of the current transaction. No commit or rollback occurs. It is an error if the savepoint does not exist.

All savepoints of the current transaction are deleted if you execute a `COMMIT`, or a `ROLLBACK` that does not name a savepoint.

A new savepoint level is created when a stored function is invoked or a trigger is activated. The savepoints on previous levels become unavailable and thus do not conflict with savepoints on the new level. When the function or trigger terminates, any savepoints it created are released and the previous savepoint level is restored.

13.3.5 LOCK TABLES and UNLOCK TABLES Syntax

```
LOCK TABLES
    tbl_name [[AS] alias] lock_type
    [, tbl_name [[AS] alias] lock_type] ...

lock_type:
    READ [LOCAL]
  | [LOW_PRIORITY] WRITE

UNLOCK TABLES
```

MySQL enables client sessions to acquire table locks explicitly for the purpose of cooperating with other sessions for access to tables, or to prevent other sessions from modifying tables during periods when a session requires exclusive access to them. A session can acquire or release locks only for itself. One session cannot acquire locks for another session or release locks held by another session.

Locks may be used to emulate transactions or to get more speed when updating tables. This is explained in more detail later in this section.

`LOCK TABLES` explicitly acquires table locks for the current client session. Table locks can be acquired for base tables or views. You must have the `LOCK TABLES` privilege, and the `SELECT` privilege for each object to be locked.

For view locking, `LOCK TABLES` adds all base tables used in the view to the set of tables to be locked and locks them automatically. If you lock a table explicitly with `LOCK TABLES`, any tables used in triggers are also locked implicitly, as described in Section 13.3.5.2, “LOCK TABLES and Triggers”.

`UNLOCK TABLES` explicitly releases any table locks held by the current session. `LOCK TABLES` implicitly releases any table locks held by the current session before acquiring new locks.

Another use for `UNLOCK TABLES` is to release the global read lock acquired with the `FLUSH TABLES WITH READ LOCK` statement, which enables you to lock all tables in all databases. See Section 13.7.6.3, “FLUSH Syntax”. (This is a very convenient way to get backups if you have a file system such as Veritas that can take snapshots in time.)

A table lock only protects against inappropriate reads or writes by other sessions. A session holding a `WRITE` lock can perform table-level operations such as `DROP TABLE` or `TRUNCATE TABLE`. For sessions holding a `READ` lock, `DROP TABLE` and `TRUNCATE TABLE` operations are not permitted.

The following discussion applies only to non-`TEMPORARY` tables. `LOCK TABLES` is permitted (but ignored) for a `TEMPORARY` table. The table can be accessed freely by the session within which it was created, regardless of what other locking may be in effect. No lock is necessary because no other session can see the table.

For information about other conditions on the use of `LOCK TABLES` and statements that cannot be used while `LOCK TABLES` is in effect, see Section 13.3.5.3, “Table-Locking Restrictions and Conditions”

Rules for Lock Acquisition

To acquire table locks within the current session, use the `LOCK TABLES` statement. The following lock types are available:

`READ [LOCAL]` lock:

- The session that holds the lock can read the table (but not write it).
- Multiple sessions can acquire a `READ` lock for the table at the same time.
- Other sessions can read the table without explicitly acquiring a `READ` lock.
- The `LOCAL` modifier enables nonconflicting `INSERT` statements (concurrent inserts) by other sessions to execute while the lock is held. (See Section 8.11.3, “Concurrent Inserts”.) However, `READ LOCAL` cannot be used if you are going to manipulate the database using processes external to the server while you hold the lock. For `InnoDB` tables, `READ LOCAL` is the same as `READ`.

`[LOW_PRIORITY] WRITE` lock:

- The session that holds the lock can read and write the table.
- Only the session that holds the lock can access the table. No other session can access it until the lock is released.
- Lock requests for the table by other sessions block while the `WRITE` lock is held.
- The `LOW_PRIORITY` modifier has no effect as of MySQL 5.5.3. Before 5.5.3, it affects lock scheduling if the `WRITE` lock request must wait, as described later.

If the `LOCK TABLES` statement must wait due to locks held by other sessions on any of the tables, it blocks until all locks can be acquired.

A session that requires locks must acquire all the locks that it needs in a single `LOCK TABLES` statement. While the locks thus obtained are held, the session can access only the locked tables. For example, in the following sequence of statements, an error occurs for the attempt to access `t2` because it was not locked in the `LOCK TABLES` statement:

```
mysql> LOCK TABLES t1 READ;
mysql> SELECT COUNT(*) FROM t1;
+----------+
| COUNT(*) |
+----------+
```

```
|        3 |
+----------+
mysql> SELECT COUNT(*) FROM t2;
ERROR 1100 (HY000): Table 't2' was not locked with LOCK TABLES
```

Tables in the `INFORMATION_SCHEMA` database are an exception. They can be accessed without being locked explicitly even while a session holds table locks obtained with `LOCK TABLES`.

You cannot refer to a locked table multiple times in a single query using the same name. Use aliases instead, and obtain a separate lock for the table and each alias:

```
mysql> LOCK TABLE t WRITE, t AS t1 READ;
mysql> INSERT INTO t SELECT * FROM t;
ERROR 1100: Table 't' was not locked with LOCK TABLES
mysql> INSERT INTO t SELECT * FROM t AS t1;
```

The error occurs for the first `INSERT` because there are two references to the same name for a locked table. The second `INSERT` succeeds because the references to the table use different names.

If your statements refer to a table by means of an alias, you must lock the table using that same alias. It does not work to lock the table without specifying the alias:

```
mysql> LOCK TABLE t READ;
mysql> SELECT * FROM t AS myalias;
ERROR 1100: Table 'myalias' was not locked with LOCK TABLES
```

Conversely, if you lock a table using an alias, you must refer to it in your statements using that alias:

```
mysql> LOCK TABLE t AS myalias READ;
mysql> SELECT * FROM t;
ERROR 1100: Table 't' was not locked with LOCK TABLES
mysql> SELECT * FROM t AS myalias;
```

`WRITE` locks normally have higher priority than `READ` locks to ensure that updates are processed as soon as possible. This means that if one session obtains a `READ` lock and then another session requests a `WRITE` lock, subsequent `READ` lock requests wait until the session that requested the `WRITE` lock has obtained the lock and released it. Before MySQL 5.5.3, the `LOW_PRIORITY` modifier can be given to affect locking behavior as follows (as of 5.5.3, it has no effect): A request for a `LOW_PRIORITY WRITE` lock permits subsequent `READ` lock requests by other sessions to be satisfied first if they occur while the `LOW_PRIORITY WRITE` request is waiting. You should use `LOW_PRIORITY WRITE` locks only if you are sure that eventually there will be a time when no sessions have a `READ` lock. For `InnoDB` tables in transactional mode (autocommit = 0), a waiting `LOW_PRIORITY WRITE` lock acts like a regular `WRITE` lock and causes subsequent `READ` lock requests to wait.

`LOCK TABLES` acquires locks as follows:

1. Sort all tables to be locked in an internally defined order. From the user standpoint, this order is undefined.

2. If a table is to be locked with a read and a write lock, put the write lock request before the read lock request.

3. Lock one table at a time until the session gets all locks.

This policy ensures that table locking is deadlock free. There are, however, other things you need to be aware of about this policy: If you are using a `LOW_PRIORITY WRITE` lock for a table, it means only that MySQL waits for this particular lock until there are no other sessions that want a `READ` lock. When the session has gotten the `WRITE` lock and is waiting to get the lock for the next table in the lock table list, all other sessions wait for the `WRITE` lock to be released. If this becomes a serious problem with your application, you should consider converting some of your tables to transaction-safe tables.

Note

`LOCK TABLES` or `UNLOCK TABLES`, when applied to a partitioned table, always locks or unlocks the entire table. See Section 19.5.4, “Partitioning and Table-Level Locking”.

Rules for Lock Release

When the table locks held by a session are released, they are all released at the same time. A session can release its locks explicitly, or locks may be released implicitly under certain conditions.

- A session can release its locks explicitly with `UNLOCK TABLES`.
- If a session issues a `LOCK TABLES` statement to acquire a lock while already holding locks, its existing locks are released implicitly before the new locks are granted.
- If a session begins a transaction (for example, with `START TRANSACTION`), an implicit `UNLOCK TABLES` is performed, which causes existing locks to be released. (For additional information about the interaction between table locking and transactions, see Section 13.3.5.1, “Interaction of Table Locking and Transactions”.)

If the connection for a client session terminates, whether normally or abnormally, the server implicitly releases all table locks held by the session (transactional and nontransactional). If the client reconnects, the locks will no longer be in effect. In addition, if the client had an active transaction, the server rolls back the transaction upon disconnect, and if reconnect occurs, the new session begins with autocommit enabled. For this reason, clients may wish to disable auto-reconnect. With auto-reconnect in effect, the client is not notified if reconnect occurs but any table locks or current transaction will have been lost. With auto-reconnect disabled, if the connection drops, an error occurs for the next statement issued. The client can detect the error and take appropriate action such as reacquiring the locks or redoing the transaction. See Section 23.8.20, “C API Automatic Reconnection Control”.

Note

If you use `ALTER TABLE` on a locked table, it may become unlocked. For example, if you attempt a second `ALTER TABLE` operation, the result may be an error `Table 'tbl_name' was not locked with LOCK TABLES`. To handle this, lock the table again prior to the second alteration. See also Section B.5.6.1, “Problems with ALTER TABLE”.

13.3.5.1 Interaction of Table Locking and Transactions

`LOCK TABLES` and `UNLOCK TABLES` interact with the use of transactions as follows:

- `LOCK TABLES` is not transaction-safe and implicitly commits any active transaction before attempting to lock the tables.
- `UNLOCK TABLES` implicitly commits any active transaction, but only if `LOCK TABLES` has been used to acquire table locks. For example, in the following set of statements, `UNLOCK TABLES` releases the global read lock but does not commit the transaction because no table locks are in effect:

```
FLUSH TABLES WITH READ LOCK;
START TRANSACTION;
SELECT ... ;
UNLOCK TABLES;
```

- Beginning a transaction (for example, with `START TRANSACTION`) implicitly commits any current transaction and releases existing table locks.
- `FLUSH TABLES WITH READ LOCK` acquires a global read lock and not table locks, so it is not subject to the same behavior as `LOCK TABLES` and `UNLOCK TABLES` with respect to table locking

and implicit commits. For example, `START TRANSACTION` does not release the global read lock. See Section 13.7.6.3, “FLUSH Syntax”.

- Other statements that implicitly cause transactions to be committed do not release existing table locks. For a list of such statements, see Section 13.3.3, “Statements That Cause an Implicit Commit”.
- The correct way to use `LOCK TABLES` and `UNLOCK TABLES` with transactional tables, such as `InnoDB` tables, is to begin a transaction with `SET autocommit = 0` (not `START TRANSACTION`) followed by `LOCK TABLES`, and to not call `UNLOCK TABLES` until you commit the transaction explicitly. For example, if you need to write to table `t1` and read from table `t2`, you can do this:

```
SET autocommit=0;
LOCK TABLES t1 WRITE, t2 READ, ...;
... do something with tables t1 and t2 here ...
COMMIT;
UNLOCK TABLES;
```

When you call `LOCK TABLES`, `InnoDB` internally takes its own table lock, and MySQL takes its own table lock. `InnoDB` releases its internal table lock at the next commit, but for MySQL to release its table lock, you have to call `UNLOCK TABLES`. You should not have `autocommit = 1`, because then `InnoDB` releases its internal table lock immediately after the call of `LOCK TABLES`, and deadlocks can very easily happen. `InnoDB` does not acquire the internal table lock at all if `autocommit = 1`, to help old applications avoid unnecessary deadlocks.

- `ROLLBACK` does not release table locks.

13.3.5.2 LOCK TABLES and Triggers

If you lock a table explicitly with `LOCK TABLES`, any tables used in triggers are also locked implicitly:

- The locks are taken as the same time as those acquired explicitly with the `LOCK TABLES` statement.
- The lock on a table used in a trigger depends on whether the table is used only for reading. If so, a read lock suffices. Otherwise, a write lock is used.
- If a table is locked explicitly for reading with `LOCK TABLES`, but needs to be locked for writing because it might be modified within a trigger, a write lock is taken rather than a read lock. (That is, an implicit write lock needed due to the table's appearance within a trigger causes an explicit read lock request for the table to be converted to a write lock request.)

Suppose that you lock two tables, `t1` and `t2`, using this statement:

```
LOCK TABLES t1 WRITE, t2 READ;
```

If `t1` or `t2` have any triggers, tables used within the triggers will also be locked. Suppose that `t1` has a trigger defined like this:

```
CREATE TRIGGER t1_a_ins AFTER INSERT ON t1 FOR EACH ROW
BEGIN
  UPDATE t4 SET count = count+1
      WHERE id = NEW.id AND EXISTS (SELECT a FROM t3);
  INSERT INTO t2 VALUES(1, 2);
END;
```

The result of the `LOCK TABLES` statement is that `t1` and `t2` are locked because they appear in the statement, and `t3` and `t4` are locked because they are used within the trigger:

- `t1` is locked for writing per the `WRITE` lock request.
- `t2` is locked for writing, even though the request is for a `READ` lock. This occurs because `t2` is inserted into within the trigger, so the `READ` request is converted to a `WRITE` request.

- `t3` is locked for reading because it is only read from within the trigger.
- `t4` is locked for writing because it might be updated within the trigger.

13.3.5.3 Table-Locking Restrictions and Conditions

You can safely use `KILL` to terminate a session that is waiting for a table lock. See Section 13.7.6.4, “KILL Syntax”.

You should *not* lock any tables that you are using with `INSERT DELAYED`. An `INSERT DELAYED` in this case results in an error because the insert must be handled by a separate thread, not by the session which holds the lock.

`LOCK TABLES` and `UNLOCK TABLES` cannot be used within stored programs.

Tables in the `performance_schema` database cannot be locked with `LOCK TABLES`, except the `setup_xxx` tables.

The following statements are prohibited while a `LOCK TABLES` statement is in effect:

- As of MySQL 5.5.3, `CREATE TABLE`, `CREATE TABLE ... LIKE`, `CREATE VIEW`, `DROP VIEW`, and DDL statements on stored procedures and functions.
- As of MySQL 5.5.8, DDL statements on events

For some operations, system tables in the `mysql` database must be accessed. For example, the `HELP` statement requires the contents of the server-side help tables, and `CONVERT_TZ()` might need to read the time zone tables. The server implicitly locks the system tables for reading as necessary so that you need not lock them explicitly. These tables are treated as just described:

```
mysql.help_category
mysql.help_keyword
mysql.help_relation
mysql.help_topic
mysql.proc
mysql.time_zone
mysql.time_zone_leap_second
mysql.time_zone_name
mysql.time_zone_transition
mysql.time_zone_transition_type
```

If you want to explicitly place a `WRITE` lock on any of those tables with a `LOCK TABLES` statement, the table must be the only one locked; no other table can be locked with the same statement.

Normally, you do not need to lock tables, because all single `UPDATE` statements are atomic; no other session can interfere with any other currently executing SQL statement. However, there are a few cases when locking tables may provide an advantage:

- If you are going to run many operations on a set of `MyISAM` tables, it is much faster to lock the tables you are going to use. Locking `MyISAM` tables speeds up inserting, updating, or deleting on them because MySQL does not flush the key cache for the locked tables until `UNLOCK TABLES` is called. Normally, the key cache is flushed after each SQL statement.

  The downside to locking the tables is that no session can update a `READ`-locked table (including the one holding the lock) and no session can access a `WRITE`-locked table other than the one holding the lock.

- If you are using tables for a nontransactional storage engine, you must use `LOCK TABLES` if you want to ensure that no other session modifies the tables between a `SELECT` and an `UPDATE`. The example shown here requires `LOCK TABLES` to execute safely:

```
LOCK TABLES trans READ, customer WRITE;
SELECT SUM(value) FROM trans WHERE customer_id=some_id;
UPDATE customer
  SET total_value=sum_from_previous_statement
  WHERE customer_id=some_id;
UNLOCK TABLES;
```

Without `LOCK TABLES`, it is possible that another session might insert a new row in the `trans` table between execution of the `SELECT` and `UPDATE` statements.

You can avoid using `LOCK TABLES` in many cases by using relative updates (`UPDATE customer SET value=value+new_value`) or the `LAST_INSERT_ID()` function.

You can also avoid locking tables in some cases by using the user-level advisory lock functions `GET_LOCK()` and `RELEASE_LOCK()`. These locks are saved in a hash table in the server and implemented with `pthread_mutex_lock()` and `pthread_mutex_unlock()` for high speed. See Section 12.17, “Miscellaneous Functions”.

See Section 8.11.1, “Internal Locking Methods”, for more information on locking policy.

13.3.6 SET TRANSACTION Syntax

```
SET [GLOBAL | SESSION] TRANSACTION ISOLATION LEVEL
  {
       REPEATABLE READ
     | READ COMMITTED
     | READ UNCOMMITTED
     | SERIALIZABLE
   }
```

This statement sets the transaction isolation level, used for operations on `InnoDB` tables.

Scope of the Isolation Level

You can set the isolation level globally, for the current session, or for the next transaction:

- With the `GLOBAL` keyword, the statement sets the default transaction level globally for all subsequent sessions. Existing sessions are unaffected.
- With the `SESSION` keyword, the statement sets the default transaction level for all subsequent transactions performed within the current session.
- Without any `SESSION` or `GLOBAL` keyword, the statement sets the isolation level for the next (not started) transaction performed within the current session. Subsequent transactions revert to using the `SESSION` isolation level.

A change to the global default isolation level requires the `SUPER` privilege. Any session is free to change its session isolation level (even in the middle of a transaction), or the isolation level for its next transaction.

`SET TRANSACTION ISOLATION LEVEL` without `GLOBAL` or `SESSION` is not permitted while there is an active transaction:

```
mysql> START TRANSACTION;
Query OK, 0 rows affected (0.02 sec)

mysql> SET TRANSACTION ISOLATION LEVEL SERIALIZABLE;
ERROR 1568 (25001): Transaction isolation level can't be changed
while a transaction is in progress
```

To set the global default isolation level at server startup, use the `--transaction-isolation=level` option to `mysqld` on the command line or in an option file. Values of *`level`* for

this option use dashes rather than spaces, so the permissible values are `READ-UNCOMMITTED`, `READ-COMMITTED`, `REPEATABLE-READ`, or `SERIALIZABLE`. For example, to set the default isolation level to `REPEATABLE READ`, use these lines in the `[mysqld]` section of an option file:

```
[mysqld]
transaction-isolation = REPEATABLE-READ
```

It is possible to check or set the global and session transaction isolation levels at runtime by using the `tx_isolation` system variable:

```
SELECT @@GLOBAL.tx_isolation, @@tx_isolation;
SET GLOBAL tx_isolation='REPEATABLE-READ';
SET SESSION tx_isolation='SERIALIZABLE';
```

Transaction Isolation Levels

For information about transaction isolation levels, see Section 14.8.2.1, “Transaction Isolation Levels”.

13.3.7 XA Transactions

Support for XA transactions is available for the `InnoDB` storage engine. The MySQL XA implementation is based on the X/Open CAE document *Distributed Transaction Processing: The XA Specification*. This document is published by The Open Group and available at http://www.opengroup.org/public/pubs/catalog/c193.htm. Limitations of the current XA implementation are described in Section C.6, “Restrictions on XA Transactions”.

On the client side, there are no special requirements. The XA interface to a MySQL server consists of SQL statements that begin with the `XA` keyword. MySQL client programs must be able to send SQL statements and to understand the semantics of the XA statement interface. They do not need be linked against a recent client library. Older client libraries also will work.

Among the MySQL Connectors, MySQL Connector/J 5.0.0 supports XA directly (by means of a class interface that handles the XA SQL statement interface for you).

XA supports distributed transactions, that is, the ability to permit multiple separate transactional resources to participate in a global transaction. Transactional resources often are RDBMSs but may be other kinds of resources.

A global transaction involves several actions that are transactional in themselves, but that all must either complete successfully as a group, or all be rolled back as a group. In essence, this extends ACID properties “up a level” so that multiple ACID transactions can be executed in concert as components of a global operation that also has ACID properties. (As with nondistributed transactions, `SERIALIZABLE` may be preferred if your applications are sensitive to read phenomena. `REPEATABLE READ` may not be sufficient for distributed transactions.)

Some examples of distributed transactions:

- An application may act as an integration tool that combines a messaging service with an RDBMS. The application makes sure that transactions dealing with message sending, retrieval, and processing that also involve a transactional database all happen in a global transaction. You can think of this as “transactional email.”
- An application performs actions that involve different database servers, such as a MySQL server and an Oracle server (or multiple MySQL servers), where actions that involve multiple servers must happen as part of a global transaction, rather than as separate transactions local to each server.
- A bank keeps account information in an RDBMS and distributes and receives money through automated teller machines (ATMs). It is necessary to ensure that ATM actions are correctly reflected

in the accounts, but this cannot be done with the RDBMS alone. A global transaction manager integrates the ATM and database resources to ensure overall consistency of financial transactions.

Applications that use global transactions involve one or more Resource Managers and a Transaction Manager:

- A Resource Manager (RM) provides access to transactional resources. A database server is one kind of resource manager. It must be possible to either commit or roll back transactions managed by the RM.
- A Transaction Manager (TM) coordinates the transactions that are part of a global transaction. It communicates with the RMs that handle each of these transactions. The individual transactions within a global transaction are “branches” of the global transaction. Global transactions and their branches are identified by a naming scheme described later.

The MySQL implementation of XA enables a MySQL server to act as a Resource Manager that handles XA transactions within a global transaction. A client program that connects to the MySQL server acts as the Transaction Manager.

To carry out a global transaction, it is necessary to know which components are involved, and bring each component to a point when it can be committed or rolled back. Depending on what each component reports about its ability to succeed, they must all commit or roll back as an atomic group. That is, either all components must commit, or all components must roll back. To manage a global transaction, it is necessary to take into account that any component or the connecting network might fail.

The process for executing a global transaction uses two-phase commit (2PC). This takes place after the actions performed by the branches of the global transaction have been executed.

1. In the first phase, all branches are prepared. That is, they are told by the TM to get ready to commit. Typically, this means each RM that manages a branch records the actions for the branch in stable storage. The branches indicate whether they are able to do this, and these results are used for the second phase.
2. In the second phase, the TM tells the RMs whether to commit or roll back. If all branches indicated when they were prepared that they will be able to commit, all branches are told to commit. If any branch indicated when it was prepared that it will not be able to commit, all branches are told to roll back.

In some cases, a global transaction might use one-phase commit (1PC). For example, when a Transaction Manager finds that a global transaction consists of only one transactional resource (that is, a single branch), that resource can be told to prepare and commit at the same time.

13.3.7.1 XA Transaction SQL Syntax

To perform XA transactions in MySQL, use the following statements:

```
XA {START|BEGIN} xid [JOIN|RESUME]

XA END xid [SUSPEND [FOR MIGRATE]]

XA PREPARE xid

XA COMMIT xid [ONE PHASE]

XA ROLLBACK xid

XA RECOVER
```

For `XA START`, the `JOIN` and `RESUME` clauses are not supported.

For `XA END` the `SUSPEND [FOR MIGRATE]` clause is not supported.

Each XA statement begins with the `XA` keyword, and most of them require an *`xid`* value. An *`xid`* is an XA transaction identifier. It indicates which transaction the statement applies to. *`xid`* values are supplied by the client, or generated by the MySQL server. An *`xid`* value has from one to three parts:

```
xid: gtrid [, bqual [, formatID ]]
```

`gtrid` is a global transaction identifier, *`bqual`* is a branch qualifier, and *`formatID`* is a number that identifies the format used by the *`gtrid`* and *`bqual`* values. As indicated by the syntax, *`bqual`* and *`formatID`* are optional. The default *`bqual`* value is `''` if not given. The default *`formatID`* value is 1 if not given.

`gtrid` and *`bqual`* must be string literals, each up to 64 bytes (not characters) long. *`gtrid`* and *`bqual`* can be specified in several ways. You can use a quoted string (`'ab'`), hex string (`X'6162'`, `0x6162`), or bit value (`b'nnnn'`).

`formatID` is an unsigned integer.

The *`gtrid`* and *`bqual`* values are interpreted in bytes by the MySQL server's underlying XA support routines. However, while an SQL statement containing an XA statement is being parsed, the server works with some specific character set. To be safe, write *`gtrid`* and *`bqual`* as hex strings.

`xid` values typically are generated by the Transaction Manager. Values generated by one TM must be different from values generated by other TMs. A given TM must be able to recognize its own *`xid`* values in a list of values returned by the `XA RECOVER` statement.

For `XA START` *`xid`* starts an XA transaction with the given *`xid`* value. Each XA transaction must have a unique *`xid`* value, so the value must not currently be used by another XA transaction. Uniqueness is assessed using the *`gtrid`* and *`bqual`* values. All following XA statements for the XA transaction must be specified using the same *`xid`* value as that given in the `XA START` statement. If you use any of those statements but specify an *`xid`* value that does not correspond to some existing XA transaction, an error occurs.

One or more XA transactions can be part of the same global transaction. All XA transactions within a given global transaction must use the same *`gtrid`* value in the *`xid`* value. For this reason, *`gtrid`* values must be globally unique so that there is no ambiguity about which global transaction a given XA transaction is part of. The *`bqual`* part of the *`xid`* value must be different for each XA transaction within a global transaction. (The requirement that *`bqual`* values be different is a limitation of the current MySQL XA implementation. It is not part of the XA specification.)

The `XA RECOVER` statement returns information for those XA transactions on the MySQL server that are in the `PREPARED` state. (See Section 13.3.7.2, “XA Transaction States”.) The output includes a row for each such XA transaction on the server, regardless of which client started it.

`XA RECOVER` output rows look like this (for an example *`xid`* value consisting of the parts `'abc'`, `'def'`, and `7`):

```
mysql> XA RECOVER;
+----------+--------------+--------------+--------+
| formatID | gtrid_length | bqual_length | data   |
+----------+--------------+--------------+--------+
|        7 |            3 |            3 | abcdef |
+----------+--------------+--------------+--------+
```

The output columns have the following meanings:

- `formatID` is the *`formatID`* part of the transaction *`xid`*
- `gtrid_length` is the length in bytes of the *`gtrid`* part of the *`xid`*
- `bqual_length` is the length in bytes of the *`bqual`* part of the *`xid`*
- `data` is the concatenation of the *`gtrid`* and *`bqual`* parts of the *`xid`*

13.3.7.2 XA Transaction States

An XA transaction progresses through the following states:

1. Use `XA START` to start an XA transaction and put it in the `ACTIVE` state.
2. For an `ACTIVE` XA transaction, issue the SQL statements that make up the transaction, and then issue an `XA END` statement. `XA END` puts the transaction in the `IDLE` state.
3. For an `IDLE` XA transaction, you can issue either an `XA PREPARE` statement or an `XA COMMIT ... ONE PHASE` statement:
   - `XA PREPARE` puts the transaction in the `PREPARED` state. An `XA RECOVER` statement at this point will include the transaction's *`xid`* value in its output, because `XA RECOVER` lists all XA transactions that are in the `PREPARED` state.
   - `XA COMMIT ... ONE PHASE` prepares and commits the transaction. The *`xid`* value will not be listed by `XA RECOVER` because the transaction terminates.
4. For a `PREPARED` XA transaction, you can issue an `XA COMMIT` statement to commit and terminate the transaction, or `XA ROLLBACK` to roll back and terminate the transaction.

Here is a simple XA transaction that inserts a row into a table as part of a global transaction:

```
mysql> XA START 'xatest';
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO mytable (i) VALUES(10);
Query OK, 1 row affected (0.04 sec)

mysql> XA END 'xatest';
Query OK, 0 rows affected (0.00 sec)

mysql> XA PREPARE 'xatest';
Query OK, 0 rows affected (0.00 sec)

mysql> XA COMMIT 'xatest';
Query OK, 0 rows affected (0.00 sec)
```

Within the context of a given client connection, XA transactions and local (non-XA) transactions are mutually exclusive. For example, if `XA START` has been issued to begin an XA transaction, a local transaction cannot be started until the XA transaction has been committed or rolled back. Conversely, if a local transaction has been started with `START TRANSACTION`, no XA statements can be used until the transaction has been committed or rolled back.

If an XA transaction is in the `ACTIVE` state, you cannot issue any statements that cause an implicit commit. That would violate the XA contract because you could not roll back the XA transaction. You will receive the following error if you try to execute such a statement:

```
ERROR 1399 (XAE07): XAER_RMFAIL: The command cannot be executed
when global transaction is in the ACTIVE state
```

Statements to which the preceding remark applies are listed at Section 13.3.3, “Statements That Cause an Implicit Commit”.

13.4 Replication Statements

Replication can be controlled through the SQL interface using the statements described in this section. One group of statements controls master servers, the other controls slave servers.

13.4.1 SQL Statements for Controlling Master Servers

This section discusses statements for managing master replication servers. Section 13.4.2, “SQL Statements for Controlling Slave Servers”, discusses statements for managing slave servers.

In addition to the statements described here, the following `SHOW` statements are used with master servers in replication. For information about these statements, see Section 13.7.5, “SHOW Syntax”.

- `SHOW BINARY LOGS`
- `SHOW BINLOG EVENTS`
- `SHOW MASTER STATUS`
- `SHOW SLAVE HOSTS`

13.4.1.1 PURGE BINARY LOGS Syntax

```
PURGE { BINARY | MASTER } LOGS
    { TO 'log_name' | BEFORE datetime_expr }
```

The binary log is a set of files that contain information about data modifications made by the MySQL server. The log consists of a set of binary log files, plus an index file (see Section 5.4.4, “The Binary Log”).

The `PURGE BINARY LOGS` statement deletes all the binary log files listed in the log index file prior to the specified log file name or date. `BINARY` and `MASTER` are synonyms. Deleted log files also are removed from the list recorded in the index file, so that the given log file becomes the first in the list.

This statement has no effect if the server was not started with the `--log-bin` option to enable binary logging.

Examples:

```
PURGE BINARY LOGS TO 'mysql-bin.010';
PURGE BINARY LOGS BEFORE '2008-04-02 22:46:26';
```

The `BEFORE` variant's *`datetime_expr`* argument should evaluate to a `DATETIME` value (a value in `'YYYY-MM-DD hh:mm:ss'` format).

This statement is safe to run while slaves are replicating. You need not stop them. If you have an active slave that currently is reading one of the log files you are trying to delete, this statement does nothing and fails with an error. However, if a slave is not connected and you happen to purge one of the log files it has yet to read, the slave will be unable to replicate after it reconnects.

To safely purge binary log files, follow this procedure:

1. On each slave server, use `SHOW SLAVE STATUS` to check which log file it is reading.
2. Obtain a listing of the binary log files on the master server with `SHOW BINARY LOGS`.
3. Determine the earliest log file among all the slaves. This is the target file. If all the slaves are up to date, this is the last log file on the list.
4. Make a backup of all the log files you are about to delete. (This step is optional, but always advisable.)
5. Purge all log files up to but not including the target file.

You can also set the `expire_logs_days` system variable to expire binary log files automatically after a given number of days (see Section 5.1.5, “Server System Variables”). If you are using replication, you should set the variable no lower than the maximum number of days your slaves might lag behind the master.

`PURGE BINARY LOGS TO` and `PURGE BINARY LOGS BEFORE` both fail with an error when binary log files listed in the `.index` file had been removed from the system by some other means (such as using `rm` on Linux). (Bug #18199, Bug #18453) To handle such errors, edit the `.index` file (which is a simple text file) manually to ensure that it lists only the binary log files that are actually present, then run again the `PURGE BINARY LOGS` statement that failed.

13.4.1.2 RESET MASTER Syntax

```
RESET MASTER
```

Deletes all binary log files listed in the index file, resets the binary log index file to be empty, and creates a new binary log file. This statement is intended to be used only when the master is started for the first time.

Important

The effects of `RESET MASTER` differ from those of `PURGE BINARY LOGS` in 2 key ways:

1. `RESET MASTER` removes *all* binary log files that are listed in the index file, leaving only a single, empty binary log file with a numeric suffix of `.000001`, whereas the numbering is not reset by `PURGE BINARY LOGS`.

2. `RESET MASTER` is *not* intended to be used while any replication slaves are running. The behavior of `RESET MASTER` when used while slaves are running is undefined (and thus unsupported), whereas `PURGE BINARY LOGS` may be safely used while replication slaves are running.

See also Section 13.4.1.1, “PURGE BINARY LOGS Syntax”.

`RESET MASTER` can prove useful when you first set up the master and the slave, so that you can verify the setup as follows:

1. Start the master and slave, and start replication (see Section 17.1.1, “How to Set Up Replication”).
2. Execute a few test queries on the master.
3. Check that the queries were replicated to the slave.
4. When replication is running correctly, issue `STOP SLAVE` followed by `RESET SLAVE` on the slave, then verify that any unwanted data no longer exists on the slave.
5. Issue `RESET MASTER` on the master to clean up the test queries.

After verifying the setup and getting rid of any unwanted and log files generated by testing, you can start the slave and begin replicating.

13.4.1.3 SET sql_log_bin Syntax

```
SET sql_log_bin = {0|1}
```

The `sql_log_bin` variable controls whether logging to the binary log is done. The default value is 1 (do logging). To change logging for the current session, change the session value of this variable. The session user must have the `SUPER` privilege to set this variable. Set this variable to 0 for a session to temporarily disable binary logging while making changes to the master which you do not want to replicate to the slave.

As of MySQL 5.5.41, the global `sql_log_bin` variable is read only and cannot be modified. The global scope is deprecated and will be removed in a future MySQL release. Prior to 5.5.41,

`sql_log_bin` can be set as a global or session variable. Setting `sql_log_bin` globally is only detected when a new session is started. Any sessions previously running are not impacted when setting `sql_log_bin` globally.

Warning

Incorrect use of `sql_log_bin` with a global scope means any changes made in an already running session are *still* being recorded to the binary log and therefore replicated. Exercise extreme caution using `sql_log_bin` with a global scope as the above situation could cause unexpected results including replication failure.

It is not possible to set `@@session.sql_log_bin` within a transaction or subquery.

13.4.2 SQL Statements for Controlling Slave Servers

This section discusses statements for managing slave replication servers. Section 13.4.1, "SQL Statements for Controlling Master Servers", discusses statements for managing master servers.

In addition to the statements described here, `SHOW SLAVE STATUS` and `SHOW RELAYLOG EVENTS` are also used with replication slaves. For information about these statements, see Section 13.7.5.35, "SHOW SLAVE STATUS Syntax", and Section 13.7.5.33, "SHOW RELAYLOG EVENTS Syntax".

13.4.2.1 CHANGE MASTER TO Syntax

```
CHANGE MASTER TO option [, option] ...

option:
    MASTER_BIND = 'interface_name'
  | MASTER_HOST = 'host_name'
  | MASTER_USER = 'user_name'
  | MASTER_PASSWORD = 'password'
  | MASTER_PORT = port_num
  | MASTER_CONNECT_RETRY = interval
  | MASTER_HEARTBEAT_PERIOD = interval
  | MASTER_LOG_FILE = 'master_log_name'
  | MASTER_LOG_POS = master_log_pos
  | RELAY_LOG_FILE = 'relay_log_name'
  | RELAY_LOG_POS = relay_log_pos
  | MASTER_SSL = {0|1}
  | MASTER_SSL_CA = 'ca_file_name'
  | MASTER_SSL_CAPATH = 'ca_directory_name'
  | MASTER_SSL_CERT = 'cert_file_name'
  | MASTER_SSL_KEY = 'key_file_name'
  | MASTER_SSL_CIPHER = 'cipher_list'
  | MASTER_SSL_VERIFY_SERVER_CERT = {0|1}
  | IGNORE_SERVER_IDS = (server_id_list)

server_id_list:
    [server_id [, server_id] ... ]
```

`CHANGE MASTER TO` changes the parameters that the slave server uses for connecting to the master server, for reading the master binary log, and reading the slave relay log. It also updates the contents of the `master.info` and `relay-log.info` files. `CHANGE MASTER TO` requires the `SUPER` privilege.

To use `CHANGE MASTER TO`, the slave replication threads must be stopped (use `STOP SLAVE` if necessary).

Options not specified retain their value, except as indicated in the following discussion. Thus, in most cases, there is no need to specify options that do not change. For example, if the password to connect to your MySQL master has changed, you just need to issue these statements to tell the slave about the new password:

```
STOP SLAVE; -- if replication was running
CHANGE MASTER TO MASTER_PASSWORD='new3cret';
START SLAVE; -- if you want to restart replication
```

`MASTER_HOST`, `MASTER_USER`, `MASTER_PASSWORD`, and `MASTER_PORT` provide information to the slave about how to connect to its master:

- `MASTER_HOST` and `MASTER_PORT` are the host name (or IP address) of the master host and its TCP/IP port.

  Note

  Replication cannot use Unix socket files. You must be able to connect to the master MySQL server using TCP/IP.

  If you specify the `MASTER_HOST` or `MASTER_PORT` option, the slave assumes that the master server is different from before (even if the option value is the same as its current value.) In this case, the old values for the master binary log file name and position are considered no longer applicable, so if you do not specify `MASTER_LOG_FILE` and `MASTER_LOG_POS` in the statement, `MASTER_LOG_FILE=''` and `MASTER_LOG_POS=4` are silently appended to it.

  Setting `MASTER_HOST=''` (that is, setting its value explicitly to an empty string) is *not* the same as not setting `MASTER_HOST` at all. Beginning with MySQL 5.5, trying to set `MASTER_HOST` to an empty string fails with an error. Previously, setting `MASTER_HOST` to an empty string caused `START SLAVE` subsequently to fail. (Bug #28796)

- `MASTER_USER` and `MASTER_PASSWORD` are the user name and password of the account to use for connecting to the master.

  In MySQL 5.5.20 and later, `MASTER_USER` cannot be made empty; setting `MASTER_USER = ''` or leaving it unset when setting a value for `MASTER_PASSWORD` causes an error (Bug #13427949).

  The password used for a MySQL Replication slave account in a `CHANGE MASTER TO` statement is limited to 32 characters in length; if the password is longer, the statement succeeds, but any excess characters are silently truncated. This is an issue specific to MySQL Replication, which is fixed in MySQL 5.7. (Bug #11752299, Bug #43439)

  The text of a running `CHANGE MASTER TO` statement, including values for `MASTER_USER` and `MASTER_PASSWORD`, can be seen in the output of a concurrent `SHOW PROCESSLIST` statement.

The `MASTER_SSL_`*`xxx`* options provide information about using SSL for the connection. They correspond to the `--ssl-`*`xxx`* options described in Section 6.4.2, “Command Options for Encrypted Connections”, and Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”. These options can be changed even on slaves that are compiled without SSL support. They are saved to the `master.info` file, but are ignored if the slave does not have SSL support enabled.

`MASTER_CONNECT_RETRY` specifies how many seconds to wait between connect retries. The default is 60. The *number* of reconnection attempts is limited by the `--master-retry-count` server option; for more information, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

The `MASTER_BIND` option is available in MySQL NDB Cluster 7.2 and later, but is not supported in mainline MySQL 5.5.

`MASTER_BIND` is for use on replication slaves having multiple network interfaces, and determines which of the slave's network interfaces is chosen for connecting to the master.

`MASTER_HEARTBEAT_PERIOD` sets the interval in seconds between replication heartbeats. Whenever the master's binary log is updated with an event, the waiting period for the next heartbeat is reset. *`interval`* is a decimal value having the range 0 to 4294967 seconds and a resolution in milliseconds; the smallest nonzero value is 0.001. Heartbeats are sent by the master only if there are no unsent events in the binary log file for a period longer than *`interval`*.

Setting *`interval`* to 0 disables heartbeats altogether. The default value for *`interval`* is equal to the value of `slave_net_timeout` divided by 2.

Setting `@@global.slave_net_timeout` to a value less than that of the current heartbeat interval results in a warning being issued. The effect of issuing `RESET SLAVE` on the heartbeat interval is to reset it to the default value.

`MASTER_LOG_FILE` and `MASTER_LOG_POS` are the coordinates at which the slave I/O thread should begin reading from the master the next time the thread starts. `RELAY_LOG_FILE` and `RELAY_LOG_POS` are the coordinates at which the slave SQL thread should begin reading from the relay log the next time the thread starts. If you specify either of `MASTER_LOG_FILE` or `MASTER_LOG_POS`, you cannot specify `RELAY_LOG_FILE` or `RELAY_LOG_POS`. If neither of `MASTER_LOG_FILE` or `MASTER_LOG_POS` is specified, the slave uses the last coordinates of the *slave SQL thread* before `CHANGE MASTER TO` was issued. This ensures that there is no discontinuity in replication, even if the slave SQL thread was late compared to the slave I/O thread, when you merely want to change, say, the password to use.

`CHANGE MASTER TO` *deletes all relay log files* and starts a new one, unless you specify `RELAY_LOG_FILE` or `RELAY_LOG_POS`. In that case, relay log files are kept; the `relay_log_purge` global variable is set silently to 0.

Prior to MySQL 5.5, `RELAY_LOG_FILE` required an absolute path. In MySQL 5.5, the path can be relative, in which case the path is assumed to be relative to the slave's data directory. (Bug #12190)

`IGNORE_SERVER_IDS` was added in MySQL 5.5. This option takes a comma-separated list of 0 or more server IDs. Events originating from the corresponding servers are ignored, with the exception of log rotation and deletion events, which are still recorded in the relay log.

In circular replication, the originating server normally acts as the terminator of its own events, so that they are not applied more than once. Thus, this option is useful in circular replication when one of the servers in the circle is removed. Suppose that you have a circular replication setup with 4 servers, having server IDs 1, 2, 3, and 4, and server 3 fails. When bridging the gap by starting replication from server 2 to server 4, you can include `IGNORE_SERVER_IDS = (3)` in the `CHANGE MASTER TO` statement that you issue on server 4 to tell it to use server 2 as its master instead of server 3. Doing so causes it to ignore and not to propagate any statements that originated with the server that is no longer in use.

When a `CHANGE MASTER TO` statement is issued without any `IGNORE_SERVER_IDS` option, any existing list is preserved. To clear the list of ignored servers, it is necessary to use the option with an empty list:

```
CHANGE MASTER TO IGNORE_SERVER_IDS = ();
```

`RESET SLAVE ALL` has no effect on the server ID list. This issue is fixed in MySQL 5.7. (Bug #18816897)

If `IGNORE_SERVER_IDS` contains the server's own ID and the server was started with the `--replicate-same-server-id` option enabled, an error results.

Also beginning with MySQL 5.5, the `master.info` file and the output of `SHOW SLAVE STATUS` are extended to provide the list of servers that are currently ignored. For more information, see Section 17.2.2.2, “Slave Status Logs”, and Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”.

Beginning with MySQL 5.5.5, invoking `CHANGE MASTER TO` causes the previous values for `MASTER_HOST`, `MASTER_PORT`, `MASTER_LOG_FILE`, and `MASTER_LOG_POS` to be written to the error log, along with other information about the slave's state prior to execution.

`CHANGE MASTER TO` is useful for setting up a slave when you have the snapshot of the master and have recorded the master binary log coordinates corresponding to the time of the snapshot. After

loading the snapshot into the slave to synchronize it with the master, you can run `CHANGE MASTER TO MASTER_LOG_FILE='log_name', MASTER_LOG_POS=log_pos` on the slave to specify the coordinates at which the slave should begin reading the master binary log.

The following example changes the master server the slave uses and establishes the master binary log coordinates from which the slave begins reading. This is used when you want to set up the slave to replicate the master:

```
CHANGE MASTER TO
  MASTER_HOST='master2.example.com',
  MASTER_USER='replication',
  MASTER_PASSWORD='bigs3cret',
  MASTER_PORT=3306,
  MASTER_LOG_FILE='master2-bin.001',
  MASTER_LOG_POS=4,
  MASTER_CONNECT_RETRY=10;
```

The next example shows an operation that is less frequently employed. It is used when the slave has relay log files that you want it to execute again for some reason. To do this, the master need not be reachable. You need only use `CHANGE MASTER TO` and start the SQL thread (`START SLAVE SQL_THREAD`):

```
CHANGE MASTER TO
  RELAY_LOG_FILE='slave-relay-bin.006',
  RELAY_LOG_POS=4025;
```

You can even use the second operation in a nonreplication setup with a standalone, nonslave server for recovery following a crash. Suppose that your server has crashed and you have restored it from a backup. You want to replay the server's own binary log files (not relay log files, but regular binary log files), named (for example) `myhost-bin.*`. First, make a backup copy of these binary log files in some safe place, in case you don't exactly follow the procedure below and accidentally have the server purge the binary log. Use `SET GLOBAL relay_log_purge=0` for additional safety. Then start the server without the `--log-bin` option, Instead, use the `--replicate-same-server-id`, `--relay-log=myhost-bin` (to make the server believe that these regular binary log files are relay log files) and `--skip-slave-start` options. After the server starts, issue these statements:

```
CHANGE MASTER TO
  RELAY_LOG_FILE='myhost-bin.153',
  RELAY_LOG_POS=410,
  MASTER_HOST='some_dummy_string';
START SLAVE SQL_THREAD;
```

The server reads and executes its own binary log files, thus achieving crash recovery. Once the recovery is finished, run `STOP SLAVE`, shut down the server, delete the `master.info` and `relay-log.info` files, and restart the server with its original options.

Specifying the `MASTER_HOST` option (even with a dummy value) is required to make the server think it is a slave.

The following table shows the maximum permissible length for the string-valued options.

Option	Maximum Length
`MASTER_HOST`	60
`MASTER_USER`	16
`MASTER_PASSWORD`	32
`MASTER_LOG_FILE`	255
`RELAY_LOG_FILE`	255

Option	Maximum Length
MASTER_SSL_CA	255
MASTER_SSL_CAPATH	255
MASTER_SSL_CERT	255
MASTER_SSL_KEY	255
MASTER_SSL_CIPHER	511

13.4.2.2 MASTER_POS_WAIT() Syntax

```
SELECT MASTER_POS_WAIT('master_log_file', master_log_pos [, timeout])
```

This is actually a function, not a statement. It is used to ensure that the slave has read and executed events up to a given position in the master's binary log. See Section 12.17, “Miscellaneous Functions”, for a full description.

13.4.2.3 RESET SLAVE Syntax

```
RESET SLAVE [ALL]
```

RESET SLAVE makes the slave forget its replication position in the master's binary log. This statement is meant to be used for a clean start: It deletes the master.info and relay-log.info files, all the relay log files, and starts a new relay log file. To use RESET SLAVE, the slave replication threads must be stopped (use STOP SLAVE if necessary).

Note

All relay log files are deleted, even if they have not been completely executed by the slave SQL thread. (This is a condition likely to exist on a replication slave if you have issued a STOP SLAVE statement or if the slave is highly loaded.)

In MySQL 5.5 (unlike the case in MySQL 5.1 and earlier), RESET SLAVE does not change any replication connection parameters such as master host, master port, master user, or master password, which are retained in memory. This means that START SLAVE can be issued without requiring a CHANGE MASTER TO statement following RESET SLAVE.

Connection parameters are reset if the slave mysqld is shut down following RESET SLAVE. In MySQL 5.5.16 and later, you can instead use RESET SLAVE ALL to reset these connection parameters (Bug #11809016).

RESET SLAVE ALL does not clear the IGNORE_SERVER_IDS list set by CHANGE MASTER TO. This issue is fixed in MySQL 5.7. (Bug #18816897)

If the slave SQL thread was in the middle of replicating temporary tables when it was stopped, and RESET SLAVE is issued, these replicated temporary tables are deleted on the slave.

Note

When used on an NDB Cluster replication slave SQL node, RESET SLAVE clears the mysql.ndb_apply_status table. You should keep in mind when using this statement that ndb_apply_status uses the NDB storage engine and so is shared by all SQL nodes attached to the slave cluster.

13.4.2.4 SET GLOBAL sql_slave_skip_counter Syntax

```
SET GLOBAL sql_slave_skip_counter = N
```

This statement skips the next *N* events from the master. This is useful for recovering from replication stops caused by a statement.

This statement is valid only when the slave threads are not running. Otherwise, it produces an error.

When using this statement, it is important to understand that the binary log is actually organized as a sequence of groups known as *event groups*. Each event group consists of a sequence of events.

- For transactional tables, an event group corresponds to a transaction.
- For nontransactional tables, an event group corresponds to a single SQL statement.

Note

A single transaction can contain changes to both transactional and nontransactional tables.

When you use `SET GLOBAL sql_slave_skip_counter` to skip events and the result is in the middle of a group, the slave continues to skip events until it reaches the end of the group. Execution then starts with the next event group.

13.4.2.5 START SLAVE Syntax

```
START SLAVE [thread_types]

START SLAVE [SQL_THREAD] UNTIL
    MASTER_LOG_FILE = 'log_name', MASTER_LOG_POS = log_pos

START SLAVE [SQL_THREAD] UNTIL
    RELAY_LOG_FILE = 'log_name', RELAY_LOG_POS = log_pos

thread_types:
    [thread_type [, thread_type] ... ]

thread_type: IO_THREAD | SQL_THREAD
```

`START SLAVE` with no *`thread_type`* options starts both of the slave threads. The I/O thread reads events from the master server and stores them in the relay log. The SQL thread reads events from the relay log and executes them. `START SLAVE` requires the `SUPER` privilege.

If `START SLAVE` succeeds in starting the slave threads, it returns without any error. However, even in that case, it might be that the slave threads start and then later stop (for example, because they do not manage to connect to the master or read its binary log, or some other problem). `START SLAVE` does not warn you about this. You must check the slave's error log for error messages generated by the slave threads, or check that they are running satisfactorily with `SHOW SLAVE STATUS`.

`START SLAVE` sends an acknowledgment to the user after both the I/O thread and the SQL thread have started. However, the I/O thread may not yet have connected. For this reason, a successful `START SLAVE` causes `SHOW SLAVE STATUS` to show `Slave_SQL_Running=Yes`, but this does not guarantee that `Slave_IO_Running=Yes` (because `Slave_IO_Running=Yes` only if the I/O thread is running *and connected*). For more information, see Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”, and Section 17.1.4.1, “Checking Replication Status”.

You can add `IO_THREAD` and `SQL_THREAD` options to the statement to name which of the threads to start.

An `UNTIL` clause may be added to specify that the slave should start and run until the SQL thread reaches a given point in the master binary log or in the slave relay log. When the SQL thread reaches that point, it stops. If the `SQL_THREAD` option is specified in the statement, it starts only the SQL thread. Otherwise, it starts both slave threads. If the SQL thread is running, the `UNTIL` clause is ignored and a warning is issued.

For an UNTIL clause, you must specify both a log file name and position. Do not mix master and relay log options.

Any UNTIL condition is reset by a subsequent STOP SLAVE statement, a START SLAVE statement that includes no UNTIL clause, or a server restart.

The UNTIL clause can be useful for debugging replication, or to cause replication to proceed until just before the point where you want to avoid having the slave replicate an event. For example, if an unwise DROP TABLE statement was executed on the master, you can use UNTIL to tell the slave to execute up to that point but no farther. To find what the event is, use mysqlbinlog with the master binary log or slave relay log, or by using a SHOW BINLOG EVENTS statement.

If you are using UNTIL to have the slave process replicated queries in sections, it is recommended that you start the slave with the --skip-slave-start option to prevent the SQL thread from running when the slave server starts. It is probably best to use this option in an option file rather than on the command line, so that an unexpected server restart does not cause it to be forgotten.

The SHOW SLAVE STATUS statement includes output fields that display the current values of the UNTIL condition.

In old versions of MySQL (before 4.0.5), this statement was called SLAVE START. This usage is still accepted in MySQL 5.5 for backward compatibility, but is deprecated and is removed in MySQL 5.6.

13.4.2.6 STOP SLAVE Syntax

```
STOP SLAVE [thread_types]

thread_types:
    [thread_type [, thread_type] ... ]

thread_type: IO_THREAD | SQL_THREAD
```

Stops the slave threads. STOP SLAVE requires the SUPER privilege. Recommended best practice is to execute STOP SLAVE on the slave before stopping the slave server (see Section 5.1.12, “The Server Shutdown Process”, for more information).

When using the row-based logging format: You should execute STOP SLAVE on the slave prior to shutting down the slave server if you are replicating any tables that use a nontransactional storage engine (see the *Note* later in this section). In MySQL 5.5.9 and later, you can also use STOP SLAVE SQL_THREAD for this purpose.

Like START SLAVE, this statement may be used with the IO_THREAD and SQL_THREAD options to name the thread or threads to be stopped.

If the current replication event group has modified one or more nontransactional tables, STOP SLAVE waits for up to 60 seconds for the event group to complete, unless you issue a KILL QUERY or KILL CONNECTION statement for the slave SQL thread. If the event group remains incomplete after the timeout, an error message is logged. (Bug #319, Bug #38205)

In old versions of MySQL (before 4.0.5), this statement was called SLAVE STOP. This usage is still accepted in MySQL 5.5 for backward compatibility, but is deprecated and is removed in MySQL 5.6.

13.5 Prepared SQL Statement Syntax

MySQL 5.5 provides support for server-side prepared statements. This support takes advantage of the efficient client/server binary protocol, provided that you use an appropriate client programming interface. Candidate interfaces include the MySQL C API client library (for C programs), MySQL Connector/J (for Java programs), and MySQL Connector/Net. For example, the C API provides a set of function calls that make up its prepared statement API. See Section 23.8.8, “C API Prepared

Statements". Other language interfaces can provide support for prepared statements that use the binary protocol by linking in the C client library, one example being the `mysqli` extension, available in PHP 5.0 and later.

An alternative SQL interface to prepared statements is available. This interface is not as efficient as using the binary protocol through a prepared statement API, but requires no programming because it is available directly at the SQL level:

- You can use it when no programming interface is available to you.
- You can use it from any program that enables you to send SQL statements to the server to be executed, such as the `mysql` client program.
- You can use it even if the client is using an old version of the client library. The only requirement is that you be able to connect to a server that is recent enough to support SQL syntax for prepared statements.

SQL syntax for prepared statements is intended to be used for situations such as these:

- You want to test how prepared statements work in your application before coding it.
- An application has problems executing prepared statements and you want to determine interactively what the problem is.
- You want to create a test case that describes a problem you are having with prepared statements, so that you can file a bug report.
- You need to use prepared statements but do not have access to a programming API that supports them.

SQL syntax for prepared statements is based on three SQL statements:

- `PREPARE` prepares a statement for execution (see Section 13.5.1, "PREPARE Syntax").
- `EXECUTE` executes a prepared statement (see Section 13.5.2, "EXECUTE Syntax").
- `DEALLOCATE PREPARE` releases a prepared statement (see Section 13.5.3, "DEALLOCATE PREPARE Syntax").

The following examples show two equivalent ways of preparing a statement that computes the hypotenuse of a triangle given the lengths of the two sides.

The first example shows how to create a prepared statement by using a string literal to supply the text of the statement:

```
mysql> PREPARE stmt1 FROM 'SELECT SQRT(POW(?,2) + POW(?,2)) AS hypotenuse';
mysql> SET @a = 3;
mysql> SET @b = 4;
mysql> EXECUTE stmt1 USING @a, @b;
+------------+
| hypotenuse |
+------------+
|          5 |
+------------+
mysql> DEALLOCATE PREPARE stmt1;
```

The second example is similar, but supplies the text of the statement as a user variable:

```
mysql> SET @s = 'SELECT SQRT(POW(?,2) + POW(?,2)) AS hypotenuse';
mysql> PREPARE stmt2 FROM @s;
mysql> SET @a = 6;
mysql> SET @b = 8;
```

```
mysql> EXECUTE stmt2 USING @a, @b;
+------------+
| hypotenuse |
+------------+
|         10 |
+------------+
mysql> DEALLOCATE PREPARE stmt2;
```

Here is an additional example that demonstrates how to choose the table on which to perform a query at runtime, by storing the name of the table as a user variable:

```
mysql> USE test;
mysql> CREATE TABLE t1 (a INT NOT NULL);
mysql> INSERT INTO t1 VALUES (4), (8), (11), (32), (80);

mysql> SET @table = 't1';
mysql> SET @s = CONCAT('SELECT * FROM ', @table);

mysql> PREPARE stmt3 FROM @s;
mysql> EXECUTE stmt3;
+----+
| a  |
+----+
|  4 |
|  8 |
| 11 |
| 32 |
| 80 |
+----+

mysql> DEALLOCATE PREPARE stmt3;
```

A prepared statement is specific to the session in which it was created. If you terminate a session without deallocating a previously prepared statement, the server deallocates it automatically.

A prepared statement is also global to the session. If you create a prepared statement within a stored routine, it is not deallocated when the stored routine ends.

To guard against too many prepared statements being created simultaneously, set the `max_prepared_stmt_count` system variable. To prevent the use of prepared statements, set the value to 0.

The following SQL statements can be used as prepared statements:

```
ALTER TABLE
ANALYZE TABLE
CACHE INDEX
CALL
CHANGE MASTER
CHECKSUM {TABLE | TABLES}
COMMIT
{CREATE | RENAME | DROP} DATABASE
{CREATE | DROP} INDEX
{CREATE | RENAME | DROP} TABLE
{CREATE | RENAME | DROP} USER
{CREATE | DROP} VIEW
DELETE
DO
FLUSH {TABLE | TABLES | TABLES WITH READ LOCK | HOSTS | PRIVILEGES
  | LOGS | STATUS | MASTER | SLAVE | DES_KEY_FILE | USER_RESOURCES}
GRANT
INSERT
INSTALL PLUGIN
KILL
LOAD INDEX INTO CACHE
OPTIMIZE TABLE
REPAIR TABLE
REPLACE
```

```
RESET {MASTER | SLAVE | QUERY CACHE}
REVOKE
SELECT
SET
SHOW {AUTHORS | CONTRIBUTORS | WARNINGS | ERRORS}
SHOW BINLOG EVENTS
SHOW CREATE {PROCEDURE | FUNCTION | EVENT | TABLE | VIEW}
SHOW {MASTER | BINARY} LOGS
SHOW {MASTER | SLAVE} STATUS
SLAVE {START | STOP}
TRUNCATE TABLE
UNINSTALL PLUGIN
UPDATE
```

Other statements are not supported in MySQL 5.5.

Generally, statements not permitted in SQL prepared statements are also not permitted in stored programs. Exceptions are noted in Section C.1, “Restrictions on Stored Programs”.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation”.

Placeholders can be used for the arguments of the `LIMIT` clause when using prepared statements. See Section 13.2.9, “SELECT Syntax”.

In prepared `CALL` statements used with `PREPARE` and `EXECUTE`, placeholder support for `OUT` and `INOUT` parameters is available beginning with MySQL 5.5. See Section 13.2.1, “CALL Syntax”, for an example and a workaround for earlier versions. Placeholders can be used for `IN` parameters regardless of version.

SQL syntax for prepared statements cannot be used in nested fashion. That is, a statement passed to `PREPARE` cannot itself be a `PREPARE`, `EXECUTE`, or `DEALLOCATE PREPARE` statement.

SQL syntax for prepared statements is distinct from using prepared statement API calls. For example, you cannot use the `mysql_stmt_prepare()` C API function to prepare a `PREPARE`, `EXECUTE`, or `DEALLOCATE PREPARE` statement.

SQL syntax for prepared statements can be used within stored procedures, but not in stored functions or triggers. However, a cursor cannot be used for a dynamic statement that is prepared and executed with `PREPARE` and `EXECUTE`. The statement for a cursor is checked at cursor creation time, so the statement cannot be dynamic.

SQL syntax for prepared statements does not support multi-statements (that is, multiple statements within a single string separated by `;` characters).

Prepared statements use the query cache under the conditions described in Section 8.10.3.1, “How the Query Cache Operates”.

To write C programs that use the `CALL` SQL statement to execute stored procedures that contain prepared statements, the `CLIENT_MULTI_RESULTS` flag must be enabled. This is because each `CALL` returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure.

`CLIENT_MULTI_RESULTS` can be enabled when you call `mysql_real_connect()`, either explicitly by passing the `CLIENT_MULTI_RESULTS` flag itself, or implicitly by passing `CLIENT_MULTI_STATEMENTS` (which also enables `CLIENT_MULTI_RESULTS`). For additional information, see Section 13.2.1, “CALL Syntax”.

13.5.1 PREPARE Syntax

```
```

```
PREPARE stmt_name FROM preparable_stmt
```

The PREPARE statement prepares a SQL statement and assigns it a name, *stmt_name*, by which to refer to the statement later. The prepared statement is executed with EXECUTE and released with DEALLOCATE PREPARE. For examples, see Section 13.5, “Prepared SQL Statement Syntax”.

Statement names are not case sensitive. *preparable_stmt* is either a string literal or a user variable that contains the text of the SQL statement. The text must represent a single statement, not multiple statements. Within the statement, ? characters can be used as parameter markers to indicate where data values are to be bound to the query later when you execute it. The ? characters should not be enclosed within quotation marks, even if you intend to bind them to string values. Parameter markers can be used only where data values should appear, not for SQL keywords, identifiers, and so forth.

If a prepared statement with the given name already exists, it is deallocated implicitly before the new statement is prepared. This means that if the new statement contains an error and cannot be prepared, an error is returned and no statement with the given name exists.

The scope of a prepared statement is the session within which it is created, which as several implications:

- A prepared statement created in one session is not available to other sessions.
- When a session ends, whether normally or abnormally, its prepared statements no longer exist. If auto-reconnect is enabled, the client is not notified that the connection was lost. For this reason, clients may wish to disable auto-reconnect. See Section 23.8.20, “C API Automatic Reconnection Control”.
- A prepared statement created within a stored program continues to exist after the program finishes executing and can be executed outside the program later.
- A statement prepared in stored program context cannot refer to stored procedure or function parameters or local variables because they go out of scope when the program ends and would be unavailable were the statement to be executed later outside the program. As a workaround, refer instead to user-defined variables, which also have session scope; see Section 9.4, “User-Defined Variables”.

13.5.2 EXECUTE Syntax

```
EXECUTE stmt_name
    [USING @var_name [, @var_name] ...]
```

After preparing a statement with PREPARE, you execute it with an EXECUTE statement that refers to the prepared statement name. If the prepared statement contains any parameter markers, you must supply a USING clause that lists user variables containing the values to be bound to the parameters. Parameter values can be supplied only by user variables, and the USING clause must name exactly as many variables as the number of parameter markers in the statement.

You can execute a given prepared statement multiple times, passing different variables to it or setting the variables to different values before each execution.

For examples, see Section 13.5, “Prepared SQL Statement Syntax”.

13.5.3 DEALLOCATE PREPARE Syntax

```
{DEALLOCATE | DROP} PREPARE stmt_name
```

To deallocate a prepared statement produced with PREPARE, use a DEALLOCATE PREPARE statement that refers to the prepared statement name. Attempting to execute a prepared statement after deallocating it results in an error.

For examples, see Section 13.5, “Prepared SQL Statement Syntax”.

13.5.4 Automatic Prepared Statement Repreparation

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. This applies to prepared statements processed at the SQL level (using the `PREPARE` statement) and those processed using the binary client/server protocol (using the `mysql_stmt_prepare()` C API function).

The server attempts repreparation up to three times. An error occurs if all attempts fail.

Metadata changes occur for DDL statements such as those that create, drop, alter, rename, or truncate tables, or that analyze, optimize, or repair tables. Repreparation also occurs after referenced tables or views are flushed from the table definition cache, either implicitly to make room for new entries in the cache, or explicitly due to `FLUSH TABLES`.

Table content changes (for example, with `INSERT` or `UPDATE`) do not cause repreparation, nor do `SELECT` statements.

Repreparation is automatic, but to the extent that it occurs, diminishes prepared statement performance.

Repreparation uses the default database and SQL mode that were in effect for the original preparation.

The `Com_stmt_reprepare` status variable tracks the number of repreparations.

13.6 Compound-Statement Syntax

This section describes the syntax for the `BEGIN ... END` compound statement and other statements that can be used in the body of stored programs: Stored procedures and functions, triggers, and events. These objects are defined in terms of SQL code that is stored on the server for later invocation (see Chapter 20, *Stored Programs and Views*).

A compound statement is a block that can contain other blocks; declarations for variables, condition handlers, and cursors; and flow control constructs such as loops and conditional tests.

13.6.1 BEGIN ... END Compound-Statement Syntax

```
[begin_label:] BEGIN
    [statement_list]
END [end_label]
```

`BEGIN ... END` syntax is used for writing compound statements, which can appear within stored programs (stored procedures and functions, triggers, and events). A compound statement can contain multiple statements, enclosed by the `BEGIN` and `END` keywords. *`statement_list`* represents a list of one or more statements, each terminated by a semicolon (`;`) statement delimiter. The *`statement_list`* itself is optional, so the empty compound statement (`BEGIN END`) is legal.

`BEGIN ... END` blocks can be nested.

Use of multiple statements requires that a client is able to send statement strings containing the `;` statement delimiter. In the `mysql` command-line client, this is handled with the `delimiter` command. Changing the `;` end-of-statement delimiter (for example, to `//`) permit `;` to be used in a program body. For an example, see Section 20.1, “Defining Stored Programs”.

A `BEGIN ... END` block can be labeled. See Section 13.6.2, “Statement Label Syntax”.

The optional `[NOT] ATOMIC` clause is not supported. This means that no transactional savepoint is set at the start of the instruction block and the `BEGIN` clause used in this context has no effect on the current transaction.

Note

Within all stored programs, the parser treats `BEGIN [WORK]` as the beginning of a `BEGIN ... END` block. To begin a transaction in this context, use `START TRANSACTION` instead.

13.6.2 Statement Label Syntax

```
[begin_label:] BEGIN
    [statement_list]
END [end_label]

[begin_label:] LOOP
    statement_list
END LOOP [end_label]

[begin_label:] REPEAT
    statement_list
UNTIL search_condition
END REPEAT [end_label]

[begin_label:] WHILE search_condition DO
    statement_list
END WHILE [end_label]
```

Labels are permitted for `BEGIN ... END` blocks and for the `LOOP`, `REPEAT`, and `WHILE` statements. Label use for those statements follows these rules:

- *`begin_label`* must be followed by a colon.
- *`begin_label`* can be given without *`end_label`*. If *`end_label`* is present, it must be the same as *`begin_label`*.
- *`end_label`* cannot be given without *`begin_label`*.
- Labels at the same nesting level must be distinct.
- Labels can be up to 16 characters long.

To refer to a label within the labeled construct, use an `ITERATE` or `LEAVE` statement. The following example uses those statements to continue iterating or terminate the loop:

```
CREATE PROCEDURE doiterate(p1 INT)
BEGIN
  label1: LOOP
    SET p1 = p1 + 1;
    IF p1 < 10 THEN ITERATE label1; END IF;
    LEAVE label1;
  END LOOP label1;
END;
```

The scope of a block label does not include the code for handlers declared within the block. For details, see Section 13.6.7.2, “DECLARE ... HANDLER Syntax”.

13.6.3 DECLARE Syntax

The `DECLARE` statement is used to define various items local to a program:

- Local variables. See Section 13.6.4, “Variables in Stored Programs”.
- Conditions and handlers. See Section 13.6.7, “Condition Handling”.
- Cursors. See Section 13.6.6, “Cursors”.

`DECLARE` is permitted only inside a `BEGIN ... END` compound statement and must be at its start, before any other statements.

Declarations must follow a certain order. Cursor declarations must appear before handler declarations. Variable and condition declarations must appear before cursor or handler declarations.

13.6.4 Variables in Stored Programs

System variables and user-defined variables can be used in stored programs, just as they can be used outside stored-program context. In addition, stored programs can use `DECLARE` to define local variables, and stored routines (procedures and functions) can be declared to take parameters that communicate values between the routine and its caller.

- To declare local variables, use the `DECLARE` statement, as described in Section 13.6.4.1, “Local Variable DECLARE Syntax”.
- Variables can be set directly with the `SET` statement. See Section 13.7.4.1, “SET Syntax for Variable Assignment”.
- Results from queries can be retrieved into local variables using `SELECT ... INTO var_list` or by opening a cursor and using `FETCH ... INTO var_list`. See Section 13.2.9.1, “SELECT ... INTO Syntax”, and Section 13.6.6, “Cursors”.

For information about the scope of local variables and how MySQL resolves ambiguous names, see Section 13.6.4.2, “Local Variable Scope and Resolution”.

13.6.4.1 Local Variable DECLARE Syntax

```
DECLARE var_name [, var_name] ... type [DEFAULT value]
```

This statement declares local variables within stored programs. To provide a default value for a variable, include a `DEFAULT` clause. The value can be specified as an expression; it need not be a constant. If the `DEFAULT` clause is missing, the initial value is `NULL`.

Local variables are treated like stored routine parameters with respect to data type and overflow checking. See Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”.

Variable declarations must appear before cursor or handler declarations.

Local variable names are not case sensitive. Permissible characters and quoting rules are the same as for other identifiers, as described in Section 9.2, “Schema Object Names”.

The scope of a local variable is the `BEGIN ... END` block within which it is declared. The variable can be referred to in blocks nested within the declaring block, except those blocks that declare a variable with the same name.

For examples of variable declarations, see Section 13.6.4.2, “Local Variable Scope and Resolution”.

13.6.4.2 Local Variable Scope and Resolution

The scope of a local variable is the `BEGIN ... END` block within which it is declared. The variable can be referred to in blocks nested within the declaring block, except those blocks that declare a variable with the same name.

Because local variables are in scope only during stored program execution, references to them are not permitted in prepared statements created within a stored program. Prepared statement scope is the current session, not the stored program, so the statement could be executed after the program ends, at which point the variables would no longer be in scope. For example, `SELECT ... INTO local_var`

cannot be used as a prepared statement. This restriction also applies to stored procedure and function parameters. See Section 13.5.1, “PREPARE Syntax”.

A local variable should not have the same name as a table column. If an SQL statement, such as a `SELECT ... INTO` statement, contains a reference to a column and a declared local variable with the same name, MySQL currently interprets the reference as the name of a variable. Consider the following procedure definition:

```
CREATE PROCEDURE sp1 (x VARCHAR(5))
BEGIN
  DECLARE xname VARCHAR(5) DEFAULT 'bob';
  DECLARE newname VARCHAR(5);
  DECLARE xid INT;

  SELECT xname, id INTO newname, xid
    FROM table1 WHERE xname = xname;
  SELECT newname;
END;
```

MySQL interprets `xname` in the `SELECT` statement as a reference to the `xname` *variable* rather than the `xname` *column*. Consequently, when the procedure `sp1()`is called, the `newname` variable returns the value `'bob'` regardless of the value of the `table1.xname` column.

Similarly, the cursor definition in the following procedure contains a `SELECT` statement that refers to `xname`. MySQL interprets this as a reference to the variable of that name rather than a column reference.

```
CREATE PROCEDURE sp2 (x VARCHAR(5))
BEGIN
  DECLARE xname VARCHAR(5) DEFAULT 'bob';
  DECLARE newname VARCHAR(5);
  DECLARE xid INT;
  DECLARE done TINYINT DEFAULT 0;
  DECLARE cur1 CURSOR FOR SELECT xname, id FROM table1;
  DECLARE CONTINUE HANDLER FOR NOT FOUND SET done = 1;

  OPEN cur1;
  read_loop: LOOP
    FETCH FROM cur1 INTO newname, xid;
    IF done THEN LEAVE read_loop; END IF;
    SELECT newname;
  END LOOP;
  CLOSE cur1;
END;
```

See also Section C.1, “Restrictions on Stored Programs”.

13.6.5 Flow Control Statements

MySQL supports the `IF`, `CASE`, `ITERATE`, `LEAVE LOOP`, `WHILE`, and `REPEAT` constructs for flow control within stored programs. It also supports `RETURN` within stored functions.

Many of these constructs contain other statements, as indicated by the grammar specifications in the following sections. Such constructs may be nested. For example, an `IF` statement might contain a `WHILE` loop, which itself contains a `CASE` statement.

MySQL does not support `FOR` loops.

13.6.5.1 CASE Syntax

```
CASE case_value
    WHEN when_value THEN statement_list
    [WHEN when_value THEN statement_list] ...
```

```
    [ELSE statement_list]
END CASE
```

Or:

```
CASE
    WHEN search_condition THEN statement_list
    [WHEN search_condition THEN statement_list] ...
    [ELSE statement_list]
END CASE
```

The `CASE` statement for stored programs implements a complex conditional construct.

Note

There is also a `CASE` *expression*, which differs from the `CASE` *statement* described here. See Section 12.4, “Control Flow Functions”. The `CASE` statement cannot have an `ELSE NULL` clause, and it is terminated with `END CASE` instead of `END`.

For the first syntax, *`case_value`* is an expression. This value is compared to the *`when_value`* expression in each `WHEN` clause until one of them is equal. When an equal *`when_value`* is found, the corresponding `THEN` clause *`statement_list`* executes. If no *`when_value`* is equal, the `ELSE` clause *`statement_list`* executes, if there is one.

This syntax cannot be used to test for equality with `NULL` because `NULL = NULL` is false. See Section 3.3.4.6, “Working with NULL Values”.

For the second syntax, each `WHEN` clause *`search_condition`* expression is evaluated until one is true, at which point its corresponding `THEN` clause *`statement_list`* executes. If no *`search_condition`* is equal, the `ELSE` clause *`statement_list`* executes, if there is one.

If no *`when_value`* or *`search_condition`* matches the value tested and the `CASE` statement contains no `ELSE` clause, a `Case not found for CASE statement` error results.

Each *`statement_list`* consists of one or more SQL statements; an empty *`statement_list`* is not permitted.

To handle situations where no value is matched by any `WHEN` clause, use an `ELSE` containing an empty `BEGIN ... END` block, as shown in this example. (The indentation used here in the `ELSE` clause is for purposes of clarity only, and is not otherwise significant.)

```
DELIMITER |

CREATE PROCEDURE p()
  BEGIN
    DECLARE v INT DEFAULT 1;

    CASE v
      WHEN 2 THEN SELECT v;
      WHEN 3 THEN SELECT 0;
      ELSE
        BEGIN
        END;
    END CASE;
  END;
  |
```

13.6.5.2 IF Syntax

```
IF search_condition THEN statement_list
    [ELSEIF search_condition THEN statement_list] ...
```

```
    [ELSE statement_list]
END IF
```

The `IF` statement for stored programs implements a basic conditional construct.

Note

There is also an `IF()` *function*, which differs from the `IF` *statement* described here. See Section 12.4, “Control Flow Functions”. The `IF` statement can have `THEN`, `ELSE`, and `ELSEIF` clauses, and it is terminated with `END IF`.

If the *`search_condition`* evaluates to true, the corresponding `THEN` or `ELSEIF` clause *`statement_list`* executes. If no *`search_condition`* matches, the `ELSE` clause *`statement_list`* executes.

Each *`statement_list`* consists of one or more SQL statements; an empty *`statement_list`* is not permitted.

An `IF ... END IF` block, like all other flow-control blocks used within stored programs, must be terminated with a semicolon, as shown in this example:

```
DELIMITER //

CREATE FUNCTION SimpleCompare(n INT, m INT)
  RETURNS VARCHAR(20)

  BEGIN
    DECLARE s VARCHAR(20);

    IF n > m THEN SET s = '>';
    ELSEIF n = m THEN SET s = '=';
    ELSE SET s = '<';
    END IF;

    SET s = CONCAT(n, ' ', s, ' ', m);

    RETURN s;
  END //

DELIMITER ;
```

As with other flow-control constructs, `IF ... END IF` blocks may be nested within other flow-control constructs, including other `IF` statements. Each `IF` must be terminated by its own `END IF` followed by a semicolon. You can use indentation to make nested flow-control blocks more easily readable by humans (although this is not required by MySQL), as shown here:

```
DELIMITER //

CREATE FUNCTION VerboseCompare (n INT, m INT)
  RETURNS VARCHAR(50)

  BEGIN
    DECLARE s VARCHAR(50);

    IF n = m THEN SET s = 'equals';
    ELSE
      IF n > m THEN SET s = 'greater';
      ELSE SET s = 'less';
      END IF;

      SET s = CONCAT('is ', s, ' than');
    END IF;

    SET s = CONCAT(n, ' ', s, ' ', m, '.');

    RETURN s;
```

```
  END //

DELIMITER ;
```

In this example, the inner `IF` is evaluated only if `n` is not equal to `m`.

13.6.5.3 ITERATE Syntax

```
ITERATE label
```

`ITERATE` can appear only within `LOOP`, `REPEAT`, and `WHILE` statements. `ITERATE` means "start the loop again."

For an example, see Section 13.6.5.5, "LOOP Syntax".

13.6.5.4 LEAVE Syntax

```
LEAVE label
```

This statement is used to exit the flow control construct that has the given label. If the label is for the outermost stored program block, `LEAVE` exits the program.

`LEAVE` can be used within `BEGIN ... END` or loop constructs (`LOOP`, `REPEAT`, `WHILE`).

For an example, see Section 13.6.5.5, "LOOP Syntax".

13.6.5.5 LOOP Syntax

```
[begin_label:] LOOP
    statement_list
END LOOP [end_label]
```

`LOOP` implements a simple loop construct, enabling repeated execution of the statement list, which consists of one or more statements, each terminated by a semicolon (`;`) statement delimiter. The statements within the loop are repeated until the loop is terminated. Usually, this is accomplished with a `LEAVE` statement. Within a stored function, `RETURN` can also be used, which exits the function entirely.

Neglecting to include a loop-termination statement results in an infinite loop.

A `LOOP` statement can be labeled. For the rules regarding label use, see Section 13.6.2, "Statement Label Syntax".

Example:

```
CREATE PROCEDURE doiterate(p1 INT)
BEGIN
  label1: LOOP
    SET p1 = p1 + 1;
    IF p1 < 10 THEN
      ITERATE label1;
    END IF;
    LEAVE label1;
  END LOOP label1;
  SET @x = p1;
END;
```

13.6.5.6 REPEAT Syntax

```
[begin_label:] REPEAT
```

```
    statement_list
UNTIL search_condition
END REPEAT [end_label]
```

The statement list within a REPEAT statement is repeated until the *search_condition* expression is true. Thus, a REPEAT always enters the loop at least once. *statement_list* consists of one or more statements, each terminated by a semicolon (;) statement delimiter.

A REPEAT statement can be labeled. For the rules regarding label use, see Section 13.6.2, “Statement Label Syntax”.

Example:

```
mysql> delimiter //

mysql> CREATE PROCEDURE dorepeat(p1 INT)
    -> BEGIN
    ->   SET @x = 0;
    ->   REPEAT
    ->     SET @x = @x + 1;
    ->   UNTIL @x > p1 END REPEAT;
    -> END
    -> //
Query OK, 0 rows affected (0.00 sec)

mysql> CALL dorepeat(1000)//
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @x//
+------+
| @x   |
+------+
| 1001 |
+------+
1 row in set (0.00 sec)
```

13.6.5.7 RETURN Syntax

```
RETURN expr
```

The RETURN statement terminates execution of a stored function and returns the value *expr* to the function caller. There must be at least one RETURN statement in a stored function. There may be more than one if the function has multiple exit points.

This statement is not used in stored procedures, triggers, or events. The LEAVE statement can be used to exit a stored program of those types.

13.6.5.8 WHILE Syntax

```
[begin_label:] WHILE search_condition DO
    statement_list
END WHILE [end_label]
```

The statement list within a WHILE statement is repeated as long as the *search_condition* expression is true. *statement_list* consists of one or more SQL statements, each terminated by a semicolon (;) statement delimiter.

A WHILE statement can be labeled. For the rules regarding label use, see Section 13.6.2, “Statement Label Syntax”.

Example:

```
```

```
CREATE PROCEDURE dowhile()
BEGIN
  DECLARE v1 INT DEFAULT 5;

  WHILE v1 > 0 DO
    ...
    SET v1 = v1 - 1;
  END WHILE;
END;
```

13.6.6 Cursors

MySQL supports cursors inside stored programs. The syntax is as in embedded SQL. Cursors have these properties:

- Asensitive: The server may or may not make a copy of its result table
- Read only: Not updatable
- Nonscrollable: Can be traversed only in one direction and cannot skip rows

Cursor declarations must appear before handler declarations and after variable and condition declarations.

Example:

```
CREATE PROCEDURE curdemo()
BEGIN
  DECLARE done INT DEFAULT FALSE;
  DECLARE a CHAR(16);
  DECLARE b, c INT;
  DECLARE cur1 CURSOR FOR SELECT id,data FROM test.t1;
  DECLARE cur2 CURSOR FOR SELECT i FROM test.t2;
  DECLARE CONTINUE HANDLER FOR NOT FOUND SET done = TRUE;

  OPEN cur1;
  OPEN cur2;

  read_loop: LOOP
    FETCH cur1 INTO a, b;
    FETCH cur2 INTO c;
    IF done THEN
      LEAVE read_loop;
    END IF;
    IF b < c THEN
      INSERT INTO test.t3 VALUES (a,b);
    ELSE
      INSERT INTO test.t3 VALUES (a,c);
    END IF;
  END LOOP;

  CLOSE cur1;
  CLOSE cur2;
END;
```

13.6.6.1 Cursor CLOSE Syntax

```
CLOSE cursor_name
```

This statement closes a previously opened cursor. For an example, see Section 13.6.6, “Cursors”.

An error occurs if the cursor is not open.

If not closed explicitly, a cursor is closed at the end of the `BEGIN ... END` block in which it was declared.

13.6.6.2 Cursor DECLARE Syntax

```
DECLARE cursor_name CURSOR FOR select_statement
```

This statement declares a cursor and associates it with a `SELECT` statement that retrieves the rows to be traversed by the cursor. To fetch the rows later, use a `FETCH` statement. The number of columns retrieved by the `SELECT` statement must match the number of output variables specified in the `FETCH` statement.

The `SELECT` statement cannot have an `INTO` clause.

Cursor declarations must appear before handler declarations and after variable and condition declarations.

A stored program may contain multiple cursor declarations, but each cursor declared in a given block must have a unique name. For an example, see Section 13.6.6, “Cursors”.

For information available through `SHOW` statements, it is possible in many cases to obtain equivalent information by using a cursor with an `INFORMATION_SCHEMA` table.

13.6.6.3 Cursor FETCH Syntax

```
FETCH [[NEXT] FROM] cursor_name INTO var_name [, var_name] ...
```

This statement fetches the next row for the `SELECT` statement associated with the specified cursor (which must be open), and advances the cursor pointer. If a row exists, the fetched columns are stored in the named variables. The number of columns retrieved by the `SELECT` statement must match the number of output variables specified in the `FETCH` statement.

If no more rows are available, a No Data condition occurs with SQLSTATE value `'02000'`. To detect this condition, you can set up a handler for it (or for a `NOT FOUND` condition). For an example, see Section 13.6.6, “Cursors”.

Be aware that another operation, such as a `SELECT` or another `FETCH`, may also cause the handler to execute by raising the same condition. If it is necessary to distinguish which operation raised the condition, place the operation within its own `BEGIN ... END` block so that it can be associated with its own handler.

13.6.6.4 Cursor OPEN Syntax

```
OPEN cursor_name
```

This statement opens a previously declared cursor. For an example, see Section 13.6.6, “Cursors”.

13.6.7 Condition Handling

Conditions may arise during stored program execution that require special handling, such as exiting the current program block or continuing execution. Handlers can be defined for general conditions such as warnings or exceptions, or for specific conditions such as a particular error code. Specific conditions can be assigned names and referred to that way in handlers.

To name a condition, use the `DECLARE ... CONDITION` statement. To declare a handler, use the `DECLARE ... HANDLER` statement. See Section 13.6.7.1, “DECLARE ... CONDITION Syntax”, and Section 13.6.7.2, “DECLARE ... HANDLER Syntax”.

To raise a condition, use the `SIGNAL` statement. To modify condition information within a condition handler, use `RESIGNAL`. See Section 13.6.7.1, “DECLARE ... CONDITION Syntax”, and Section 13.6.7.2, “DECLARE ... HANDLER Syntax”.

Another statement related to conditions is `GET DIAGNOSTICS`. The `GET DIAGNOSTICS` statement is not supported until MySQL 5.6.

Before MySQL 5.6.3, if a statement that generates a warning or error causes a condition handler to be invoked, the handler may not clear the diagnostic area. This might lead to the appearance that the handler was not invoked. The following discussion demonstrates the issue and provides a workaround.

Suppose that a table `t1` is empty. The following procedure selects from it, raising a No Data condition:

```
CREATE PROCEDURE p1()
BEGIN
  DECLARE a INT;
  DECLARE CONTINUE HANDLER FOR NOT FOUND
    BEGIN
      SET @handler_invoked = 1;
    END;
  SELECT c1 INTO a FROM t1;
END;
```

As can be seen from the following sequence of statements, the condition is not cleared by handler invocation (otherwise, the `SHOW WARNINGS` output would be empty). But as can be seen by the value of `@handler_invoked`, the handler was indeed invoked (otherwise its value would be 0).

```
mysql> SET @handler_invoked = 0;
Query OK, 0 rows affected (0.00 sec)

mysql> CALL p1();
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> SHOW WARNINGS;
+---------+------+-----------------------------------------------------+
| Level   | Code | Message                                             |
+---------+------+-----------------------------------------------------+
| Warning | 1329 | No data - zero rows fetched, selected, or processed |
+---------+------+-----------------------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @handler_invoked;
+------------------+
| @handler_invoked |
+------------------+
|                1 |
+------------------+
1 row in set (0.00 sec)
```

To work around this issue, use a condition handler containing a statement that clears warnings:

```
CREATE PROCEDURE p1()
BEGIN
  DECLARE a INT;
  DECLARE CONTINUE HANDLER FOR NOT FOUND
    BEGIN
      SELECT 1 INTO @handler_invoked FROM (SELECT 1) AS t;
    END;
  SELECT c1 INTO a FROM t1;
END;
```

This works for `CONTINUE` and `EXIT` handlers.

This issue is resolved as of MySQL 5.6.3 and no workaround is needed.

13.6.7.1 DECLARE ... CONDITION Syntax

```
DECLARE condition_name CONDITION FOR condition_value
```

```
condition_value:
    mysql_error_code
  | SQLSTATE [VALUE] sqlstate_value
```

The `DECLARE ... CONDITION` statement declares a named error condition, associating a name with a condition that needs specific handling. The name can be referred to in a subsequent `DECLARE ... HANDLER` statement (see Section 13.6.7.2, “DECLARE ... HANDLER Syntax”).

Condition declarations must appear before cursor or handler declarations.

The *`condition_value`* for `DECLARE ... CONDITION` indicates the specific condition or class of conditions to associate with the condition name. It can take the following forms:

- *`mysql_error_code`*: An integer literal indicating a MySQL error code.

  Do not use MySQL error code 0 because that indicates success rather than an error condition. For a list of MySQL error codes, see Section B.3, “Server Error Codes and Messages”.

- SQLSTATE [VALUE] *`sqlstate_value`*: A 5-character string literal indicating an SQLSTATE value.

  Do not use SQLSTATE values that begin with `'00'` because those indicate success rather than an error condition. For a list of SQLSTATE values, see Section B.3, “Server Error Codes and Messages”.

Condition names referred to in `SIGNAL` or use `RESIGNAL` statements must be associated with SQLSTATE values, not MySQL error codes.

Using names for conditions can help make stored program code clearer. For example, this handler applies to attempts to drop a nonexistent table, but that is apparent only if you know that 1051 is the MySQL error code for “unknown table”:

```
DECLARE CONTINUE HANDLER FOR 1051
  BEGIN
    -- body of handler
  END;
```

By declaring a name for the condition, the purpose of the handler is more readily seen:

```
DECLARE no_such_table CONDITION FOR 1051;
DECLARE CONTINUE HANDLER FOR no_such_table
  BEGIN
    -- body of handler
  END;
```

Here is a named condition for the same condition, but based on the corresponding SQLSTATE value rather than the MySQL error code:

```
DECLARE no_such_table CONDITION FOR SQLSTATE '42S02';
DECLARE CONTINUE HANDLER FOR no_such_table
  BEGIN
    -- body of handler
  END;
```

13.6.7.2 DECLARE ... HANDLER Syntax

```
DECLARE handler_action HANDLER
    FOR condition_value [, condition_value] ...
    statement

handler_action:
```

```
    CONTINUE
  | EXIT
  | UNDO

condition_value:
    mysql_error_code
  | SQLSTATE [VALUE] sqlstate_value
  | condition_name
  | SQLWARNING
  | NOT FOUND
  | SQLEXCEPTION
```

The `DECLARE ... HANDLER` statement specifies a handler that deals with one or more conditions. If one of these conditions occurs, the specified *`statement`* executes. *`statement`* can be a simple statement such as `SET var_name = value`, or a compound statement written using `BEGIN` and `END` (see Section 13.6.1, “BEGIN ... END Compound-Statement Syntax”).

Handler declarations must appear after variable or condition declarations.

The *`handler_action`* value indicates what action the handler takes after execution of the handler statement:

- `CONTINUE`: Execution of the current program continues.
- `EXIT`: Execution terminates for the `BEGIN ... END` compound statement in which the handler is declared. This is true even if the condition occurs in an inner block.
- `UNDO`: Not supported.

The *`condition_value`* for `DECLARE ... HANDLER` indicates the specific condition or class of conditions that activates the handler. It can take the following forms:

- *`mysql_error_code`*: An integer literal indicating a MySQL error code, such as 1051 to specify “unknown table”:

  ```
  DECLARE CONTINUE HANDLER FOR 1051
    BEGIN
      -- body of handler
    END;
  ```

  Do not use MySQL error code 0 because that indicates success rather than an error condition. For a list of MySQL error codes, see Section B.3, “Server Error Codes and Messages”.

- SQLSTATE [VALUE] *`sqlstate_value`*: A 5-character string literal indicating an SQLSTATE value, such as `'42S01'` to specify “unknown table”:

  ```
  DECLARE CONTINUE HANDLER FOR SQLSTATE '42S02'
    BEGIN
      -- body of handler
    END;
  ```

  Do not use SQLSTATE values that begin with `'00'` because those indicate success rather than an error condition. For a list of SQLSTATE values, see Section B.3, “Server Error Codes and Messages”.

- *`condition_name`*: A condition name previously specified with `DECLARE ... CONDITION`. A condition name can be associated with a MySQL error code or SQLSTATE value. See Section 13.6.7.1, “DECLARE ... CONDITION Syntax”.

- `SQLWARNING`: Shorthand for the class of SQLSTATE values that begin with `'01'`.

  ```
  DECLARE CONTINUE HANDLER FOR SQLWARNING
  ```

```
  BEGIN
    -- body of handler
  END;
```

- `NOT FOUND`: Shorthand for the class of SQLSTATE values that begin with `'02'`. This is relevant within the context of cursors and is used to control what happens when a cursor reaches the end of a data set. If no more rows are available, a No Data condition occurs with SQLSTATE value `'02000'`. To detect this condition, you can set up a handler for it or for a `NOT FOUND` condition.

```
DECLARE CONTINUE HANDLER FOR NOT FOUND
  BEGIN
    -- body of handler
  END;
```

  For another example, see Section 13.6.6, “Cursors”. The `NOT FOUND` condition also occurs for `SELECT ... INTO var_list` statements that retrieve no rows.

- `SQLEXCEPTION`: Shorthand for the class of SQLSTATE values that do not begin with `'00'`, `'01'`, or `'02'`.

```
DECLARE CONTINUE HANDLER FOR SQLEXCEPTION
  BEGIN
    -- body of handler
  END;
```

If a condition occurs for which no handler has been declared, the action taken depends on the condition class:

- For `SQLEXCEPTION` conditions, the stored program terminates at the statement that raised the condition, as if there were an `EXIT` handler. If the program was called by another stored program, the calling program handles the condition using the handler selection rules applied to its own handlers.
- For `SQLWARNING` conditions, the program continues executing, as if there were a `CONTINUE` handler.
- For `NOT FOUND` conditions, if the condition was raised normally, the action is `CONTINUE`. If it was raised by `SIGNAL` or `RESIGNAL`, the action is `EXIT`.

The following example uses a handler for `SQLSTATE '23000'`, which occurs for a duplicate-key error:

```
mysql> CREATE TABLE test.t (s1 INT, PRIMARY KEY (s1));
Query OK, 0 rows affected (0.00 sec)

mysql> delimiter //

mysql> CREATE PROCEDURE handlerdemo ()
    -> BEGIN
    ->   DECLARE CONTINUE HANDLER FOR SQLSTATE '23000' SET @x2 = 1;
    ->   SET @x = 1;
    ->   INSERT INTO test.t VALUES (1);
    ->   SET @x = 2;
    ->   INSERT INTO test.t VALUES (1);
    ->   SET @x = 3;
    -> END;
    -> //
Query OK, 0 rows affected (0.00 sec)

mysql> CALL handlerdemo()//
Query OK, 0 rows affected, 1 warning (0.01 sec)

mysql> SHOW WARNINGS//
+-------+------+---------------------------------------+
| Level | Code | Message                               |
+-------+------+---------------------------------------+
```

```
| Error | 1062 | Duplicate entry '1' for key 'PRIMARY' |
+-------+------+---------------------------------------+
1 row in set (0.00 sec)


mysql> SELECT @x//
    +------+
    | @x   |
    +------+
    | 3    |
    +------+
    1 row in set (0.00 sec)
```

Notice that `@x` is `3` after the procedure executes, which shows that execution continued to the end of the procedure after the error occurred. If the `DECLARE ... HANDLER` statement had not been present, MySQL would have taken the default action (`EXIT`) after the second `INSERT` failed due to the `PRIMARY KEY` constraint, and `SELECT @x` would have returned `2`.

To ignore a condition, declare a `CONTINUE` handler for it and associate it with an empty block. For example:

```
DECLARE CONTINUE HANDLER FOR SQLWARNING BEGIN END;
```

The scope of a block label does not include the code for handlers declared within the block. Therefore, the statement associated with a handler cannot use `ITERATE` or `LEAVE` to refer to labels for blocks that enclose the handler declaration. Consider the following example, where the `REPEAT` block has a label of `retry`:

```
CREATE PROCEDURE p ()
BEGIN
  DECLARE i INT DEFAULT 3;
  retry:
    REPEAT
      BEGIN
        DECLARE CONTINUE HANDLER FOR SQLWARNING
          BEGIN
            ITERATE retry;    # illegal
          END;
        IF i < 0 THEN
          LEAVE retry;        # legal
        END IF;
        SET i = i - 1;
      END;
    UNTIL FALSE END REPEAT;
END;
```

The `retry` label is in scope for the `IF` statement within the block. It is not in scope for the `CONTINUE` handler, so the reference there is invalid and results in an error:

```
ERROR 1308 (42000): LEAVE with no matching label: retry
```

To avoid references to outer labels in handlers, use one of these strategies:

- To leave the block, use an `EXIT` handler. If no block cleanup is required, the `BEGIN ... END` handler body can be empty:

  ```
  DECLARE EXIT HANDLER FOR SQLWARNING BEGIN END;
  ```

  Otherwise, put the cleanup statements in the handler body:

  ```
  DECLARE EXIT HANDLER FOR SQLWARNING
    BEGIN
      block cleanup statements
  ```

```
  END;
```

- To continue execution, set a status variable in a `CONTINUE` handler that can be checked in the enclosing block to determine whether the handler was invoked. The following example uses the variable `done` for this purpose:

```
CREATE PROCEDURE p ()
BEGIN
  DECLARE i INT DEFAULT 3;
  DECLARE done INT DEFAULT FALSE;
  retry:
    REPEAT
      BEGIN
        DECLARE CONTINUE HANDLER FOR SQLWARNING
          BEGIN
            SET done = TRUE;
          END;
        IF done OR i < 0 THEN
          LEAVE retry;
        END IF;
        SET i = i - 1;
      END;
    UNTIL FALSE END REPEAT;
END;
```

13.6.7.3 RESIGNAL Syntax

```
RESIGNAL [condition_value]
    [SET signal_information_item
    [, signal_information_item] ...]

condition_value:
    SQLSTATE [VALUE] sqlstate_value
  | condition_name

signal_information_item:
    condition_information_item_name = simple_value_specification

condition_information_item_name:
    CLASS_ORIGIN
  | SUBCLASS_ORIGIN
  | MESSAGE_TEXT
  | MYSQL_ERRNO
  | CONSTRAINT_CATALOG
  | CONSTRAINT_SCHEMA
  | CONSTRAINT_NAME
  | CATALOG_NAME
  | SCHEMA_NAME
  | TABLE_NAME
  | COLUMN_NAME
  | CURSOR_NAME

condition_name, simple_value_specification:
    (see following discussion)
```

`RESIGNAL` passes on the error condition information that is available during execution of a condition handler within a compound statement inside a stored procedure or function, trigger, or event. `RESIGNAL` may change some or all information before passing it on. `RESIGNAL` is related to `SIGNAL`, but instead of originating a condition as `SIGNAL` does, `RESIGNAL` relays existing condition information, possibly after modifying it.

`RESIGNAL` makes it possible to both handle an error and return the error information. Otherwise, by executing an SQL statement within the handler, information that caused the handler's activation is destroyed. `RESIGNAL` also can make some procedures shorter if a given handler can handle part of a situation, then pass the condition “up the line” to another handler.

No special privileges are required to execute the `RESIGNAL` statement.

All forms of RESIGNAL require that the current context be a condition handler. Otherwise, RESIGNAL is illegal and a RESIGNAL when handler not active error occurs.

For *condition_value* and *signal_information_item*, the definitions and rules are the same for RESIGNAL as for SIGNAL. For example, the *condition_value* can be an SQLSTATE value, and the value can indicate errors, warnings, or "not found." For additional information, see Section 13.6.7.4, "SIGNAL Syntax".

The RESIGNAL statement takes *condition_value* and SET clauses, both of which are optional. This leads to several possible uses:

- RESIGNAL alone:

```
RESIGNAL;
```

- RESIGNAL with new signal information:

```
RESIGNAL SET signal_information_item [, signal_information_item] ...;
```

- RESIGNAL with a condition value and possibly new signal information:

```
RESIGNAL condition_value
    [SET signal_information_item [, signal_information_item] ...];
```

These use cases all cause changes to the diagnostics and condition areas:

- A diagnostics area contains one or more condition areas.
- A condition area contains condition information items, such as the SQLSTATE value, MYSQL_ERRNO, or MESSAGE_TEXT.

The maximum number of condition areas in a diagnostics area is determined by the value of the max_error_count system variable.

RESIGNAL Alone

A simple RESIGNAL alone means "pass on the error with no change." It restores the last diagnostics area and makes it the current diagnostics area. That is, it "pops" the diagnostics area stack.

Within a condition handler that catches a condition, one use for RESIGNAL alone is to perform some other actions, and then pass on without change the original condition information (the information that existed before entry into the handler).

Example:

```
DROP TABLE IF EXISTS xx;
delimiter //
CREATE PROCEDURE p ()
BEGIN
  DECLARE EXIT HANDLER FOR SQLEXCEPTION
  BEGIN
    SET @error_count = @error_count + 1;
    IF @a = 0 THEN RESIGNAL; END IF;
  END;
  DROP TABLE xx;
END//
delimiter ;
SET @error_count = 0;
SET @a = 0;
CALL p();
```

Suppose that the DROP TABLE xx statement fails. The diagnostics area stack looks like this:

```
DA 1. ERROR 1051 (42S02): Unknown table 'xx'
```

Then execution enters the `EXIT` handler. It starts by pushing a diagnostics area to the top of the stack, which now looks like this:

```
DA 1. ERROR 1051 (42S02): Unknown table 'xx'
DA 2. ERROR 1051 (42S02): Unknown table 'xx'
```

Usually a procedure statement clears the first diagnostics area (also called the “current” diagnostics area). `BEGIN` is an exception, it does not clear, it does nothing. `SET` is not an exception, it clears, performs the operation, and produces a result of “success.” The diagnostics area stack now looks like this:

```
DA 1. ERROR 0000 (00000): Successful operation
DA 2. ERROR 1051 (42S02): Unknown table 'xx'
```

At this point, if `@a = 0`, `RESIGNAL` pops the diagnostics area stack, which now looks like this:

```
DA 1. ERROR 1051 (42S02): Unknown table 'xx'
```

And that is what the caller sees.

If `@a` is not 0, the handler simply ends, which means that there is no more use for the current diagnostics area (it has been “handled”), so it can be thrown away, causing the stacked diagnostics area to become the current diagnostics area again. The diagnostics area stack looks like this:

```
DA 1. ERROR 0000 (00000): Successful operation
```

The details make it look complex, but the end result is quite useful: Handlers can execute without destroying information about the condition that caused activation of the handler.

RESIGNAL with New Signal Information

`RESIGNAL` with a `SET` clause provides new signal information, so the statement means “pass on the error with changes”:

```
RESIGNAL SET signal_information_item [, signal_information_item] ...;
```

As with `RESIGNAL` alone, the idea is to pop the diagnostics area stack so that the original information will go out. Unlike `RESIGNAL` alone, anything specified in the `SET` clause changes.

Example:

```
DROP TABLE IF EXISTS xx;
delimiter //
CREATE PROCEDURE p ()
BEGIN
  DECLARE EXIT HANDLER FOR SQLEXCEPTION
  BEGIN
    SET @error_count = @error_count + 1;
    IF @a = 0 THEN RESIGNAL SET MYSQL_ERRNO = 5; END IF;
  END;
  DROP TABLE xx;
END//
delimiter ;
SET @error_count = 0;
SET @a = 0;
CALL p();
```

Remember from the previous discussion that `RESIGNAL` alone results in a diagnostics area stack like this:

```
DA 1. ERROR 1051 (42S02): Unknown table 'xx'
```

The `RESIGNAL SET MYSQL_ERRNO = 5` statement results in this stack instead, which is what the caller sees:

```
DA 1. ERROR 5 (42S02): Unknown table 'xx'
```

In other words, it changes the error number, and nothing else.

The `RESIGNAL` statement can change any or all of the signal information items, making the first condition area of the diagnostics area look quite different.

RESIGNAL with a Condition Value and Optional New Signal Information

`RESIGNAL` with a condition value means “push a condition into the current diagnostics area.” If the `SET` clause is present, it also changes the error information.

```
RESIGNAL condition_value
    [SET signal_information_item [, signal_information_item] ...];
```

This form of `RESIGNAL` restores the last diagnostics area and makes it the current diagnostics area. That is, it “pops” the diagnostics area stack, which is the same as what a simple `RESIGNAL` alone would do. However, it also changes the diagnostics area depending on the condition value or signal information.

Example:

```
DROP TABLE IF EXISTS xx;
delimiter //
CREATE PROCEDURE p ()
BEGIN
  DECLARE EXIT HANDLER FOR SQLEXCEPTION
  BEGIN
    SET @error_count = @error_count + 1;
    IF @a = 0 THEN RESIGNAL SQLSTATE '45000' SET MYSQL_ERRNO=5; END IF;
  END;
  DROP TABLE xx;
END//
delimiter ;
SET @error_count = 0;
SET @a = 0;
SET @@max_error_count = 2;
CALL p();
SHOW ERRORS;
```

This is similar to the previous example, and the effects are the same, except that if `RESIGNAL` happens, the current condition area looks different at the end. (The reason the condition adds to rather than replaces the existing condition is the use of a condition value.)

The `RESIGNAL` statement includes a condition value (`SQLSTATE '45000'`), so it adds a new condition area, resulting in a diagnostics area stack that looks like this:

```
DA 1. (condition 2) ERROR 1051 (42S02): Unknown table 'xx'
      (condition 1) ERROR 5 (45000) Unknown table 'xx'
```

The result of `CALL p()` and `SHOW ERRORS` for this example is:

```
mysql> CALL p();
ERROR 5 (45000): Unknown table 'xx'
mysql> SHOW ERRORS;
```

```
+-------+------+---------------------------------+
| Level | Code | Message                         |
+-------+------+---------------------------------+
| Error | 1051 | Unknown table 'xx'              |
| Error |    5 | Unknown table 'xx'              |
+-------+------+---------------------------------+
```

RESIGNAL Requires Condition Handler Context

All forms of `RESIGNAL` require that the current context be a condition handler. Otherwise, `RESIGNAL` is illegal and a `RESIGNAL when handler not active` error occurs. For example:

```
mysql> CREATE PROCEDURE p () RESIGNAL;
Query OK, 0 rows affected (0.00 sec)

mysql> CALL p();
ERROR 1645 (0K000): RESIGNAL when handler not active
```

Here is a more difficult example:

```
delimiter //
CREATE FUNCTION f () RETURNS INT
BEGIN
  RESIGNAL;
  RETURN 5;
END//
CREATE PROCEDURE p ()
BEGIN
  DECLARE EXIT HANDLER FOR SQLEXCEPTION SET @a=f();
  SIGNAL SQLSTATE '55555';
END//
delimiter ;
CALL p();
```

`RESIGNAL` occurs within the stored function `f()`, which is invoked from within the `EXIT` handler. Thus, a handler is active at the time `RESIGNAL` executes, even though `RESIGNAL` is not defined inside the handler.

13.6.7.4 SIGNAL Syntax

```
SIGNAL condition_value
    [SET signal_information_item
    [, signal_information_item] ...]

condition_value:
    SQLSTATE [VALUE] sqlstate_value
  | condition_name

signal_information_item:
    condition_information_item_name = simple_value_specification

condition_information_item_name:
    CLASS_ORIGIN
  | SUBCLASS_ORIGIN
  | MESSAGE_TEXT
  | MYSQL_ERRNO
  | CONSTRAINT_CATALOG
  | CONSTRAINT_SCHEMA
  | CONSTRAINT_NAME
  | CATALOG_NAME
  | SCHEMA_NAME
  | TABLE_NAME
  | COLUMN_NAME
  | CURSOR_NAME

condition_name, simple_value_specification:
    (see following discussion)
```

`SIGNAL` is the way to “return” an error. `SIGNAL` provides error information to a handler, to an outer portion of the application, or to the client. Also, it provides control over the error's characteristics (error number, `SQLSTATE` value, message). Without `SIGNAL`, it is necessary to resort to workarounds such as deliberately referring to a nonexistent table to cause a routine to return an error.

No special privileges are required to execute the `SIGNAL` statement.

The *`condition_value`* in a `SIGNAL` statement indicates the error value to be returned. It can be an `SQLSTATE` value (a 5-character string literal) or a *`condition_name`* that refers to a named condition previously defined with `DECLARE ... CONDITION` (see Section 13.6.7.1, “DECLARE ... CONDITION Syntax”).

An `SQLSTATE` value can indicate errors, warnings, or “not found.” The first two characters of the value indicate its error class, as discussed in Signal Condition Information Items. Some signal values cause statement termination; see Effect of Signals on Handlers, Cursors, and Statements.

The `SQLSTATE` value for a `SIGNAL` statement should not start with `'00'` because such values indicate success and are not valid for signaling an error. This is true whether the `SQLSTATE` value is specified directly in the `SIGNAL` statement or in a named condition referred to in the statement. If the value is invalid, a `Bad SQLSTATE` error occurs.

To signal a generic `SQLSTATE` value, use `'45000'`, which means “unhandled user-defined exception.”

The `SIGNAL` statement optionally includes a `SET` clause that contains multiple signal items, in a comma-separated list of *`condition_information_item_name`* = *`simple_value_specification`* assignments.

Each *`condition_information_item_name`* may be specified only once in the `SET` clause. Otherwise, a `Duplicate condition information item` error occurs.

Valid *`simple_value_specification`* designators can be specified using stored procedure or function parameters, stored program local variables declared with `DECLARE`, user-defined variables, system variables, or literals. A character literal may include a *`_charset`* introducer.

For information about permissible *`condition_information_item_name`* values, see Signal Condition Information Items.

The following procedure signals an error or warning depending on the value of `pval`, its input parameter:

```
CREATE PROCEDURE p (pval INT)
BEGIN
  DECLARE specialty CONDITION FOR SQLSTATE '45000';
  IF pval = 0 THEN
    SIGNAL SQLSTATE '01000';
  ELSEIF pval = 1 THEN
    SIGNAL SQLSTATE '45000'
      SET MESSAGE_TEXT = 'An error occurred';
  ELSEIF pval = 2 THEN
    SIGNAL specialty
      SET MESSAGE_TEXT = 'An error occurred';
  ELSE
    SIGNAL SQLSTATE '01000'
      SET MESSAGE_TEXT = 'A warning occurred', MYSQL_ERRNO = 1000;
    SIGNAL SQLSTATE '45000'
      SET MESSAGE_TEXT = 'An error occurred', MYSQL_ERRNO = 1001;
  END IF;
END;
```

If `pval` is 0, `p()` signals a warning because `SQLSTATE` values that begin with `'01'` are signals in the warning class. The warning does not terminate the procedure, and can be seen with `SHOW WARNINGS` after the procedure returns.

If `pval` is 1, `p()` signals an error and sets the `MESSAGE_TEXT` condition information item. The error terminates the procedure, and the text is returned with the error information.

If `pval` is 2, the same error is signaled, although the `SQLSTATE` value is specified using a named condition in this case.

If `pval` is anything else, `p()` first signals a warning and sets the message text and error number condition information items. This warning does not terminate the procedure, so execution continues and `p()` then signals an error. The error does terminate the procedure. The message text and error number set by the warning are replaced by the values set by the error, which are returned with the error information.

`SIGNAL` is typically used within stored programs, but it is a MySQL extension that it is permitted outside handler context. For example, if you invoke the `mysql` client program, you can enter any of these statements at the prompt:

```
mysql> SIGNAL SQLSTATE '77777';
mysql> CREATE TRIGGER t_bi BEFORE INSERT ON t
    -> FOR EACH ROW SIGNAL SQLSTATE '77777';
mysql> CREATE EVENT e ON SCHEDULE EVERY 1 SECOND
    -> DO SIGNAL SQLSTATE '77777';
```

`SIGNAL` executes according to the following rules:

If the `SIGNAL` statement indicates a particular `SQLSTATE` value, that value is used to signal the condition specified. Example:

```
CREATE PROCEDURE p (divisor INT)
BEGIN
  IF divisor = 0 THEN
    SIGNAL SQLSTATE '22012';
  END IF;
END;
```

If the `SIGNAL` statement uses a named condition, the condition must be declared in some scope that applies to the `SIGNAL` statement, and must be defined using an `SQLSTATE` value, not a MySQL error number. Example:

```
CREATE PROCEDURE p (divisor INT)
BEGIN
  DECLARE divide_by_zero CONDITION FOR SQLSTATE '22012';
  IF divisor = 0 THEN
    SIGNAL divide_by_zero;
  END IF;
END;
```

If the named condition does not exist in the scope of the `SIGNAL` statement, an `Undefined CONDITION` error occurs.

If `SIGNAL` refers to a named condition that is defined with a MySQL error number rather than an `SQLSTATE` value, a `SIGNAL/RESIGNAL can only use a CONDITION defined with SQLSTATE` error occurs. The following statements cause that error because the named condition is associated with a MySQL error number:

```
DECLARE no_such_table CONDITION FOR 1051;
SIGNAL no_such_table;
```

If a condition with a given name is declared multiple times in different scopes, the declaration with the most local scope applies. Consider the following procedure:

```
CREATE PROCEDURE p (divisor INT)
BEGIN
  DECLARE my_error CONDITION FOR SQLSTATE '45000';
  IF divisor = 0 THEN
    BEGIN
      DECLARE my_error CONDITION FOR SQLSTATE '22012';
      SIGNAL my_error;
    END;
  END IF;
  SIGNAL my_error;
END;
```

If `divisor` is 0, the first `SIGNAL` statement executes. The innermost `my_error` condition declaration applies, raising `SQLSTATE '22012'`.

If `divisor` is not 0, the second `SIGNAL` statement executes. The outermost `my_error` condition declaration applies, raising `SQLSTATE '45000'`.

Signals can be raised within exception handlers:

```
CREATE PROCEDURE p ()
BEGIN
  DECLARE EXIT HANDLER FOR SQLEXCEPTION
  BEGIN
    SIGNAL SQLSTATE VALUE '99999'
      SET MESSAGE_TEXT = 'An error occurred';
  END;
  DROP TABLE no_such_table;
END;
```

`CALL p()` reaches the `DROP TABLE` statement. There is no table named `no_such_table`, so the error handler is activated. The error handler destroys the original error (“no such table”) and makes a new error with `SQLSTATE '99999'` and message `An error occurred`.

Signal Condition Information Items

The following table lists the names of diagnostics area condition information items that can be set in a `SIGNAL` (or `RESIGNAL`) statement. All items are standard SQL except `MYSQL_ERRNO`, which is a MySQL extension.

```
Item Name             Definition
---------             ----------
CLASS_ORIGIN          VARCHAR(64)
SUBCLASS_ORIGIN       VARCHAR(64)
CONSTRAINT_CATALOG    VARCHAR(64)
CONSTRAINT_SCHEMA     VARCHAR(64)
CONSTRAINT_NAME       VARCHAR(64)
CATALOG_NAME          VARCHAR(64)
SCHEMA_NAME           VARCHAR(64)
TABLE_NAME            VARCHAR(64)
COLUMN_NAME           VARCHAR(64)
CURSOR_NAME           VARCHAR(64)
MESSAGE_TEXT          VARCHAR(128)
MYSQL_ERRNO           SMALLINT UNSIGNED
```

The character set for character items is UTF-8.

It is illegal to assign `NULL` to a condition information item in a `SIGNAL` statement.

A `SIGNAL` statement always specifies an `SQLSTATE` value, either directly, or indirectly by referring to a named condition defined with an `SQLSTATE` value. The first two characters of an `SQLSTATE` value are its class, and the class determines the default value for the condition information items:

- Class = `'00'` (success)

Illegal. SQLSTATE values that begin with '00' indicate success and are not valid for SIGNAL.

- Class = '01' (warning)

```
MESSAGE_TEXT = 'Unhandled user-defined warning condition';
MYSQL_ERRNO = ER_SIGNAL_WARN
```

- Class = '02' (not found)

```
MESSAGE_TEXT = 'Unhandled user-defined not found condition';
MYSQL_ERRNO = ER_SIGNAL_NOT_FOUND
```

- Class > '02' (exception)

```
MESSAGE_TEXT = 'Unhandled user-defined exception condition';
MYSQL_ERRNO = ER_SIGNAL_EXCEPTION
```

For legal classes, the other condition information items are set as follows:

```
CLASS_ORIGIN = SUBCLASS_ORIGIN = '';
CONSTRAINT_CATALOG = CONSTRAINT_SCHEMA = CONSTRAINT_NAME = '';
CATALOG_NAME = SCHEMA_NAME = TABLE_NAME = COLUMN_NAME = '';
CURSOR_NAME = '';
```

The error values that are accessible after SIGNAL executes are the SQLSTATE value raised by the SIGNAL statement and the MESSAGE_TEXT and MYSQL_ERRNO items. These values are available from the C API:

- SQLSTATE value: Call mysql_sqlstate()
- MYSQL_ERRNO value: Call mysql_errno()
- MESSAGE_TEXT value: Call mysql_error()

From SQL, the output from SHOW WARNINGS and SHOW ERRORS indicates the MYSQL_ERRNO and MESSAGE_TEXT values in the Code and Message columns.

Other condition information items can be set, but currently have no effect, in the sense that they are not accessible from error returns. For example, you can set CLASS_ORIGIN in a SIGNAL statement, but cannot see it after SIGNAL executes. In MySQL 5.6, condition information can be inspected with the GET DIAGNOSTICS statement.

Effect of Signals on Handlers, Cursors, and Statements

Signals have different effects on statement execution depending on the signal class. The class determines how severe an error is. MySQL ignores the value of the sql_mode system variable; in particular, strict SQL mode does not matter. MySQL also ignores IGNORE: The intent of SIGNAL is to raise a user-generated error explicitly, so a signal is never ignored.

In the following descriptions, “unhandled” means that no handler for the signaled SQLSTATE value has been defined with DECLARE ... HANDLER.

- Class = '00' (success)

  Illegal. SQLSTATE values that begin with '00' indicate success and are not valid for SIGNAL.

- Class = '01' (warning)

  The value of the warning_count system variable goes up. SHOW WARNINGS shows the signal. SQLWARNING handlers catch the signal. If the signal is unhandled in a function, statements do not end.

- Class = `'02'` (not found)

  `NOT FOUND` handlers catch the signal. There is no effect on cursors. If the signal is unhandled in a function, statements end.

- Class > `'02'` (exception)

  `SQLEXCEPTION` handlers catch the signal. If the signal is unhandled in a function, statements end.

- Class = `'40'`

  Treated as an ordinary exception.

Example:

```
mysql> delimiter //
mysql> CREATE FUNCTION f () RETURNS INT
    -> BEGIN
    ->   SIGNAL SQLSTATE '01234';  -- signal a warning
    ->   RETURN 5;
    -> END//
mysql> delimiter ;
mysql> CREATE TABLE t (s1 INT);
mysql> INSERT INTO t VALUES (f());
```

The result is that a row containing 5 is inserted into table `t`. The warning that is signaled can be viewed with `SHOW WARNINGS`.

13.7 Database Administration Statements

13.7.1 Account Management Statements

MySQL account information is stored in the tables of the `mysql` database. This database and the access control system are discussed extensively in Chapter 5, *MySQL Server Administration*, which you should consult for additional details.

Important

Some MySQL releases introduce changes to the structure of the grant tables to add new privileges or features. To make sure that you can take advantage of any new capabilities, update your grant tables to have the current structure whenever you upgrade MySQL. See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

When the `read_only` system variable is enabled, account-management statements require the `SUPER` privilege, in addition to any other required privileges. This is because they modify tables in the `mysql` database.

13.7.1.1 CREATE USER Syntax

```
CREATE USER
    user [auth_option] [, user [auth_option]] ...

user:
    (see Section 6.2.3, “Specifying Account Names”)

auth_option: {
    IDENTIFIED BY 'auth_string'
  | IDENTIFIED BY PASSWORD 'hash_string'
  | IDENTIFIED WITH auth_plugin
  | IDENTIFIED WITH auth_plugin AS 'hash_string'
}
```

The `CREATE USER` statement creates new MySQL accounts. An error occurs if you try to create an account that already exists.

To use `CREATE USER`, you must have the global `CREATE USER` privilege, or the `INSERT` privilege for the `mysql` database. When the `read_only` system variable is enabled, `CREATE USER` additionally requires the `SUPER` privilege.

Important

`CREATE USER` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, “Passwords and Logging”. For similar information about client-side logging, see Section 4.5.1.3, “mysql Logging”.

For each account, `CREATE USER` creates a new row in the `mysql.user` system table with no privileges and assigns the account an authentication plugin. Depending on the syntax used, `CREATE USER` may also assign the account a password.

An account when first created has no privileges. To assign privileges, use the `GRANT` statement.

Each *`user`* value naming an account may be followed by an optional *`auth_option`* value that specifies how authentication occurs for clients that use the account. This part of `CREATE USER` syntax is shared with `GRANT`, so the description here applies to `GRANT` as well.

Each account name uses the format described in Section 6.2.3, “Specifying Account Names”. For example:

```
CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'password';
```

The host name part of the account name, if omitted, defaults to `'%'`.

The server assigns an authentication plugin and password to each account as follows, depending on whether the user specification clause includes `IDENTIFIED WITH` to specify a plugin or `IDENTIFIED BY` to specify a password:

- With `IDENTIFIED WITH`, the server assigns the specified plugin and the account has no password. If the optional `AS 'hash_string'` clause is also given, the string is stored as is in the `authentication_string` column (it is assumed to be already hashed in the format required by the plugin).
- With `IDENTIFIED BY`, the server assigns no plugin and assigns the specified password.
- With neither `IDENTIFIED WITH` nor `IDENTIFIED BY`, the server assigns no plugin and the account has no password.

If the account has no password, the `Password` column in the account's `mysql.user` table row remains empty, which is insecure. To set the password, use `SET PASSWORD`. See Section 13.7.1.6, “SET PASSWORD Syntax”.

If the server assigns no plugin to the account, the `plugin` column in the account's `mysql.user` table row remains empty.

For client connections that use a given account, the server invokes the authentication plugin assigned to the account and the client must provide credentials as required by the authentication method that the plugin implements. If the server cannot find the plugin, either at account-creation time or connect time, an error occurs.

If an account's `mysql.user` table row has a nonempty `plugin` column:

- The server authenticates client connection attempts using the named plugin.
- Changes to the account password using `SET PASSWORD` with `PASSWORD()` must be made with the `old_passwords` system variable set to the value required by the authentication plugin, so that `PASSWORD()` uses the appropriate password hashing method. If the plugin is `mysql_old_password`, the password can also be changed using `SET PASSWORD` with `OLD_PASSWORD()`, which uses pre-4.1 password hashing regardless of the value of `old_passwords`.

If an account's `mysql.user` table row has an empty `plugin` column:

- The server authenticates client connection attempts using the `mysql_native_password` or `mysql_old_password` authentication plugin, depending on the hash format of the password stored in the `Password` column.
- Changes to the account password using `SET PASSWORD` can be made with `PASSWORD()`, with `old_passwords` set to 0 or 1 for 4.1 or pre-4.1 password hashing, respectively, or with `OLD_PASSWORD()`, which uses pre-4.1 password hashing regardless of the value of `old_passwords`.

`CREATE USER` examples:

- To specify an authentication plugin for an account, use `IDENTIFIED WITH *auth_plugin*`. The plugin name can be a quoted string literal or an unquoted name. `'*auth_string*'` is an optional quoted string literal to pass to the plugin. The plugin interprets the meaning of the string, so its format is plugin specific and it is stored in the `authentication_string` column as given. (This value is meaningful only for plugins that use that column.) Consult the documentation for a given plugin for information about the authentication string values it accepts, if any.

  ```
  CREATE USER 'jeffrey'@'localhost' IDENTIFIED WITH mysql_native_password;
  ```

  The server assigns the given authentication plugin to the account but no password. Clients must provide no password when they connect. However, an account with no password is insecure. To ensure that an account uses a specific authentication plugin and has a password with the corresponding hash format, specify the plugin explicitly with `IDENTIFIED WITH`, then use `SET PASSWORD` to set the password:

  ```
  CREATE USER 'jeffrey'@'localhost' IDENTIFIED WITH mysql_native_password;
  SET old_passwords = 0;
  SET PASSWORD FOR 'jeffrey'@'localhost' = PASSWORD('password');
  ```

  Changes to the account password using `SET PASSWORD` with `PASSWORD()` must be made with the `old_passwords` system variable set to the value required by the account's authentication plugin, so that `PASSWORD()` uses the appropriate password hashing method. Therefore, to use the `mysql_old_password` plugin instead, name that plugin in the `CREATE USER` statement and set `old_passwords` to 1 before using `SET PASSWORD`.

- To specify a password for an account at account-creation time, use `IDENTIFIED BY` with the literal cleartext password value:

  ```
  CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'password';
  ```

  The server assigns the given password to the account but no authentication plugin. Clients must provide the password when they connect.

- To avoid specifying the cleartext password if you know its hash value (the value that `PASSWORD()` would return for the password), specify the hash value preceded by the keyword `PASSWORD`:

  ```
  CREATE USER 'jeffrey'@'localhost'
  ```

```
IDENTIFIED BY PASSWORD '*90E462C37378CED12064BB3388827D2BA3A9B689';
```

The server assigns the given password to the account but no authentication plugin. Clients must provide the password when they connect.

- To enable the user to connect with no password, include no `IDENTIFIED BY` clause:

```
CREATE USER 'jeffrey'@'localhost';
```

The server assigns no authentication plugin or password to the account. Clients must provide no password when they connect. However, an account with no password is insecure. To avoid this, use `SET PASSWORD` to set the account password.

For additional information about setting passwords and authentication plugins, see Section 6.3.5, “Assigning Account Passwords”, and Section 6.3.6, “Pluggable Authentication”.

13.7.1.2 DROP USER Syntax

```
DROP USER user [, user] ...
```

The `DROP USER` statement removes one or more MySQL accounts and their privileges. It removes privilege rows for the account from all grant tables. An error occurs for accounts that do not exist.

To use `DROP USER`, you must have the global `CREATE USER` privilege, or the `DELETE` privilege for the `mysql` database. When the `read_only` system variable is enabled, `DROP USER` additionally requires the `SUPER` privilege.

Each account name uses the format described in Section 6.2.3, “Specifying Account Names”. For example:

```
DROP USER 'jeffrey'@'localhost';
```

The host name part of the account name, if omitted, defaults to `'%'`.

Important

`DROP USER` does not automatically close any open user sessions. Rather, in the event that a user with an open session is dropped, the statement does not take effect until that user's session is closed. Once the session is closed, the user is dropped, and that user's next attempt to log in will fail. *This is by design*.

`DROP USER` does not automatically drop or invalidate databases or objects within them that the old user created. This includes stored programs or views for which the `DEFINER` attribute names the dropped user. Attempts to access such objects may produce an error if they execute in definer security context. (For information about security context, see Section 20.6, “Access Control for Stored Programs and Views”.)

13.7.1.3 GRANT Syntax

```
GRANT
    priv_type [(column_list)]
      [, priv_type [(column_list)]] ...
    ON [object_type] priv_level
    TO user [auth_option] [, user [auth_option]] ...
    [REQUIRE {NONE | tls_option [[AND] tls_option] ...}]
    [WITH {GRANT OPTION | resource_option} ...]

GRANT PROXY ON user
    TO user [, user] ...
```

```
    [WITH GRANT OPTION]

object_type: {
    TABLE
  | FUNCTION
  | PROCEDURE
}

priv_level: {
    *
  | *.*
  | db_name.*
  | db_name.tbl_name
  | tbl_name
  | db_name.routine_name
}

user:
    (see Section 6.2.3, “Specifying Account Names”)

auth_option: {
    IDENTIFIED BY 'auth_string'
  | IDENTIFIED BY PASSWORD 'hash_string'
  | IDENTIFIED WITH auth_plugin
  | IDENTIFIED WITH auth_plugin AS 'hash_string'
}

tls_option: {
    SSL
  | X509
  | CIPHER 'cipher'
  | ISSUER 'issuer'
  | SUBJECT 'subject'
}

resource_option: {
  | MAX_QUERIES_PER_HOUR count
  | MAX_UPDATES_PER_HOUR count
  | MAX_CONNECTIONS_PER_HOUR count
  | MAX_USER_CONNECTIONS count
}
```

The `GRANT` statement grants privileges to MySQL user accounts. `GRANT` also serves to specify other account characteristics such as use of secure connections and limits on access to server resources.

To use `GRANT`, you must have the `GRANT OPTION` privilege, and you must have the privileges that you are granting. When the `read_only` system variable is enabled, `GRANT` additionally requires the `SUPER` privilege.

The `REVOKE` statement is related to `GRANT` and enables administrators to remove account privileges. See Section 13.7.1.5, “REVOKE Syntax”.

Each account name uses the format described in Section 6.2.3, “Specifying Account Names”. For example:

```
GRANT ALL ON db1.* TO 'jeffrey'@'localhost';
```

The host name part of the account, if omitted, defaults to `'%'`.

Normally, a database administrator first uses `CREATE USER` to create an account, then `GRANT` to define its privileges and characteristics. For example:

```
CREATE USER 'jeffrey'@'localhost' IDENTIFIED BY 'password';
GRANT ALL ON db1.* TO 'jeffrey'@'localhost';
GRANT SELECT ON db2.invoice TO 'jeffrey'@'localhost';
GRANT USAGE ON *.* TO 'jeffrey'@'localhost' WITH MAX_QUERIES_PER_HOUR 90;
```

Note

Examples shown here include no `IDENTIFIED` clause. It is assumed that you establish passwords with `CREATE USER` at account-creation time to avoid creating insecure accounts.

If an account named in a `GRANT` statement does not already exist, `GRANT` may create it under the conditions described later in the discussion of the `NO_AUTO_CREATE_USER` SQL mode.

From the `mysql` program, `GRANT` responds with `Query OK, 0 rows affected` when executed successfully. To determine what privileges result from the operation, use `SHOW GRANTS`. See Section 13.7.5.22, “SHOW GRANTS Syntax”.

Important

`GRANT` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, “Passwords and Logging”. For similar information about client-side logging, see Section 4.5.1.3, “mysql Logging”.

`GRANT` supports host names up to 60 characters long. User names can be up to 16 characters. Database, table, column, and routine names can be up to 64 characters.

Warning

Do not attemt to change the permissible length for user names by altering the `mysql.user` table. Doing so results in unpredictable behavior which may even make it impossible for users to log in to the MySQL server. Never alter the structure of tables in the `mysql` database in any manner except by means of the procedure described in Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

There are several aspects to the `GRANT` statement, described under the following topics:

- Object Quoting Guidelines
- Privileges Supported by MySQL
- Global Privileges
- Database Privileges
- Table Privileges
- Column Privileges
- Stored Routine Privileges
- Proxy User Privileges
- Account Names and Passwords
- Implicit Account Creation
- Other Account Characteristics
- MySQL and Standard SQL Versions of GRANT

Object Quoting Guidelines

Several objects within `GRANT` statements are subject to quoting, although quoting is optional in many cases: Account, database, table, column, and routine names. For example, if a *`user_name`*

or *host_name* value in an account name is legal as an unquoted identifier, you need not quote it. However, quotation marks are necessary to specify a *user_name* string containing special characters (such as -), or a *host_name* string containing special characters or wildcard characters (such as %); for example, 'test-user'@'%.com'. Quote the user name and host name separately.

To specify quoted values, quote database, table, column, and routine names as identifiers. Quote user names and host names as identifiers or as strings. Quote passwords as strings. For string-quoting and identifier-quoting guidelines, see Section 9.1.1, "String Literals", and Section 9.2, "Schema Object Names".

The _ and % wildcards are permitted when specifying database names in GRANT statements that grant privileges at the database level. This means, for example, that if you want to use a _ character as part of a database name, you should specify it as _ in the GRANT statement, to prevent the user from being able to access additional databases matching the wildcard pattern; for example, GRANT ... ON `foo\_bar`.* TO ....

Privileges Supported by MySQL

The following table summarizes the permissible *priv_type* privilege types that can be specified for the GRANT and REVOKE statements, and the levels at which each privilege can be granted. For additional information about each privilege, see Section 6.2.1, "Privileges Provided by MySQL".

Table 13.3 Permissible Privileges for GRANT and REVOKE

Privilege	Meaning and Grantable Levels
ALL [PRIVILEGES]	Grant all privileges at specified access level except GRANT OPTION and PROXY.
ALTER	Enable use of ALTER TABLE. Levels: Global, database, table.
ALTER ROUTINE	Enable stored routines to be altered or dropped. Levels: Global, database, procedure.
CREATE	Enable database and table creation. Levels: Global, database, table.
CREATE ROUTINE	Enable stored routine creation. Levels: Global, database.
CREATE TABLESPACE	Enable tablespaces and log file groups to be created, altered, or dropped. Level: Global.
CREATE TEMPORARY TABLES	Enable use of CREATE TEMPORARY TABLE. Levels: Global, database.
CREATE USER	Enable use of CREATE USER, DROP USER, RENAME USER, and REVOKE ALL PRIVILEGES. Level: Global.
CREATE VIEW	Enable views to be created or altered. Levels: Global, database, table.
DELETE	Enable use of DELETE. Level: Global, database, table.
DROP	Enable databases, tables, and views to be dropped. Levels: Global, database, table.
EVENT	Enable use of events for the Event Scheduler. Levels: Global, database.
EXECUTE	Enable the user to execute stored routines. Levels: Global, database, table.
FILE	Enable the user to cause the server to read or write files. Level: Global.
GRANT OPTION	Enable privileges to be granted to or removed from other accounts. Levels: Global, database, table, procedure, proxy.
INDEX	Enable indexes to be created or dropped. Levels: Global, database, table.
INSERT	Enable use of INSERT. Levels: Global, database, table, column.

Privilege	Meaning and Grantable Levels
LOCK TABLES	Enable use of LOCK TABLES on tables for which you have the SELECT privilege. Levels: Global, database.
PROCESS	Enable the user to see all processes with SHOW PROCESSLIST. Level: Global.
PROXY	Enable user proxying. Level: From user to user.
REFERENCES	Enable foreign key creation. Levels: Global, database, table, column.
RELOAD	Enable use of FLUSH operations. Level: Global.
REPLICATION CLIENT	Enable the user to ask where master or slave servers are. Level: Global.
REPLICATION SLAVE	Enable replication slaves to read binary log events from the master. Level: Global.
SELECT	Enable use of SELECT. Levels: Global, database, table, column.
SHOW DATABASES	Enable SHOW DATABASES to show all databases. Level: Global.
SHOW VIEW	Enable use of SHOW CREATE VIEW. Levels: Global, database, table.
SHUTDOWN	Enable use of mysqladmin shutdown. Level: Global.
SUPER	Enable use of other administrative operations such as CHANGE MASTER TO, KILL, PURGE BINARY LOGS, SET GLOBAL, and mysqladmin debug command. Level: Global.
TRIGGER	Enable trigger operations. Levels: Global, database, table.
UPDATE	Enable use of UPDATE. Levels: Global, database, table, column.
USAGE	Synonym for “no privileges”

A trigger is associated with a table. To create or drop a trigger, you must have the TRIGGER privilege for the table, not the trigger.

In GRANT statements, the ALL [PRIVILEGES] or PROXY privilege must be named by itself and cannot be specified along with other privileges. ALL [PRIVILEGES] stands for all privileges available for the level at which privileges are to be granted except for the GRANT OPTION and PROXY privileges.

USAGE can be specified to create a user that has no privileges, or to specify the REQUIRE or WITH clauses for an account without changing its existing privileges.

MySQL account information is stored in the tables of the mysql database. For additional details, consult Section 6.2, “The MySQL Access Privilege System”, which discusses the mysql database and the access control system extensively.

If the grant tables hold privilege rows that contain mixed-case database or table names and the lower_case_table_names system variable is set to a nonzero value, REVOKE cannot be used to revoke these privileges. It will be necessary to manipulate the grant tables directly. (GRANT will not create such rows when lower_case_table_names is set, but such rows might have been created prior to setting that variable.)

Privileges can be granted at several levels, depending on the syntax used for the ON clause. For REVOKE, the same ON syntax specifies which privileges to remove.

For the global, database, table, and routine levels, GRANT ALL assigns only the privileges that exist at the level you are granting. For example, GRANT ALL ON *db_name*.* is a database-level statement, so it does not grant any global-only privileges such as FILE. Granting ALL does not assign the GRANT OPTION or PROXY privilege.

The *object_type* clause, if present, should be specified as TABLE, FUNCTION, or PROCEDURE when the following object is a table, a stored function, or a stored procedure.

The privileges for a database, table, column, or routine are formed additively as the logical `OR` of the privileges at each of the privilege levels. For example, if a user has a global `SELECT` privilege, the privilege cannot be denied by an absence of the privilege at the database, table, or column level. Details of the privilege-checking procedure are presented in Section 6.2.5, “Access Control, Stage 2: Request Verification”.

If you are using table, column, or routine privileges for even one user, the server examines table, column, and routine privileges for all users and this slows down MySQL a bit. Similarly, if you limit the number of queries, updates, or connections for any users, the server must monitor these values.

MySQL enables you to grant privileges on databases or tables that do not exist. For tables, the privileges to be granted must include the `CREATE` privilege. *This behavior is by design*, and is intended to enable the database administrator to prepare user accounts and privileges for databases or tables that are to be created at a later time.

Important

MySQL does not automatically revoke any privileges when you drop a database or table. However, if you drop a routine, any routine-level privileges granted for that routine are revoked.

Global Privileges

Global privileges are administrative or apply to all databases on a given server. To assign global privileges, use `ON *.*` syntax:

```
GRANT ALL ON *.* TO 'someuser'@'somehost';
GRANT SELECT, INSERT ON *.* TO 'someuser'@'somehost';
```

The `CREATE TABLESPACE`, `CREATE USER`, `FILE`, `PROCESS`, `RELOAD`, `REPLICATION CLIENT`, `REPLICATION SLAVE`, `SHOW DATABASES`, `SHUTDOWN`, and `SUPER` privileges are administrative and can only be granted globally.

Other privileges can be granted globally or at more specific levels.

`GRANT OPTION` granted at the global level for any global privilege applies to all global privileges.

MySQL stores global privileges in the `mysql.user` system table.

Database Privileges

Database privileges apply to all objects in a given database. To assign database-level privileges, use `ON db_name.*` syntax:

```
GRANT ALL ON mydb.* TO 'someuser'@'somehost';
GRANT SELECT, INSERT ON mydb.* TO 'someuser'@'somehost';
```

If you use `ON *` syntax (rather than `ON *.*`) and you have selected a default database, privileges are assigned at the database level for the default database. An error occurs if there is no default database.

The `CREATE`, `DROP`, `EVENT`, `GRANT OPTION`, `LOCK TABLES`, and `REFERENCES` privileges can be specified at the database level. Table or routine privileges also can be specified at the database level, in which case they apply to all tables or routines in the database.

MySQL stores database privileges in the `mysql.db` system table.

Table Privileges

Table privileges apply to all columns in a given table. To assign table-level privileges, use `ON db_name.tbl_name` syntax:

```
GRANT ALL ON mydb.mytbl TO 'someuser'@'somehost';
GRANT SELECT, INSERT ON mydb.mytbl TO 'someuser'@'somehost';
```

If you specify *`tbl_name`* rather than *`db_name.tbl_name`*, the statement applies to *`tbl_name`* in the default database. An error occurs if there is no default database.

The permissible *`priv_type`* values at the table level are `ALTER`, `CREATE VIEW`, `CREATE`, `DELETE`, `DROP`, `GRANT OPTION`, `INDEX`, `INSERT`, `REFERENCES`, `SELECT`, `SHOW VIEW`, `TRIGGER`, and `UPDATE`.

MySQL stores table privileges in the `mysql.tables_priv` system table.

Column Privileges

Column privileges apply to single columns in a given table. Each privilege to be granted at the column level must be followed by the column or columns, enclosed within parentheses.

```
GRANT SELECT (col1), INSERT (col1,col2) ON mydb.mytbl TO 'someuser'@'somehost';
```

The permissible *`priv_type`* values for a column (that is, when you use a *`column_list`* clause) are `INSERT`, `REFERENCES`, `SELECT`, and `UPDATE`.

MySQL stores column privileges in the `mysql.columns_priv` system table.

Stored Routine Privileges

The `ALTER ROUTINE`, `CREATE ROUTINE`, `EXECUTE`, and `GRANT OPTION` privileges apply to stored routines (procedures and functions). They can be granted at the global and database levels. Except for `CREATE ROUTINE`, these privileges can be granted at the routine level for individual routines.

```
GRANT CREATE ROUTINE ON mydb.* TO 'someuser'@'somehost';
GRANT EXECUTE ON PROCEDURE mydb.myproc TO 'someuser'@'somehost';
```

The permissible *`priv_type`* values at the routine level are `ALTER ROUTINE`, `EXECUTE`, and `GRANT OPTION`. `CREATE ROUTINE` is not a routine-level privilege because you must have this privilege to create a routine in the first place.

MySQL stores routine-level privileges in the `mysql.procs_priv` system table.

Proxy User Privileges

The `PROXY` privilege enables one user to be a proxy for another. The proxy user impersonates or takes the identity of the proxied user.

```
GRANT PROXY ON 'localuser'@'localhost' TO 'externaluser'@'somehost';
```

When `PROXY` is granted, it must be the only privilege named in the `GRANT` statement, the `REQUIRE` clause cannot be given, and the only permitted `WITH` option is `WITH GRANT OPTION`.

Proxying requires that the proxy user authenticate through a plugin that returns the name of the proxied user to the server when the proxy user connects, and that the proxy user have the `PROXY` privilege for the proxied user. For details and examples, see Section 6.3.7, “Proxy Users”.

MySQL stores proxy privileges in the `mysql.proxies_priv` system table.

Account Names and Passwords

A *`user`* value in a `GRANT` statement indicates a MySQL account to which the statement applies. To accommodate granting rights to users from arbitrary hosts, MySQL supports specifying the *`user`* value in the form *`'user_name'@'host_name'`*.

You can specify wildcards in the host name. For example, `'user_name'@'%.example.com'` applies to *`user_name`* for any host in the `example.com` domain, and `'user_name'@'198.51.100.%'` applies to *`user_name`* for any host in the `198.51.100` class C subnet.

The simple form `'user_name'` is a synonym for `'user_name'@'%'`.

MySQL does not support wildcards in user names. To refer to an anonymous user, specify an account with an empty user name with the `GRANT` statement:

```
GRANT ALL ON test.* TO ''@'localhost' ...;
```

In this case, any user who connects from the local host with the correct password for the anonymous user will be permitted access, with the privileges associated with the anonymous-user account.

For additional information about user name and host name values in account names, see Section 6.2.3, “Specifying Account Names”.

Warning

If you permit local anonymous users to connect to the MySQL server, you should also grant privileges to all local users as `'user_name'@'localhost'`. Otherwise, the anonymous user account for `localhost` in the `mysql.user` system table (created during MySQL installation) is used when named users try to log in to the MySQL server from the local machine. For details, see Section 6.2.4, “Access Control, Stage 1: Connection Verification”.

To determine whether this issue applies to you, execute the following query, which lists any anonymous users:

```
SELECT Host, User FROM mysql.user WHERE User='';
```

To avoid the problem just described, delete the local anonymous user account using this statement:

```
DROP USER ''@'localhost';
```

For `GRANT` syntaxes that permit an *`auth_option`* value to follow a *`user`* value, *`auth_option`* begins with `IDENTIFIED` and indicates how the account authenticates by specifying an account authentication plugin, credentials (for example, a password), or both. Syntax of the *`auth_option`* clause is the same as for the `CREATE USER` statement. For details, see Section 13.7.1.1, “CREATE USER Syntax”.

When `IDENTIFIED` is present and you have the global grant privilege (`GRANT OPTION`), any password specified becomes the new password for the account, even if the account exists and already has a password. Without `IDENTIFIED`, the account password remains unchanged.

Implicit Account Creation

If an account named in a `GRANT` statement does not exist, the action taken depends on the `NO_AUTO_CREATE_USER` SQL mode:

- If `NO_AUTO_CREATE_USER` is not enabled, `GRANT` creates the account. *This is very insecure* unless you specify a nonempty password using `IDENTIFIED BY`.
- If `NO_AUTO_CREATE_USER` is enabled, `GRANT` fails and does not create the account, unless you specify a nonempty password using `IDENTIFIED BY` or name an authentication plugin using `IDENTIFIED WITH`.

Other Account Characteristics

MySQL can check X509 certificate attributes in addition to the usual authentication that is based on the user name and credentials. For background information on the use of SSL with MySQL, see Section 6.4, “Using Encrypted Connections”.

The optional `REQUIRE` clause specifies SSL-related options for a MySQL account, using one or more *`tls_option`* values.

Order of `REQUIRE` options does not matter, but no option can be specified twice. The `AND` keyword is optional between `REQUIRE` options.

`GRANT` permits these *`tls_option`* values:

- `NONE`

  Indicates that the account has no SSL or X509 requirements.

  ```
  GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
    REQUIRE SSL;
  ```

  Unencrypted connections are permitted if the user name and password are valid. Encrypted connections can be used, at the client's option, if the client has the proper certificate and key files. That is, the client need not specify any SSL command options, in which case the connection will be unencrypted. To use an encrypted connection, the client must specify either the `--ssl-ca` option, or all three of the `--ssl-ca`, `--ssl-key`, and `--ssl-cert` options.

  `NONE` is the default if no SSL-related `REQUIRE` options are specified.

- `SSL`

  Tells the server to permit only encrypted connections for the account.

  ```
  GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
    REQUIRE NONE;
  ```

  To connect, the client must specify the `--ssl-ca` option to authenticate the server certificate, and may additionally specify the `--ssl-key` and `--ssl-cert` options. If neither the `--ssl-ca` option nor `--ssl-capath` option is specified, the client does not authenticate the server certificate.

- `X509`

  Requires that clients present a valid certificate, but the exact certificate, issuer, and subject do not matter. The only requirement is that it should be possible to verify its signature with one of the CA certificates. Use of X509 certificates always implies encryption, so the `SSL` option is unnecessary in this case.

  ```
  GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
    REQUIRE X509;
  ```

  For accounts with `REQUIRE X509`, clients must specify the `--ssl-key` and `--ssl-cert` options to connect. (It is recommended but not required that `--ssl-ca` also be specified so that the public certificate provided by the server can be verified.) This is true for `ISSUER` and `SUBJECT` as well because those `REQUIRE` options imply the requirements of `X509`.

- `ISSUER '`*`issuer`*`'`

  Requires that clients present a valid X509 certificate issued by CA `'`*`issuer`*`'`. If a client presents a certificate that is valid but has a different issuer, the server rejects the connection. Use of X509 certificates always implies encryption, so the `SSL` option is unnecessary in this case.

  ```
  GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
  ```

```
  REQUIRE ISSUER '/C=SE/ST=Stockholm/L=Stockholm/
    O=MySQL/CN=CA/emailAddress=ca@example.com';
```

Because `ISSUER` implies the requirements of `X509`, clients must specify the `--ssl-key` and `--ssl-cert` options to connect. (It is recommended but not required that `--ssl-ca` also be specified so that the public certificate provided by the server can be verified.)

Note

If MySQL is linked against a version of OpenSSL older than 0.9.6h, use `Email` rather than `emailAddress` in the *`'issuer'`* value.

- `SUBJECT '`*`subject`*`'`

  Requires that clients present a valid X509 certificate containing the subject *`subject`*. If a client presents a certificate that is valid but has a different subject, the server rejects the connection. Use of X509 certificates always implies encryption, so the `SSL` option is unnecessary in this case.

```
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
  REQUIRE SUBJECT '/C=SE/ST=Stockholm/L=Stockholm/
    O=MySQL demo client certificate/
    CN=client/emailAddress=client@example.com';
```

  MySQL does a simple string comparison of the *`'subject'`* value to the value in the certificate, so lettercase and component ordering must be given exactly as present in the certificate.

Note

Regarding `emailAddress`, see the note in the description of `REQUIRE ISSUER`.

  Because `SUBJECT` implies the requirements of `X509`, clients must specify the `--ssl-key` and `--ssl-cert` options to connect. (It is recommended but not required that `--ssl-ca` also be specified so that the public certificate provided by the server can be verified.)

- `CIPHER '`*`cipher`*`'`

  Requires a specific cipher method for encrypting connections. This option is needed to ensure that ciphers and key lengths of sufficient strength are used. SSL itself can be weak if old algorithms using short encryption keys are used.

```
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
  REQUIRE CIPHER 'EDH-RSA-DES-CBC3-SHA';
```

The `SUBJECT`, `ISSUER`, and `CIPHER` options can be combined in the `REQUIRE` clause like this:

```
GRANT ALL PRIVILEGES ON test.* TO 'root'@'localhost'
  REQUIRE SUBJECT '/C=SE/ST=Stockholm/L=Stockholm/
    O=MySQL demo client certificate/
    CN=client/emailAddress=client@example.com'
  AND ISSUER '/C=SE/ST=Stockholm/L=Stockholm/
    O=MySQL/CN=CA/emailAddress=ca@example.com'
  AND CIPHER 'EDH-RSA-DES-CBC3-SHA';
```

The optional `WITH` clause is used for these purposes:

- To enable a user to grant privileges to other users
- To specify resource limits for a user

The `WITH GRANT OPTION` clause gives the user the ability to give to other users any privileges the user has at the specified privilege level.

To grant the GRANT OPTION privilege to an account without otherwise changing its privileges, do this:

```
GRANT USAGE ON *.* TO 'someuser'@'somehost' WITH GRANT OPTION;
```

Be careful to whom you give the GRANT OPTION privilege because two users with different privileges may be able to combine privileges!

You cannot grant another user a privilege which you yourself do not have; the GRANT OPTION privilege enables you to assign only those privileges which you yourself possess.

Be aware that when you grant a user the GRANT OPTION privilege at a particular privilege level, any privileges the user possesses (or may be given in the future) at that level can also be granted by that user to other users. Suppose that you grant a user the INSERT privilege on a database. If you then grant the SELECT privilege on the database and specify WITH GRANT OPTION, that user can give to other users not only the SELECT privilege, but also INSERT. If you then grant the UPDATE privilege to the user on the database, the user can grant INSERT, SELECT, and UPDATE.

For a nonadministrative user, you should not grant the ALTER privilege globally or for the mysql database. If you do that, the user can try to subvert the privilege system by renaming tables!

For additional information about security risks associated with particular privileges, see Section 6.2.1, “Privileges Provided by MySQL”.

It is possible to place limits on use of server resources by an account, as discussed in Section 6.3.4, “Setting Account Resource Limits”. To do so, use a WITH clause that specifies one or more *resource_option* values. Limits not specified retain their current values.

Order of WITH options does not matter, except that if a given resource limit is specified multiple times, the last instance takes precedence.

GRANT permits these *resource_option* values:

- MAX_QUERIES_PER_HOUR *count*, MAX_UPDATES_PER_HOUR *count*, MAX_CONNECTIONS_PER_HOUR *count*

  These options restrict how many queries, updates, and connections to the server are permitted to this account during any given one-hour period. (Queries for which results are served from the query cache do not count against the MAX_QUERIES_PER_HOUR limit.) If *count* is 0 (the default), this means that there is no limitation for the account.

- MAX_USER_CONNECTIONS *count*

  Restricts the maximum number of simultaneous connections to the server by the account. A nonzero *count* specifies the limit for the account explicitly. If *count* is 0 (the default), the server determines the number of simultaneous connections for the account from the global value of the max_user_connections system variable. If max_user_connections is also zero, there is no limit for the account.

To specify resource limits for an existing user without affecting existing privileges, use GRANT USAGE at the global level (ON *.*) and name the limits to be changed. For example:

```
GRANT USAGE ON *.* TO ...
  WITH MAX_QUERIES_PER_HOUR 500 MAX_UPDATES_PER_HOUR 100;
```

MySQL and Standard SQL Versions of GRANT

The biggest differences between the MySQL and standard SQL versions of GRANT are:

- MySQL associates privileges with the combination of a host name and user name and not with only a user name.

- Standard SQL does not have global or database-level privileges, nor does it support all the privilege types that MySQL supports.
- MySQL does not support the standard SQL `UNDER` privilege.
- Standard SQL privileges are structured in a hierarchical manner. If you remove a user, all privileges the user has been granted are revoked. This is also true in MySQL if you use `DROP USER`. See Section 13.7.1.2, “DROP USER Syntax”.
- In standard SQL, when you drop a table, all privileges for the table are revoked. In standard SQL, when you revoke a privilege, all privileges that were granted based on that privilege are also revoked. In MySQL, privileges can be dropped only with explicit `DROP USER` or `REVOKE` statements or by manipulating the MySQL grant tables directly.
- In MySQL, it is possible to have the `INSERT` privilege for only some of the columns in a table. In this case, you can still execute `INSERT` statements on the table, provided that you insert values only for those columns for which you have the `INSERT` privilege. The omitted columns are set to their implicit default values if strict SQL mode is not enabled. In strict mode, the statement is rejected if any of the omitted columns have no default value. (Standard SQL requires you to have the `INSERT` privilege on all columns.) For information about strict SQL mode and implicit default values, see Section 5.1.8, “Server SQL Modes”, and Section 11.6, “Data Type Default Values”.

13.7.1.4 RENAME USER Syntax

```
RENAME USER old_user TO new_user
    [, old_user TO new_user] ...
```

The `RENAME USER` statement renames existing MySQL accounts. An error occurs for old accounts that do not exist or new accounts that already exist.

To use `RENAME USER`, you must have the global `CREATE USER` privilege, or the `UPDATE` privilege for the `mysql` database. When the `read_only` system variable is enabled, `RENAME USER` additionally requires the `SUPER` privilege.

Each account name uses the format described in Section 6.2.3, “Specifying Account Names”. For example:

```
RENAME USER 'jeffrey'@'localhost' TO 'jeff'@'127.0.0.1';
```

The host name part of the account name, if omitted, defaults to `'%'`.

`RENAME USER` causes the privileges held by the old user to be those held by the new user. However, `RENAME USER` does not automatically drop or invalidate databases or objects within them that the old user created. This includes stored programs or views for which the `DEFINER` attribute names the old user. Attempts to access such objects may produce an error if they execute in definer security context. (For information about security context, see Section 20.6, “Access Control for Stored Programs and Views”.)

The privilege changes take effect as indicated in Section 6.2.6, “When Privilege Changes Take Effect”.

13.7.1.5 REVOKE Syntax

```
REVOKE
    priv_type [(column_list)]
      [, priv_type [(column_list)]] ...
    ON [object_type] priv_level
    FROM user [, user] ...

REVOKE ALL [PRIVILEGES], GRANT OPTION
    FROM user [, user] ...
```

```
REVOKE PROXY ON user
    FROM user [, user] ...
```

The REVOKE statement enables system administrators to revoke privileges from MySQL accounts.

When the read_only system variable is enabled, REVOKE requires the SUPER privilege in addition to any other required privileges described in the following discussion.

Each account name uses the format described in Section 6.2.3, “Specifying Account Names”. For example:

```
REVOKE INSERT ON *.* FROM 'jeffrey'@'localhost';
```

The host name part of the account name, if omitted, defaults to '%'.

For details on the levels at which privileges exist, the permissible *priv_type*, *priv_level*, and *object_type* values, and the syntax for specifying users and passwords, see Section 13.7.1.3, “GRANT Syntax”

To use the first REVOKE syntax, you must have the GRANT OPTION privilege, and you must have the privileges that you are revoking.

To revoke all privileges, use the second syntax, which drops all global, database, table, column, and routine privileges for the named user or users:

```
REVOKE ALL PRIVILEGES, GRANT OPTION FROM user [, user] ...
```

To use this REVOKE syntax, you must have the global CREATE USER privilege, or the UPDATE privilege for the mysql database.

User accounts from which privileges are to be revoked must exist.

REVOKE removes privileges, but does not drop mysql.user table entries. To remove a user account entirely, use DROP USER. See Section 13.7.1.2, “DROP USER Syntax”.

If the grant tables hold privilege rows that contain mixed-case database or table names and the lower_case_table_names system variable is set to a nonzero value, REVOKE cannot be used to revoke these privileges. It will be necessary to manipulate the grant tables directly. (GRANT will not create such rows when lower_case_table_names is set, but such rows might have been created prior to setting the variable.)

When successfully executed from the mysql program, REVOKE responds with Query OK, 0 rows affected. To determine what privileges remain after the operation, use SHOW GRANTS. See Section 13.7.5.22, “SHOW GRANTS Syntax”.

13.7.1.6 SET PASSWORD Syntax

```
SET PASSWORD [FOR user] = password_option

password_option: {
    PASSWORD('auth_string')
  | OLD_PASSWORD('auth_string')
  | 'hash_string'
}
```

The SET PASSWORD statement assigns a password to a MySQL user account, specified as either a cleartext (unencrypted) or encrypted value:

- *'auth_string'* represents a cleartext password.
- *'hash_string'* represents an encrypted password.

Important

`SET PASSWORD` may be recorded in server logs or on the client side in a history file such as `~/.mysql_history`, which means that cleartext passwords may be read by anyone having read access to that information. For information about password logging in the server logs, see Section 6.1.2.3, "Passwords and Logging". For similar information about client-side logging, see Section 4.5.1.3, "mysql Logging".

`SET PASSWORD` can be used with or without a `FOR` clause that explicitly names a user account:

- With a `FOR user` clause, the statement sets the password for the named account, which must exist:

```
SET PASSWORD FOR 'jeffrey'@'localhost' = password_option;
```

- With no `FOR user` clause, the statement sets the password for the current user:

```
SET PASSWORD = password_option;
```

  Any client who connects to the server using a nonanonymous account can change the password for that account. To see which account the server authenticated you as, invoke the `CURRENT_USER()` function:

```
SELECT CURRENT_USER();
```

Setting the password for a named account (with a `FOR` clause) requires the `UPDATE` privilege for the `mysql` database. Setting the password for yourself (for a nonanonymous account with no `FOR` clause) requires no special privileges. When the `read_only` system variable is enabled, `SET PASSWORD` requires the `SUPER` privilege in addition to any other required privileges.

If a `FOR user` clause is given, the account name uses the format described in Section 6.2.3, "Specifying Account Names". For example:

```
SET PASSWORD FOR 'bob'@'%.example.org' = PASSWORD('auth_string');
```

The host name part of the account name, if omitted, defaults to `'%'`.

The password can be specified in these ways:

- Use the `PASSWORD()` function

  The `PASSWORD()` argument is the cleartext (unencrypted) password. `PASSWORD()` hashes the password and returns the encrypted password string for storage in the `mysql.user` account row.

  The `PASSWORD()` function hashes the password using the hashing method determined by the value of the `old_passwords` system variable value. It should be set to a value compatible with the hash format required by the account authentication plugin. For example, if the account uses the `mysql_native_password` authentication plugin, `old_passwords` should be 0 for `PASSWORD()` to produce a hash value in the correct format. For `mysql_old_password`, `old_passwords` should be 1.

  Permitted `old_passwords` values are described later in this section.

- Use the `OLD_PASSWORD()` function:

  The `'auth_string'` function argument is the cleartext (unencrypted) password. `OLD_PASSWORD()` hashes the password using pre-4.1 hashing and returns the encrypted password string for storage in the `mysql.user` account row. This hashing method is appropriate only for accounts that use the `mysql_old_password` authentication plugin.

- Use an already encrypted password string

  The password is specified as a string literal. It must represent the already encrypted password value, in the hash format required by the authentication method used for the account.

The following table shows, for each password hashing method, the permitted value of `old_passwords` and which authentication plugins use the hashing method.

Password Hashing Method	old_passwords Value	Associated Authentication Plugin
MySQL 4.1 native hashing	`0` or `OFF`	`mysql_native_password`
Pre-4.1 (“old”) hashing	`1` or `ON`	`mysql_old_password`

Caution

If you are connecting to a MySQL 4.1 or later server using a pre-4.1 client program, do not change your password without first reading Section 6.1.2.4, “Password Hashing in MySQL”. The default password hashing format changed in MySQL 4.1, and if you change your password, it might be stored using a hashing format that pre-4.1 clients cannot generate, thus preventing you from connecting to the server afterward.

For additional information about setting passwords and authentication plugins, see Section 6.3.5, “Assigning Account Passwords”, and Section 6.3.6, “Pluggable Authentication”.

13.7.2 Table Maintenance Statements

13.7.2.1 ANALYZE TABLE Syntax

```
ANALYZE [NO_WRITE_TO_BINLOG | LOCAL]
    TABLE tbl_name [, tbl_name] ...
```

`ANALYZE TABLE` performs a key distribution analysis and stores the distribution for the named table or tables. For `MyISAM` tables, this statement is equivalent to using `myisamchk --analyze`.

This statement requires `SELECT` and `INSERT` privileges for the table.

`ANALYZE TABLE` works with `InnoDB`, `NDB`, and `MyISAM` tables. It does not work with views.

`ANALYZE TABLE` is supported for partitioned tables, and you can use `ALTER TABLE ... ANALYZE PARTITION` to analyze one or more partitions; for more information, see Section 13.1.7, “ALTER TABLE Syntax”, and Section 19.3.3, “Maintenance of Partitions”.

During the analysis, the table is locked with a read lock for `InnoDB` and `MyISAM`.

By default, the server writes `ANALYZE TABLE` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

- ANALYZE TABLE Output
- Key Distribution Analysis

ANALYZE TABLE Output

`ANALYZE TABLE` returns a result set with the columns shown in the following table.

Column	Value
`Table`	The table name
`Op`	Always `analyze`

Column	Value
`Msg_type`	`status`, `error`, `info`, `note`, or `warning`
`Msg_text`	An informational message

Key Distribution Analysis

If the table has not changed since the last key distribution analysis, the table is not analyzed again.

MySQL uses the stored key distribution to decide the table join order for joins on something other than a constant. In addition, key distributions can be used when deciding which indexes to use for a specific table within a query.

For more information on how key distribution analysis works within `InnoDB`, see Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”. Also see Section 14.9.11.1, “Estimating ANALYZE TABLE Complexity for InnoDB Tables” and Section 14.11.1.7, “Limits on InnoDB Tables”.

To check the stored key distribution cardinality, use the `SHOW INDEX` statement or the `INFORMATION_SCHEMA.STATISTICS` table. See Section 13.7.5.23, “SHOW INDEX Syntax”, and Section 21.20, “The INFORMATION_SCHEMA STATISTICS Table”.

13.7.2.2 CHECK TABLE Syntax

```
CHECK TABLE tbl_name [, tbl_name] ... [option] ...

option = {
    FOR UPGRADE
  | QUICK
  | FAST
  | MEDIUM
  | EXTENDED
  | CHANGED
}
```

`CHECK TABLE` checks a table or tables for errors. For `MyISAM` tables, the key statistics are updated as well. `CHECK TABLE` can also check views for problems, such as tables that are referenced in the view definition that no longer exist.

To check a table, you must have some privilege for it.

`CHECK TABLE` works for `InnoDB`, `MyISAM`, `ARCHIVE`, and `CSV` tables.

Before running `CHECK TABLE` on `InnoDB` tables, see CHECK TABLE Usage Notes for InnoDB Tables.

`CHECK TABLE` is supported for partitioned tables, and you can use `ALTER TABLE ... CHECK PARTITION` to check one or more partitions; for more information, see Section 13.1.7, “ALTER TABLE Syntax”, and Section 19.3.3, “Maintenance of Partitions”.

- CHECK TABLE Output
- Checking Version Compatibility
- Checking Data Consistency
- CHECK TABLE Usage Notes for InnoDB Tables

CHECK TABLE Output

`CHECK TABLE` returns a result set with the columns shown in the following table.

Column	Value
`Table`	The table name
`Op`	Always `check`

Column	Value
`Msg_type`	`status`, `error`, `info`, `note`, or `warning`
`Msg_text`	An informational message

The statement might produce many rows of information for each checked table. The last row has a `Msg_type` value of `status` and the `Msg_text` normally should be `OK`. For a `MyISAM` table, if you don't get `OK` or `Table is already up to date`, you should normally run a repair of the table. See Section 7.6, “MyISAM Table Maintenance and Crash Recovery”. `Table is already up to date` means that the storage engine for the table indicated that there was no need to check the table.

Checking Version Compatibility

The `FOR UPGRADE` option checks whether the named tables are compatible with the current version of MySQL. With `FOR UPGRADE`, the server checks each table to determine whether there have been any incompatible changes in any of the table's data types or indexes since the table was created. If not, the check succeeds. Otherwise, if there is a possible incompatibility, the server runs a full check on the table (which might take some time). If the full check succeeds, the server marks the table's `.frm` file with the current MySQL version number. Marking the `.frm` file ensures that further checks for the table with the same version of the server will be fast.

Incompatibilities might occur because the storage format for a data type has changed or because its sort order has changed. Our aim is to avoid these changes, but occasionally they are necessary to correct problems that would be worse than an incompatibility between releases.

`FOR UPGRADE` discovers these incompatibilities:

- The indexing order for end-space in `TEXT` columns for `InnoDB` and `MyISAM` tables changed between MySQL 4.1 and 5.0.
- The storage method of the new `DECIMAL` data type changed between MySQL 5.0.3 and 5.0.5.
- If your table was created by a different version of the MySQL server than the one you are currently running, `FOR UPGRADE` indicates that the table has an `.frm` file with an incompatible version. In this case, the result set returned by `CHECK TABLE` contains a line with a `Msg_type` value of `error` and a `Msg_text` value of `Table upgrade required. Please do "REPAIR TABLE` `` `tbl_name` `` `" to fix it!`
- Changes are sometimes made to character sets or collations that require table indexes to be rebuilt. For details about such changes, see Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”. For information about rebuilding tables, see Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”.

Checking Data Consistency

The following table shows the other check options that can be given. These options are passed to the storage engine, which may use or ignore them.

Type	Meaning
`QUICK`	Do not scan the rows to check for incorrect links. Applies to `InnoDB` and `MyISAM` tables and views.
`FAST`	Check only tables that have not been closed properly. Applies only to `MyISAM` tables and views; ignored for `InnoDB`.
`CHANGED`	Check only tables that have been changed since the last check or that have not been closed properly. Applies only to `MyISAM` tables and views; ignored for `InnoDB`.
`MEDIUM`	Scan rows to verify that deleted links are valid. This also calculates a key checksum for the rows and verifies this with a calculated checksum for the keys. Applies only to `MyISAM` tables and views; ignored for `InnoDB`.

Type	Meaning
EXTENDED	Do a full key lookup for all keys for each row. This ensures that the table is 100% consistent, but takes a long time. Applies only to MyISAM tables and views; ignored for InnoDB.

If none of the options QUICK, MEDIUM, or EXTENDED are specified, the default check type for dynamic-format MyISAM tables is MEDIUM. This has the same result as running myisamchk --medium-check *tbl_name* on the table. The default check type also is MEDIUM for static-format MyISAM tables, unless CHANGED or FAST is specified. In that case, the default is QUICK. The row scan is skipped for CHANGED and FAST because the rows are very seldom corrupted.

You can combine check options, as in the following example that does a quick check on the table to determine whether it was closed properly:

```
CHECK TABLE test_table FAST QUICK;
```

Note

If CHECK TABLE finds no problems with a table that is marked as "corrupted" or "not closed properly", CHECK TABLE may remove the mark.

If a table is corrupted, the problem is most likely in the indexes and not in the data part. All of the preceding check types check the indexes thoroughly and should thus find most errors.

To check a table that you assume is okay, use no check options or the QUICK option. The latter should be used when you are in a hurry and can take the very small risk that QUICK does not find an error in the data file. (In most cases, under normal usage, MySQL should find any error in the data file. If this happens, the table is marked as "corrupted" and cannot be used until it is repaired.)

FAST and CHANGED are mostly intended to be used from a script (for example, to be executed from cron) to check tables periodically. In most cases, FAST is to be preferred over CHANGED. (The only case when it is not preferred is when you suspect that you have found a bug in the MyISAM code.)

EXTENDED is to be used only after you have run a normal check but still get errors from a table when MySQL tries to update a row or find a row by key. This is very unlikely if a normal check has succeeded.

Use of CHECK TABLE ... EXTENDED might influence execution plans generated by the query optimizer.

Some problems reported by CHECK TABLE cannot be corrected automatically:

- Found row where the auto_increment column has the value 0.

  This means that you have a row in the table where the AUTO_INCREMENT index column contains the value 0. (It is possible to create a row where the AUTO_INCREMENT column is 0 by explicitly setting the column to 0 with an UPDATE statement.)

  This is not an error in itself, but could cause trouble if you decide to dump the table and restore it or do an ALTER TABLE on the table. In this case, the AUTO_INCREMENT column changes value according to the rules of AUTO_INCREMENT columns, which could cause problems such as a duplicate-key error.

  To get rid of the warning, execute an UPDATE statement to set the column to some value other than 0.

CHECK TABLE Usage Notes for InnoDB Tables

The following notes apply to InnoDB tables:

- If CHECK TABLE encounters a corrupt page, the server exits to prevent error propagation (Bug #10132). If the corruption occurs in a secondary index but table data is readable, running CHECK TABLE can still cause a server exit.
- If CHECK TABLE encounters a corrupted DB_TRX_ID or DB_ROLL_PTR field in a clustered index, CHECK TABLE can cause InnoDB to access an invalid undo log record, resulting in an MVCC-related server exit.
- If CHECK TABLE encounters errors in InnoDB tables or indexes, it reports an error, and usually marks the index and sometimes marks the table as corrupted, preventing further use of the index or table. Such errors include an incorrect number of entries in a secondary index or incorrect links.
- If CHECK TABLE finds an incorrect number of entries in a secondary index, it reports an error but does not cause a server exit or prevent access to the file.
- CHECK TABLE surveys the index page structure, then surveys each key entry. It does not validate the key pointer to a clustered record or follow the path for BLOB pointers.
- When an InnoDB table is stored in its own .ibd file, the first 3 pages of the .ibd file contain header information rather than table or index data. The CHECK TABLE statement does not detect inconsistencies that affect only the header data. To verify the entire contents of an InnoDB .ibd file, use the innochecksum command.
- When running CHECK TABLE on large InnoDB tables, other threads may be blocked during CHECK TABLE execution. To avoid timeouts, the semaphore wait threshold (600 seconds) is extended by 2 hours (7200 seconds) for CHECK TABLE operations. If InnoDB detects semaphore waits of 240 seconds or more, it starts printing InnoDB monitor output to the error log. If a lock request extends beyond the semaphore wait threshold, InnoDB aborts the process. To avoid the possibility of a semaphore wait timeout entirely, run CHECK TABLE QUICK instead of CHECK TABLE.

13.7.2.3 CHECKSUM TABLE Syntax

```
CHECKSUM TABLE tbl_name [, tbl_name] ... [QUICK | EXTENDED]
```

CHECKSUM TABLE reports a table checksum.

This statement requires the SELECT privilege for the table.

This statement is not supported for views. If you run CHECKSUM TABLE against a view, the Checksum value is always NULL, and a warning is returned.

For a nonexistent table, CHECKSUM TABLE returns NULL and generates a warning.

During the checksum operation, the table is locked with a read lock for InnoDB and MyISAM.

With QUICK, the live table checksum is reported if it is available, or NULL otherwise. This is very fast. A live checksum is enabled by specifying the CHECKSUM=1 table option when you create the table; currently, this is supported only for MyISAM tables. The QUICK method is not supported with InnoDB tables. See Section 13.1.17, “CREATE TABLE Syntax”.

With EXTENDED, the entire table is read row by row and the checksum is calculated. This can be very slow for large tables.

If neither QUICK nor EXTENDED is specified, MySQL returns a live checksum if the table storage engine supports it and scans the table otherwise.

In MySQL 5.5, CHECKSUM TABLE returns 0 for partitioned tables unless you include the EXTENDED option. This issue is resolved in MySQL 5.6. (Bug #11933226, Bug #60681)

The checksum value depends on the table row format. If the row format changes, the checksum also changes. For example, the storage format for temporal types such as TIME, DATETIME, and

TIMESTAMP changes in MySQL 5.6 prior to MySQL 5.6.5, so if a 5.5 table is upgraded to MySQL 5.6, the checksum value may change.

Important

If the checksums for two tables are different, then it is almost certain that the tables are different in some way. However, because the hashing function used by CHECKSUM TABLE is not guaranteed to be collision-free, there is a slight chance that two tables which are not identical can produce the same checksum.

13.7.2.4 OPTIMIZE TABLE Syntax

```
OPTIMIZE [NO_WRITE_TO_BINLOG | LOCAL]
    TABLE tbl_name [, tbl_name] ...
```

OPTIMIZE TABLE reorganizes the physical storage of table data and associated index data, to reduce storage space and improve I/O efficiency when accessing the table. The exact changes made to each table depend on the storage engine used by that table.

Use OPTIMIZE TABLE in these cases, depending on the type of table:

- After doing substantial insert, update, or delete operations on an InnoDB table that has its own .ibd file because it was created with the innodb_file_per_table option enabled. The table and indexes are reorganized, and disk space can be reclaimed for use by the operating system.
- After deleting a large part of a MyISAM or ARCHIVE table, or making many changes to a MyISAM or ARCHIVE table with variable-length rows (tables that have VARCHAR, VARBINARY, BLOB, or TEXT columns). Deleted rows are maintained in a linked list and subsequent INSERT operations reuse old row positions. You can use OPTIMIZE TABLE to reclaim the unused space and to defragment the data file. After extensive changes to a table, this statement may also improve performance of statements that use the table, sometimes significantly.

This statement requires SELECT and INSERT privileges for the table.

OPTIMIZE TABLE works for InnoDB, MyISAM, and ARCHIVE tables. OPTIMIZE TABLE is also supported for dynamic columns of in-memory NDB tables. It does not work for fixed-width columns of in-memory tables, nor does it work for Disk Data tables. The performance of OPTIMIZE on NDB Cluster tables can be tuned using --ndb_optimization_delay, which controls the length of time to wait between processing batches of rows by OPTIMIZE TABLE. For more information, see Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”.

For NDB Cluster tables, OPTIMIZE TABLE can be interrupted by (for example) killing the SQL thread performing the OPTIMIZE operation.

By default, OPTIMIZE TABLE does *not* work for tables created using any other storage engine and returns a result indicating this lack of support. You can make OPTIMIZE TABLE work for other storage engines by starting mysqld with the --skip-new option. In this case, OPTIMIZE TABLE is just mapped to ALTER TABLE.

This statement does not work with views.

OPTIMIZE TABLE is supported for partitioned tables. For information about using this statement with partitioned tables and table partitions, see Section 19.3.3, “Maintenance of Partitions”.

By default, the server writes OPTIMIZE TABLE statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional NO_WRITE_TO_BINLOG keyword or its alias LOCAL.

- OPTIMIZE TABLE Output

- InnoDB Details
- MyISAM Details
- Other Considerations

OPTIMIZE TABLE Output

`OPTIMIZE TABLE` returns a result set with the columns shown in the following table.

Column	Value
`Table`	The table name
`Op`	Always `optimize`
`Msg_type`	`status`, `error`, `info`, `note`, or `warning`
`Msg_text`	An informational message

`OPTIMIZE TABLE` table catches and throws any errors that occur while copying table statistics from the old file to the newly created file. For example. if the user ID of the owner of the `.frm`, `.MYD`, or `.MYI` file is different from the user ID of the `mysqld` process, `OPTIMIZE TABLE` generates a "cannot change ownership of the file" error unless `mysqld` is started by the `root` user.

InnoDB Details

For `InnoDB` tables, `OPTIMIZE TABLE` is mapped to `ALTER TABLE`, which rebuilds the table to update index statistics and free unused space in the clustered index. This is displayed in the output of `OPTIMIZE TABLE` when you run it on an `InnoDB` table, as shown here:

```
mysql> OPTIMIZE TABLE foo;
+----------+----------+----------+-------------------------------------------------------------------+
| Table    | Op       | Msg_type | Msg_text                                                          |
+----------+----------+----------+-------------------------------------------------------------------+
| test.foo | optimize | note     | Table does not support optimize, doing recreate + analyze instead |
| test.foo | optimize | status   | OK                                                                |
+----------+----------+----------+-------------------------------------------------------------------+
```

This operation does not use fast index creation. Secondary indexes are not created as efficiently because keys are inserted in the order they appeared in the primary key. See Section 14.16.6, “Limitations of Fast Index Creation”.

`InnoDB` stores data using a page-allocation method and does not suffer from fragmentation in the same way that legacy storage engines (such as `MyISAM`) will. When considering whether or not to run optimize, consider the workload of transactions that your server will process:

- Some level of fragmentation is expected. `InnoDB` only fills pages 93% full, to leave room for updates without having to split pages.
- Delete operations might leave gaps that leave pages less filled than desired, which could make it worthwhile to optimize the table.
- Updates to rows usually rewrite the data within the same page, depending on the data type and row format, when sufficient space is available. See Section 14.12.5, “How Compression Works for InnoDB Tables” and Section 14.14.1, “Overview of InnoDB Row Storage”.
- High-concurrency workloads might leave gaps in indexes over time, as `InnoDB` retains multiple versions of the same data due through its MVCC mechanism. See Section 14.6, “InnoDB Multi-Versioning”.

MyISAM Details

For `MyISAM` tables, `OPTIMIZE TABLE` works as follows:

1. If the table has deleted or split rows, repair the table.
2. If the index pages are not sorted, sort them.
3. If the table's statistics are not up to date (and the repair could not be accomplished by sorting the index), update them.

Other Considerations

Note that MySQL locks the table during the time `OPTIMIZE TABLE` is running.

`OPTIMIZE TABLE` does not sort R-tree indexes, such as spatial indexes on `POINT` columns. (Bug #23578)

13.7.2.5 REPAIR TABLE Syntax

```
REPAIR [NO_WRITE_TO_BINLOG | LOCAL]
    TABLE tbl_name [, tbl_name] ...
    [QUICK] [EXTENDED] [USE_FRM]
```

`REPAIR TABLE` repairs a possibly corrupted table, for certain storage engines only.

This statement requires `SELECT` and `INSERT` privileges for the table.

Although normally you should never have to run `REPAIR TABLE`, if disaster strikes, this statement is very likely to get back all your data from a `MyISAM` table. If your tables become corrupted often, try to find the reason for it, to eliminate the need to use `REPAIR TABLE`. See Section B.5.3.3, “What to Do If MySQL Keeps Crashing”, and Section 15.3.4, “MyISAM Table Problems”.

`REPAIR TABLE` checks the table to see whether an upgrade is required. If so, it performs the upgrade, following the same rules as `CHECK TABLE ... FOR UPGRADE`. See Section 13.7.2.2, “CHECK TABLE Syntax”, for more information.

Important

- Make a backup of a table before performing a table repair operation; under some circumstances the operation might cause data loss. Possible causes include but are not limited to file system errors. See Chapter 7, *Backup and Recovery*.
- If the server crashes during a `REPAIR TABLE` operation, it is essential after restarting it that you immediately execute another `REPAIR TABLE` statement for the table before performing any other operations on it. In the worst case, you might have a new clean index file without information about the data file, and then the next operation you perform could overwrite the data file. This is an unlikely but possible scenario that underscores the value of making a backup first.
- In the event that a table on the master becomes corrupted and you run `REPAIR TABLE` on it, any resulting changes to the original table are *not* propagated to slaves.

- REPAIR TABLE Storage Engine and Partitioning Support
- REPAIR TABLE Options
- REPAIR TABLE Output
- Table Repair Considerations

REPAIR TABLE Storage Engine and Partitioning Support

`REPAIR TABLE` works for `MyISAM`, `ARCHIVE`, and `CSV` tables. For `MyISAM` tables, it has the same effect as `myisamchk --recover tbl_name` by default. This statement does not work with views.

`REPAIR TABLE` is supported for partitioned tables. However, the `USE_FRM` option cannot be used with this statement on a partitioned table.

You can use `ALTER TABLE ... REPAIR PARTITION` to repair one or more partitions; for more information, see Section 13.1.7, “ALTER TABLE Syntax”, and Section 19.3.3, “Maintenance of Partitions”.

REPAIR TABLE Options

- `NO_WRITE_TO_BINLOG` or `LOCAL`

  By default, the server writes `REPAIR TABLE` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

- `QUICK`

  If you use the `QUICK` option, `REPAIR TABLE` tries to repair only the index file, and not the data file. This type of repair is like that done by `myisamchk --recover --quick`.

- `EXTENDED`

  If you use the `EXTENDED` option, MySQL creates the index row by row instead of creating one index at a time with sorting. This type of repair is like that done by `myisamchk --safe-recover`.

- `USE_FRM`

  The `USE_FRM` option is available for use if the `.MYI` index file is missing or if its header is corrupted. This option tells MySQL not to trust the information in the `.MYI` file header and to re-create it using information from the `.frm` file. This kind of repair cannot be done with `myisamchk`.

Caution

Use the `USE_FRM` option *only* if you cannot use regular `REPAIR` modes. Telling the server to ignore the `.MYI` file makes important table metadata stored in the `.MYI` unavailable to the repair process, which can have deleterious consequences:

- The current `AUTO_INCREMENT` value is lost.
- The link to deleted records in the table is lost, which means that free space for deleted records will remain unoccupied thereafter.
- The `.MYI` header indicates whether the table is compressed. If the server ignores this information, it cannot tell that a table is compressed and repair can cause change or loss of table contents. This means that `USE_FRM` should not be used with compressed tables. That should not be necessary, anyway: Compressed tables are read only, so they should not become corrupt.

If you use `USE_FRM` for a table that was created by a different version of the MySQL server than the one you are currently running, `REPAIR TABLE` does not attempt to repair the table. In this case, the result set returned by `REPAIR TABLE` contains a line with a `Msg_type` value of `error` and a `Msg_text` value of `Failed repairing incompatible .FRM file`.

If `USE_FRM` is used, `REPAIR TABLE` does not check the table to see whether an upgrade is required.

REPAIR TABLE Output

`REPAIR TABLE` returns a result set with the columns shown in the following table.

Column	Value
`Table`	The table name
`Op`	Always `repair`
`Msg_type`	`status`, `error`, `info`, `note`, or `warning`
`Msg_text`	An informational message

The `REPAIR TABLE` statement might produce many rows of information for each repaired table. The last row has a `Msg_type` value of `status` and `Msg_test` normally should be `OK`. For a `MyISAM` table, if you do not get `OK`, you should try repairing it with `myisamchk --safe-recover`. (`REPAIR TABLE` does not implement all the options of `myisamchk`. With `myisamchk --safe-recover`, you can also use options that `REPAIR TABLE` does not support, such as `--max-record-length`.)

`REPAIR TABLE` table catches and throws any errors that occur while copying table statistics from the old corrupted file to the newly created file. For example. if the user ID of the owner of the `.frm`, `.MYD`, or `.MYI` file is different from the user ID of the `mysqld` process, `REPAIR TABLE` generates a "cannot change ownership of the file" error unless `mysqld` is started by the `root` user.

Table Repair Considerations

You may be able to increase `REPAIR TABLE` performance by setting certain system variables. See Section 8.6.3, “Optimizing REPAIR TABLE Statements”.

13.7.3 Plugin and User-Defined Function Statements

13.7.3.1 CREATE FUNCTION Syntax for User-Defined Functions

```
CREATE [AGGREGATE] FUNCTION function_name
    RETURNS {STRING|INTEGER|REAL|DECIMAL}
    SONAME shared_library_name
```

A user-defined function (UDF) is a way to extend MySQL with a new function that works like a native (built-in) MySQL function such as `ABS()` or `CONCAT()`.

`function_name` is the name that should be used in SQL statements to invoke the function. The `RETURNS` clause indicates the type of the function's return value. `DECIMAL` is a legal value after `RETURNS`, but currently `DECIMAL` functions return string values and should be written like `STRING` functions.

`shared_library_name` is the base name of the shared library file that contains the code that implements the function. The file must be located in the plugin directory. This directory is given by the value of the `plugin_dir` system variable. For more information, see Section 24.4.2.5, “UDF Compiling and Installing”.

To create a function, you must have the `INSERT` privilege for the `mysql` database. This is necessary because `CREATE FUNCTION` adds a row to the `mysql.func` system table that records the function's name, type, and shared library name. If you do not have this table, you should run the `mysql_upgrade` command to create it. See Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”.

An active function is one that has been loaded with `CREATE FUNCTION` and not removed with `DROP FUNCTION`. All active functions are reloaded each time the server starts, unless you start `mysqld` with the `--skip-grant-tables` option. In this case, UDF initialization is skipped and UDFs are unavailable.

For instructions on writing user-defined functions, see Section 24.4.2, “Adding a New User-Defined Function”. For the UDF mechanism to work, functions must be written in C or C++ (or another language that can use C calling conventions), your operating system must support dynamic loading and you must have compiled `mysqld` dynamically (not statically).

An `AGGREGATE` function works exactly like a native MySQL aggregate (summary) function such as `SUM` or `COUNT()`. For `AGGREGATE` to work, your `mysql.func` table must contain a `type` column. If your `mysql.func` table does not have this column, you should run the `mysql_upgrade` program to create it (see Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”).

Note

To upgrade the shared library associated with a UDF, issue a `DROP FUNCTION` statement, upgrade the shared library, and then issue a `CREATE FUNCTION` statement. If you upgrade the shared library first and then use `DROP FUNCTION`, the server may crash.

13.7.3.2 DROP FUNCTION Syntax

```
DROP FUNCTION function_name
```

This statement drops the user-defined function (UDF) named *`function_name`*.

To drop a function, you must have the `DELETE` privilege for the `mysql` database. This is because `DROP FUNCTION` removes a row from the `mysql.func` system table that records the function's name, type, and shared library name.

Note

To upgrade the shared library associated with a UDF, issue a `DROP FUNCTION` statement, upgrade the shared library, and then issue a `CREATE FUNCTION` statement. If you upgrade the shared library first and then use `DROP FUNCTION`, the server may crash.

`DROP FUNCTION` is also used to drop stored functions (see Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Syntax”).

13.7.3.3 INSTALL PLUGIN Syntax

```
INSTALL PLUGIN plugin_name SONAME 'shared_library_name'
```

This statement installs a server plugin. It requires the `INSERT` privilege for the `mysql.plugin` system table.

`plugin_name` is the name of the plugin as defined in the plugin descriptor structure contained in the library file (see Section 24.2.4.2, “Plugin Data Structures”). Plugin names are not case sensitive. For maximal compatibility, plugin names should be limited to ASCII letters, digits, and underscore because they are used in C source files, shell command lines, M4 and Bourne shell scripts, and SQL environments.

`shared_library_name` is the name of the shared library that contains the plugin code. The name includes the file name extension (for example, `libmyplugin.so`, `libmyplugin.dll`, or `libmyplugin.dylib`).

The shared library must be located in the plugin directory (the directory named by the `plugin_dir` system variable). The library must be in the plugin directory itself, not in a subdirectory. By default, `plugin_dir` is the `plugin` directory under the directory named by the `pkglibdir` configuration variable, but it can be changed by setting the value of `plugin_dir` at server startup. For example, set its value in a `my.cnf` file:

```
[mysqld]
plugin_dir=/path/to/plugin/directory
```

If the value of `plugin_dir` is a relative path name, it is taken to be relative to the MySQL base directory (the value of the `basedir` system variable).

`INSTALL PLUGIN` loads and initializes the plugin code to make the plugin available for use. A plugin is initialized by executing its initialization function, which handles any setup that the plugin must perform before it can be used. When the server shuts down, it executes the deinitialization function for each plugin that is loaded so that the plugin has a chance to perform any final cleanup.

`INSTALL PLUGIN` also registers the plugin by adding a line that indicates the plugin name and library file name to the `mysql.plugin` table. At server startup, the server loads and initializes any plugin that is listed in the `mysql.plugin` table. This means that a plugin is installed with `INSTALL PLUGIN` only once, not every time the server starts. Plugin loading at startup does not occur if the server is started with the `--skip-grant-tables` option.

A plugin library can contain multiple plugins. For each of them to be installed, use a separate `INSTALL PLUGIN` statement. Each statement names a different plugin, but all of them specify the same library name.

`INSTALL PLUGIN` causes the server to read option (`my.cnf`) files just as during server startup. This enables the plugin to pick up any relevant options from those files. It is possible to add plugin options to an option file even before loading a plugin (if the `loose` prefix is used). It is also possible to uninstall a plugin, edit `my.cnf`, and install the plugin again. Restarting the plugin this way enables it to the new option values without a server restart.

For options that control individual plugin loading at server startup, see Section 5.5.1, “Installing and Uninstalling Plugins”. If you need to load plugins for a single server startup when the `--skip-grant-tables` option is given (which tells the server not to read system tables), use the `--plugin-load` option. See Section 5.1.4, “Server Command Options”.

To remove a plugin, use the `UNINSTALL PLUGIN` statement.

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To see what plugins are installed, use the `SHOW PLUGINS` statement or query the `INFORMATION_SCHEMA.PLUGINS` table.

If you recompile a plugin library and need to reinstall it, you can use either of the following methods:

- Use `UNINSTALL PLUGIN` to uninstall all plugins in the library, install the new plugin library file in the plugin directory, and then use `INSTALL PLUGIN` to install all plugins in the library. This procedure has the advantage that it can be used without stopping the server. However, if the plugin library contains many plugins, you must issue many `INSTALL PLUGIN` and `UNINSTALL PLUGIN` statements.
- Stop the server, install the new plugin library file in the plugin directory, and restart the server.

13.7.3.4 UNINSTALL PLUGIN Syntax

```
UNINSTALL PLUGIN plugin_name
```

This statement removes an installed server plugin. It requires the `DELETE` privilege for the `mysql.plugin` system table. `UNINSTALL PLUGIN` is the complement of `INSTALL PLUGIN`.

`plugin_name` must be the name of some plugin that is listed in the `mysql.plugin` table. The server executes the plugin's deinitialization function and removes the row for the plugin from the `mysql.plugin` table, so that subsequent server restarts will not load and initialize the plugin. `UNINSTALL PLUGIN` does not remove the plugin's shared library file.

You cannot uninstall a plugin if any table that uses it is open.

Plugin removal has implications for the use of associated tables. For example, if a full-text parser plugin is associated with a `FULLTEXT` index on the table, uninstalling the plugin makes the table unusable. Any attempt to access the table results in an error. The table cannot even be opened, so you cannot drop an index for which the plugin is used. This means that uninstalling a plugin is something to do with care unless you do not care about the table contents. If you are uninstalling a plugin with no intention of reinstalling it later and you care about the table contents, you should dump the table with `mysqldump` and remove the `WITH PARSER` clause from the dumped `CREATE TABLE` statement so that you can reload the table later. If you do not care about the table, `DROP TABLE` can be used even if any plugins associated with the table are missing.

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

13.7.4 SET Syntax

The `SET` statement has several forms. Descriptions for those forms that are not associated with a specific server capability appear in subsections of this section:

- `SET` *`var_name = value`* enables you to assign values to variables that affect the operation of the server or clients. See Section 13.7.4.1, “SET Syntax for Variable Assignment”.
- `SET CHARACTER SET` and `SET NAMES` assign values to character set and collation variables associated with the current connection to the server. See Section 13.7.4.2, “SET CHARACTER SET Syntax”, and Section 13.7.4.3, “SET NAMES Syntax”.

Descriptions for the other forms appear elsewhere, grouped with other statements related to the capability they help implement:

- `SET PASSWORD` assigns account passwords. See Section 13.7.1.6, “SET PASSWORD Syntax”.
- `SET TRANSACTION ISOLATION LEVEL` sets the isolation level for transaction processing. See Section 13.3.6, “SET TRANSACTION Syntax”.

13.7.4.1 SET Syntax for Variable Assignment

```
SET variable_assignment [, variable_assignment] ...

variable_assignment:
      user_var_name = expr
    | param_name = expr
    | local_var_name = expr
    | [GLOBAL | SESSION]
        system_var_name = expr
    | [@@global. | @@session. | @@]
        system_var_name = expr

SET ONE_SHOT system_var_name = expr
```

`SET` syntax for variable assignment enables you to assign values to different types of variables that affect the operation of the server or clients:

- System variables. See Section 5.1.5, “Server System Variables”. System variables also can be set at server startup, as described in Section 5.1.6, “Using System Variables”. (To *display* system variable names and values, use the `SHOW VARIABLES` statement; see Section 13.7.5.40, “SHOW VARIABLES Syntax”.)
- User-defined variables. See Section 9.4, “User-Defined Variables”.
- Stored procedure and function parameters, and stored program local variables. See Section 13.6.4, “Variables in Stored Programs”.

Older versions of MySQL employed `SET OPTION`, but this syntax is deprecated in favor of `SET` without `OPTION`.

A `SET` statement that assigns variable values is not written to the binary log, so in replication scenarios it affects only the host on which you execute it. To affect all replication hosts, execute the statement on each one.

The following examples illustrate `SET` syntax for setting variables. They use the `=` assignment operator, but the `:=` assignment operator is also permitted for this purpose.

A user variable is written as *`@var_name`* and is assigned an expression value as follows:

```
SET @var_name = expr;
```

Examples:

```
SET @name = 43;
SET @total_tax = (SELECT SUM(tax) FROM taxable_transactions);
```

The *`expr`* can range from simple (a literal value) to more complex (the value returned by a scalar subquery).

`SET` applies to parameters and local variables in the context of the stored object within which they are defined. The following procedure uses the `counter` local variable as a loop counter:

```
CREATE PROCEDURE p()
BEGIN
  DECLARE counter INT DEFAULT 0;
  WHILE counter < 10 DO
    -- ... do work ...
    SET counter = counter + 1;
  END WHILE;
END;
```

Many system variables are dynamic and can be changed at runtime by using the `SET` statement. For a list, see Section 5.1.6.2, “Dynamic System Variables”. To change a system variable with `SET`, refer to it by name, optionally preceded by a modifier:

- To indicate that a variable is a global variable, precede its name by the `GLOBAL` keyword or the `@@global.` qualifier:

  ```
  SET GLOBAL max_connections = 1000;
  SET @@global.max_connections = 1000;
  ```

  The `SUPER` privilege is required to set global variables.

- To indicate that a variable is a session variable, precede its name by the `SESSION` keyword or either the `@@session.` or `@@` qualifier:

  ```
  SET SESSION sql_mode = 'TRADITIONAL';
  SET @@session.sql_mode = 'TRADITIONAL';
  SET @@sql_mode = 'TRADITIONAL';
  ```

  Setting a session variable normally requires no special privilege, although there are exceptions that require the `SUPER` privilege (such as `sql_log_bin`). A client can change its own session variables, but not those of any other client.

- `LOCAL` and `@@local.` are synonyms for `SESSION` and `@@session.`.

- If no modifier is present, `SET` changes the session variable.

- An error occurs under these circumstances:
  - Use of `SET GLOBAL` (or `@@global.`) when setting a variable that has only a session value:

```
mysql> SET GLOBAL sql_log_bin = ON;
ERROR 1231 (42000): Variable 'sql_log_bin' can't be
set to the value of 'ON'
```

  - Omission of `GLOBAL` (or `@@global.`) when setting a variable that has only a global value:

```
mysql> SET max_connections = 1000;
ERROR 1229 (HY000): Variable 'max_connections' is a
GLOBAL variable and should be set with SET GLOBAL
```

  - Use of `SET SESSION` (or `@@SESSION.`) when setting a variable that has only a global value:

```
mysql> SET SESSION max_connections = 1000;
ERROR 1229 (HY000): Variable 'max_connections' is a
GLOBAL variable and should be set with SET GLOBAL
```

The preceding modifiers apply only to system variables. An error occurs for attempts to apply them to user-defined variables, stored procedure or function parameters, or stored program local variables.

A `SET` statement can contain multiple variable assignments, separated by commas. This statement assigns values to a user-defined variable and a system variable:

```
SET @x = 1, SESSION sql_mode = '';
```

If you set multiple system variables, the most recent `GLOBAL` or `SESSION` modifier in the statement is used for following assignments that have no modifier specified.

Examples of multiple-variable assignment:

```
SET GLOBAL sort_buffer_size = 1000000, SESSION sort_buffer_size = 1000000;
SET @@global.sort_buffer_size = 1000000, @@local.sort_buffer_size = 1000000;
SET GLOBAL max_connections = 1000, sort_buffer_size = 1000000;
```

If any variable assignment in a `SET` statement fails, the entire statement fails and no variables are changed.

If you change a session system variable, the value remains in effect within your session until you change the variable to a different value or the session ends. The change has no effect on other sessions.

If you change a global system variable, the value is remembered and used for new sessions until you change the variable to a different value or the server exits. The change is visible to any client that accesses the global variable. However, the change affects the corresponding session variable only for clients that connect after the change. The global variable change does not affect the session variable for any current client sessions (not even the session within which the `SET GLOBAL` statement occurred).

To make a global system variable setting permanent so that it applies across server restarts, you should also set it in an option file.

To set a `GLOBAL` value to the compiled-in MySQL default value or a `SESSION` variable to the current corresponding `GLOBAL` value, set the variable to the value `DEFAULT`. For example, the following two statements are identical in setting the session value of `max_join_size` to the current global value:

```
SET @@session.max_join_size=DEFAULT;
SET @@session.max_join_size=@@global.max_join_size;
```

Not all system variables can be set to `DEFAULT`. In such cases, assigning `DEFAULT` results in an error.

It is not permitted to assign `DEFAULT` to user-defined variables, and not supported for stored procedure or function parameters or stored program local variables. This results in an error for user-defined variables, and the results are undefined for parameters or local variables.

To refer to the value of a system variable in expressions, use one of the `@@`-modifiers. For example, you can retrieve values in a `SELECT` statement like this:

```
SELECT @@global.sql_mode, @@session.sql_mode, @@sql_mode;
```

For a reference to a system variable in an expression as *`@@var_name`* (rather than with `@@global.` or `@@session.`), MySQL returns the session value if it exists and the global value otherwise. This differs from `SET @@var_name = expr`, which always refers to the session value.

The `SET ONE_SHOT` syntax is *only* for internal use for replication: `mysqlbinlog` uses `SET ONE_SHOT` to modify temporarily the values of character set, collation, and time zone variables to reflect at rollforward what they were originally. `ONE_SHOT` is for internal use only and is deprecated for MySQL 5.0 and up.

`ONE_SHOT` is intended for use only with the permitted set of variables. It changes the variables as requested, but only for the next non-`SET` statement. After that, the server resets all character set, collation, and time zone-related system variables to their previous values. Example:

```
mysql> SET ONE_SHOT character_set_connection = latin5;

mysql> SET ONE_SHOT collation_connection = latin5_turkish_ci;

mysql> SHOW VARIABLES LIKE '%_connection';
+--------------------------+-------------------+
| Variable_name            | Value             |
+--------------------------+-------------------+
| character_set_connection | latin5            |
| collation_connection     | latin5_turkish_ci |
+--------------------------+-------------------+

mysql> SHOW VARIABLES LIKE '%_connection';
+--------------------------+-------------------+
| Variable_name            | Value             |
+--------------------------+-------------------+
| character_set_connection | latin1            |
| collation_connection     | latin1_swedish_ci |
+--------------------------+-------------------+
```

13.7.4.2 SET CHARACTER SET Syntax

```
SET {CHARACTER SET | CHARSET}
    {'charset_name' | DEFAULT}
```

This statement maps all strings sent between the server and the current client with the given mapping. `SET CHARACTER SET` sets three session system variables: `character_set_client` and `character_set_results` are set to the given character set, and `character_set_connection` to the value of `character_set_database`. See Section 10.1.4, “Connection Character Sets and Collations”.

`charset_name` may be quoted or unquoted.

The default character set mapping can be restored by using the value `DEFAULT`. The default depends on the server configuration.

`ucs2`, `utf16`, and `utf32` cannot be used as a client character set, which means that they do not work for `SET CHARACTER SET`.

13.7.4.3 SET NAMES Syntax

```
SET NAMES {'charset_name'
    [COLLATE 'collation_name'] | DEFAULT}
```

This statement sets the three session system variables `character_set_client`, `character_set_connection`, and `character_set_results` to the given character set. Setting `character_set_connection` to `charset_name` also sets `collation_connection` to the default collation for `charset_name`. See Section 10.1.4, “Connection Character Sets and Collations”.

The optional `COLLATE` clause may be used to specify a collation explicitly. If given, the collation must one of the permitted collations for *`charset_name`*.

`charset_name` and *`collation_name`* may be quoted or unquoted.

The default mapping can be restored by using a value of `DEFAULT`. The default depends on the server configuration.

`ucs2`, `utf16`, and `utf32` cannot be used as a client character set, which means that they do not work for `SET NAMES`.

13.7.5 SHOW Syntax

`SHOW` has many forms that provide information about databases, tables, columns, or status information about the server. This section describes those following:

```
SHOW AUTHORS
SHOW {BINARY | MASTER} LOGS
SHOW BINLOG EVENTS [IN 'log_name'] [FROM pos] [LIMIT [offset,] row_count]
SHOW CHARACTER SET [like_or_where]
SHOW COLLATION [like_or_where]
SHOW [FULL] COLUMNS FROM tbl_name [FROM db_name] [like_or_where]
SHOW CONTRIBUTORS
SHOW CREATE DATABASE db_name
SHOW CREATE EVENT event_name
SHOW CREATE FUNCTION func_name
SHOW CREATE PROCEDURE proc_name
SHOW CREATE TABLE tbl_name
SHOW CREATE TRIGGER trigger_name
SHOW CREATE VIEW view_name
SHOW DATABASES [like_or_where]
SHOW ENGINE engine_name {STATUS | MUTEX}
SHOW [STORAGE] ENGINES
SHOW ERRORS [LIMIT [offset,] row_count]
SHOW EVENTS
SHOW FUNCTION CODE func_name
SHOW FUNCTION STATUS [like_or_where]
SHOW GRANTS FOR user
SHOW INDEX FROM tbl_name [FROM db_name]
SHOW MASTER STATUS
SHOW OPEN TABLES [FROM db_name] [like_or_where]
SHOW PLUGINS
SHOW PROCEDURE CODE proc_name
SHOW PROCEDURE STATUS [like_or_where]
SHOW PRIVILEGES
SHOW [FULL] PROCESSLIST
SHOW PROFILE [types] [FOR QUERY n] [OFFSET n] [LIMIT n]
SHOW PROFILES
SHOW RELAYLOG EVENTS [IN 'log_name'] [FROM pos] [LIMIT [offset,] row_count]
SHOW SLAVE HOSTS
SHOW SLAVE STATUS
SHOW [GLOBAL | SESSION] STATUS [like_or_where]
SHOW TABLE STATUS [FROM db_name] [like_or_where]
SHOW [FULL] TABLES [FROM db_name] [like_or_where]
SHOW TRIGGERS [FROM db_name] [like_or_where]
SHOW [GLOBAL | SESSION] VARIABLES [like_or_where]
```

```
SHOW WARNINGS [LIMIT [offset,] row_count]

like_or_where:
    LIKE 'pattern'
  | WHERE expr
```

If the syntax for a given SHOW statement includes a LIKE 'pattern' part, 'pattern' is a string that can contain the SQL % and _ wildcard characters. The pattern is useful for restricting statement output to matching values.

Several SHOW statements also accept a WHERE clause that provides more flexibility in specifying which rows to display. See Section 21.31, “Extensions to SHOW Statements”.

Many MySQL APIs (such as PHP) enable you to treat the result returned from a SHOW statement as you would a result set from a SELECT; see Chapter 23, *Connectors and APIs*, or your API documentation for more information. In addition, you can work in SQL with results from queries on tables in the INFORMATION_SCHEMA database, which you cannot easily do with results from SHOW statements. See Chapter 21, *INFORMATION_SCHEMA Tables*.

13.7.5.1 SHOW AUTHORS Syntax

```
SHOW AUTHORS
```

The SHOW AUTHORS statement displays information about the people who work on MySQL. For each author, it displays Name, Location, and Comment values.

This statement is deprecated as of MySQL 5.5.29 and is removed in MySQL 5.6.

13.7.5.2 SHOW BINARY LOGS Syntax

```
SHOW BINARY LOGS
SHOW MASTER LOGS
```

Lists the binary log files on the server. This statement is used as part of the procedure described in Section 13.4.1.1, “PURGE BINARY LOGS Syntax”, that shows how to determine which logs can be purged.

```
mysql> SHOW BINARY LOGS;
+---------------+-----------+
| Log_name      | File_size |
+---------------+-----------+
| binlog.000015 |    724935 |
| binlog.000016 |    733481 |
+---------------+-----------+
```

SHOW MASTER LOGS is equivalent to SHOW BINARY LOGS.

In MySQL 5.5.24 and earlier, the SUPER privilege was required to use this statement. Starting with MySQL 5.5.25, a user with the REPLICATION CLIENT privilege may also execute this statement.

13.7.5.3 SHOW BINLOG EVENTS Syntax

```
SHOW BINLOG EVENTS
   [IN 'log_name']
   [FROM pos]
   [LIMIT [offset,] row_count]
```

Shows the events in the binary log. If you do not specify 'log_name', the first binary log is displayed.

The LIMIT clause has the same syntax as for the SELECT statement. See Section 13.2.9, “SELECT Syntax”.

Note

Issuing a `SHOW BINLOG EVENTS` with no `LIMIT` clause could start a very time- and resource-consuming process because the server returns to the client the complete contents of the binary log (which includes all statements executed by the server that modify data). As an alternative to `SHOW BINLOG EVENTS`, use the `mysqlbinlog` utility to save the binary log to a text file for later examination and analysis. See Section 4.6.7, "`mysqlbinlog` — Utility for Processing Binary Log Files".

Note

Some events relating to the setting of user and system variables are not included in the output from `SHOW BINLOG EVENTS`. To get complete coverage of events within a binary log, use `mysqlbinlog`.

Note

`SHOW BINLOG EVENTS` does *not* work with relay log files. You can use `SHOW RELAYLOG EVENTS` for this purpose.

13.7.5.4 SHOW CHARACTER SET Syntax

```
SHOW CHARACTER SET
    [LIKE 'pattern' | WHERE expr]
```

The `SHOW CHARACTER SET` statement shows all available character sets. The `LIKE` clause, if present, indicates which character set names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, "Extensions to SHOW Statements". For example:

```
mysql> SHOW CHARACTER SET LIKE 'latin%';
+---------+-----------------------------+-------------------+--------+
| Charset | Description                 | Default collation | Maxlen |
+---------+-----------------------------+-------------------+--------+
| latin1  | cp1252 West European        | latin1_swedish_ci |      1 |
| latin2  | ISO 8859-2 Central European | latin2_general_ci |      1 |
| latin5  | ISO 8859-9 Turkish          | latin5_turkish_ci |      1 |
| latin7  | ISO 8859-13 Baltic          | latin7_general_ci |      1 |
+---------+-----------------------------+-------------------+--------+
```

The `Maxlen` column shows the maximum number of bytes required to store one character.

The `filename` character set is for internal use only; consequently, `SHOW CHARACTER SET` does not display it.

You can also obtain information about character sets from `INFORMATION_SCHEMA`, which contains a `CHARACTER_SETS` table. See Section 21.1, "The INFORMATION_SCHEMA CHARACTER_SETS Table".

13.7.5.5 SHOW COLLATION Syntax

```
SHOW COLLATION
    [LIKE 'pattern' | WHERE expr]
```

This statement lists collations supported by the server. By default, the output from `SHOW COLLATION` includes all available collations. The `LIKE` clause, if present, indicates which collation names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, "Extensions to SHOW Statements". For example:

```
mysql> SHOW COLLATION WHERE Charset = 'latin1';
+-------------------+---------+----+---------+----------+---------+
| Collation         | Charset | Id | Default | Compiled | Sortlen |
+-------------------+---------+----+---------+----------+---------+
| latin1_german1_ci | latin1  |  5 |         | Yes      |       1 |
| latin1_swedish_ci | latin1  |  8 | Yes     | Yes      |       1 |
| latin1_danish_ci  | latin1  | 15 |         | Yes      |       1 |
| latin1_german2_ci | latin1  | 31 |         | Yes      |       2 |
| latin1_bin        | latin1  | 47 |         | Yes      |       1 |
| latin1_general_ci | latin1  | 48 |         | Yes      |       1 |
| latin1_general_cs | latin1  | 49 |         | Yes      |       1 |
| latin1_spanish_ci | latin1  | 94 |         | Yes      |       1 |
+-------------------+---------+----+---------+----------+---------+
```

The `Collation` and `Charset` columns indicate the names of the collation and the character set with which it is associated. `Id` is the collation ID. `Default` indicates whether the collation is the default for its character set. `Compiled` indicates whether the character set is compiled into the server. `Sortlen` is related to the amount of memory required to sort strings expressed in the character set.

To see the default collation for each character set, use the following statement. `Default` is a reserved word, so to use it as an identifier, it must be quoted as such:

```
mysql> SHOW COLLATION WHERE `Default` = 'Yes';
+---------------------+----------+----+---------+----------+---------+
| Collation           | Charset  | Id | Default | Compiled | Sortlen |
+---------------------+----------+----+---------+----------+---------+
| big5_chinese_ci     | big5     |  1 | Yes     | Yes      |       1 |
| dec8_swedish_ci     | dec8     |  3 | Yes     | Yes      |       1 |
| cp850_general_ci    | cp850    |  4 | Yes     | Yes      |       1 |
| hp8_english_ci      | hp8      |  6 | Yes     | Yes      |       1 |
| koi8r_general_ci    | koi8r    |  7 | Yes     | Yes      |       1 |
| latin1_swedish_ci   | latin1   |  8 | Yes     | Yes      |       1 |
...
```

You can also obtain information about collations from `INFORMATION_SCHEMA`, which contains a `COLLATIONS` table. See Section 21.2, “The INFORMATION_SCHEMA COLLATIONS Table”.

13.7.5.6 SHOW COLUMNS Syntax

```
SHOW [FULL] {COLUMNS | FIELDS}
    {FROM | IN} tbl_name
    [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW COLUMNS` displays information about the columns in a given table. It also works for views. `SHOW COLUMNS` displays information only for those columns for which you have some privilege.

You can use *`db_name.tbl_name`* as an alternative to the *`tbl_name FROM db_name`* syntax. In other words, these two statements are equivalent:

```
SHOW COLUMNS FROM mytable FROM mydb;
SHOW COLUMNS FROM mydb.mytable;
```

The optional `FULL` keyword causes the output to include the column collation and comments, as well as the privileges you have for each column.

The `LIKE` clause, if present, indicates which column names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

```
mysql> SHOW COLUMNS FROM City;
+------------+----------+------+-----+---------+----------------+
| Field      | Type     | Null | Key | Default | Extra          |
+------------+----------+------+-----+---------+----------------+
```

```
| ID          | int(11)  | NO   | PRI | NULL    | auto_increment |
| Name        | char(35) | NO   |     |         |                |
| CountryCode | char(3)  | NO   | MUL |         |                |
| District    | char(20) | NO   |     |         |                |
| Population  | int(11)  | NO   |     | 0       |                |
+-------------+----------+------+-----+---------+----------------+
```

The data types may differ from what you expect them to be based on a `CREATE TABLE` statement because MySQL sometimes changes data types when you create or alter a table. The conditions under which this occurs are described in Section 13.1.17.7, “Silent Column Specification Changes”.

`SHOW COLUMNS` displays the following values for each table column:

- `Field`

  The column name.

- `Type`

  The column data type.

- `Collation`

  The collation for nonbinary string columns, or `NULL` for other columns. This value is displayed only if you use the `FULL` keyword.

- `Null`

  Column nullability. The value is `YES` if `NULL` values can be stored in the column, `NO` if not.

- `Key`

  Whether the column is indexed:

  - If `Key` is empty, the column either is not indexed or is indexed only as a secondary column in a multiple-column, nonunique index.
  - If `Key` is `PRI`, the column is a `PRIMARY KEY` or is one of the columns in a multiple-column `PRIMARY KEY`.
  - If `Key` is `UNI`, the column is the first column of a `UNIQUE` index. (A `UNIQUE` index permits multiple `NULL` values, but you can tell whether the column permits `NULL` by checking the `Null` field.)
  - If `Key` is `MUL`, the column is the first column of a nonunique index in which multiple occurrences of a given value are permitted within the column.

  If more than one of the `Key` values applies to a given column of a table, `Key` displays the one with the highest priority, in the order `PRI`, `UNI`, `MUL`.

  A `UNIQUE` index may be displayed as `PRI` if it cannot contain `NULL` values and there is no `PRIMARY KEY` in the table. A `UNIQUE` index may display as `MUL` if several columns form a composite `UNIQUE` index; although the combination of the columns is unique, each column can still hold multiple occurrences of a given value.

- `Default`

  The default value for the column. This is `NULL` if the column has an explicit default of `NULL`, or if the column definition includes no `DEFAULT` clause.

- `Extra`

  Any additional information that is available about a given column. The value is nonempty in these cases: `auto_increment` for columns that have the `AUTO_INCREMENT` attribute; `on update`

CURRENT_TIMESTAMP for TIMESTAMP columns that have the ON UPDATE CURRENT_TIMESTAMP attribute.

- Privileges

  The privileges you have for the column. This value is displayed only if you use the FULL keyword.

- Comment

  Any comment included in the column definition. This value is displayed only if you use the FULL keyword.

You can also obtain information about table columns from INFORMATION_SCHEMA, which contains a COLUMNS table. See Section 21.4, "The INFORMATION_SCHEMA COLUMNS Table".

You can list a table's columns with the mysqlshow *db_name tbl_name* command.

The DESCRIBE statement provides information similar to SHOW COLUMNS. See Section 13.8.1, "DESCRIBE Syntax".

The SHOW CREATE TABLE, SHOW TABLE STATUS, and SHOW INDEX statements also provide information about tables. See Section 13.7.5, "SHOW Syntax".

13.7.5.7 SHOW CONTRIBUTORS Syntax

```
SHOW CONTRIBUTORS
```

The SHOW CONTRIBUTORS statement displays information about the people who contribute to MySQL source or to causes that we support. For each contributor, it displays Name, Location, and Comment values.

This statement is deprecated as of MySQL 5.5.29 and is removed in MySQL 5.6.

13.7.5.8 SHOW CREATE DATABASE Syntax

```
SHOW CREATE {DATABASE | SCHEMA} [IF NOT EXISTS] db_name
```

Shows the CREATE DATABASE statement that creates the named database. If the SHOW statement includes an IF NOT EXISTS clause, the output too includes such a clause. SHOW CREATE SCHEMA is a synonym for SHOW CREATE DATABASE.

```
mysql> SHOW CREATE DATABASE test\G
*************************** 1. row ***************************
       Database: test
Create Database: CREATE DATABASE `test`
                 /*!40100 DEFAULT CHARACTER SET latin1 */

mysql> SHOW CREATE SCHEMA test\G
*************************** 1. row ***************************
       Database: test
Create Database: CREATE DATABASE `test`
                 /*!40100 DEFAULT CHARACTER SET latin1 */
```

SHOW CREATE DATABASE quotes table and column names according to the value of the sql_quote_show_create option. See Section 5.1.5, "Server System Variables".

13.7.5.9 SHOW CREATE EVENT Syntax

```
SHOW CREATE EVENT event_name
```

This statement displays the `CREATE EVENT` statement needed to re-create a given event. It requires the `EVENT` privilege for the database from which the event is to be shown. For example (using the same event `e_daily` defined and then altered in Section 13.7.5.19, “SHOW EVENTS Syntax”):

```
mysql> SHOW CREATE EVENT test.e_daily\G
*************************** 1. row ***************************
               Event: e_daily
            sql_mode:
           time_zone: SYSTEM
        Create Event: CREATE EVENT `e_daily`
                        ON SCHEDULE EVERY 1 DAY
                        STARTS CURRENT_TIMESTAMP + INTERVAL 6 HOUR
                        ON COMPLETION NOT PRESERVE
                        ENABLE
                        COMMENT 'Saves total number of sessions then
                                clears the table each day'
                        DO BEGIN
                          INSERT INTO site_activity.totals (time, total)
                            SELECT CURRENT_TIMESTAMP, COUNT(*)
                            FROM site_activity.sessions;
                          DELETE FROM site_activity.sessions;
                        END
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

`character_set_client` is the session value of the `character_set_client` system variable when the event was created. `collation_connection` is the session value of the `collation_connection` system variable when the event was created. `Database Collation` is the collation of the database with which the event is associated.

Note that the output reflects the current status of the event (`ENABLE`) rather than the status with which it was created.

13.7.5.10 SHOW CREATE FUNCTION Syntax

```
SHOW CREATE FUNCTION func_name
```

This statement is similar to `SHOW CREATE PROCEDURE` but for stored functions. See Section 13.7.5.11, “SHOW CREATE PROCEDURE Syntax”.

13.7.5.11 SHOW CREATE PROCEDURE Syntax

```
SHOW CREATE PROCEDURE proc_name
```

This statement is a MySQL extension. It returns the exact string that can be used to re-create the named stored procedure. A similar statement, `SHOW CREATE FUNCTION`, displays information about stored functions (see Section 13.7.5.10, “SHOW CREATE FUNCTION Syntax”).

To use either statement, you must be the user named in the routine `DEFINER` clause or have `SELECT` access to the `mysql.proc` table. If you do not have privileges for the routine itself, the value displayed for the `Create Procedure` or `Create Function` field will be `NULL`.

```
mysql> SHOW CREATE PROCEDURE test.simpleproc\G
*************************** 1. row ***************************
           Procedure: simpleproc
            sql_mode:
    Create Procedure: CREATE PROCEDURE `simpleproc`(OUT param1 INT)
                      BEGIN
                      SELECT COUNT(*) INTO param1 FROM t;
                      END
character_set_client: latin1
collation_connection: latin1_swedish_ci
```

```
  Database Collation: latin1_swedish_ci

mysql> SHOW CREATE FUNCTION test.hello\G
*************************** 1. row ***************************
            Function: hello
            sql_mode:
     Create Function: CREATE FUNCTION `hello`(s CHAR(20))
                      RETURNS CHAR(50)
                      RETURN CONCAT('Hello, ',s,'!')
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

`character_set_client` is the session value of the `character_set_client` system variable when the routine was created. `collation_connection` is the session value of the `collation_connection` system variable when the routine was created. `Database Collation` is the collation of the database with which the routine is associated.

13.7.5.12 SHOW CREATE TABLE Syntax

```
SHOW CREATE TABLE tbl_name
```

Shows the `CREATE TABLE` statement that creates the named table. To use this statement, you must have some privilege for the table. This statement also works with views.

```
mysql> SHOW CREATE TABLE t\G
*************************** 1. row ***************************
       Table: t
Create Table: CREATE TABLE `t` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `s` char(60) DEFAULT NULL,
  PRIMARY KEY (`id`)
) ENGINE=InnoDB DEFAULT CHARSET=latin1
```

`SHOW CREATE TABLE` quotes table and column names according to the value of the `sql_quote_show_create` option. See Section 5.1.5, “Server System Variables”.

For information about how `CREATE TABLE` statements are stored by MySQL, see Section 13.1.17.1, “CREATE TABLE Statement Retention”.

13.7.5.13 SHOW CREATE TRIGGER Syntax

```
SHOW CREATE TRIGGER trigger_name
```

This statement shows the `CREATE TRIGGER` statement that creates the named trigger. This statement requires the `TRIGGER` privilege for the table associated with the trigger.

```
mysql> SHOW CREATE TRIGGER ins_sum\G
*************************** 1. row ***************************
               Trigger: ins_sum
              sql_mode:
SQL Original Statement: CREATE DEFINER=`bob`@`localhost` TRIGGER ins_sum
                        BEFORE INSERT ON account
                        FOR EACH ROW SET @sum = @sum + NEW.amount
  character_set_client: latin1
  collation_connection: latin1_swedish_ci
    Database Collation: latin1_swedish_ci
```

`SHOW CREATE TRIGGER` output has the following columns:

- `Trigger`: The trigger name.
- `sql_mode`: The SQL mode in effect when the trigger executes.

- `SQL Original Statement`: The `CREATE TRIGGER` statement that defines the trigger.
- `character_set_client`: The session value of the `character_set_client` system variable when the trigger was created.
- `collation_connection`: The session value of the `collation_connection` system variable when the trigger was created.
- `Database Collation`: The collation of the database with which the trigger is associated.

You can also obtain information about trigger objects from `INFORMATION_SCHEMA`, which contains a `TRIGGERS` table. See Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”.

13.7.5.14 SHOW CREATE VIEW Syntax

```
SHOW CREATE VIEW view_name
```

This statement shows the `CREATE VIEW` statement that creates the named view.

```
mysql> SHOW CREATE VIEW v\G
*************************** 1. row ***************************
                View: v
         Create View: CREATE ALGORITHM=UNDEFINED
                      DEFINER=`bob`@`localhost`
                      SQL SECURITY DEFINER VIEW
                      `v` AS select 1 AS `a`,2 AS `b`
character_set_client: latin1
collation_connection: latin1_swedish_ci
```

`character_set_client` is the session value of the `character_set_client` system variable when the view was created. `collation_connection` is the session value of the `collation_connection` system variable when the view was created.

Use of `SHOW CREATE VIEW` requires the `SHOW VIEW` privilege, and the `SELECT` privilege for the view in question.

You can also obtain information about view objects from `INFORMATION_SCHEMA`, which contains a `VIEWS` table. See Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”.

MySQL lets you use different `sql_mode` settings to tell the server the type of SQL syntax to support. For example, you might use the `ANSI` SQL mode to ensure MySQL correctly interprets the standard SQL concatenation operator, the double bar (`||`), in your queries. If you then create a view that concatenates items, you might worry that changing the `sql_mode` setting to a value different from `ANSI` could cause the view to become invalid. But this is not the case. No matter how you write out a view definition, MySQL always stores it the same way, in a canonical form. Here is an example that shows how the server changes a double bar concatenation operator to a `CONCAT()` function:

```
mysql> SET sql_mode = 'ANSI';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE VIEW test.v AS SELECT 'a' || 'b' as col1;
Query OK, 0 rows affected (0.01 sec)

mysql> SHOW CREATE VIEW test.v\G
*************************** 1. row ***************************
                View: v
         Create View: CREATE VIEW "v" AS select concat('a','b') AS "col1"
...
1 row in set (0.00 sec)
```

The advantage of storing a view definition in canonical form is that changes made later to the value of `sql_mode` will not affect the results from the view. However an additional consequence is that comments prior to `SELECT` are stripped from the definition by the server.

13.7.5.15 SHOW DATABASES Syntax

```
SHOW {DATABASES | SCHEMAS}
    [LIKE 'pattern' | WHERE expr]
```

`SHOW DATABASES` lists the databases on the MySQL server host. `SHOW SCHEMAS` is a synonym for `SHOW DATABASES`. The `LIKE` clause, if present, indicates which database names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

You see only those databases for which you have some kind of privilege, unless you have the global `SHOW DATABASES` privilege. You can also get this list using the `mysqlshow` command.

If the server was started with the `--skip-show-database` option, you cannot use this statement at all unless you have the `SHOW DATABASES` privilege.

MySQL implements databases as directories in the data directory, so this statement simply lists directories in that location. However, the output may include names of directories that do not correspond to actual databases.

13.7.5.16 SHOW ENGINE Syntax

```
SHOW ENGINE engine_name {STATUS | MUTEX}
```

`SHOW ENGINE` displays operational information about a storage engine. It requires the `PROCESS` privilege. The statement has these variants:

```
SHOW ENGINE INNODB STATUS
SHOW ENGINE INNODB MUTEX
SHOW ENGINE {NDB | NDBCLUSTER} STATUS
SHOW ENGINE PERFORMANCE_SCHEMA STATUS
```

`SHOW ENGINE INNODB STATUS` displays extensive information from the standard `InnoDB` Monitor about the state of the `InnoDB` storage engine. For information about the standard monitor and other `InnoDB` Monitors that provide information about `InnoDB` processing, see Section 14.20, “InnoDB Monitors”.

`SHOW ENGINE INNODB MUTEX` displays `InnoDB` mutex and rw-lock statistics. Statement output has the following columns:

- `Type`

  Always `InnoDB`.

- `Name`

  The source file where the mutex is implemented, and the line number in the file where the mutex is created. The line number is specific to your version of MySQL.

- `Status`

  The mutex status. This field displays several values if `UNIV_DEBUG` was defined at MySQL compilation time (for example, in `include/univ.i` in the `InnoDB` part of the MySQL source tree). If `UNIV_DEBUG` was not defined, the statement displays only the `os_waits` value. In the latter case (without `UNIV_DEBUG`), the information on which the output is based is insufficient to distinguish regular mutexes and mutexes that protect rw-locks (which permit multiple readers or a single writer). Consequently, the output may appear to contain multiple rows for the same mutex.

  - `count` indicates how many times the mutex was requested.

- `spin_waits` indicates how many times the spinlock had to run.
- `spin_rounds` indicates the number of spinlock rounds. (`spin_rounds` divided by `spin_waits` provides the average round count.)
- `os_waits` indicates the number of operating system waits. This occurs when the spinlock did not work (the mutex was not locked during the spinlock and it was necessary to yield to the operating system and wait).
- `os_yields` indicates the number of times a thread trying to lock a mutex gave up its timeslice and yielded to the operating system (on the presumption that permitting other threads to run will free the mutex so that it can be locked).
- `os_wait_times` indicates the amount of time (in ms) spent in operating system waits. In MySQL 5.5 timing is disabled and this value is always 0.

`SHOW ENGINE INNODB MUTEX` skips the mutexes and rw-locks of buffer pool blocks, as the amount of output can be overwhelming on systems with a large buffer pool. (There is one mutex and one rw-lock in each 16K buffer pool block, and there are 65,536 blocks per gigabyte.) `SHOW ENGINE INNODB MUTEX` also does not list any mutexes or rw-locks that have never been waited on (`os_waits=0`). Thus, `SHOW ENGINE INNODB MUTEX` only displays information about mutexes and rw-locks outside of the buffer pool that have caused at least one OS-level wait.

`SHOW ENGINE INNODB MUTEX` information can be used to diagnose system problems. For example, large values of `spin_waits` and `spin_rounds` may indicate scalability problems.

Use `SHOW ENGINE PERFORMANCE_SCHEMA STATUS` to inspect the internal operation of the Performance Schema code:

```
mysql> SHOW ENGINE PERFORMANCE_SCHEMA STATUS\G
...
*************************** 3. row ***************************
  Type: performance_schema
  Name: events_waits_history.row_size
Status: 76
*************************** 4. row ***************************
  Type: performance_schema
  Name: events_waits_history.row_count
Status: 10000
*************************** 5. row ***************************
  Type: performance_schema
  Name: events_waits_history.memory
Status: 760000
...
*************************** 57. row ***************************
  Type: performance_schema
  Name: performance_schema.memory
Status: 26459600
...
```

This statement is intended to help the DBA understand the effects that different Performance Schema options have on memory requirements.

`Name` values consist of two parts, which name an internal buffer and a buffer attribute, respectively. Interpret buffer names as follows:

- An internal buffer that is not exposed as a table is named within parentheses. Examples: `(pfs_cond_class).row_size`, `(pfs_mutex_class).memory`.
- An internal buffer that is exposed as a table in the `performance_schema` database is named after the table, without parentheses. Examples: `events_waits_history.row_size`, `mutex_instances.row_count`.

- A value that applies to the Performance Schema as a whole begins with `performance_schema`. Example: `performance_schema.memory`.

Buffer attributes have these meanings:

- `row_size` is the size of the internal record used by the implementation, such as the size of a row in a table. `row_size` values cannot be changed.
- `row_count` is the number of internal records, such as the number of rows in a table. `row_count` values can be changed using Performance Schema configuration options.
- For a table, *`tbl_name`*`.memory` is the product of `row_size` and `row_count`. For the Performance Schema as a whole, `performance_schema.memory` is the sum of all the memory used (the sum of all other `memory` values).

In some cases, there is a direct relationship between a Performance Schema configuration parameter and a `SHOW ENGINE` value. For example, `events_waits_history_long.row_count` corresponds to `performance_schema_events_waits_history_long_size`. In other cases, the relationship is more complex. For example, `events_waits_history.row_count` corresponds to `performance_schema_events_waits_history_size` (the number of rows per thread) multiplied by `performance_schema_max_thread_instances` (the number of threads).

If the server has the `NDBCLUSTER` storage engine enabled, `SHOW ENGINE NDB STATUS` displays cluster status information such as the number of connected data nodes, the cluster connectstring, and cluster binary log epochs, as well as counts of various Cluster API objects created by the MySQL Server when connected to the cluster. Sample output from this statement is shown here:

```
mysql> SHOW ENGINE NDB STATUS;
+------------+----------------------+--------------------------------------------------+
| Type       | Name                 | Status                                           |
+------------+----------------------+--------------------------------------------------+
| ndbcluster | connection           | cluster_node_id=7,
  connected_host=198.51.100.103, connected_port=1186, number_of_data_nodes=4,
  number_of_ready_data_nodes=3, connect_count=0                                       |
| ndbcluster | NdbTransaction       | created=6, free=0, sizeof=212                    |
| ndbcluster | NdbOperation         | created=8, free=8, sizeof=660                    |
| ndbcluster | NdbIndexScanOperation | created=1, free=1, sizeof=744                   |
| ndbcluster | NdbIndexOperation    | created=0, free=0, sizeof=664                    |
| ndbcluster | NdbRecAttr           | created=1285, free=1285, sizeof=60               |
| ndbcluster | NdbApiSignal         | created=16, free=16, sizeof=136                  |
| ndbcluster | NdbLabel             | created=0, free=0, sizeof=196                    |
| ndbcluster | NdbBranch            | created=0, free=0, sizeof=24                     |
| ndbcluster | NdbSubroutine        | created=0, free=0, sizeof=68                     |
| ndbcluster | NdbCall              | created=0, free=0, sizeof=16                     |
| ndbcluster | NdbBlob              | created=1, free=1, sizeof=264                    |
| ndbcluster | NdbReceiver          | created=4, free=0, sizeof=68                     |
| ndbcluster | binlog               | latest_epoch=155467, latest_trans_epoch=148126,
  latest_received_binlog_epoch=0, latest_handled_binlog_epoch=0,
  latest_applied_binlog_epoch=0                                                       |
+------------+----------------------+--------------------------------------------------+
```

The rows with `connection` and `binlog` in the `Name` column were added to the output of this statement in MySQL 5.1. The `Status` column in each of these rows provides information about the MySQL server's connection to the cluster and about the cluster binary log's status, respectively. The `Status` information is in the form of comma-delimited set of name/value pairs.

The `connection` row's `Status` column contains the name/value pairs described in the following table.

Name	Value
`cluster_node_id`	The node ID of the MySQL server in the cluster
`connected_host`	The host name or IP address of the cluster management server to which the MySQL server is connected

Name	Value
connected_port	The port used by the MySQL server to connect to the management server (connected_host)
number_of_data_nodes	The number of data nodes configured for the cluster (that is, the number of [ndbd] sections in the cluster config.ini file)
number_of_ready_data_nodes	The number of data nodes in the cluster that are actually running
connect_count	The number of times this mysqld has connected or reconnected to cluster data nodes

The binlog row's Status column contains information relating to NDB Cluster Replication. The name/value pairs it contains are described in the following table.

Name	Value
latest_epoch	The most recent epoch most recently run on this MySQL server (that is, the sequence number of the most recent transaction run on the server)
latest_trans_epoch	The most recent epoch processed by the cluster's data nodes
latest_received_binlog_epoch	The most recent epoch received by the binary log thread
latest_handled_binlog_epoch	The most recent epoch processed by the binary log thread (for writing to the binary log)
latest_applied_binlog_epoch	The most recent epoch actually written to the binlog

See Section 18.6, “NDB Cluster Replication”, for more information.

The remaining rows from the output of SHOW ENGINE NDB STATUS which are most likely to prove useful in monitoring the cluster are listed here by Name:

- NdbTransaction: The number and size of NdbTransaction objects that have been created. An NdbTransaction is created each time a table schema operation (such as CREATE TABLE or ALTER TABLE) is performed on an NDB table.
- NdbOperation: The number and size of NdbOperation objects that have been created.
- NdbIndexScanOperation: The number and size of NdbIndexScanOperation objects that have been created.
- NdbIndexOperation: The number and size of NdbIndexOperation objects that have been created.
- NdbRecAttr: The number and size of NdbRecAttr objects that have been created. In general, one of these is created each time a data manipulation statement is performed by an SQL node.
- NdbBlob: The number and size of NdbBlob objects that have been created. An NdbBlob is created for each new operation involving a BLOB column in an NDB table.
- NdbReceiver: The number and size of any NdbReceiver object that have been created. The number in the created column is the same as the number of data nodes in the cluster to which the MySQL server has connected.

Note

SHOW ENGINE NDB STATUS returns an empty result if no operations involving NDB tables have been performed during the current session by the MySQL client accessing the SQL node on which this statement is run.

13.7.5.17 SHOW ENGINES Syntax

```
SHOW [STORAGE] ENGINES
```

`SHOW ENGINES` displays status information about the server's storage engines. This is particularly useful for checking whether a storage engine is supported, or to see what the default engine is. This information can also be obtained from the `INFORMATION_SCHEMA ENGINES` table. See Section 21.6, "The INFORMATION_SCHEMA ENGINES Table".

```
mysql> SHOW ENGINES\G
*************************** 1. row ***************************
      Engine: FEDERATED
     Support: NO
     Comment: Federated MySQL storage engine
Transactions: NULL
          XA: NULL
  Savepoints: NULL
*************************** 2. row ***************************
      Engine: MRG_MYISAM
     Support: YES
     Comment: Collection of identical MyISAM tables
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 3. row ***************************
      Engine: MyISAM
     Support: YES
     Comment: MyISAM storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 4. row ***************************
      Engine: BLACKHOLE
     Support: YES
     Comment: /dev/null storage engine (anything you write to it disappears)
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 5. row ***************************
      Engine: CSV
     Support: YES
     Comment: CSV storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 6. row ***************************
      Engine: MEMORY
     Support: YES
     Comment: Hash based, stored in memory, useful for temporary tables
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 7. row ***************************
      Engine: ARCHIVE
     Support: YES
     Comment: Archive storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 8. row ***************************
      Engine: InnoDB
     Support: DEFAULT
     Comment: Supports transactions, row-level locking, and foreign keys
Transactions: YES
          XA: YES
  Savepoints: YES
*************************** 9. row ***************************
      Engine: PERFORMANCE_SCHEMA
     Support: YES
```

```
     Comment: Performance Schema
Transactions: NO
          XA: NO
  Savepoints: NO
```

The output from `SHOW ENGINES` may vary according to the MySQL version used and other factors. The values shown in the `Support` column indicate the server's level of support for the storage engine, as shown in the following table.

Value	Meaning
`YES`	The engine is supported and is active
`DEFAULT`	Like `YES`, plus this is the default engine
`NO`	The engine is not supported
`DISABLED`	The engine is supported but has been disabled

A value of `NO` means that the server was compiled without support for the engine, so it cannot be enabled at runtime.

A value of `DISABLED` occurs either because the server was started with an option that disables the engine, or because not all options required to enable it were given. In the latter case, the error log should contain a reason indicating why the option is disabled. See Section 5.4.2, “The Error Log”.

You might also see `DISABLED` for a storage engine if the server was compiled to support it, but was started with a `--skip-`*`engine_name`* option. For the `NDBCLUSTER` storage engine, `DISABLED` means the server was compiled with support for NDB Cluster, but was not started with the `--ndbcluster` option.

All MySQL servers support `MyISAM` tables. It is not possible to disable `MyISAM`.

The `Transactions`, `XA`, and `Savepoints` columns indicate whether the storage engine supports transactions, XA transactions, and savepoints, respectively.

13.7.5.18 SHOW ERRORS Syntax

```
SHOW ERRORS [LIMIT [offset,] row_count]
SHOW COUNT(*) ERRORS
```

`SHOW ERRORS` is a diagnostic statement that is similar to `SHOW WARNINGS`, except that it displays information only for errors, rather than for errors, warnings, and notes.

The `LIMIT` clause has the same syntax as for the `SELECT` statement. See Section 13.2.9, “SELECT Syntax”.

The `SHOW COUNT(*) ERRORS` statement displays the number of errors. You can also retrieve this number from the `error_count` variable:

```
SHOW COUNT(*) ERRORS;
SELECT @@error_count;
```

`SHOW ERRORS` and `error_count` apply only to errors, not warnings or notes. In other respects, they are similar to `SHOW WARNINGS` and `warning_count`. In particular, `SHOW ERRORS` cannot display information for more than `max_error_count` messages, and `error_count` can exceed the value of `max_error_count` if the number of errors exceeds `max_error_count`.

For more information, see Section 13.7.5.41, “SHOW WARNINGS Syntax”.

13.7.5.19 SHOW EVENTS Syntax

```
SHOW EVENTS
    [{FROM | IN} schema_name]
    [LIKE 'pattern' | WHERE expr]
```

This statement displays information about Event Manager events. It requires the `EVENT` privilege for the database from which the events are to be shown.

In its simplest form, `SHOW EVENTS` lists all of the events in the current schema:

```
mysql> SELECT CURRENT_USER(), SCHEMA();
+----------------+----------+
| CURRENT_USER() | SCHEMA() |
+----------------+----------+
| jon@ghidora    | myschema |
+----------------+----------+
1 row in set (0.00 sec)

mysql> SHOW EVENTS\G
*************************** 1. row ***************************
                  Db: myschema
                Name: e_daily
             Definer: jon@ghidora
           Time zone: SYSTEM
                Type: RECURRING
          Execute at: NULL
      Interval value: 10
      Interval field: SECOND
              Starts: 2006-02-09 10:41:23
                Ends: NULL
              Status: ENABLED
          Originator: 0
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

To see events for a specific schema, use the `FROM` clause. For example, to see events for the `test` schema, use the following statement:

```
SHOW EVENTS FROM test;
```

The `LIKE` clause, if present, indicates which event names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

`SHOW EVENTS` output has the following columns:

- `Db`: The schema (database) on which the event is defined.
- `Name`: The name of the event.
- `Time zone`: The event time zone, which is the time zone used for scheduling the event and that is in effect within the event as it executes. The default value is `SYSTEM`.
- `Definer`: The account of the user who created the event, in *`'user_name'@'host_name'`* format.
- `Type`: The event repetition type, either `ONE TIME` (transient) or `RECURRING` (repeating).
- `Execute At`: The date and time when a transient event is set to execute. Shown as a `DATETIME` value.

  For a recurring event, the value of this column is always `NULL`.
- `Interval Value`: For a recurring event, the number of intervals to wait between event executions.

  For a transient event, the value of this column is always `NULL`.

- `Interval Field`: The time units used for the interval which a recurring event waits before repeating.

  For a transient event, the value of this column is always `NULL`.

- `Starts`: The start date and time for a recurring event. This is displayed as a `DATETIME` value, and is `NULL` if no start date and time are defined for the event.

  For a transient event, this column is always `NULL`.

- `Ends`: The end date and time for a recurring event. This is displayed as a `DATETIME` value, and defaults to `NULL` if no end date and time is defined for the event.

  For a transient event, this column is always `NULL`.

- `Status`: The event status. One of `ENABLED`, `DISABLED`, or `SLAVESIDE_DISABLED`.

  `SLAVESIDE_DISABLED` indicates that the creation of the event occurred on another MySQL server acting as a replication master and replicated to the current MySQL server which is acting as a slave, but the event is not presently being executed on the slave.

- `Originator`: The server ID of the MySQL server on which the event was created. Defaults to 0.

- `character_set_client` is the session value of the `character_set_client` system variable when the routine was created. `collation_connection` is the session value of the `collation_connection` system variable when the routine was created. `Database Collation` is the collation of the database with which the routine is associated.

For more information about `SLAVE_DISABLED` and the `Originator` column, see Section 17.4.1.15, “Replication of Invoked Features”.

The event action statement is not shown in the output of `SHOW EVENTS`. Use `SHOW CREATE EVENT` or the `INFORMATION_SCHEMA.EVENTS` table.

Times displayed by `SHOW EVENTS` are given in the event time zone, as discussed in Section 20.4.4, “Event Metadata”.

The columns in the output of `SHOW EVENTS` are similar to, but not identical to the columns in the `INFORMATION_SCHEMA.EVENTS` table. See Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”.

13.7.5.20 SHOW FUNCTION CODE Syntax

```
SHOW FUNCTION CODE func_name
```

This statement is similar to `SHOW PROCEDURE CODE` but for stored functions. See Section 13.7.5.28, “SHOW PROCEDURE CODE Syntax”.

13.7.5.21 SHOW FUNCTION STATUS Syntax

```
SHOW FUNCTION STATUS
    [LIKE 'pattern' | WHERE expr]
```

This statement is similar to `SHOW PROCEDURE STATUS` but for stored functions. See Section 13.7.5.29, “SHOW PROCEDURE STATUS Syntax”.

13.7.5.22 SHOW GRANTS Syntax

```
SHOW GRANTS [FOR user]
```

This statement displays the privileges that are assigned to a MySQL user account, in the form of `GRANT` statements that must be executed to duplicate the privilege assignments.

`SHOW GRANTS` requires the `SELECT` privilege for the `mysql` database, except to display privileges for the current user. For output that includes an `IDENTIFIED BY PASSWORD` clause displaying an account password hash value, the `SUPER` privilege is required to see the actual hash value. Otherwise, the value displays as `<secret>`.

To name the account for `SHOW GRANTS`, use the same format as for the `GRANT` statement; for example, `'jeffrey'@'localhost'`:

```
mysql> SHOW GRANTS FOR 'jeffrey'@'localhost';
+-----------------------------------------------------------------+
| Grants for jeffrey@localhost                                    |
+-----------------------------------------------------------------+
| GRANT USAGE ON *.* TO `jeffrey`@`localhost`                     |
| GRANT SELECT, INSERT, UPDATE ON `db1`.* TO `jeffrey`@`localhost` |
+-----------------------------------------------------------------+
```

The host part, if omitted, defaults to `'%'`. For additional information about specifying account names, see Section 6.2.3, “Specifying Account Names”.

To display the privileges granted to the current user (the account you are using to connect to the server), you can use any of the following statements:

```
SHOW GRANTS;
SHOW GRANTS FOR CURRENT_USER;
SHOW GRANTS FOR CURRENT_USER();
```

If `SHOW GRANTS FOR CURRENT_USER` (or any of the equivalent syntaxes) is used in definer context, such as within a stored procedure that executes with definer rather than invoker privileges), the grants displayed are those of the definer and not the invoker.

`SHOW GRANTS` does not display privileges that are available to the named account but are granted to a different account. For example, if an anonymous account exists, the named account might be able to use its privileges, but `SHOW GRANTS` does not display them.

13.7.5.23 SHOW INDEX Syntax

```
SHOW {INDEX | INDEXES | KEYS}
    {FROM | IN} tbl_name
    [{FROM | IN} db_name]
    [WHERE expr]
```

`SHOW INDEX` returns table index information. The format resembles that of the `SQLStatistics` call in ODBC. This statement requires some privilege for any column in the table.

You can use *`db_name.tbl_name`* as an alternative to the *`tbl_name FROM db_name`* syntax. These two statements are equivalent:

```
SHOW INDEX FROM mytable FROM mydb;
SHOW INDEX FROM mydb.mytable;
```

The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

```
mysql> SHOW INDEX FROM City\G
*************************** 1. row ***************************
```

```
        Table: city
   Non_unique: 0
     Key_name: PRIMARY
 Seq_in_index: 1
  Column_name: ID
    Collation: A
  Cardinality: 4321
     Sub_part: NULL
       Packed: NULL
         Null:
   Index_type: BTREE
      Comment:
Index_comment:
*************************** 2. row ***************************
        Table: city
   Non_unique: 1
     Key_name: CountryCode
 Seq_in_index: 1
  Column_name: CountryCode
    Collation: A
  Cardinality: 4321
     Sub_part: NULL
       Packed: NULL
         Null:
   Index_type: BTREE
      Comment:
Index_comment:
```

`SHOW INDEX` returns the following fields:

- `Table`

  The name of the table.

- `Non_unique`

  0 if the index cannot contain duplicates, 1 if it can.

- `Key_name`

  The name of the index. If the index is the primary key, the name is always `PRIMARY`.

- `Seq_in_index`

  The column sequence number in the index, starting with 1.

- `Column_name`

  The column name.

- `Collation`

  How the column is sorted in the index. This can have values `A` (ascending) or `NULL` (not sorted).

- `Cardinality`

  An estimate of the number of unique values in the index. To update this number, run `ANALYZE TABLE` or (for `MyISAM` tables) `myisamchk -a`.

  `Cardinality` is counted based on statistics stored as integers, so the value is not necessarily exact even for small tables. The higher the cardinality, the greater the chance that MySQL uses the index when doing joins.

- `Sub_part`

  The index prefix. That is, the number of indexed characters if the column is only partly indexed, `NULL` if the entire column is indexed.

Note

Prefix limits are measured in bytes, whereas the prefix length in `CREATE TABLE`, `ALTER TABLE`, and `CREATE INDEX` statements is interpreted as number of characters for nonbinary string types (`CHAR`, `VARCHAR`, `TEXT`) and number of bytes for binary string types (`BINARY`, `VARBINARY`, `BLOB`). Take this into account when specifying a prefix length for a nonbinary string column that uses a multibyte character set.

For additional information about index prefixes, see Section 8.3.4, “Column Indexes”, and Section 13.1.13, “CREATE INDEX Syntax”.

- `Packed`

  Indicates how the key is packed. `NULL` if it is not.

- `Null`

  Contains `YES` if the column may contain `NULL` values and `''` if not.

- `Index_type`

  The index method used (`BTREE`, `FULLTEXT`, `HASH`, `RTREE`).

- `Comment`

  Information about the index not described in its own column, such as `disabled` if the index is disabled.

- `Index_comment`

  Any comment provided for the index with a `COMMENT` attribute when the index was created.

You can also obtain information about table indexes from `INFORMATION_SCHEMA`, which contains a `STATISTICS` table. See Section 21.20, “The INFORMATION_SCHEMA STATISTICS Table”.

You can list a table's indexes with the `mysqlshow -k db_name tbl_name` command.

13.7.5.24 SHOW MASTER STATUS Syntax

```
SHOW MASTER STATUS
```

This statement provides status information about the binary log files of the master. It requires either the `SUPER` or `REPLICATION CLIENT` privilege.

Example:

```
mysql> SHOW MASTER STATUS;
+--------------+----------+--------------+------------------+
| File         | Position | Binlog_Do_DB | Binlog_Ignore_DB |
+--------------+----------+--------------+------------------+
| mysql-bin.003 | 73       | test         | manual,mysql     |
+--------------+----------+--------------+------------------+
```

13.7.5.25 SHOW OPEN TABLES Syntax

```
SHOW OPEN TABLES
    [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW OPEN TABLES` lists the non-`TEMPORARY` tables that are currently open in the table cache. See Section 8.4.3.1, “How MySQL Opens and Closes Tables”. The `FROM` clause, if present, restricts the

tables shown to those present in the *db_name* database. The `LIKE` clause, if present, indicates which table names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

`SHOW OPEN TABLES` output has the following columns:

- `Database`

  The database containing the table.

- `Table`

  The table name.

- `In_use`

  The number of table locks or lock requests there are for the table. For example, if one client acquires a lock for a table using `LOCK TABLE t1 WRITE`, `In_use` will be 1. If another client issues `LOCK TABLE t1 WRITE` while the table remains locked, the client will block waiting for the lock, but the lock request causes `In_use` to be 2. If the count is zero, the table is open but not currently being used. `In_use` is also increased by the `HANDLER ... OPEN` statement and decreased by `HANDLER ... CLOSE`.

- `Name_locked`

  Whether the table name is locked. Name locking is used for operations such as dropping or renaming tables.

If you have no privileges for a table, it does not show up in the output from `SHOW OPEN TABLES`.

13.7.5.26 SHOW PLUGINS Syntax

```
SHOW PLUGINS
```

`SHOW PLUGINS` displays information about server plugins. Plugin information is also available in the `INFORMATION_SCHEMA.PLUGINS` table. See Section 21.13, “The INFORMATION_SCHEMA PLUGINS Table”.

Example of `SHOW PLUGINS` output:

```
mysql> SHOW PLUGINS\G
*************************** 1. row ***************************
   Name: binlog
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
*************************** 2. row ***************************
   Name: CSV
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
*************************** 3. row ***************************
   Name: MEMORY
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
*************************** 4. row ***************************
   Name: MyISAM
 Status: ACTIVE
   Type: STORAGE ENGINE
Library: NULL
License: GPL
```

```
...
```

`SHOW PLUGINS` output has the following columns:

- `Name`: The name used to refer to the plugin in statements such as `INSTALL PLUGIN` and `UNINSTALL PLUGIN`.
- `Status`: The plugin status, one of `ACTIVE`, `INACTIVE`, `DISABLED`, or `DELETED`.
- `Type`: The type of plugin, such as `STORAGE ENGINE`, `INFORMATION_SCHEMA`, or `AUTHENTICATION`.
- `Library`: The name of the plugin shared library file. This is the name used to refer to the plugin file in statements such as `INSTALL PLUGIN` and `UNINSTALL PLUGIN`. This file is located in the directory named by the `plugin_dir` system variable. If the library name is `NULL`, the plugin is compiled in and cannot be uninstalled with `UNINSTALL PLUGIN`.
- `License`: How the plugin is licensed; for example, `GPL`.

For plugins installed with `INSTALL PLUGIN`, the `Name` and `Library` values are also registered in the `mysql.plugin` table.

For information about plugin data structures that form the basis of the information displayed by `SHOW PLUGINS`, see Section 24.2, “The MySQL Plugin API”.

13.7.5.27 SHOW PRIVILEGES Syntax

```
SHOW PRIVILEGES
```

`SHOW PRIVILEGES` shows the list of system privileges that the MySQL server supports. The exact list of privileges depends on the version of your server.

```
mysql> SHOW PRIVILEGES\G
*************************** 1. row ***************************
Privilege: Alter
  Context: Tables
  Comment: To alter the table
*************************** 2. row ***************************
Privilege: Alter routine
  Context: Functions,Procedures
  Comment: To alter or drop stored functions/procedures
*************************** 3. row ***************************
Privilege: Create
  Context: Databases,Tables,Indexes
  Comment: To create new databases and tables
*************************** 4. row ***************************
Privilege: Create routine
  Context: Databases
  Comment: To use CREATE FUNCTION/PROCEDURE
*************************** 5. row ***************************
Privilege: Create temporary tables
  Context: Databases
  Comment: To use CREATE TEMPORARY TABLE
...
```

Privileges belonging to a specific user are displayed by the `SHOW GRANTS` statement. See Section 13.7.5.22, “SHOW GRANTS Syntax”, for more information.

13.7.5.28 SHOW PROCEDURE CODE Syntax

```
SHOW PROCEDURE CODE proc_name
```

This statement is a MySQL extension that is available only for servers that have been built with debugging support. It displays a representation of the internal implementation of the named stored

procedure. A similar statement, `SHOW FUNCTION CODE`, displays information about stored functions (see Section 13.7.5.20, “SHOW FUNCTION CODE Syntax”).

To use either statement, you must be the owner of the routine or have `SELECT` access to the `mysql.proc` table.

If the named routine is available, each statement produces a result set. Each row in the result set corresponds to one “instruction” in the routine. The first column is `Pos`, which is an ordinal number beginning with 0. The second column is `Instruction`, which contains an SQL statement (usually changed from the original source), or a directive which has meaning only to the stored-routine handler.

```
mysql> DELIMITER //
mysql> CREATE PROCEDURE p1 ()
    -> BEGIN
    ->   DECLARE fanta INT DEFAULT 55;
    ->   DROP TABLE t2;
    ->   LOOP
    ->     INSERT INTO t3 VALUES (fanta);
    ->     END LOOP;
    ->   END//
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW PROCEDURE CODE p1//
+-----+----------------------------------------+
| Pos | Instruction                            |
+-----+----------------------------------------+
|   0 | set fanta@0 55                         |
|   1 | stmt 9 "DROP TABLE t2"                 |
|   2 | stmt 5 "INSERT INTO t3 VALUES (fanta)" |
|   3 | jump 2                                 |
+-----+----------------------------------------+
4 rows in set (0.00 sec)
```

In this example, the nonexecutable `BEGIN` and `END` statements have disappeared, and for the `DECLARE` *`variable_name`* statement, only the executable part appears (the part where the default is assigned). For each statement that is taken from source, there is a code word `stmt` followed by a type (9 means `DROP`, 5 means `INSERT`, and so on). The final row contains an instruction `jump 2`, meaning `GOTO instruction #2`.

13.7.5.29 SHOW PROCEDURE STATUS Syntax

```
SHOW PROCEDURE STATUS
    [LIKE 'pattern' | WHERE expr]
```

This statement is a MySQL extension. It returns characteristics of a stored procedure, such as the database, name, type, creator, creation and modification dates, and character set information. A similar statement, `SHOW FUNCTION STATUS`, displays information about stored functions (see Section 13.7.5.21, “SHOW FUNCTION STATUS Syntax”).

The `LIKE` clause, if present, indicates which procedure or function names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

```
mysql> SHOW PROCEDURE STATUS LIKE 'sp1'\G
*************************** 1. row ***************************
                  Db: test
                Name: sp1
                Type: PROCEDURE
             Definer: testuser@localhost
            Modified: 2004-08-03 15:29:37
             Created: 2004-08-03 15:29:37
       Security_type: DEFINER
             Comment:
character_set_client: latin1
```

```
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

`character_set_client` is the session value of the `character_set_client` system variable when the routine was created. `collation_connection` is the session value of the `collation_connection` system variable when the routine was created. `Database Collation` is the collation of the database with which the routine is associated.

You can also get information about stored routines from the `ROUTINES` table in `INFORMATION_SCHEMA`. See Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”.

13.7.5.30 SHOW PROCESSLIST Syntax

```
SHOW [FULL] PROCESSLIST
```

`SHOW PROCESSLIST` shows you which threads are running. You can also get this information from the `INFORMATION_SCHEMA PROCESSLIST` table or the `mysqladmin processlist` command. If you have the `PROCESS` privilege, you can see all threads. Otherwise, you can see only your own threads (that is, threads associated with the MySQL account that you are using). If you do not use the `FULL` keyword, only the first 100 characters of each statement are shown in the `Info` field.

This statement is very useful if you get the “too many connections” error message and want to find out what is going on. MySQL reserves one extra connection to be used by accounts that have the `SUPER` privilege, to ensure that administrators should always be able to connect and check the system (assuming that you are not giving this privilege to all your users).

Threads can be killed with the `KILL` statement. See Section 13.7.6.4, “KILL Syntax”.

Here is an example of `SHOW PROCESSLIST` output:

```
mysql> SHOW FULL PROCESSLIST\G
*************************** 1. row ***************************
Id: 1
User: system user
Host:
db: NULL
Command: Connect
Time: 1030455
State: Waiting for master to send event
Info: NULL
*************************** 2. row ***************************
Id: 2
User: system user
Host:
db: NULL
Command: Connect
Time: 1004
State: Has read all relay log; waiting for the slave
       I/O thread to update it
Info: NULL
*************************** 3. row ***************************
Id: 3112
User: replikator
Host: artemis:2204
db: NULL
Command: Binlog Dump
Time: 2144
State: Has sent all binlog to slave; waiting for binlog to be updated
Info: NULL
*************************** 4. row ***************************
Id: 3113
User: replikator
Host: iconnect2:45781
db: NULL
Command: Binlog Dump
Time: 2086
```

```
State: Has sent all binlog to slave; waiting for binlog to be updated
Info: NULL
*************************** 5. row ***************************
Id: 3123
User: stefan
Host: localhost
db: apollon
Command: Query
Time: 0
State: NULL
Info: SHOW FULL PROCESSLIST
5 rows in set (0.00 sec)
```

The columns produced by `SHOW PROCESSLIST` have the following meanings:

- `Id`

  The connection identifier. This is the same type of value displayed in the `ID` column of the `INFORMATION_SCHEMA.PROCESSLIST` table, the `PROCESSLIST_ID` column of the Performance Schema `threads` table, and returned by the `CONNECTION_ID()` function.

- `User`

  The MySQL user who issued the statement. If this is `system user`, it refers to a nonclient thread spawned by the server to handle tasks internally. This could be the I/O or SQL thread used on replication slaves or a delayed-row handler. `unauthenticated user` refers to a thread that has become associated with a client connection but for which authentication of the client user has not yet been done. `event_scheduler` refers to the thread that monitors scheduled events. For `system user`, there is no host specified in the `Host` column.

- `Host`

  The host name of the client issuing the statement (except for `system user` where there is no host). `SHOW PROCESSLIST` reports the host name for TCP/IP connections in *`host_name:client_port`* format to make it easier to determine which client is doing what.

- `db`

  The default database, if one is selected, otherwise `NULL`.

- `Command`

  The type of command the thread is executing. For descriptions for thread commands, see Section 8.14, “Examining Thread Information”. The value of this column corresponds to the `COM_`*`xxx`* commands of the client/server protocol and `Com_`*`xxx`* status variables. See Section 5.1.7, “Server Status Variables”

- `Time`

  The time in seconds that the thread has been in its current state. For a slave SQL thread, the value is the number of seconds between the timestamp of the last replicated event and the real time of the slave machine. See Section 17.2.1, “Replication Implementation Details”.

- `State`

  An action, event, or state that indicates what the thread is doing. Descriptions for `State` values can be found at Section 8.14, “Examining Thread Information”.

  Most states correspond to very quick operations. If a thread stays in a given state for many seconds, there might be a problem that needs to be investigated.

  For the `SHOW PROCESSLIST` statement, the value of `State` is `NULL`.

- `Info`

The statement the thread is executing, or `NULL` if it is not executing any statement. The statement might be the one sent to the server, or an innermost statement if the statement executes other statements. For example, if a `CALL` statement executes a stored procedure that is executing a `SELECT` statement, the `Info` value shows the `SELECT` statement.

13.7.5.31 SHOW PROFILE Syntax

```
SHOW PROFILE [type [, type] ... ]
    [FOR QUERY n]
    [LIMIT row_count [OFFSET offset]]

type:
    ALL
  | BLOCK IO
  | CONTEXT SWITCHES
  | CPU
  | IPC
  | MEMORY
  | PAGE FAULTS
  | SOURCE
  | SWAPS
```

The `SHOW PROFILE` and `SHOW PROFILES` statements display profiling information that indicates resource usage for statements executed during the course of the current session.

Profiling is controlled by the `profiling` session variable, which has a default value of 0 (`OFF`). Profiling is enabled by setting `profiling` to 1 or `ON`:

```
mysql> SET profiling = 1;
```

`SHOW PROFILES` displays a list of the most recent statements sent to the server. The size of the list is controlled by the `profiling_history_size` session variable, which has a default value of 15. The maximum value is 100. Setting the value to 0 has the practical effect of disabling profiling.

All statements are profiled except `SHOW PROFILE` and `SHOW PROFILES`, so you will find neither of those statements in the profile list. Malformed statements are profiled. For example, `SHOW PROFILING` is an illegal statement, and a syntax error occurs if you try to execute it, but it will show up in the profiling list.

`SHOW PROFILE` displays detailed information about a single statement. Without the `FOR QUERY n` clause, the output pertains to the most recently executed statement. If `FOR QUERY n` is included, `SHOW PROFILE` displays information for statement *`n`*. The values of *`n`* correspond to the `Query_ID` values displayed by `SHOW PROFILES`.

The `LIMIT row_count` clause may be given to limit the output to *`row_count`* rows. If `LIMIT` is given, `OFFSET offset` may be added to begin the output *`offset`* rows into the full set of rows.

By default, `SHOW PROFILE` displays `Status` and `Duration` columns. The `Status` values are like the `State` values displayed by `SHOW PROCESSLIST`, although there might be some minor differences in interpretion for the two statements for some status values (see Section 8.14, “Examining Thread Information”).

Optional *`type`* values may be specified to display specific additional types of information:

- `ALL` displays all information
- `BLOCK IO` displays counts for block input and output operations
- `CONTEXT SWITCHES` displays counts for voluntary and involuntary context switches
- `CPU` displays user and system CPU usage times
- `IPC` displays counts for messages sent and received

- `MEMORY` is not currently implemented
- `PAGE FAULTS` displays counts for major and minor page faults
- `SOURCE` displays the names of functions from the source code, together with the name and line number of the file in which the function occurs
- `SWAPS` displays swap counts

Profiling is enabled per session. When a session ends, its profiling information is lost.

```
mysql> SELECT @@profiling;
+-------------+
| @@profiling |
+-------------+
|           0 |
+-------------+
1 row in set (0.00 sec)

mysql> SET profiling = 1;
Query OK, 0 rows affected (0.00 sec)

mysql> DROP TABLE IF EXISTS t1;
Query OK, 0 rows affected, 1 warning (0.00 sec)

mysql> CREATE TABLE T1 (id INT);
Query OK, 0 rows affected (0.01 sec)

mysql> SHOW PROFILES;
+----------+----------+--------------------------+
| Query_ID | Duration | Query                    |
+----------+----------+--------------------------+
|        0 | 0.000088 | SET PROFILING = 1        |
|        1 | 0.000136 | DROP TABLE IF EXISTS t1  |
|        2 | 0.011947 | CREATE TABLE t1 (id INT) |
+----------+----------+--------------------------+
3 rows in set (0.00 sec)

mysql> SHOW PROFILE;
+----------------------+----------+
| Status               | Duration |
+----------------------+----------+
| checking permissions | 0.000040 |
| creating table       | 0.000056 |
| After create         | 0.011363 |
| query end            | 0.000375 |
| freeing items        | 0.000089 |
| logging slow query   | 0.000019 |
| cleaning up          | 0.000005 |
+----------------------+----------+
7 rows in set (0.00 sec)

mysql> SHOW PROFILE FOR QUERY 1;
+--------------------+----------+
| Status             | Duration |
+--------------------+----------+
| query end          | 0.000107 |
| freeing items      | 0.000008 |
| logging slow query | 0.000015 |
| cleaning up        | 0.000006 |
+--------------------+----------+
4 rows in set (0.00 sec)

mysql> SHOW PROFILE CPU FOR QUERY 2;
+----------------------+----------+----------+------------+
| Status               | Duration | CPU_user | CPU_system |
+----------------------+----------+----------+------------+
| checking permissions | 0.000040 | 0.000038 |   0.000002 |
| creating table       | 0.000056 | 0.000028 |   0.000028 |
| After create         | 0.011363 | 0.000217 |   0.001571 |
```

```
| query end            | 0.000375 | 0.000013 |   0.000028 |
| freeing items        | 0.000089 | 0.000010 |   0.000014 |
| logging slow query   | 0.000019 | 0.000009 |   0.000010 |
| cleaning up          | 0.000005 | 0.000003 |   0.000002 |
+----------------------+----------+----------+------------+
7 rows in set (0.00 sec)
```

Note

Profiling is only partially functional on some architectures. For values that depend on the `getrusage()` system call, `NULL` is returned on systems such as Windows that do not support the call. In addition, profiling is per process and not per thread. This means that activity on threads within the server other than your own may affect the timing information that you see.

You can also get profiling information from the `PROFILING` table in `INFORMATION_SCHEMA`. See Section 21.15, “The INFORMATION_SCHEMA PROFILING Table”. For example, the following queries produce the same result:

```
SHOW PROFILE FOR QUERY 2;

SELECT STATE, FORMAT(DURATION, 6) AS DURATION
FROM INFORMATION_SCHEMA.PROFILING
WHERE QUERY_ID = 2 ORDER BY SEQ;
```

13.7.5.32 SHOW PROFILES Syntax

```
SHOW PROFILES
```

The `SHOW PROFILES` statement, together with `SHOW PROFILE`, displays profiling information that indicates resource usage for statements executed during the course of the current session. For more information, see Section 13.7.5.31, “SHOW PROFILE Syntax”.

13.7.5.33 SHOW RELAYLOG EVENTS Syntax

```
SHOW RELAYLOG EVENTS
    [IN 'log_name']
    [FROM pos]
    [LIMIT [offset,] row_count]
```

Shows the events in the relay log of a replication slave. If you do not specify `'log_name'`, the first relay log is displayed. This statement has no effect on the master.

The `LIMIT` clause has the same syntax as for the `SELECT` statement. See Section 13.2.9, “SELECT Syntax”.

Note

Issuing a `SHOW RELAYLOG EVENTS` with no `LIMIT` clause could start a very time- and resource-consuming process because the server returns to the client the complete contents of the relay log (including all statements modifying data that have been received by the slave).

Note

Some events relating to the setting of user and system variables are not included in the output from `SHOW RELAYLOG EVENTS`. To get complete coverage of events within a relay log, use `mysqlbinlog`.

13.7.5.34 SHOW SLAVE HOSTS Syntax

```
SHOW SLAVE HOSTS
```

Displays a list of replication slaves currently registered with the master.

`SHOW SLAVE HOSTS` should be executed on a server that acts as a replication master. The statement displays information about servers that are or have been connected as replication slaves, with each row of the result corresponding to one slave server, as shown here:

```
mysql> SHOW SLAVE HOSTS;
+------------+-----------+------+-----------+
| Server_id  | Host      | Port | Master_id |
+------------+-----------+------+-----------+
|  192168010 | iconnect2 | 3306 | 192168011 |
| 1921680101 | athena    | 3306 | 192168011 |
+------------+-----------+------+-----------+
```

- `Server_id`: The unique server ID of the slave server, as configured in the slave server's option file, or on the command line with `--server-id=value`.
- `Host`: The host name of the slave server as specified on the slave with the `--report-host` option. This can differ from the machine name as configured in the operating system.
- `User`: The slave server user name as, specified on the slave with the `--report-user` option. Statement output includes this column only if the master server is started with the `--show-slave-auth-info` option.
- `Password`: The slave server password as, specified on the slave with the `--report-password` option. Statement output includes this column only if the master server is started with the `--show-slave-auth-info` option.
- `Port`: The port on the master to which the slave server is listening, as specified on the slave with the `--report-port` option.

  In MySQL 5.5.23 and later, a zero in this column means that the slave port (`--report-port`) was not set. Prior to MySQL 5.5.23, 3306 was used as the default in such cases (Bug #13333431).
- `Master_id`: The unique server ID of the master server that the slave server is replicating from. This is the server ID of the server on which `SHOW SLAVE HOSTS` is executed, so this same value is listed for each row in the result.

13.7.5.35 SHOW SLAVE STATUS Syntax

```
SHOW SLAVE STATUS
```

This statement provides status information on essential parameters of the slave threads. It requires either the `SUPER` or `REPLICATION CLIENT` privilege.

If you issue this statement using the `mysql` client, you can use a `\G` statement terminator rather than a semicolon to obtain a more readable vertical layout:

```
mysql> SHOW SLAVE STATUS\G
*************************** 1. row ***************************
               Slave_IO_State: Waiting for master to send event
                  Master_Host: localhost
                  Master_User: root
                  Master_Port: 3306
                Connect_Retry: 3
              Master_Log_File: gbichot-bin.005
          Read_Master_Log_Pos: 79
               Relay_Log_File: gbichot-relay-bin.005
                Relay_Log_Pos: 548
        Relay_Master_Log_File: gbichot-bin.005
             Slave_IO_Running: Yes
            Slave_SQL_Running: Yes
```

```
             Replicate_Do_DB:
         Replicate_Ignore_DB:
          Replicate_Do_Table:
      Replicate_Ignore_Table:
     Replicate_Wild_Do_Table:
  Replicate_Wild_Ignore_Table:
                   Last_Errno: 0
                   Last_Error:
                 Skip_Counter: 0
          Exec_Master_Log_Pos: 79
              Relay_Log_Space: 552
              Until_Condition: None
               Until_Log_File:
                Until_Log_Pos: 0
           Master_SSL_Allowed: No
           Master_SSL_CA_File:
           Master_SSL_CA_Path:
              Master_SSL_Cert:
            Master_SSL_Cipher:
               Master_SSL_Key:
        Seconds_Behind_Master: 8
Master_SSL_Verify_Server_Cert: No
                Last_IO_Errno: 0
                Last_IO_Error:
               Last_SQL_Errno: 0
               Last_SQL_Error:
  Replicate_Ignore_Server_Ids: 0
             Master_Server_Id: 1
```

The following list describes the fields returned by `SHOW SLAVE STATUS`. For additional information about interpreting their meanings, see Section 8.14.6, “Replication Slave I/O Thread States”.

- `Slave_IO_State`

  A copy of the `State` field of the `SHOW PROCESSLIST` output for the slave I/O thread. This tells you what the thread is doing: trying to connect to the master, waiting for events from the master, reconnecting to the master, and so on. For a listing of possible states, see Section 8.14.6, “Replication Slave I/O Thread States”.

- `Master_Host`

  The master host that the slave is connected to.

- `Master_User`

  The user name of the account used to connect to the master.

- `Master_Port`

  The port used to connect to the master.

- `Connect_Retry`

  The number of seconds between connect retries (default 60). This can be set with the `CHANGE MASTER TO` statement.

- `Master_Log_File`

  The name of the master binary log file from which the I/O thread is currently reading.

- `Read_Master_Log_Pos`

  The position in the current master binary log file up to which the I/O thread has read.

- `Relay_Log_File`

  The name of the relay log file from which the SQL thread is currently reading and executing.

- `Relay_Log_Pos`

  The position in the current relay log file up to which the SQL thread has read and executed.

- `Relay_Master_Log_File`

  The name of the master binary log file containing the most recent event executed by the SQL thread.

- `Slave_IO_Running`

  Whether the I/O thread is started and has connected successfully to the master. Internally, the state of this thread is represented by one of the following three values:

  - **MYSQL_SLAVE_NOT_RUN.** The slave I/O thread is not running. For this state, `Slave_IO_Running` is `No`.
  - **MYSQL_SLAVE_RUN_NOT_CONNECT.** The slave I/O thread is running, but is not connected to a replication master. For this state, `Slave_IO_Running` is `Connecting`.
  - **MYSQL_SLAVE_RUN_CONNECT.** The slave I/O thread is running, and is connected to a replication master. For this state, `Slave_IO_Running` is `Yes`.

  The value of the `Slave_running` system status variable corresponds with this value.

- `Slave_SQL_Running`

  Whether the SQL thread is started.

- `Replicate_Do_DB`, `Replicate_Ignore_DB`

  The lists of databases that were specified with the `--replicate-do-db` and `--replicate-ignore-db` options, if any.

- `Replicate_Do_Table`, `Replicate_Ignore_Table`, `Replicate_Wild_Do_Table`, `Replicate_Wild_Ignore_Table`

  The lists of tables that were specified with the `--replicate-do-table`, `--replicate-ignore-table`, `--replicate-wild-do-table`, and `--replicate-wild-ignore-table` options, if any.

- `Last_Errno`, `Last_Error`

  These columns are aliases for `Last_SQL_Errno` and `Last_SQL_Error`.

  Issuing `RESET MASTER` or `RESET SLAVE` resets the values shown in these columns.

  Note

  When the slave SQL thread receives an error, it reports the error first, then stops the SQL thread. This means that there is a small window of time during which `SHOW SLAVE STATUS` shows a nonzero value for `Last_SQL_Errno` even though `Slave_SQL_Running` still displays `Yes`.

- `Skip_Counter`

  The current value of the `sql_slave_skip_counter` system variable. See Section 13.4.2.4, “SET GLOBAL sql_slave_skip_counter Syntax”.

- `Exec_Master_Log_Pos`

  The position in the current master binary log file to which the SQL thread has read and executed, marking the start of the next transaction or event to be processed. You can use this value with the `CHANGE MASTER TO` statement's `MASTER_LOG_POS` option when starting a new slave

from an existing slave, so that the new slave reads from this point. The coordinates given by (`Relay_Master_Log_File`, `Exec_Master_Log_Pos`) in the master's binary log correspond to the coordinates given by (`Relay_Log_File`, `Relay_Log_Pos`) in the relay log.

- `Relay_Log_Space`

  The total combined size of all existing relay log files.

- `Until_Condition`, `Until_Log_File`, `Until_Log_Pos`

  The values specified in the `UNTIL` clause of the `START SLAVE` statement.

  `Until_Condition` has these values:

  - `None` if no `UNTIL` clause was specified
  - `Master` if the slave is reading until a given position in the master's binary log
  - `Relay` if the slave is reading until a given position in its relay log

  `Until_Log_File` and `Until_Log_Pos` indicate the log file name and position that define the coordinates at which the SQL thread stops executing.

- `Master_SSL_Allowed`, `Master_SSL_CA_File`, `Master_SSL_CA_Path`, `Master_SSL_Cert`, `Master_SSL_Cipher`, `Master_SSL_Key`, `Master_SSL_Verify_Server_Cert`

  These fields show the SSL parameters used by the slave to connect to the master, if any.

  `Master_SSL_Allowed` has these values:

  - `Yes` if an SSL connection to the master is permitted
  - `No` if an SSL connection to the master is not permitted
  - `Ignored` if an SSL connection is permitted but the slave server does not have SSL support enabled

  The values of the other SSL-related fields correspond to the values of the `MASTER_SSL_CA`, `MASTER_SSL_CAPATH`, `MASTER_SSL_CERT`, `MASTER_SSL_CIPHER`, `MASTER_SSL_KEY`, and `MASTER_SSL_VERIFY_SERVER_CERT` options to the `CHANGE MASTER TO` statement. See Section 13.4.2.1, “CHANGE MASTER TO Syntax”.

- `Seconds_Behind_Master`

  This field is an indication of how “late” the slave is:

  - When the slave is actively processing updates, this field shows the difference between the current timestamp on the slave and the original timestamp logged on the master for the event currently being processed on the slave.
  - When no event is currently being processed on the slave, this value is 0.

  In essence, this field measures the time difference in seconds between the slave SQL thread and the slave I/O thread. If the network connection between master and slave is fast, the slave I/O thread is very close to the master, so this field is a good approximation of how late the slave SQL thread is compared to the master. If the network is slow, this is *not* a good approximation; the slave SQL thread may quite often be caught up with the slow-reading slave I/O thread, so `Seconds_Behind_Master` often shows a value of 0, even if the I/O thread is late compared to the master. In other words, *this column is useful only for fast networks*.

  This time difference computation works even if the master and slave do not have identical clock times, provided that the difference, computed when the slave I/O thread starts, remains constant

from then on. Any changes—including NTP updates—can lead to clock skews that can make calculation of `Seconds_Behind_Master` less reliable.

This field is `NULL` (undefined or unknown) if the slave SQL thread is not running, or if the slave I/O thread is not running or is not connected to the master. For example, if the slave I/O thread is running but is not connected to the master and is sleeping for the number of seconds given by the `CHANGE MASTER TO` statement or `--master-connect-retry` option (default 60) before reconnecting, the value is `NULL`. This is because the slave cannot know what the master is doing, and so cannot say reliably how late it is.

The value of `Seconds_Behind_Master` is based on the timestamps stored in events, which are preserved through replication. This means that if a master M1 is itself a slave of M0, any event from M1's binary log that originates from M0's binary log has M0's timestamp for that event. This enables MySQL to replicate `TIMESTAMP` successfully. However, the problem for `Seconds_Behind_Master` is that if M1 also receives direct updates from clients, the `Seconds_Behind_Master` value randomly fluctuates because sometimes the last event from M1 originates from M0 and sometimes is the result of a direct update on M1.

- `Last_IO_Errno`, `Last_IO_Error`

  The error number and error message of the most recent error that caused the I/O thread to stop. An error number of 0 and message of the empty string mean “no error.” If the `Last_IO_Error` value is not empty, the error values also appear in the slave's error log.

  Issuing `RESET MASTER` or `RESET SLAVE` resets the values shown in these columns.

- `Last_SQL_Errno`, `Last_SQL_Error`

  The error number and error message of the most recent error that caused the SQL thread to stop. An error number of 0 and message of the empty string mean “no error.” If the `Last_SQL_Error` value is not empty, the error values also appear in the slave's error log.

  Example:

  ```
  Last_SQL_Errno: 1051
  Last_SQL_Error: error 'Unknown table 'z'' on query 'drop table z'
  ```

  The message indicates that the table `z` existed on the master and was dropped there, but it did not exist on the slave, so `DROP TABLE` failed on the slave. (This might occur, for example, if you forget to copy the table to the slave when setting up replication.)

  Issuing `RESET MASTER` or `RESET SLAVE` resets the values shown in these columns.

- `Replicate_Ignore_Server_Ids`

  You can tell a slave to ignore events from 0 or more masters using the `IGNORE_SERVER_IDS` option of the `CHANGE MASTER TO` statement. This is normally of interest only when using a circular or other multi-master replication setup.

  The message shown for `Replicate_Ignore_Server_Ids` consists of a space-delimited list of one or more numbers, the first value indicating the number of servers to be ignored; if not 0 (the default), this server-count value is followed by the actual server IDs. For example, if a `CHANGE MASTER TO` statement containing the `IGNORE_SERVER_IDS = (2,6,9)` option has been issued to tell a slave to ignore masters having the server ID 2, 6, or 9, that information appears as shown here:

  ```
  Replicate_Ignore_Server_Ids: 3 2 6 9
  ```

  `Replicate_Ignore_Server_Ids` filtering is performed by the I/O thread, rather than by the SQL thread, which means that events which are filtered out are not written to the relay log. This differs

from the filtering actions taken by server options such `--replicate-do-table`, which apply to the SQL thread.

- `Master_Server_Id`

  The `server_id` value from the master.

13.7.5.36 SHOW STATUS Syntax

```
SHOW [GLOBAL | SESSION] STATUS
    [LIKE 'pattern' | WHERE expr]
```

`SHOW STATUS` provides server status information (see Section 5.1.7, “Server Status Variables”). This statement does not require any privilege. It requires only the ability to connect to the server.

Status variable information is also available from these sources:

- The `GLOBAL_STATUS` and `SESSION_STATUS` tables. See Section 21.8, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”.
- The `mysqladmin extended-status` command. See Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”.

For `SHOW STATUS`, a `LIKE` clause, if present, indicates which variable names to match. A `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

`SHOW STATUS` accepts an optional `GLOBAL` or `SESSION` variable scope modifier:

- With a `GLOBAL` modifier, the statement displays the global status values. A global status variable may represent status for some aspect of the server itself (for example, `Aborted_connects`), or the aggregated status over all connections to MySQL (for example, `Bytes_received` and `Bytes_sent`). If a variable has no global value, the session value is displayed.
- With a `SESSION` modifier, the statement displays the status variable values for the current connection. If a variable has no session value, the global value is displayed. `LOCAL` is a synonym for `SESSION`.
- If no modifier is present, the default is `SESSION`.

The scope for each status variable is listed at Section 5.1.7, “Server Status Variables”.

Each invocation of the `SHOW STATUS` statement uses an internal temporary table and increments the global `Created_tmp_tables` value.

Partial output is shown here. The list of names and values may differ for your server. The meaning of each variable is given in Section 5.1.7, “Server Status Variables”.

```
mysql> SHOW STATUS;
+--------------------------+------------+
| Variable_name            | Value      |
+--------------------------+------------+
| Aborted_clients          | 0          |
| Aborted_connects         | 0          |
| Bytes_received           | 155372598  |
| Bytes_sent               | 1176560426 |
| Connections              | 30023      |
| Created_tmp_disk_tables  | 0          |
| Created_tmp_tables       | 8340       |
| Created_tmp_files        | 60         |
...
| Open_tables              | 1          |
```

```
| Open_files                | 2          |
| Open_streams              | 0          |
| Opened_tables             | 44600      |
| Questions                 | 2026873    |
...
| Table_locks_immediate     | 1920382    |
| Table_locks_waited        | 0          |
| Threads_cached            | 0          |
| Threads_created           | 30022      |
| Threads_connected         | 1          |
| Threads_running           | 1          |
| Uptime                    | 80380      |
+---------------------------+------------+
```

With a `LIKE` clause, the statement displays only rows for those variables with names that match the pattern:

```
mysql> SHOW STATUS LIKE 'Key%';
+--------------------+----------+
| Variable_name      | Value    |
+--------------------+----------+
| Key_blocks_used    | 14955    |
| Key_read_requests  | 96854827 |
| Key_reads          | 162040   |
| Key_write_requests | 7589728  |
| Key_writes         | 3813196  |
+--------------------+----------+
```

13.7.5.37 SHOW TABLE STATUS Syntax

```
SHOW TABLE STATUS
    [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW TABLE STATUS` works likes `SHOW TABLES`, but provides a lot of information about each non-`TEMPORARY` table. You can also get this list using the `mysqlshow --status db_name` command. The `LIKE` clause, if present, indicates which table names to match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

This statement also displays information about views.

`SHOW TABLE STATUS` output has the following columns:

- `Name`

  The name of the table.

- `Engine`

  The storage engine for the table. See Chapter 15, *Alternative Storage Engines*.

- `Version`

  The version number of the table's `.frm` file.

- `Row_format`

  The row-storage format (`Fixed`, `Dynamic`, `Compressed`, `Redundant`, `Compact`). For `MyISAM` tables, `Dynamic` corresponds to what `myisamchk -dvv` reports as `Packed`. `InnoDB` table format is either `Redundant` or `Compact` when using the `Antelope` file format, or `Compressed` or `Dynamic` when using the `Barracuda` file format.

- `Rows`

The number of rows. Some storage engines, such as `MyISAM`, store the exact count. For other storage engines, such as `InnoDB`, this value is an approximation, and may vary from the actual value by as much as 40 to 50%. In such cases, use `SELECT COUNT(*)` to obtain an accurate count.

The `Rows` value is `NULL` for tables in the `INFORMATION_SCHEMA` database.

- `Avg_row_length`

  The average row length.

  Refer to the notes at the end of this section for related information.

- `Data_length`

  For `MyISAM`, `Data_length` is the length of the data file, in bytes.

  For `InnoDB`, `Data_length` is the approximate amount of memory allocated for the clustered index, in bytes. Specifically, it is the clustered index size, in pages, multiplied by the `InnoDB` page size.

  Refer to the notes at the end of this section for information regarding other storage engines.

- `Max_data_length`

  For `MyISAM`, `Max_data_length` is maximum length of the data file. This is the total number of bytes of data that can be stored in the table, given the data pointer size used.

  Unused for `InnoDB`.

  Refer to the notes at the end of this section for information regarding other storage engines.

- `Index_length`

  For `MyISAM`, `Index_length` is the length of the index file, in bytes.

  For `InnoDB`, `Index_length` is the approximate amount of memory allocated for non-clustered indexes, in bytes. Specifically, it is the sum of non-clustered index sizes, in pages, multiplied by the `InnoDB` page size.

  Refer to the notes at the end of this section for information regarding other storage engines.

- `Data_free`

  The number of allocated but unused bytes.

  This information is also shown for `InnoDB` tables (previously, it was in the `Comment` value). `InnoDB` tables report the free space of the tablespace to which the table belongs. For a table located in the shared tablespace, this is the free space of the shared tablespace. If you are using multiple tablespaces and the table has its own tablespace, the free space is for only that table. Free space means the number of bytes in completely free extents minus a safety margin. Even if free space displays as 0, it may be possible to insert rows as long as new extents need not be allocated.

  For partitioned tables, this value is only an estimate and may not be absolutely correct. A more accurate method of obtaining this information in such cases is to query the `INFORMATION_SCHEMA.PARTITIONS` table, as shown in this example:

```
SELECT    SUM(DATA_FREE)
    FROM  INFORMATION_SCHEMA.PARTITIONS
    WHERE TABLE_SCHEMA = 'mydb'
    AND   TABLE_NAME   = 'mytable';
```

  For more information, see Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”.

- `Auto_increment`

  The next `AUTO_INCREMENT` value.

- `Create_time`

  When the table was created.

- `Update_time`

  When the data file was last updated. For some storage engines, this value is `NULL`. For example, `InnoDB` stores multiple tables in its system tablespace and the data file timestamp does not apply. Even with file-per-table mode with each `InnoDB` table in a separate `.ibd` file, change buffering can delay the write to the data file, so the file modification time is different from the time of the last insert, update, or delete. For `MyISAM`, the data file timestamp is used; however, on Windows the timestamp is not updated by updates so the value is inaccurate.

- `Check_time`

  When the table was last checked. Not all storage engines update this time, in which case the value is always `NULL`.

- `Collation`

  The table's character set and collation.

- `Checksum`

  The live checksum value (if any).

- `Create_options`

  Extra options used with `CREATE TABLE`. The original options supplied when `CREATE TABLE` is called are retained and the options reported here may differ from the active table settings and options.

- `Comment`

  The comment used when creating the table (or information as to why MySQL could not access the table information).

Notes:

- For `MEMORY` tables, the `Data_length`, `Max_data_length`, and `Index_length` values approximate the actual amount of allocated memory. The allocation algorithm reserves memory in large amounts to reduce the number of allocation operations.
- For `NDBCLUSTER` tables, the output of this statement shows appropriate values for the `Avg_row_length` and `Data_length` columns, with the exception that `BLOB` columns are not taken into account
- For views, all the fields displayed by `SHOW TABLE STATUS` are `NULL` except that `Name` indicates the view name and `Comment` says `view`.

13.7.5.38 SHOW TABLES Syntax

```
SHOW [FULL] TABLES
    [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW TABLES` lists the non-`TEMPORARY` tables in a given database. You can also get this list using the `mysqlshow db_name` command. The `LIKE` clause, if present, indicates which table names to

match. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

Matching performed by the `LIKE` clause is dependent on the setting of the `lower_case_table_names` system variable.

This statement also lists any views in the database. The optional `FULL` modifier causes `SHOW TABLES` to display a second output column with values of `BASE TABLE` for a table and `VIEW` for a view.

If you have no privileges for a base table or view, it does not show up in the output from `SHOW TABLES` or `mysqlshow db_name`.

13.7.5.39 SHOW TRIGGERS Syntax

```
SHOW TRIGGERS
    [{FROM | IN} db_name]
    [LIKE 'pattern' | WHERE expr]
```

`SHOW TRIGGERS` lists the triggers currently defined for tables in a database (the default database unless a `FROM` clause is given). This statement returns results only for databases and tables for which you have the `TRIGGER` privilege. The `LIKE` clause, if present, indicates which table names to match (not trigger names) and causes the statement to display triggers for those tables. The `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

For the trigger `ins_sum` as defined in Section 20.3, “Using Triggers”, the output of this statement is as shown here:

```
mysql> SHOW TRIGGERS LIKE 'acc%'\G
*************************** 1. row ***************************
             Trigger: ins_sum
               Event: INSERT
               Table: account
           Statement: SET @sum = @sum + NEW.amount
              Timing: BEFORE
             Created: NULL
            sql_mode:
             Definer: myname@localhost
character_set_client: latin1
collation_connection: latin1_swedish_ci
  Database Collation: latin1_swedish_ci
```

`SHOW TRIGGERS` output has the following columns:

- `Trigger`: The trigger name.
- `Event`: The type of operation that causes trigger activation. The value is `'INSERT'`, `'UPDATE'`, or `'DELETE'`.
- `Table`: The table for which the trigger is defined.
- `Statement`: The trigger body; that is, the statement executed when the trigger activates.
- `Timing`: Whether the trigger activates before or after the triggering event. The value is `'BEFORE'` or `'AFTER'`.
- `Created`: The value of this column is always `NULL`.
- `sql_mode`: The SQL mode in effect when the trigger executes.
- `Definer`: The account of the user who created the trigger, in *`'user_name'@'host_name'`* format.
- `character_set_client`: The session value of the `character_set_client` system variable when the trigger was created.

- `collation_connection`: The session value of the `collation_connection` system variable when the trigger was created.
- `Database Collation`: The collation of the database with which the trigger is associated.

You can also obtain information about trigger objects from `INFORMATION_SCHEMA`, which contains a `TRIGGERS` table. See Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”.

13.7.5.40 SHOW VARIABLES Syntax

```
SHOW [GLOBAL | SESSION] VARIABLES
    [LIKE 'pattern' | WHERE expr]
```

`SHOW VARIABLES` shows the values of MySQL system variables (see Section 5.1.5, “Server System Variables”). This statement does not require any privilege. It requires only the ability to connect to the server.

System variable information is also available from these sources:

- The `GLOBAL_VARIABLES` and `SESSION_VARIABLES` tables. See Section 21.9, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”.
- The `mysqladmin variables` command. See Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”.

For `SHOW VARIABLES`, a `LIKE` clause, if present, indicates which variable names to match. A `WHERE` clause can be given to select rows using more general conditions, as discussed in Section 21.31, “Extensions to SHOW Statements”.

`SHOW VARIABLES` accepts an optional `GLOBAL` or `SESSION` variable scope modifier:

- With a `GLOBAL` modifier, the statement displays global system variable values. These are the values used to initialize the corresponding session variables for new connections to MySQL. If a variable has no global value, no value is displayed.
- With a `SESSION` modifier, the statement displays the system varaible values that are in effect for the current connection. If a variable has no session value, the global value is displayed. `LOCAL` is a synonym for `SESSION`.
- If no modifier is present, the default is `SESSION`.

The scope for each system variable is listed at Section 5.1.5, “Server System Variables”.

`SHOW VARIABLES` is subject to a version-dependent display-width limit. For variables with very long values that are not completely displayed, use `SELECT` as a workaround. For example:

```
SELECT @@GLOBAL.innodb_data_file_path;
```

Most system variables can be set at server startup (read-only variables such as `version_comment` are exceptions). Many can be changed at runtime with the `SET` statement. See Section 5.1.6, “Using System Variables”, and Section 13.7.4.1, “SET Syntax for Variable Assignment”.

Partial output is shown here. The list of names and values may differ for your server. Section 5.1.5, “Server System Variables”, describes the meaning of each variable, and Section 5.1.1, “Configuring the Server”, provides information about tuning them.

```
mysql> SHOW VARIABLES;
+---------------------------------------+----------------------------+
| Variable_name                         | Value                      |
```

```
+---------------------------------------+---------------------------+
| auto_increment_increment              | 1                         |
| auto_increment_offset                 | 1                         |
| autocommit                            | ON                        |
| automatic_sp_privileges               | ON                        |
| back_log                              | 50                        |
| basedir                               | /home/jon/bin/mysql-5.5   |
| big_tables                            | OFF                       |
| binlog_cache_size                     | 32768                     |
| binlog_direct_non_transactional_updates | OFF                     |
| binlog_format                         | STATEMENT                 |
| binlog_stmt_cache_size                | 32768                     |
| bulk_insert_buffer_size               | 8388608                   |
...
| max_allowed_packet                    | 1048576                   |
| max_binlog_cache_size                 | 18446744073709547520      |
| max_binlog_size                       | 1073741824                |
| max_binlog_stmt_cache_size            | 18446744073709547520      |
| max_connect_errors                    | 10                        |
| max_connections                       | 151                       |
| max_delayed_threads                   | 20                        |
| max_error_count                       | 64                        |
| max_heap_table_size                   | 16777216                  |
| max_insert_delayed_threads            | 20                        |
| max_join_size                         | 18446744073709551615      |
...

| thread_handling                       | one-thread-per-connection |
| thread_stack                          | 262144                    |
| time_format                           | %H:%i:%s                  |
| time_zone                             | SYSTEM                    |
| timed_mutexes                         | OFF                       |
| timestamp                             | 1316689732                |
| tmp_table_size                        | 16777216                  |
| tmpdir                                | /tmp                      |
| transaction_alloc_block_size          | 8192                      |
| transaction_prealloc_size             | 4096                      |
| tx_isolation                          | REPEATABLE-READ           |
| unique_checks                         | ON                        |
| updatable_views_with_limit            | YES                       |
| version                               | 5.5.17-log                |
| version_comment                       | Source distribution       |
| version_compile_machine               | x86_64                    |
| version_compile_os                    | Linux                     |
| wait_timeout                          | 28800                     |
| warning_count                         | 0                         |
+---------------------------------------+---------------------------+
```

With a `LIKE` clause, the statement displays only rows for those variables with names that match the pattern. To obtain the row for a specific variable, use a `LIKE` clause as shown:

```
SHOW VARIABLES LIKE 'max_join_size';
SHOW SESSION VARIABLES LIKE 'max_join_size';
```

To get a list of variables whose name match a pattern, use the `%` wildcard character in a `LIKE` clause:

```
SHOW VARIABLES LIKE '%size%';
SHOW GLOBAL VARIABLES LIKE '%size%';
```

Wildcard characters can be used in any position within the pattern to be matched. Strictly speaking, because `_` is a wildcard that matches any single character, you should escape it as `\_` to match it literally. In practice, this is rarely necessary.

13.7.5.41 SHOW WARNINGS Syntax

```
SHOW WARNINGS [LIMIT [offset,] row_count]
SHOW COUNT(*) WARNINGS
```

`SHOW WARNINGS` is a diagnostic statement that displays information about the conditions (errors, warnings, and notes) resulting from executing a statement in the current session. Warnings are generated for DML statements such as `INSERT`, `UPDATE`, and `LOAD DATA INFILE` as well as DDL statements such as `CREATE TABLE` and `ALTER TABLE`.

The `LIMIT` clause has the same syntax as for the `SELECT` statement. See Section 13.2.9, “SELECT Syntax”.

`SHOW WARNINGS` is also used following `EXPLAIN EXTENDED`, to display the extra information generated by `EXPLAIN` when the `EXTENDED` keyword is used. See Section 8.8.3, “Extended EXPLAIN Output Format”.

`SHOW WARNINGS` displays information about the conditions resulting from the most recent statement in the current session that generated messages. It shows nothing if the most recent statement used a table and generated no messages. (That is, statements that use a table but generate no messages clear the message list.) Statements that do not use tables and do not generate messages have no effect on the message list.

The `SHOW COUNT(*) WARNINGS` diagnostic statement displays the total number of errors, warnings, and notes. You can also retrieve this number from the `warning_count` system variable:

```
SHOW COUNT(*) WARNINGS;
SELECT @@warning_count;
```

A related diagnostic statement, `SHOW ERRORS`, shows only error conditions (it excludes warnings and notes), and `SHOW COUNT(*) ERRORS` statement displays the total number of errors. See Section 13.7.5.18, “SHOW ERRORS Syntax”.

Here is a simple example that shows data-conversion warnings for `INSERT`:

```
mysql> CREATE TABLE t1 (a TINYINT NOT NULL, b CHAR(4));
Query OK, 0 rows affected (0.05 sec)

mysql> INSERT INTO t1 VALUES(10,'mysql'), (NULL,'test'), (300,'xyz');
Query OK, 3 rows affected, 3 warnings (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 3

mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1265
Message: Data truncated for column 'b' at row 1
*************************** 2. row ***************************
  Level: Warning
   Code: 1048
Message: Column 'a' cannot be null
*************************** 3. row ***************************
  Level: Warning
   Code: 1264
Message: Out of range value for column 'a' at row 3
3 rows in set (0.00 sec)
```

The `max_error_count` system variable controls the maximum number of error, warning, and note messages for which the server stores information, and thus the number of messages that `SHOW WARNINGS` displays. To change the number of messages the server can store, change the value of `max_error_count`. The default is 64.

`max_error_count` controls only how many messages are stored, not how many are counted. The value of `warning_count` is not limited by `max_error_count`, even if the number of messages generated exceeds `max_error_count`. The following example demonstrates this. The `ALTER TABLE` statement produces three warning messages (strict SQL mode is disabled for the example to prevent an error from occuring after a single conversion issue). Only one message is stored and displayed

because `max_error_count` has been set to 1, but all three are counted (as shown by the value of `warning_count`):

```
mysql> SHOW VARIABLES LIKE 'max_error_count';
+-----------------+-------+
| Variable_name   | Value |
+-----------------+-------+
| max_error_count | 64    |
+-----------------+-------+
1 row in set (0.00 sec)

mysql> SET max_error_count=1, sql_mode = '';
Query OK, 0 rows affected (0.00 sec)

mysql> ALTER TABLE t1 MODIFY b CHAR;
Query OK, 3 rows affected, 3 warnings (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 3

mysql> SHOW WARNINGS;
+---------+------+---------------------------------------+
| Level   | Code | Message                               |
+---------+------+---------------------------------------+
| Warning | 1263 | Data truncated for column 'b' at row 1 |
+---------+------+---------------------------------------+
1 row in set (0.00 sec)

mysql> SELECT @@warning_count;
+-----------------+
| @@warning_count |
+-----------------+
|               3 |
+-----------------+
1 row in set (0.01 sec)
```

To disable message storage, set `max_error_count` to 0. In this case, `warning_count` still indicates how many warnings occurred, but messages are not stored and cannot be displayed.

The `sql_notes` system variable controls whether note messages increment `warning_count` and whether the server stores them. By default, `sql_notes` is 1, but if set to 0, notes do not increment `warning_count` and the server does not store them:

```
mysql> SET sql_notes = 1;
mysql> DROP TABLE IF EXISTS test.no_such_table;
Query OK, 0 rows affected, 1 warning (0.00 sec)
mysql> SHOW WARNINGS;
+-------+------+-------------------------------+
| Level | Code | Message                       |
+-------+------+-------------------------------+
| Note  | 1051 | Unknown table 'no_such_table' |
+-------+------+-------------------------------+
1 row in set (0.00 sec)

mysql> SET sql_notes = 0;
mysql> DROP TABLE IF EXISTS test.no_such_table;
Query OK, 0 rows affected (0.00 sec)
mysql> SHOW WARNINGS;
Empty set (0.00 sec)
```

The MySQL server sends to each client a count indicating the total number of errors, warnings, and notes resulting from the most recent statement executed by that client. From the C API, this value can be obtained by calling `mysql_warning_count()`. See Section 23.8.7.72, “mysql_warning_count()”.

In the `mysql` client, you can enable and disable automatic warnings display using the `warnings` and `nowarning` commands, respectively, or their shortcuts, `\W` and `\w` (see Section 4.5.1.2, “mysql Commands”). For example:

```
mysql> \W
Show warnings enabled.
mysql> SELECT 1/0;
+------+
| 1/0  |
+------+
| NULL |
+------+
1 row in set, 1 warning (0.03 sec)

Warning (Code 1365): Division by 0
mysql> \w
Show warnings disabled.
```

13.7.6 Other Administrative Statements

13.7.6.1 BINLOG Syntax

```
BINLOG 'str'
```

`BINLOG` is an internal-use statement. It is generated by the `mysqlbinlog` program as the printable representation of certain events in binary log files. (See Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”.) The `'str'` value is a base 64-encoded string the that server decodes to determine the data change indicated by the corresponding event. This statement requires the `SUPER` privilege.

13.7.6.2 CACHE INDEX Syntax

```
CACHE INDEX
  tbl_index_list [, tbl_index_list] ...
  [PARTITION (partition_list | ALL)]
  IN key_cache_name

tbl_index_list:
  tbl_name [[INDEX|KEY] (index_name[, index_name] ...)]

partition_list:
  partition_name[, partition_name][, ...]
```

The `CACHE INDEX` statement assigns table indexes to a specific key cache. It is used only for `MyISAM` tables. After the indexes have been assigned, they can be preloaded into the cache if desired with `LOAD INDEX INTO CACHE`.

The following statement assigns indexes from the tables `t1`, `t2`, and `t3` to the key cache named `hot_cache`:

```
mysql> CACHE INDEX t1, t2, t3 IN hot_cache;
+---------+--------------------+----------+----------+
| Table   | Op                 | Msg_type | Msg_text |
+---------+--------------------+----------+----------+
| test.t1 | assign_to_keycache | status   | OK       |
| test.t2 | assign_to_keycache | status   | OK       |
| test.t3 | assign_to_keycache | status   | OK       |
+---------+--------------------+----------+----------+
```

The syntax of `CACHE INDEX` enables you to specify that only particular indexes from a table should be assigned to the cache. The current implementation assigns all the table's indexes to the cache, so there is no reason to specify anything other than the table name.

The key cache referred to in a `CACHE INDEX` statement can be created by setting its size with a parameter setting statement or in the server parameter settings. For example:

```
mysql> SET GLOBAL keycache1.key_buffer_size=128*1024;
```

Key cache parameters can be accessed as members of a structured system variable. See Section 5.1.6.1, “Structured System Variables”.

A key cache must exist before you can assign indexes to it:

```
mysql> CACHE INDEX t1 IN non_existent_cache;
ERROR 1284 (HY000): Unknown key cache 'non_existent_cache'
```

By default, table indexes are assigned to the main (default) key cache created at the server startup. When a key cache is destroyed, all indexes assigned to it become assigned to the default key cache again.

Index assignment affects the server globally: If one client assigns an index to a given cache, this cache is used for all queries involving the index, no matter which client issues the queries.

In MySQL 5.5, this statement is also supported for partitioned `MyISAM` tables. You can assign one or more indexes for one, several, or all partitions to a given key cache. For example, you can do the following:

```
CREATE TABLE pt (c1 INT, c2 VARCHAR(50), INDEX i(c1))
    ENGINE=MyISAM
    PARTITION BY HASH(c1)
    PARTITIONS 4;

SET GLOBAL kc_fast.key_buffer_size = 128 * 1024;
SET GLOBAL kc_slow.key_buffer_size = 128 * 1024;

CACHE INDEX pt PARTITION (p0) IN kc_fast;
CACHE INDEX pt PARTITION (p1, p3) IN kc_slow;
```

The previous set of statements performs the following actions:

- Creates a partitioned table with 4 partitions; these partitions are automatically named `p0`, ..., `p3`; this table has an index named `i` on column `c1`.
- Creates 2 key caches named `kc_fast` and `kc_slow`
- Assigns the index for partition `p0` to the `kc_fast` key cache and the index for partitions `p1` and `p3` to the `kc_slow` key cache; the index for the remaining partition (`p2`) uses the server's default key cache.

If you wish instead to assign the indexes for all partitions in table `pt` to a single key cache named `kc_all`, you can use either one of the following 2 statements:

```
CACHE INDEX pt PARTITION (ALL) IN kc_all;

CACHE INDEX pt IN kc_all;
```

The two statements just shown are equivalent, and issuing either one of them has exactly the same effect. In other words, if you wish to assign indexes for all partitions of a partitioned table to the same key cache, then the `PARTITION (ALL)` clause is optional.

When assigning indexes for multiple partitions to a key cache, the partitions do not have to be contiguous, and you are not required to list their names in any particular order. Indexes for any partitions that are not explicitly assigned to a key cache automatically use the server's default key cache.

Index preloading is also supported for partitioned `MyISAM` tables. For more information, see Section 13.7.6.5, “LOAD INDEX INTO CACHE Syntax”.

13.7.6.3 FLUSH Syntax

```
FLUSH [NO_WRITE_TO_BINLOG | LOCAL] {
    flush_option [, flush_option] ...
  | tables_option
}

flush_option: {
    BINARY LOGS
  | DES_KEY_FILE
  | ENGINE LOGS
  | ERROR LOGS
  | GENERAL LOGS
  | HOSTS
  | LOGS
  | MASTER
  | PRIVILEGES
  | QUERY CACHE
  | RELAY LOGS
  | SLAVE
  | SLOW LOGS
  | STATUS
  | USER_RESOURCES
}

tables_option: {
    TABLES
  | TABLES tbl_name [, tbl_name] ...
  | TABLES WITH READ LOCK
  | TABLES tbl_name [, tbl_name] ... WITH READ LOCK
}
```

The `FLUSH` statement has several variant forms that clear or reload various internal caches, flush tables, or acquire locks. To execute `FLUSH`, you must have the `RELOAD` privilege. Specific flush options might require additional privileges, as described later.

Note

It is not possible to issue `FLUSH` statements within stored functions or triggers. However, you may use `FLUSH` in stored procedures, so long as these are not called from stored functions or triggers. See Section C.1, “Restrictions on Stored Programs”.

By default, the server writes `FLUSH` statements to the binary log so that they replicate to replication slaves. To suppress logging, specify the optional `NO_WRITE_TO_BINLOG` keyword or its alias `LOCAL`.

Note

`FLUSH LOGS`, `FLUSH MASTER`, `FLUSH SLAVE`, and `FLUSH TABLES WITH READ LOCK` (with or without a table list) are not written to the binary log in any case because they would cause problems if replicated to a slave.

The `FLUSH` statement causes an implicit commit. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

The `mysqladmin` utility provides a command-line interface to some flush operations, using commands such as `flush-hosts`, `flush-logs`, `flush-privileges`, `flush-status`, and `flush-tables`. See Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”.

Sending a `SIGHUP` signal to the server causes several flush operations to occur that are similar to various forms of the `FLUSH` statement. See Section 5.1.11, “Server Response to Signals”.

The `RESET` statement is similar to `FLUSH`. See Section 13.7.6.6, “RESET Syntax”, for information about using the `RESET` statement with replication.

The following list describes the permitted `FLUSH` statement *`flush_option`* values. For descriptions of `FLUSH TABLES` variants, see FLUSH TABLES Syntax.

- `FLUSH BINARY LOGS`

  Closes and reopens any binary log file to which the server is writing. If binary logging is enabled, the sequence number of the binary log file is incremented by one relative to the previous file.

- `FLUSH DES_KEY_FILE`

  Reloads the DES keys from the file that was specified with the `--des-key-file` option at server startup time.

- `FLUSH ENGINE LOGS`

  Closes and reopens any flushable logs for installed storage engines. This causes `InnoDB` to flush its logs to disk.

- `FLUSH ERROR LOGS`

  Closes and reopens any error log file to which the server is writing.

- `FLUSH GENERAL LOGS`

  Closes and reopens any general query log file to which the server is writing.

- `FLUSH HOSTS`

  Empties the host cache. Flush the host cache if some of your hosts change IP address or if the error message `Host 'host_name' is blocked` occurs for connections from legitimate hosts. (See Section B.5.2.6, “Host 'host_name' is blocked”.) When more than `max_connect_errors` errors occur successively for a given host while connecting to the MySQL server, MySQL assumes that something is wrong and blocks the host from further connection requests. Flushing the host cache enables further connection attempts from the host. The default value of `max_connect_errors` is 10. To avoid this error message, start the server with `max_connect_errors` set to a large value.

- `FLUSH LOGS`

  Closes and reopens any log file to which the server is writing. If binary logging is enabled, the sequence number of the binary log file is incremented by one relative to the previous file. If relay logging is enabled, the sequence number of the relay log file is incremented by one relative to the previous file.

  `FLUSH LOGS` has no effect on tables used for the general query log or for the slow query log (see Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”).

- `FLUSH MASTER`

  Deletes all binary logs, resets the binary log index file and creates a new binary log. `FLUSH MASTER` is deprecated in favor of `RESET MASTER`. `FLUSH MASTER` is still accepted in MySQL 5.5 for backward compatibility, but is removed in MySQL 5.6. See Section 13.4.1.2, “RESET MASTER Syntax”.

- `FLUSH PRIVILEGES`

  Reloads the privileges from the grant tables in the `mysql` system database.

  The server caches information in memory as a result of `GRANT`, `CREATE USER`, `CREATE SERVER`, and `INSTALL PLUGIN` statements. This memory is not released by the corresponding `REVOKE`, `DROP USER`, `DROP SERVER`, and `UNINSTALL PLUGIN` statements, so for a server that executes many instances of the statements that cause caching, there will be an increase in memory use. This cached memory can be freed with `FLUSH PRIVILEGES`.

- `FLUSH QUERY CACHE`

  Defragment the query cache to better utilize its memory. `FLUSH QUERY CACHE` does not remove any queries from the cache, unlike `FLUSH TABLES` or `RESET QUERY CACHE`.

- `FLUSH RELAY LOGS`

  Closes and reopens any relay log file to which the server is writing. If relay logging is enabled, the sequence number of the relay log file is incremented by one relative to the previous file.

- `FLUSH SLAVE`

  Resets all replication slave parameters, including relay log files and replication position in the master's binary logs. `FLUSH SLAVE` is deprecated in favor of `RESET SLAVE`. `FLUSH SLAVE` is still accepted in MySQL 5.5 for backward compatibility, but is removed in MySQL 5.6. See Section 13.4.2.3, “RESET SLAVE Syntax”.

- `FLUSH SLOW LOGS`

  Closes and reopens any slow query log file to which the server is writing.

- `FLUSH STATUS`

  This option adds the current thread's session status variable values to the global values and resets the session values to zero. Some global variables may be reset to zero as well. It also resets the counters for key caches (default and named) to zero and sets `Max_used_connections` to the current number of open connections. This information may be of use when debugging a query. See Section 1.6, “How to Report Bugs or Problems”.

- `FLUSH USER_RESOURCES`

  Resets all per-hour user resources to zero. This enables clients that have reached their hourly connection, query, or update limits to resume activity immediately. `FLUSH USER_RESOURCES` does not apply to the limit on maximum simultaneous connections that is controlled by the `max_user_connections` system variable. See Section 6.3.4, “Setting Account Resource Limits”.

FLUSH TABLES Syntax

`FLUSH TABLES` flushes tables, and, depending on the variant used, acquires locks. Any `TABLES` variant used in a `FLUSH` statement must be the only option used. `FLUSH TABLE` is a synonym for `FLUSH TABLES`.

Note

The descriptions here that indicate tables are flushed by closing them apply differently for `InnoDB`, which flushes table contents to disk but leaves them open. This still permits table files to be copied while the tables are open, as long as other activity does not modify them.

- `FLUSH TABLES`

  Closes all open tables, forces all tables in use to be closed, and flushes the query cache. `FLUSH TABLES` also removes all query results from the query cache, like the `RESET QUERY CACHE` statement.

  `FLUSH TABLES` is not permitted when there is an active `LOCK TABLES ... READ`. To flush and lock tables, use `FLUSH TABLES tbl_name ... WITH READ LOCK` instead.

- `FLUSH TABLES tbl_name [, tbl_name] ...`

  With a list of one or more comma-separated table names, this statement is like `FLUSH TABLES` with no names except that the server flushes only the named tables. If a named table does not exist, no error occurs.

- `FLUSH TABLES WITH READ LOCK`

  Closes all open tables and locks all tables for all databases with a global read lock. This is a very convenient way to get backups if you have a file system such as Veritas or ZFS that can take snapshots in time. Use `UNLOCK TABLES` to release the lock.

  `FLUSH TABLES WITH READ LOCK` acquires a global read lock rather than table locks, so it is not subject to the same behavior as `LOCK TABLES` and `UNLOCK TABLES` with respect to table locking and implicit commits:

  - `UNLOCK TABLES` implicitly commits any active transaction only if any tables currently have been locked with `LOCK TABLES`. The commit does not occur for `UNLOCK TABLES` following `FLUSH TABLES WITH READ LOCK` because the latter statement does not acquire table locks.
  - Beginning a transaction causes table locks acquired with `LOCK TABLES` to be released, as though you had executed `UNLOCK TABLES`. Beginning a transaction does not release a global read lock acquired with `FLUSH TABLES WITH READ LOCK`.

  `FLUSH TABLES WITH READ LOCK` is not compatible with XA transactions.

  `FLUSH TABLES WITH READ LOCK` does not prevent the server from inserting rows into the log tables (see Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”).

- `FLUSH TABLES` *`tbl_name`* `[, ` *`tbl_name`* `] ... WITH READ LOCK`

  This statement flushes and acquires read locks for the named tables. The statement first acquires exclusive metadata locks for the tables, so it waits for transactions that have those tables open to complete. Then the statement flushes the tables from the table cache, reopens the tables, acquires table locks (like `LOCK TABLES ... READ`), and downgrades the metadata locks from exclusive to shared. After the statement acquires locks and downgrades the metadata locks, other sessions can read but not modify the tables.

  Because this statement acquires table locks, you must have the `LOCK TABLES` privilege for each table, in addition to the `RELOAD` privilege that is required to use any `FLUSH` statement.

  This statement applies only to existing base (non-`TEMPORARY`) tables. If a name refers to a base table, that table is used. If it refers to a `TEMPORARY` table, it is ignored. If a name applies to a view, an `ER_WRONG_OBJECT` error occurs. Otherwise, an `ER_NO_SUCH_TABLE` error occurs.

  Use `UNLOCK TABLES` to release the locks, `LOCK TABLES` to release the locks and acquire other locks, or `START TRANSACTION` to release the locks and begin a new transaction.

  This `FLUSH TABLES` variant enables tables to be flushed and locked in a single operation. It provides a workaround for the restriction that `FLUSH TABLES` is not permitted when there is an active `LOCK TABLES ... READ`.

  This statement does not perform an implicit `UNLOCK TABLES`, so an error results if you use the statement while there is any active `LOCK TABLES` or use it a second time without first releasing the locks acquired.

  If a flushed table was opened with `HANDLER`, the handler is implicitly flushed and loses its position.

13.7.6.4 KILL Syntax

```
KILL [CONNECTION | QUERY] processlist_id
```

Each connection to `mysqld` runs in a separate thread. You can kill a thread with the `KILL` *`processlist_id`* statement.

Thread processlist identifiers can be determined from the `ID` column of the `INFORMATION_SCHEMA.PROCESSLIST` table, the `Id` column of `SHOW PROCESSLIST` output, and

the PROCESSLIST_ID column of the Performance Schema threads table. The value for the current thread is returned by the CONNECTION_ID() function.

KILL permits an optional CONNECTION or QUERY modifier:

- KILL CONNECTION is the same as KILL with no modifier: It terminates the connection associated with the given *processlist_id*, after terminating any statement the connection is executing.
- KILL QUERY terminates the statement the connection is currently executing, but leaves the connection itself intact.

If you have the PROCESS privilege, you can see all threads. If you have the SUPER privilege, you can kill all threads and statements. Otherwise, you can see and kill only your own threads and statements.

You can also use the mysqladmin processlist and mysqladmin kill commands to examine and kill threads.

Note

You cannot use KILL with the Embedded MySQL Server library because the embedded server merely runs inside the threads of the host application. It does not create any connection threads of its own.

When you use KILL, a thread-specific kill flag is set for the thread. In most cases, it might take some time for the thread to die because the kill flag is checked only at specific intervals:

- During SELECT operations, for ORDER BY and GROUP BY loops, the flag is checked after reading a block of rows. If the kill flag is set, the statement is aborted.
- ALTER TABLE operations that make a table copy check the kill flag periodically for each few copied rows read from the original table. If the kill flag was set, the statement is aborted and the temporary table is deleted.

  The KILL statement returns without waiting for confirmation, but the kill flag check aborts the operation within a reasonably small amount of time. Aborting the operation to perform any necessary cleanup also takes some time.
- During UPDATE or DELETE operations, the kill flag is checked after each block read and after each updated or deleted row. If the kill flag is set, the statement is aborted. If you are not using transactions, the changes are not rolled back.
- GET_LOCK() aborts and returns NULL.
- An INSERT DELAYED thread quickly flushes (inserts) all rows it has in memory and then terminates.
- If the thread is in the table lock handler (state: Locked), the table lock is quickly aborted.
- If the thread is waiting for free disk space in a write call, the write is aborted with a “disk full” error message.

Warning

Killing a REPAIR TABLE or OPTIMIZE TABLE operation on a MyISAM table results in a table that is corrupted and unusable. Any reads or writes to such a table fail until you optimize or repair it again (without interruption).

13.7.6.5 LOAD INDEX INTO CACHE Syntax

```
LOAD INDEX INTO CACHE
  tbl_index_list [, tbl_index_list] ...

tbl_index_list:
  tbl_name
    [PARTITION (partition_list | ALL)]
```

```
    [[INDEX|KEY] (index_name[, index_name] ...)]
    [IGNORE LEAVES]

partition_list:
    partition_name[, partition_name][, ...]
```

The `LOAD INDEX INTO CACHE` statement preloads a table index into the key cache to which it has been assigned by an explicit `CACHE INDEX` statement, or into the default key cache otherwise.

`LOAD INDEX INTO CACHE` is used only for `MyISAM` tables. In MySQL 5.5, it is also supported for partitioned `MyISAM` tables; in addition, indexes on partitioned tables can be preloaded for one, several, or all partitions.

The `IGNORE LEAVES` modifier causes only blocks for the nonleaf nodes of the index to be preloaded.

`IGNORE LEAVES` is also supported for partitioned `MyISAM` tables.

The following statement preloads nodes (index blocks) of indexes for the tables `t1` and `t2`:

```
mysql> LOAD INDEX INTO CACHE t1, t2 IGNORE LEAVES;
+---------+--------------+----------+----------+
| Table   | Op           | Msg_type | Msg_text |
+---------+--------------+----------+----------+
| test.t1 | preload_keys | status   | OK       |
| test.t2 | preload_keys | status   | OK       |
+---------+--------------+----------+----------+
```

This statement preloads all index blocks from `t1`. It preloads only blocks for the nonleaf nodes from `t2`.

The syntax of `LOAD INDEX INTO CACHE` enables you to specify that only particular indexes from a table should be preloaded. The current implementation preloads all the table's indexes into the cache, so there is no reason to specify anything other than the table name.

In MySQL 5.5, it is possible to preload indexes on specific partitions of partitioned `MyISAM` tables. For example, of the following 2 statements, the first preloads indexes for partition `p0` of a partitioned table `pt`, while the second preloads the indexes for partitions `p1` and `p3` of the same table:

```
LOAD INDEX INTO CACHE pt PARTITION (p0);
LOAD INDEX INTO CACHE pt PARTITION (p1, p3);
```

To preload the indexes for all partitions in table `pt`, you can use either one of the following 2 statements:

```
LOAD INDEX INTO CACHE pt PARTITION (ALL);

LOAD INDEX INTO CACHE pt;
```

The two statements just shown are equivalent, and issuing either one of them has exactly the same effect. In other words, if you wish to preload indexes for all partitions of a partitioned table, then the `PARTITION (ALL)` clause is optional.

When preloading indexes for multiple partitions, the partitions do not have to be contiguous, and you are not required to list their names in any particular order.

`LOAD INDEX INTO CACHE ... IGNORE LEAVES` fails unless all indexes in a table have the same block size. You can determine index block sizes for a table by using `myisamchk -dv` and checking the `Blocksize` column.

13.7.6.6 RESET Syntax

```
RESET reset_option [, reset_option] ...

reset_option: {
```

```
    MASTER
  | QUERY CACHE
  | SLAVE
}
```

The `RESET` statement is used to clear the state of various server operations. You must have the `RELOAD` privilege to execute `RESET`.

`RESET` acts as a stronger version of the `FLUSH` statement. See Section 13.7.6.3, “FLUSH Syntax”.

The `RESET` statement causes an implicit commit. See Section 13.3.3, “Statements That Cause an Implicit Commit”.

The following list describes the permitted `RESET` statement *`reset_option`* values:

- `RESET MASTER`

  Deletes all binary logs listed in the index file, resets the binary log index file to be empty, and creates a new binary log file.

- `RESET QUERY CACHE`

  Removes all query results from the query cache.

- `RESET SLAVE`

  Makes the slave forget its replication position in the master binary logs. Also resets the relay log by deleting any existing relay log files and beginning a new one.

13.8 Utility Statements

13.8.1 DESCRIBE Syntax

The `DESCRIBE` and `EXPLAIN` statements are synonyms, used either to obtain information about table structure or query execution plans. For more information, see Section 13.7.5.6, “SHOW COLUMNS Syntax”, and Section 13.8.2, “EXPLAIN Syntax”.

13.8.2 EXPLAIN Syntax

```
{EXPLAIN | DESCRIBE | DESC}
    tbl_name [col_name | wild]

{EXPLAIN | DESCRIBE | DESC}
    [explain_type] SELECT select_options

explain_type: {EXTENDED | PARTITIONS}
```

The `DESCRIBE` and `EXPLAIN` statements are synonyms. In practice, the `DESCRIBE` keyword is more often used to obtain information about table structure, whereas `EXPLAIN` is used to obtain a query execution plan (that is, an explanation of how MySQL would execute a query).

The following discussion uses the `DESCRIBE` and `EXPLAIN` keywords in accordance with those uses, but the MySQL parser treats them as completely synonymous.

- Obtaining Table Structure Information
- Obtaining Execution Plan Information

Obtaining Table Structure Information

`DESCRIBE` provides information about the columns in a table:

```
mysql> DESCRIBE City;
+------------+----------+------+-----+---------+----------------+
| Field      | Type     | Null | Key | Default | Extra          |
+------------+----------+------+-----+---------+----------------+
| Id         | int(11)  | NO   | PRI | NULL    | auto_increment |
| Name       | char(35) | NO   |     |         |                |
| Country    | char(3)  | NO   | UNI |         |                |
| District   | char(20) | YES  | MUL |         |                |
| Population | int(11)  | NO   |     | 0       |                |
+------------+----------+------+-----+---------+----------------+
```

`DESCRIBE` is a shortcut for `SHOW COLUMNS`. These statements also display information for views. The description for `SHOW COLUMNS` provides more information about the output columns. See Section 13.7.5.6, “SHOW COLUMNS Syntax”.

By default, `DESCRIBE` displays information about all columns in the table. *`col_name`*, if given, is the name of a column in the table. In this case, the statement displays information only for the named column. *`wild`*, if given, is a pattern string. It can contain the SQL `%` and `_` wildcard characters. In this case, the statement displays output only for the columns with names matching the string. There is no need to enclose the string within quotation marks unless it contains spaces or other special characters.

The `DESCRIBE` statement is provided for compatibility with Oracle.

The `SHOW CREATE TABLE`, `SHOW TABLE STATUS`, and `SHOW INDEX` statements also provide information about tables. See Section 13.7.5, “SHOW Syntax”.

Obtaining Execution Plan Information

The `EXPLAIN` statement provides information about how MySQL executes statements:

- When you precede a `SELECT` statement with the keyword `EXPLAIN`, MySQL displays information from the optimizer about the statement execution plan. That is, MySQL explains how it would process the statement, including information about how tables are joined and in which order. For information about using `EXPLAIN` to obtain execution plan information, see Section 8.8.2, “EXPLAIN Output Format”.
- `EXPLAIN EXTENDED` can be used to obtain additional execution plan information. See Section 8.8.3, “Extended EXPLAIN Output Format”.
- `EXPLAIN PARTITIONS` is useful for examining queries involving partitioned tables. See Section 19.3.4, “Obtaining Information About Partitions”.

`EXPLAIN` requires the `SELECT` privilege for any tables or views accessed, including any underlying tables of views. For views, `EXPLAIN` also requires the `SHOW VIEW` privilege.

With the help of `EXPLAIN`, you can see where you should add indexes to tables so that the statement executes faster by using indexes to find rows. You can also use `EXPLAIN` to check whether the optimizer joins the tables in an optimal order. To give a hint to the optimizer to use a join order corresponding to the order in which the tables are named in a `SELECT` statement, begin the statement with `SELECT STRAIGHT_JOIN` rather than just `SELECT`. (See Section 13.2.9, “SELECT Syntax”.)

If you have a problem with indexes not being used when you believe that they should be, run `ANALYZE TABLE` to update table statistics, such as cardinality of keys, that can affect the choices the optimizer makes. See Section 13.7.2.1, “ANALYZE TABLE Syntax”.

Note

MySQL Workbench has a Visual Explain capability that provides a visual representation of `EXPLAIN` output. See Tutorial: Using Visual Explain to Improve Query Performance.

13.8.3 HELP Syntax

```
HELP 'search_string'
```

The `HELP` statement returns online information from the MySQL Reference manual. Its proper operation requires that the help tables in the `mysql` database be initialized with help topic information (see Section 5.1.10, “Server-Side Help”).

The `HELP` statement searches the help tables for the given search string and displays the result of the search. The search string is not case sensitive.

The search string can contain the wildcard characters `%` and `_`. These have the same meaning as for pattern-matching operations performed with the `LIKE` operator. For example, `HELP 'rep%'` returns a list of topics that begin with `rep`.

The HELP statement understands several types of search strings:

- At the most general level, use `contents` to retrieve a list of the top-level help categories:

  ```
  HELP 'contents'
  ```

- For a list of topics in a given help category, such as `Data Types`, use the category name:

  ```
  HELP 'data types'
  ```

- For help on a specific help topic, such as the `ASCII()` function or the `CREATE TABLE` statement, use the associated keyword or keywords:

  ```
  HELP 'ascii'
  HELP 'create table'
  ```

In other words, the search string matches a category, many topics, or a single topic. You cannot necessarily tell in advance whether a given search string will return a list of items or the help information for a single help topic. However, you can tell what kind of response `HELP` returned by examining the number of rows and columns in the result set.

The following descriptions indicate the forms that the result set can take. Output for the example statements is shown using the familiar “tabular” or “vertical” format that you see when using the `mysql` client, but note that `mysql` itself reformats `HELP` result sets in a different way.

- Empty result set

  No match could be found for the search string.

- Result set containing a single row with three columns

  This means that the search string yielded a hit for the help topic. The result has three columns:

  - `name`: The topic name.
  - `description`: Descriptive help text for the topic.
  - `example`: Usage example or examples. This column might be blank.

  Example: `HELP 'replace'`

  Yields:

  ```
  name: REPLACE
  description: Syntax:
  REPLACE(str,from_str,to_str)

  Returns the string str with all occurrences of the string from_str
  replaced by the string to_str. REPLACE() performs a case-sensitive
  ```

```
match when searching for from_str.
example: mysql> SELECT REPLACE('www.mysql.com', 'w', 'Ww');
        -> 'WwWwWw.mysql.com'
```

- Result set containing multiple rows with two columns

  This means that the search string matched many help topics. The result set indicates the help topic names:

  - `name`: The help topic name.
  - `is_it_category`: `Y` if the name represents a help category, `N` if it does not. If it does not, the `name` value when specified as the argument to the `HELP` statement should yield a single-row result set containing a description for the named item.

  Example: `HELP 'status'`

  Yields:

```
+----------------------+----------------+
| name                 | is_it_category |
+----------------------+----------------+
| SHOW                 | N              |
| SHOW ENGINE          | N              |
| SHOW MASTER STATUS   | N              |
| SHOW PROCEDURE STATUS | N              |
| SHOW SLAVE STATUS    | N              |
| SHOW STATUS          | N              |
| SHOW TABLE STATUS    | N              |
+----------------------+----------------+
```

- Result set containing multiple rows with three columns

  This means the search string matches a category. The result set contains category entries:

  - `source_category_name`: The help category name.
  - `name`: The category or topic name
  - `is_it_category`: `Y` if the name represents a help category, `N` if it does not. If it does not, the `name` value when specified as the argument to the `HELP` statement should yield a single-row result set containing a description for the named item.

  Example: `HELP 'functions'`

  Yields:

```
+---------------------+-------------------------+----------------+
| source_category_name | name                    | is_it_category |
+---------------------+-------------------------+----------------+
| Functions           | CREATE FUNCTION         | N              |
| Functions           | DROP FUNCTION           | N              |
| Functions           | Bit Functions           | Y              |
| Functions           | Comparison operators    | Y              |
| Functions           | Control flow functions  | Y              |
| Functions           | Date and Time Functions | Y              |
| Functions           | Encryption Functions    | Y              |
| Functions           | Information Functions   | Y              |
| Functions           | Logical operators       | Y              |
| Functions           | Miscellaneous Functions | Y              |
| Functions           | Numeric Functions       | Y              |
| Functions           | String Functions        | Y              |
+---------------------+-------------------------+----------------+
```

13.8.4 USE Syntax

```
USE db_name
```

The `USE db_name` statement tells MySQL to use the *`db_name`* database as the default (current) database for subsequent statements. The database remains the default until the end of the session or another `USE` statement is issued:

```
USE db1;
SELECT COUNT(*) FROM mytable;   # selects from db1.mytable
USE db2;
SELECT COUNT(*) FROM mytable;   # selects from db2.mytable
```

Making a particular database the default by means of the `USE` statement does not preclude you from accessing tables in other databases. The following example accesses the `author` table from the `db1` database and the `editor` table from the `db2` database:

```
USE db1;
SELECT author_name,editor_name FROM author,db2.editor
  WHERE author.editor_id = db2.editor.editor_id;
```

Chapter 14 The InnoDB Storage Engine

Table of Contents

14.1 Introduction to InnoDB 1600
14.1.1 Benefits of Using InnoDB Tables 1602
14.1.2 Best Practices for InnoDB Tables 1603
14.1.3 Checking InnoDB Availability 1603
14.1.4 Upward and Downward Compatibility 1604
14.1.5 Testing and Benchmarking with InnoDB 1604
14.1.6 Turning Off InnoDB 1605
14.1.7 Third-Party Software Contributions 1605
14.2 Installing the InnoDB Storage Engine 1607
14.3 Upgrading the InnoDB Storage Engine 1608
14.4 Downgrading the InnoDB Storage Engine 1608
14.5 InnoDB and the ACID Model 1608
14.6 InnoDB Multi-Versioning 1609
14.7 InnoDB Architecture 1610
14.7.1 Buffer Pool 1610
14.7.2 Change Buffer 1611
14.7.3 Adaptive Hash Index 1612
14.7.4 Redo Log Buffer 1613
14.7.5 System Tablespace 1613
14.7.6 InnoDB Data Dictionary 1613
14.7.7 Doublewrite Buffer 1614
14.7.8 Undo Logs 1614
14.7.9 File-Per-Table Tablespaces 1614
14.7.10 Redo Log 1614
14.8 InnoDB Locking and Transaction Model 1615
14.8.1 InnoDB Locking 1615
14.8.2 InnoDB Transaction Model 1619
14.8.3 Locks Set by Different SQL Statements in InnoDB 1627
14.8.4 Phantom Rows 1630
14.8.5 Deadlocks in InnoDB 1630
14.9 InnoDB Configuration 1633
14.9.1 InnoDB Startup Configuration 1634
14.9.2 InnoDB Buffer Pool Configuration 1638
14.9.3 Configuring the Memory Allocator for InnoDB 1646
14.9.4 Configuring InnoDB Change Buffering 1647
14.9.5 Configuring Thread Concurrency for InnoDB 1648
14.9.6 Configuring the Number of Background InnoDB I/O Threads 1649
14.9.7 Using Asynchronous I/O on Linux 1650
14.9.8 Configuring the InnoDB Master Thread I/O Rate 1651
14.9.9 Configuring Spin Lock Polling 1651
14.9.10 Configuring InnoDB Purge Scheduling 1651
14.9.11 Configuring Optimizer Statistics for InnoDB 1652
14.10 InnoDB Tablespaces 1653
14.10.1 Resizing the InnoDB System Tablespace 1653
14.10.2 Changing the Number or Size of InnoDB Redo Log Files 1654
14.10.3 Using Raw Disk Partitions for the System Tablespace 1654
14.10.4 InnoDB File-Per-Table Tablespaces 1656
14.11 InnoDB Tables and Indexes 1659
14.11.1 InnoDB Tables 1660
14.11.2 InnoDB Indexes 1680
14.12 InnoDB Table Compression 1681
14.12.1 Overview of Table Compression 1681

14.12.2 Enabling Compression for a Table 1681
14.12.3 Tuning Compression for InnoDB Tables 1682
14.12.4 Monitoring InnoDB Table Compression at Runtime 1685
14.12.5 How Compression Works for InnoDB Tables 1686
14.12.6 SQL Compression Syntax Warnings and Errors 1689
14.13 InnoDB File-Format Management 1691
14.13.1 Enabling File Formats 1692
14.13.2 Verifying File Format Compatibility 1692
14.13.3 Identifying the File Format in Use 1695
14.13.4 Downgrading the File Format 1695
14.14 InnoDB Row Storage and Row Formats 1696
14.14.1 Overview of InnoDB Row Storage 1696
14.14.2 Specifying the Row Format for a Table 1696
14.14.3 DYNAMIC and COMPRESSED Row Formats 1696
14.14.4 COMPACT and REDUNDANT Row Formats 1697
14.15 InnoDB Disk I/O and File Space Management 1697
14.15.1 InnoDB Disk I/O 1698
14.15.2 File Space Management 1698
14.15.3 InnoDB Checkpoints 1700
14.15.4 Defragmenting a Table 1700
14.15.5 Reclaiming Disk Space with TRUNCATE TABLE 1701
14.16 InnoDB Fast Index Creation 1701
14.16.1 Overview of Fast Index Creation 1701
14.16.2 Examples of Fast Index Creation 1701
14.16.3 Implementation Details of Fast Index Creation 1702
14.16.4 Concurrency Considerations for Fast Index Creation 1702
14.16.5 How Crash Recovery Works with Fast Index Creation 1703
14.16.6 Limitations of Fast Index Creation 1703
14.17 InnoDB Startup Options and System Variables 1704
14.18 InnoDB INFORMATION_SCHEMA Tables 1742
14.18.1 InnoDB INFORMATION_SCHEMA Tables about Compression 1742
14.18.2 InnoDB INFORMATION_SCHEMA Transaction and Locking Information 1743
14.18.3 InnoDB INFORMATION_SCHEMA Buffer Pool Tables 1749
14.19 InnoDB Integration with MySQL Performance Schema 1753
14.19.1 Monitoring InnoDB Mutex Waits Using Performance Schema 1755
14.20 InnoDB Monitors 1757
14.20.1 InnoDB Monitor Types 1757
14.20.2 Enabling InnoDB Monitors 1758
14.20.3 InnoDB Standard Monitor and Lock Monitor Output 1760
14.20.4 InnoDB Tablespace Monitor Output 1765
14.20.5 InnoDB Table Monitor Output 1767
14.21 InnoDB Backup and Recovery 1770
14.21.1 InnoDB Backup 1770
14.21.2 InnoDB Recovery 1771
14.22 InnoDB and MySQL Replication 1773
14.23 InnoDB Troubleshooting 1775
14.23.1 Troubleshooting InnoDB I/O Problems 1775
14.23.2 Forcing InnoDB Recovery 1776
14.23.3 Troubleshooting InnoDB Data Dictionary Operations 1777
14.23.4 InnoDB Error Handling 1779

14.1 Introduction to InnoDB

`InnoDB` is a general-purpose storage engine that balances high reliability and high performance. Starting from MySQL 5.5.5, the default storage engine for new tables is `InnoDB` rather than `MyISAM`. Unless you have configured a different default storage engine, issuing a `CREATE TABLE` statement without an `ENGINE=` clause creates an `InnoDB` table. Given this change of default behavior, MySQL

5.5 might be a logical point to evaluate whether tables that use `MyISAM` could benefit from switching to `InnoDB`.

`InnoDB` includes all the features that were part of the InnoDB Plugin for MySQL 5.1, plus new features specific to MySQL 5.5 and higher.

Note

The `mysql` and `INFORMATION_SCHEMA` databases that implement some of the MySQL internals still use `MyISAM`. In particular, you cannot switch the grant tables to use `InnoDB`.

Key Advantages of InnoDB

Key advantages of `InnoDB` include:

- Its DML operations follow the ACID model, with transactions featuring commit, rollback, and crash-recovery capabilities to protect user data. See Section 14.5, “InnoDB and the ACID Model” for more information.
- Row-level locking and Oracle-style consistent reads increase multi-user concurrency and performance. See Section 14.8, “InnoDB Locking and Transaction Model” for more information.
- `InnoDB` tables arrange your data on disk to optimize queries based on primary keys. Each `InnoDB` table has a primary key index called the clustered index that organizes the data to minimize I/O for primary key lookups. See Section 14.11.2.1, “Clustered and Secondary Indexes” for more information.
- To maintain data integrity, `InnoDB` supports `FOREIGN KEY` constraints. With foreign keys, inserts, updates, and deletes are checked to ensure they do not result in inconsistencies across different tables. See Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints” for more information.

Table 14.1 InnoDB Storage Engine Features

Storage limits	64TB	**Transactions**	Yes	**Locking granularity**	Row
MVCC	Yes	**Geospatial data type support**	Yes	**Geospatial indexing support**	Yes[a]
B-tree indexes	Yes	**T-tree indexes**	No	**Hash indexes**	No[b]
Full-text search indexes	Yes[c]	**Clustered indexes**	Yes	**Data caches**	Yes
Index caches	Yes	**Compressed data**	Yes[d]	**Encrypted data**[e]	Yes
Cluster database support	No	**Replication support**[f]	Yes	**Foreign key support**	Yes
Backup / point-in-time recovery[g]	Yes	**Query cache support**	Yes	**Update statistics for data dictionary**	Yes

[a] InnoDB support for geospatial indexing is available in MySQL 5.7.5 and later.

[b] InnoDB utilizes hash indexes internally for its Adaptive Hash Index feature.

[c] InnoDB support for FULLTEXT indexes is available in MySQL 5.6.4 and later.

[d] Compressed InnoDB tables require the InnoDB Barracuda file format.

[e] Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and later.

[f] Implemented in the server, rather than in the storage engine.

[g] Implemented in the server, rather than in the storage engine.

To compare the features of `InnoDB` with other storage engines provided with MySQL, see the *Storage Engine Features* table in Chapter 15, *Alternative Storage Engines*.

InnoDB Enhancements and New Features

The InnoDB storage engine in MySQL 5.5 releases includes a number performance improvements that in MySQL 5.1 were only available by installing the InnoDB Plugin. This latest InnoDB offers new features, improved performance and scalability, enhanced reliability and new capabilities for flexibility and ease of use.

For information about InnoDB enhancements and new features in MySQL 5.5, refer to:

- The InnoDB enhancements list in Section 1.4, “What Is New in MySQL 5.5”.
- The Release Notes.

Additional InnoDB Information and Resources

- For InnoDB-related terms and definitions, see MySQL Glossary.
- For a forum dedicated to the InnoDB storage engine, see MySQL Forums::InnoDB.
- InnoDB is published under the same GNU GPL License Version 2 (of June 1991) as MySQL. For more information on MySQL licensing, see http://www.mysql.com/company/legal/licensing/.

14.1.1 Benefits of Using InnoDB Tables

If you use MyISAM tables but are not committed to them for technical reasons, you may find InnoDB tables beneficial for the following reasons:

- If your server crashes because of a hardware or software issue, regardless of what was happening in the database at the time, you don't need to do anything special after restarting the database. InnoDB crash recovery automatically finalizes any changes that were committed before the time of the crash, and undoes any changes that were in process but not committed. Just restart and continue where you left off. This process is now much faster than in MySQL 5.1 and earlier.
- The InnoDB storage engine maintains its own buffer pool that caches table and index data in main memory as data is accessed. Frequently used data is processed directly from memory. This cache applies to many types of information and speeds up processing. On dedicated database servers, up to 80% of physical memory is often assigned to the InnoDB buffer pool.
- If you split up related data into different tables, you can set up foreign keys that enforce referential integrity. Update or delete data, and the related data in other tables is updated or deleted automatically. Try to insert data into a secondary table without corresponding data in the primary table, and the bad data gets kicked out automatically.
- If data becomes corrupted on disk or in memory, a checksum mechanism alerts you to the bogus data before you use it.
- When you design your database with appropriate primary key columns for each table, operations involving those columns are automatically optimized. It is very fast to reference the primary key columns in WHERE clauses, ORDER BY clauses, GROUP BY clauses, and join operations.
- Inserts, updates, deletes are optimized by an automatic mechanism called change buffering. InnoDB not only allows concurrent read and write access to the same table, it caches changed data to streamline disk I/O.
- Performance benefits are not limited to giant tables with long-running queries. When the same rows are accessed over and over from a table, a feature called the Adaptive Hash Index takes over to make these lookups even faster, as if they came out of a hash table.
- You can freely mix InnoDB tables with tables from other MySQL storage engines, even within the same statement. For example, you can use a join operation to combine data from InnoDB and MEMORY tables in a single query.

- InnoDB has been designed for CPU efficiency and maximum performance when processing large data volumes.
- InnoDB tables can handle large quantities of data, even on operating systems where file size is limited to 2GB.

For InnoDB-specific tuning techniques you can apply in your application code, see Section 8.5, “Optimizing for InnoDB Tables”.

14.1.2 Best Practices for InnoDB Tables

This section describes best practices when using InnoDB tables.

- Specify a primary key for every table using the most frequently queried column or columns, or an auto-increment value if there is no obvious primary key.
- Using joins wherever data is pulled from multiple tables based on identical ID values from those tables. For fast join performance, define foreign keys on the join columns, and declare those columns with the same data type in each table. Adding foreign keys ensures that referenced columns are indexed, which can improve performance. Foreign keys also propagate deletes or updates to all affected tables, and prevent insertion of data in a child table if the corresponding IDs are not present in the parent table.
- Turning off autocommit. Committing hundreds of times a second puts a cap on performance (limited by the write speed of your storage device).
- Grouping sets of related DML operations into transactions, by bracketing them with START TRANSACTION and COMMIT statements. While you don't want to commit too often, you also don't want to issue huge batches of INSERT, UPDATE, or DELETE statements that run for hours without committing.
- Not using LOCK TABLES statements. InnoDB can handle multiple sessions all reading and writing to the same table at once, without sacrificing reliability or high performance. To get exclusive write access to a set of rows, use the SELECT ... FOR UPDATE syntax to lock just the rows you intend to update.
- Enabling the innodb_file_per_table option to put the data and indexes for individual tables into separate files, instead of in a single giant system tablespace. This setting is required to use some of the other features, such as table compression and fast truncation.
- Evaluating whether your data and access patterns benefit from the InnoDB table compression feature (ROW_FORMAT=COMPRESSED) on the CREATE TABLE statement. You can compress InnoDB tables without sacrificing read/write capability.
- Running your server with the option --sql_mode=NO_ENGINE_SUBSTITUTION to prevent tables being created with a different storage engine if there is an issue with the one specified in the ENGINE= clause of CREATE TABLE.

14.1.3 Checking InnoDB Availability

To determine whether your server supports InnoDB:

- Issue the command SHOW ENGINES; to see all the different MySQL storage engines. Look for DEFAULT in the InnoDB line. Alternatively, query the INFORMATION_SCHEMA ENGINES table. (Now that InnoDB is the default MySQL storage engine, only very specialized environments might not support it.)
- Issue the command SHOW VARIABLES LIKE 'have_innodb'; to confirm that InnoDB is available.
- If InnoDB is not present, you have a mysqld binary that was compiled without InnoDB support and you need to get a different one.

- If `InnoDB` is present but disabled, go back through your startup options and configuration file and get rid of any `skip-innodb` option.

14.1.4 Upward and Downward Compatibility

The ability to use the `InnoDB` table compression feature introduced in MySQL 5.5 and the new row format require the use of a new `InnoDB` file format called Barracuda. The previous file format, used by the built-in InnoDB in MySQL 5.1 and earlier, is now called Antelope and does not support these features, but does support the other features introduced with the InnoDB storage engine.

The InnoDB storage engine is upward compatible from standard `InnoDB` as built in to, and distributed with, MySQL. Existing databases can be used with the InnoDB Storage Engine for MySQL. The new parameter `innodb_file_format` can help protect upward and downward compatibility between `InnoDB` versions and database files, allowing users to enable or disable use of new features that can only be used with certain versions of `InnoDB.`

`InnoDB` since version 5.0.21 has a safety feature that prevents it from opening tables that are in an unknown format. However, the system tablespace may contain references to new-format tables that confuse the built-in InnoDB in MySQL 5.1 and earlier. These references are cleared in a slow shutdown.

With previous versions of `InnoDB`, no error would be returned until you try to access a table that is in a format “too new” for the software. To provide early feedback, `InnoDB` now checks the system tablespace before startup to ensure that the file format used in the database is supported by the storage engine. See Section 14.13.2.1, “Compatibility Check When InnoDB Is Started” for the details.

14.1.5 Testing and Benchmarking with InnoDB

Even before completing your upgrade to MySQL 5.5, you can preview whether your database server or application works correctly with `InnoDB` as the default storage engine. To set up `InnoDB` as the default storage engine with an earlier MySQL release, either specify on the command line `--default-storage-engine=InnoDB`, or add to your `my.cnf` file `default-storage-engine=innodb` in the `[mysqld]` section, then restart the server.

Since changing the default storage engine only affects new tables as they are created, run all your application installation and setup steps to confirm that everything installs properly. Then exercise all the application features to make sure all the data loading, editing, and querying features work. If a table relies on some `MyISAM`-specific feature, you'll receive an error; add the `ENGINE=MyISAM` clause to the `CREATE TABLE` statement to avoid the error (for example, tables that rely on full-text search must be `MyISAM` tables rather than `InnoDB` ones).

If you did not make a deliberate decision about the storage engine, and you just want to preview how certain tables work when they're created under `InnoDB`, issue the command `ALTER TABLE table_name ENGINE=InnoDB;` for each table. Or, to run test queries and other statements without disturbing the original table, make a copy like so:

```
CREATE TABLE InnoDB_Table (...) ENGINE=InnoDB AS SELECT * FROM MyISAM_Table;
```

Since there are so many performance enhancements in the `InnoDB` that is part of MySQL 5.5, to get a true idea of the performance with a full application under a realistic workload, install the real MySQL 5.5 and run benchmarks.

Test the full application lifecycle, from installation, through heavy usage, and server restart. Kill the server process while the database is busy to simulate a power failure, and verify that the data is recovered successfully when you restart the server.

Test any replication configurations, especially if you use different MySQL versions and options on the master and the slaves.

14.1.6 Turning Off InnoDB

Oracle recommends `InnoDB` as the preferred storage engine for typical database applications, from single-user wikis and blogs running on a local system, to high-end applications pushing the limits of performance. As of MySQL 5.5, `InnoDB` is the default storage engine for new tables.

If you do not want to use `InnoDB` tables:

- Start the server with the `--innodb=OFF` or `--skip-innodb` option to disable the `InnoDB` storage engine.
- Because the default storage engine is `InnoDB`, the server will not start unless you also use `--default-storage-engine` to set the default to some other engine.
- To prevent the server from crashing when the `InnoDB`-related `information_schema` tables are queried, also disable the plugins associated with those tables. Specify in the `[mysqld]` section of the MySQL configuration file:

```
loose-innodb-trx=0
loose-innodb-locks=0
loose-innodb-lock-waits=0
loose-innodb-cmp=0
loose-innodb-cmp-per-index=0
loose-innodb-cmp-per-index-reset=0
loose-innodb-cmp-reset=0
loose-innodb-cmpmem=0
loose-innodb-cmpmem-reset=0
loose-innodb-buffer-page=0
loose-innodb-buffer-page-lru=0
loose-innodb-buffer-pool-stats=0
```

14.1.7 Third-Party Software Contributions

Oracle acknowledges that certain Third Party and Open Source software has been used to develop or is incorporated in the InnoDB storage engine. This appendix includes required third-party license information.

14.1.7.1 Performance Patches from Google

Oracle gratefully acknowledges the following contributions from Google, Inc. to improve InnoDB performance:

- Replacing InnoDB's use of Pthreads mutexes with calls to GCC atomic builtins. This change means that InnoDB mutex and rw-lock operations take less CPU time, and improves throughput on those platforms where the atomic operations are available.
- Controlling master thread `I/O` rate, as discussed in Section 14.9.8, “Configuring the InnoDB Master Thread I/O Rate”. The master thread in InnoDB is a thread that performs various tasks in the background. Historically, InnoDB has used a hard coded value as the total `I/O` capacity of the server. With this change, user can control the number of `I/O` operations that can be performed per second based on their own workload.

Changes from the Google contributions were incorporated in the following source code files: `btr0cur.c`, `btr0sea.c`, `buf0buf.c`, `buf0buf.ic`, `ha_innodb.cc`, `log0log.c`, `log0log.h`, `os0sync.h`, `row0sel.c`, `srv0srv.c`, `srv0srv.h`, `srv0start.c`, `sync0arr.c`, `sync0rw.c`, `sync0rw.h`, `sync0rw.ic`, `sync0sync.c`, `sync0sync.h`, `sync0sync.ic`, and `univ.i`.

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ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE
POSSIBILITY OF SUCH DAMAGE.
```

14.1.7.2 Multiple Background I/O Threads Patch from Percona

Oracle gratefully acknowledges the contribution of Percona, Inc. to improve InnoDB performance by implementing configurable background threads, as discussed in Section 14.9.6, “Configuring the Number of Background InnoDB I/O Threads”. InnoDB uses background threads to service various types of I/O requests. The change provides another way to make InnoDB more scalable on high end systems.

Changes from the Percona, Inc. contribution were incorporated in the following source code files: `ha_innodb.cc`, `os0file.c`, `os0file.h`, `srv0srv.c`, `srv0srv.h`, and `srv0start.c`.

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14.1.7.3 Performance Patches from Sun Microsystems

Oracle gratefully acknowledges the following contributions from Sun Microsystems, Inc. to improve InnoDB performance:

- Introducing the `PAUSE` instruction inside spin loops. This change increases performance in high concurrency, CPU-bound workloads.
- Enabling inlining of functions and prefetch with Sun Studio.

Changes from the Sun Microsystems, Inc. contribution were incorporated in the following source code files: `univ.i`, `ut0ut.c`, and `ut0ut.h`.

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```

14.2 Installing the InnoDB Storage Engine

When you use the InnoDB storage engine 1.1 and above, with MySQL 5.5 and above, you do not need to do anything special to install: everything comes configured as part of the MySQL source and binary distributions. This is a change from earlier releases of the InnoDB Plugin, where you were required to match up MySQL and InnoDB version numbers and update your build and configuration processes.

The InnoDB storage engine is included in the MySQL distribution, starting from MySQL 5.1.38. From MySQL 5.1.46 and up, this is the only download location for the InnoDB storage engine; it is not available from the InnoDB web site.

If you used any scripts or configuration files with the earlier InnoDB storage engine from the InnoDB web site, be aware that the filename of the shared library as supplied by MySQL is `ha_innodb_plugin.so` or `ha_innodb_plugin.dll`, as opposed to `ha_innodb.so` or `ha_innodb.dll` in the older Plugin downloaded from the InnoDB web site. You might need to change the applicable file names in your startup or configuration scripts.

Because the InnoDB storage engine has now replaced the built-in InnoDB, you no longer need to specify options like `--ignore-builtin-innodb` and `--plugin-load` during startup.

To take best advantage of current InnoDB features, we recommend specifying the following options in your configuration file:

```
innodb_file_per_table=1
innodb_file_format=barracuda
innodb_strict_mode=1
```

For information about these features, see Section 14.17, “InnoDB Startup Options and System Variables”, Section 14.13, “InnoDB File-Format Management”, and `innodb_strict_mode`. You might need to continue to use the previous values for these parameters in some replication and similar configurations involving both new and older versions of MySQL.

14.3 Upgrading the InnoDB Storage Engine

Prior to MySQL 5.5, some upgrade scenarios involved upgrading the separate instance of InnoDB known as the InnoDB Plugin. In MySQL 5.5 and higher, the features of the InnoDB Plugin have been folded back into built-in InnoDB, so the upgrade procedure for InnoDB is the same as the one for the MySQL server. For details, see Section 2.11.1, “Upgrading MySQL”.

14.4 Downgrading the InnoDB Storage Engine

Prior to MySQL 5.5, some downgrade scenarios involved switching the separate instance of InnoDB known as the InnoDB Plugin back to the built-in InnoDB storage engine. In MySQL 5.5 and higher, the features of the InnoDB Plugin have been folded back into built-in InnoDB, so the downgrade procedure for InnoDB is the same as the one for the MySQL server. For details, see Section 2.11.2, “Downgrading MySQL”.

14.5 InnoDB and the ACID Model

The ACID model is a set of database design principles that emphasize aspects of reliability that are important for business data and mission-critical applications. MySQL includes components such as the `InnoDB` storage engine that adhere closely to the ACID model, so that data is not corrupted and results are not distorted by exceptional conditions such as software crashes and hardware malfunctions. When you rely on ACID-compliant features, you do not need to reinvent the wheel of consistency checking and crash recovery mechanisms. In cases where you have additional software safeguards, ultra-reliable hardware, or an application that can tolerate a small amount of data loss or inconsistency, you can adjust MySQL settings to trade some of the ACID reliability for greater performance or throughput.

The following sections discuss how MySQL features, in particular the `InnoDB` storage engine, interact with the categories of the ACID model:

- **A**: atomicity.
- **C**: consistency.
- **I:**: isolation.
- **D**: durability.

Atomicity

The **atomicity** aspect of the ACID model mainly involves `InnoDB` transactions. Related MySQL features include:

- Autocommit setting.
- `COMMIT` statement.
- `ROLLBACK` statement.

- Operational data from the `INFORMATION_SCHEMA` tables.

Consistency

The **consistency** aspect of the ACID model mainly involves internal `InnoDB` processing to protect data from crashes. Related MySQL features include:

- `InnoDB` doublewrite buffer.
- `InnoDB` crash recovery.

Isolation

The **isolation** aspect of the ACID model mainly involves `InnoDB` transactions, in particular the isolation level that applies to each transaction. Related MySQL features include:

- Autocommit setting.
- `SET ISOLATION LEVEL` statement.
- The low-level details of `InnoDB` locking. During performance tuning, you see these details through `INFORMATION_SCHEMA` tables.

Durability

The **durability** aspect of the ACID model involves MySQL software features interacting with your particular hardware configuration. Because of the many possibilities depending on the capabilities of your CPU, network, and storage devices, this aspect is the most complicated to provide concrete guidelines for. (And those guidelines might take the form of buy “new hardware”.) Related MySQL features include:

- `InnoDB` doublewrite buffer, turned on and off by the `innodb_doublewrite` configuration option.
- Configuration option `innodb_flush_log_at_trx_commit`.
- Configuration option `sync_binlog`.
- Configuration option `innodb_file_per_table`.
- Write buffer in a storage device, such as a disk drive, SSD, or RAID array.
- Battery-backed cache in a storage device.
- The operating system used to run MySQL, in particular its support for the `fsync()` system call.
- Uninterruptible power supply (UPS) protecting the electrical power to all computer servers and storage devices that run MySQL servers and store MySQL data.
- Your backup strategy, such as frequency and types of backups, and backup retention periods.
- For distributed or hosted data applications, the particular characteristics of the data centers where the hardware for the MySQL servers is located, and network connections between the data centers.

14.6 InnoDB Multi-Versioning

`InnoDB` is a multi-versioned storage engine: it keeps information about old versions of changed rows, to support transactional features such as concurrency and rollback. This information is stored in the tablespace in a data structure called a rollback segment (after an analogous data structure in Oracle). `InnoDB` uses the information in the rollback segment to perform the undo operations needed in a transaction rollback. It also uses the information to build earlier versions of a row for a consistent read.

Internally, `InnoDB` adds three fields to each row stored in the database. A 6-byte `DB_TRX_ID` field indicates the transaction identifier for the last transaction that inserted or updated the row. Also, a

deletion is treated internally as an update where a special bit in the row is set to mark it as deleted. Each row also contains a 7-byte `DB_ROLL_PTR` field called the roll pointer. The roll pointer points to an undo log record written to the rollback segment. If the row was updated, the undo log record contains the information necessary to rebuild the content of the row before it was updated. A 6-byte `DB_ROW_ID` field contains a row ID that increases monotonically as new rows are inserted. If `InnoDB` generates a clustered index automatically, the index contains row ID values. Otherwise, the `DB_ROW_ID` column does not appear in any index.

Undo logs in the rollback segment are divided into insert and update undo logs. Insert undo logs are needed only in transaction rollback and can be discarded as soon as the transaction commits. Update undo logs are used also in consistent reads, but they can be discarded only after there is no transaction present for which `InnoDB` has assigned a snapshot that in a consistent read could need the information in the update undo log to build an earlier version of a database row.

Commit your transactions regularly, including those transactions that issue only consistent reads. Otherwise, `InnoDB` cannot discard data from the update undo logs, and the rollback segment may grow too big, filling up your tablespace.

The physical size of an undo log record in the rollback segment is typically smaller than the corresponding inserted or updated row. You can use this information to calculate the space needed for your rollback segment.

In the `InnoDB` multi-versioning scheme, a row is not physically removed from the database immediately when you delete it with an SQL statement. `InnoDB` only physically removes the corresponding row and its index records when it discards the update undo log record written for the deletion. This removal operation is called a purge, and it is quite fast, usually taking the same order of time as the SQL statement that did the deletion.

If you insert and delete rows in smallish batches at about the same rate in the table, the purge thread can start to lag behind and the table can grow bigger and bigger because of all the “dead” rows, making everything disk-bound and very slow. In such a case, throttle new row operations, and allocate more resources to the purge thread by tuning the `innodb_max_purge_lag` system variable. See Section 14.17, “InnoDB Startup Options and System Variables” for more information.

Multi-Versioning and Secondary Indexes

`InnoDB` multiversion concurrency control (MVCC) treats secondary indexes differently than clustered indexes. Records in a clustered index are updated in-place, and their hidden system columns point undo log entries from which earlier versions of records can be reconstructed. Unlike clustered index records, secondary index records do not contain hidden system columns nor are they updated in-place.

When a secondary index column is updated, old secondary index records are delete-marked, new records are inserted, and delete-marked records are eventually purged. When a secondary index record is delete-marked or the secondary index page is updated by a newer transaction, `InnoDB` looks up the database record in the clustered index. In the clustered index, the record's `DB_TRX_ID` is checked, and the correct version of the record is retrieved from the undo log if the record was modified after the reading transaction was initiated.

If a secondary index record is marked for deletion or the secondary index page is updated by a newer transaction, the covering index technique is not used. Instead of returning values from the index structure, `InnoDB` looks up the record in the clustered index.

14.7 InnoDB Architecture

This section provides an introduction to major components of the `InnoDB` storage engine architecture.

14.7.1 Buffer Pool

The buffer pool is an area in main memory where `InnoDB` caches table and index data as data is accessed. The buffer pool allows frequently used data to be processed directly from memory,

which speeds up processing. On dedicated database servers, up to 80% of physical memory is often assigned to the InnoDB buffer pool.

For efficiency of high-volume read operations, the buffer pool is divided into pages that can potentially hold multiple rows. For efficiency of cache management, the buffer pool is implemented as a linked list of pages; data that is rarely used is aged out of the cache, using a variation of the LRU algorithm.

For more information, see Section 14.9.2.1, “The InnoDB Buffer Pool”, and Section 14.9.2, “InnoDB Buffer Pool Configuration”.

14.7.2 Change Buffer

The change buffer is a special data structure that caches changes to secondary index pages when affected pages are not in the buffer pool. The buffered changes, which may result from INSERT, UPDATE, or DELETE operations (DML), are merged later when the pages are loaded into the buffer pool by other read operations.

Unlike clustered indexes, secondary indexes are usually non-unique, and inserts into secondary indexes happen in a relatively random order. Similarly, deletes and updates may affect secondary index pages that are not adjacently located in an index tree. Merging cached changes at a later time, when affected pages are read into the buffer pool by other operations, avoids substantial random access I/O that would be required to read-in secondary index pages from disk.

Periodically, the purge operation that runs when the system is mostly idle, or during a slow shutdown, writes the updated index pages to disk. The purge operation can write disk blocks for a series of index values more efficiently than if each value were written to disk immediately.

Change buffer merging may take several hours when there are numerous secondary indexes to update and many affected rows. During this time, disk I/O is increased, which can cause a significant slowdown for disk-bound queries. Change buffer merging may also continue to occur after a transaction is committed. In fact, change buffer merging may continue to occur after a server shutdown and restart (see Section 14.23.2, “Forcing InnoDB Recovery” for more information).

In memory, the change buffer occupies part of the InnoDB buffer pool. On disk, the change buffer is part of the system tablespace, so that index changes remain buffered across database restarts.

The type of data cached in the change buffer is governed by the innodb_change_buffering configuration option. For more information, see Section 14.9.4, “Configuring InnoDB Change Buffering”.

Monitoring the Change Buffer

The following options are available for change buffer monitoring:

- InnoDB Standard Monitor output includes status information for the change buffer. To view monitor data, issue the SHOW ENGINE INNODB STATUS command.

```
mysql> SHOW ENGINE INNODB STATUS\G
```

Change buffer status information is located under the INSERT BUFFER AND ADAPTIVE HASH INDEX heading and appears similar to the following:

```
-------------------------------------
INSERT BUFFER AND ADAPTIVE HASH INDEX
-------------------------------------
Ibuf: size 1, free list len 0, seg size 2, 0 merges
merged operations:
 insert 0, delete mark 0, delete 0
discarded operations:
 insert 0, delete mark 0, delete 0
Hash table size 276707, node heap has 1 buffer(s)
```

```
15.81 hash searches/s, 46.33 non-hash searches/s
```

For more information, see Section 14.20.3, “InnoDB Standard Monitor and Lock Monitor Output”.

- The `INFORMATION_SCHEMA.INNODB_BUFFER_PAGE` table provides metadata about each page in the buffer pool, including change buffer index and change buffer bitmap pages. Change buffer pages are identified by `PAGE_TYPE`. `IBUF_INDEX` is the page type for change buffer index pages, and `IBUF_BITMAP` is the page type for change buffer bitmap pages.

  Warning

  Querying the `INNODB_BUFFER_PAGE` table can introduce significant performance overhead. To avoid impacting performance, reproduce the issue you want to investigate on a test instance and run your queries on the test instance.

  For example, you can query the `INNODB_BUFFER_PAGE` table to determine the approximate number of `IBUF_INDEX` and `IBUF_BITMAP` pages as a percentage of total buffer pool pages.

```
mysql> SELECT (SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
       WHERE PAGE_TYPE LIKE 'IBUF%') AS change_buffer_pages,
       (SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE) AS total_pages,
       (SELECT ((change_buffer_pages/total_pages)*100))
       AS change_buffer_page_percentage;
+---------------------+-------------+-------------------------------+
| change_buffer_pages | total_pages | change_buffer_page_percentage |
+---------------------+-------------+-------------------------------+
|                  25 |        8192 |                        0.3052 |
+---------------------+-------------+-------------------------------+
```

For information about other data provided by the `INNODB_BUFFER_PAGE` table, see Section 21.28.1, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table”. For related usage information, see Section 14.18.3, “InnoDB INFORMATION_SCHEMA Buffer Pool Tables”.

- Performance Schema provides change buffer mutex wait instrumentation for advanced performance monitoring. To view change buffer instrumentation, issue the following query (Performance Schema must be enabled):

```
mysql> SELECT * FROM performance_schema.setup_instruments
       WHERE NAME LIKE '%wait/synch/mutex/innodb/ibuf%';
+-----------------------------------------------------+---------+-------+
| NAME                                                | ENABLED | TIMED |
+-----------------------------------------------------+---------+-------+
| wait/synch/mutex/innodb/ibuf_bitmap_mutex           | YES     | YES   |
| wait/synch/mutex/innodb/ibuf_mutex                  | YES     | YES   |
| wait/synch/mutex/innodb/ibuf_pessimistic_insert_mutex | YES     | YES   |
+-----------------------------------------------------+---------+-------+
```

For information about monitoring `InnoDB` mutex waits, see Section 14.19.1, “Monitoring InnoDB Mutex Waits Using Performance Schema”.

14.7.3 Adaptive Hash Index

The adaptive hash index (AHI) lets `InnoDB` perform more like an in-memory database on systems with appropriate combinations of workload and ample memory for the buffer pool, without sacrificing any transactional features or reliability. This feature is enabled by the `innodb_adaptive_hash_index` option, or turned off by `--skip-innodb_adaptive_hash_index` at server startup.

Based on the observed pattern of searches, MySQL builds a hash index using a prefix of the index key. The prefix of the key can be any length, and it may be that only some of the values in the B-tree appear in the hash index. Hash indexes are built on demand for those pages of the index that are often accessed.

If a table fits almost entirely in main memory, a hash index can speed up queries by enabling direct lookup of any element, turning the index value into a sort of pointer. `InnoDB` has a mechanism that monitors index searches. If `InnoDB` notices that queries could benefit from building a hash index, it does so automatically.

With some workloads, the speedup from hash index lookups greatly outweighs the extra work to monitor index lookups and maintain the hash index structure. Sometimes, the read/write lock that guards access to the adaptive hash index can become a source of contention under heavy workloads, such as multiple concurrent joins. Queries with `LIKE` operators and `%` wildcards also tend not to benefit from the AHI. For workloads where the adaptive hash index is not needed, turning it off reduces unnecessary performance overhead. Because it is difficult to predict in advance whether this feature is appropriate for a particular system, consider running benchmarks with it both enabled and disabled, using a realistic workload.

The hash index is always built based on an existing B-tree index on the table. `InnoDB` can build a hash index on a prefix of any length of the key defined for the B-tree, depending on the pattern of searches that `InnoDB` observes for the B-tree index. A hash index can be partial, covering only those pages of the index that are often accessed.

You can monitor the use of the adaptive hash index and the contention for its use in the `SEMAPHORES` section of the output of the `SHOW ENGINE INNODB STATUS` command. If you see many threads waiting on an RW-latch created in `btr0sea.c`, then it might be useful to disable adaptive hash indexing.

For more information about the performance characteristics of hash indexes, see Section 8.3.8, “Comparison of B-Tree and Hash Indexes”.

14.7.4 Redo Log Buffer

The redo log buffer is the memory area that holds data to be written to the redo log. Redo log buffer size is defined by the `innodb_log_buffer_size` configuration option. The redo log buffer is periodically flushed to the log file on disk. A large redo log buffer enables large transactions to run without the need to write redo log to disk before the transactions commit. Thus, if you have transactions that update, insert, or delete many rows, making the log buffer larger saves disk I/O.

The `innodb_flush_log_at_trx_commit` option controls how the contents of the redo log buffer are written to the log file. The `innodb_flush_log_at_timeout` option controls redo log flushing frequency.

14.7.5 System Tablespace

The `InnoDB` system tablespace contains the `InnoDB` data dictionary (metadata for `InnoDB`-related objects) and is the storage area for the doublewrite buffer, the change buffer, and undo logs. The system tablespace also contains table and index data for any user-created tables that are created in the system tablespace. The system tablespace is considered a shared tablespace since it is shared by multiple tables.

The system tablespace is represented by one or more data files. By default, one system data file, named `ibdata1`, is created in the MySQL `data` directory. The size and number of system data files is controlled by the `innodb_data_file_path` startup option.

For related information, see Section 14.9.1, “InnoDB Startup Configuration”, and Section 14.10.1, “Resizing the InnoDB System Tablespace”.

14.7.6 InnoDB Data Dictionary

The `InnoDB` data dictionary is comprised of internal system tables that contain metadata used to keep track of objects such as tables, indexes, and table columns. The metadata is physically located in the `InnoDB` system tablespace. For historical reasons, data dictionary metadata overlaps to some degree with information stored in `InnoDB` table metadata files (`.frm` files).

14.7.7 Doublewrite Buffer

The doublewrite buffer is a storage area located in the system tablespace where `InnoDB` writes pages that are flushed from the `InnoDB` buffer pool, before the pages are written to their proper positions in the data file. Only after flushing and writing pages to the doublewrite buffer, does `InnoDB` write pages to their proper positions. If there is an operating system, storage subsystem, or `mysqld` process crash in the middle of a page write, `InnoDB` can later find a good copy of the page from the doublewrite buffer during crash recovery.

Although data is always written twice, the doublewrite buffer does not require twice as much I/O overhead or twice as many I/O operations. Data is written to the doublewrite buffer itself as a large sequential chunk, with a single `fsync()` call to the operating system.

The doublewrite buffer is enabled by default. To disable the doublewrite buffer, set `innodb_doublewrite` to 0.

14.7.8 Undo Logs

An undo log is a collection of undo log records associated with a single transaction. An undo log record contains information about how to undo the latest change by a transaction to a clustered index record. If another transaction needs to see the original data (as part of a consistent read operation), the unmodified data is retrieved from the undo log records. Undo logs exist within undo log segments, which are contained within rollback segments. Rollback segments are physically part of the system tablespace. For related information, see Section 14.6, “InnoDB Multi-Versioning”.

Prior to MySQL 5.5.4, `InnoDB` supported a single rollback segment which supported a maximum of 1023 concurrent data-modifying transactions (read-only transactions do not count against the maximum limit). In MySQL 5.5.4, the single rollback segment was divided into 128 rollback segments, each supporting up to 1023 concurrent data-modifying transactions, creating a new limit of approximately 128K concurrent data-modifying transactions. The `innodb_rollback_segments` option defines how many of the rollback segments in the system tablespace are used for `InnoDB` transactions.

Each transaction is assigned to one of the rollback segments, and remains tied to that rollback segment for the duration. The increased limit for concurrent data-modifying transactions improves both scalability (higher number of concurrent transactions) and performance (less contention when different transactions access the rollback segments).

14.7.9 File-Per-Table Tablespaces

A file-per-table tablespace is a single-table tablespace that is created in its own data file rather than in the system tablespace. Tables are created in file-per-table tablespaces when the `innodb_file_per_table` option is enabled. Otherwise, `InnoDB` tables are created in the system tablespace. Each file-per-table tablespace is represented by a single `.ibd` data file, which is created in the database directory by default.

File per-table tablespaces support `DYNAMIC` and `COMPRESSED` row formats which support features such as off-page storage for variable length data and table compression. For information about these features, and about other advantages of file-per-table tablespaces, see Section 14.10.4, “InnoDB File-Per-Table Tablespaces”.

14.7.10 Redo Log

The redo log is a disk-based data structure used during crash recovery to correct data written by incomplete transactions. During normal operations, the redo log encodes requests to change `InnoDB` table data that result from SQL statements or low-level API calls. Modifications that did not finish updating the data files before an unexpected shutdown are replayed automatically during initialization, and before the connections are accepted. For information about the role of the redo log in crash recovery, see Section 14.21.2, “InnoDB Recovery”.

By default, the redo log is physically represented on disk as a set of files, named `ib_logfile0` and `ib_logfile1`. MySQL writes to the redo log files in a circular fashion. Data in the redo log is encoded in terms of records affected; this data is collectively referred to as redo. The passage of data through the redo log is represented by an ever-increasing LSN value.

For related information, see:

- Section 14.9.1, “InnoDB Startup Configuration”
- Section 8.5.3, “Optimizing InnoDB Redo Logging”
- Section 14.10.2, “Changing the Number or Size of InnoDB Redo Log Files”
- InnoDB Crash Recovery

14.7.10.1 Group Commit for Redo Log Flushing

`InnoDB`, like any other ACID-compliant database engine, flushes the redo log of a transaction before it is committed. `InnoDB` uses group commit functionality to group multiple such flush requests together to avoid one flush for each commit. With group commit, `InnoDB` issues a single write to the redo log file to perform the commit action for multiple user transactions that commit at about the same time, significantly improving throughput.

Group commit in `InnoDB` worked in earlier releases of MySQL and works once again with MySQL 5.1 with the `InnoDB` Plugin, and MySQL 5.5 and higher. The introduction of support for the distributed transactions and Two Phase Commit (2PC) in MySQL 5.0 interfered with the `InnoDB` group commit functionality. This issue is now resolved.

The group commit functionality inside `InnoDB` works with the Two Phase Commit protocol in MySQL. Re-enabling of the group commit functionality fully ensures that the ordering of commit in the MySQL binary log and the `InnoDB` logfile is the same as it was before. It means it is safe to use the MySQL Enterprise Backup product with `InnoDB` 1.0.4 (that is, the `InnoDB` Plugin with MySQL 5.1) and above.

For more information about performance of `COMMIT` and other transactional operations, see Section 8.5.2, “Optimizing InnoDB Transaction Management”.

14.8 InnoDB Locking and Transaction Model

To implement a large-scale, busy, or highly reliable database application, to port substantial code from a different database system, or to tune MySQL performance, it is important to understand `InnoDB` locking and the `InnoDB` transaction model.

This section discusses several topics related to `InnoDB` locking and the `InnoDB` transaction model with which you should be familiar.

- Section 14.8.1, “InnoDB Locking” describes lock types used by `InnoDB`.
- Section 14.8.2, “InnoDB Transaction Model” describes transaction isolation levels and the locking strategies used by each. It also discusses the use of `autocommit`, consistent non-locking reads, and locking reads.
- Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB” discusses specific types of locks set in `InnoDB` for various statements.
- Section 14.8.4, “Phantom Rows” describes how `InnoDB` uses next-key locking to avoid phantom rows.
- Section 14.8.5, “Deadlocks in InnoDB” provides a deadlock example, discusses deadlock detection and rollback, and provides tips for minimizing and handling deadlocks in `InnoDB`.

14.8.1 InnoDB Locking

This section describes lock types used by `InnoDB`.

- Shared and Exclusive Locks
- Intention Locks
- Record Locks
- Gap Locks
- Next-Key Locks
- Insert Intention Locks
- AUTO-INC Locks

Shared and Exclusive Locks

`InnoDB` implements standard row-level locking where there are two types of locks, shared (*S*) locks and exclusive (*X*) locks.

- A shared (*S*) lock permits the transaction that holds the lock to read a row.
- An exclusive (*X*) lock permits the transaction that holds the lock to update or delete a row.

If transaction `T1` holds a shared (*S*) lock on row `r`, then requests from some distinct transaction `T2` for a lock on row `r` are handled as follows:

- A request by `T2` for an *S* lock can be granted immediately. As a result, both `T1` and `T2` hold an *S* lock on `r`.
- A request by `T2` for an *X* lock cannot be granted immediately.

If a transaction `T1` holds an exclusive (*X*) lock on row `r`, a request from some distinct transaction `T2` for a lock of either type on `r` cannot be granted immediately. Instead, transaction `T2` has to wait for transaction `T1` to release its lock on row `r`.

Intention Locks

`InnoDB` supports *multiple granularity locking* which permits coexistence of row-level locks and locks on entire tables. To make locking at multiple granularity levels practical, additional types of locks called intention locks are used. Intention locks are table-level locks in `InnoDB` that indicate which type of lock (shared or exclusive) a transaction requires later for a row in that table. There are two types of intention locks used in `InnoDB` (assume that transaction `T` has requested a lock of the indicated type on table `t`):

- Intention shared (*IS*): Transaction `T` intends to set *S* locks on individual rows in table `t`.
- Intention exclusive (*IX*): Transaction `T` intends to set *X* locks on those rows.

For example, `SELECT ... LOCK IN SHARE MODE` sets an *IS* lock and `SELECT ... FOR UPDATE` sets an *IX* lock.

The intention locking protocol is as follows:

- Before a transaction can acquire an *S* lock on a row in table `t`, it must first acquire an *IS* or stronger lock on `t`.
- Before a transaction can acquire an *X* lock on a row, it must first acquire an *IX* lock on `t`.

These rules can be conveniently summarized by means of the following *lock type compatibility matrix*.

	X	***IX***	***S***	***IS***
X	Conflict	Conflict	Conflict	Conflict
IX	Conflict	Compatible	Conflict	Compatible
S	Conflict	Conflict	Compatible	Compatible

	X	*IX*	*S*	*IS*
IS	Conflict	Compatible	Compatible	Compatible

A lock is granted to a requesting transaction if it is compatible with existing locks, but not if it conflicts with existing locks. A transaction waits until the conflicting existing lock is released. If a lock request conflicts with an existing lock and cannot be granted because it would cause deadlock, an error occurs.

Thus, intention locks do not block anything except full table requests (for example, `LOCK TABLES ... WRITE`). The main purpose of *IX* and *IS* locks is to show that someone is locking a row, or going to lock a row in the table.

Transaction data for an intention lock appears similar to the following in `SHOW ENGINE INNODB STATUS` and InnoDB monitor output:

```
TABLE LOCK table `test`.`t` trx id 10080 lock mode IX
```

Record Locks

A record lock is a lock on an index record. For example, `SELECT c1 FROM t WHERE c1 = 10 FOR UPDATE;` prevents any other transaction from inserting, updating, or deleting rows where the value of `t.c1` is `10`.

Record locks always lock index records, even if a table is defined with no indexes. For such cases, `InnoDB` creates a hidden clustered index and uses this index for record locking. See Section 14.11.2.1, “Clustered and Secondary Indexes”.

Transaction data for a record lock appears similar to the following in `SHOW ENGINE INNODB STATUS` and InnoDB monitor output:

```
RECORD LOCKS space id 58 page no 3 n bits 72 index `PRIMARY` of table `test`.`t`
trx id 10078 lock_mode X locks rec but not gap
Record lock, heap no 2 PHYSICAL RECORD: n_fields 3; compact format; info bits 0
 0: len 4; hex 8000000a; asc     ;;
 1: len 6; hex 00000000274f; asc     'O;;
 2: len 7; hex b60000019d0110; asc        ;;
```

Gap Locks

A gap lock is a lock on a gap between index records, or a lock on the gap before the first or after the last index record. For example, `SELECT c1 FROM t WHERE c1 BETWEEN 10 and 20 FOR UPDATE;` prevents other transactions from inserting a value of `15` into column `t.c1`, whether or not there was already any such value in the column, because the gaps between all existing values in the range are locked.

A gap might span a single index value, multiple index values, or even be empty.

Gap locks are part of the tradeoff between performance and concurrency, and are used in some transaction isolation levels and not others.

Gap locking is not needed for statements that lock rows using a unique index to search for a unique row. (This does not include the case that the search condition includes only some columns of a multiple-column unique index; in that case, gap locking does occur.) For example, if the `id` column has a unique index, the following statement uses only an index-record lock for the row having `id` value 100 and it does not matter whether other sessions insert rows in the preceding gap:

```
SELECT * FROM child WHERE id = 100;
```

If `id` is not indexed or has a nonunique index, the statement does lock the preceding gap.

It is also worth noting here that conflicting locks can be held on a gap by different transactions. For example, transaction A can hold a shared gap lock (gap S-lock) on a gap while transaction B holds an

exclusive gap lock (gap X-lock) on the same gap. The reason conflicting gap locks are allowed is that if a record is purged from an index, the gap locks held on the record by different transactions must be merged.

Gap locks in `InnoDB` are “purely inhibitive”, which means they only stop other transactions from inserting to the gap. They do not prevent different transactions from taking gap locks on the same gap. Thus, a gap X-lock has the same effect as a gap S-lock.

Gap locking can be disabled explicitly. This occurs if you change the transaction isolation level to `READ COMMITTED` or enable the `innodb_locks_unsafe_for_binlog` system variable. Under these circumstances, gap locking is disabled for searches and index scans and is used only for foreign-key constraint checking and duplicate-key checking.

There are also other effects of using the `READ COMMITTED` isolation level or enabling `innodb_locks_unsafe_for_binlog`. Record locks for nonmatching rows are released after MySQL has evaluated the `WHERE` condition. For `UPDATE` statements, `InnoDB` does a “semi-consistent” read, such that it returns the latest committed version to MySQL so that MySQL can determine whether the row matches the `WHERE` condition of the `UPDATE`.

Next-Key Locks

A next-key lock is a combination of a record lock on the index record and a gap lock on the gap before the index record.

`InnoDB` performs row-level locking in such a way that when it searches or scans a table index, it sets shared or exclusive locks on the index records it encounters. Thus, the row-level locks are actually index-record locks. A next-key lock on an index record also affects the “gap” before that index record. That is, a next-key lock is an index-record lock plus a gap lock on the gap preceding the index record. If one session has a shared or exclusive lock on record `R` in an index, another session cannot insert a new index record in the gap immediately before `R` in the index order.

Suppose that an index contains the values 10, 11, 13, and 20. The possible next-key locks for this index cover the following intervals, where a round bracket denotes exclusion of the interval endpoint and a square bracket denotes inclusion of the endpoint:

```
(negative infinity, 10]
(10, 11]
(11, 13]
(13, 20]
(20, positive infinity)
```

For the last interval, the next-key lock locks the gap above the largest value in the index and the “supremum” pseudo-record having a value higher than any value actually in the index. The supremum is not a real index record, so, in effect, this next-key lock locks only the gap following the largest index value.

By default, `InnoDB` operates in `REPEATABLE READ` transaction isolation level and with the `innodb_locks_unsafe_for_binlog` system variable disabled. In this case, `InnoDB` uses next-key locks for searches and index scans, which prevents phantom rows (see Section 14.8.4, “Phantom Rows”).

Transaction data for a next-key lock appears similar to the following in `SHOW ENGINE INNODB STATUS` and InnoDB monitor output:

```
RECORD LOCKS space id 58 page no 3 n bits 72 index `PRIMARY` of table `test`.`t`
trx id 10080 lock_mode X
Record lock, heap no 1 PHYSICAL RECORD: n_fields 1; compact format; info bits 0
 0: len 8; hex 73757072656d756d; asc supremum;;

Record lock, heap no 2 PHYSICAL RECORD: n_fields 3; compact format; info bits 0
 0: len 4; hex 8000000a; asc     ;;
 1: len 6; hex 00000000274f; asc     'O;;
 2: len 7; hex b60000019d0110; asc        ;;
```

Insert Intention Locks

An insert intention lock is a type of gap lock set by `INSERT` operations prior to row insertion. This lock signals the intent to insert in such a way that multiple transactions inserting into the same index gap need not wait for each other if they are not inserting at the same position within the gap. Suppose that there are index records with values of 4 and 7. Separate transactions that attempt to insert values of 5 and 6, respectively, each lock the gap between 4 and 7 with insert intention locks prior to obtaining the exclusive lock on the inserted row, but do not block each other because the rows are nonconflicting.

The following example demonstrates a transaction taking an insert intention lock prior to obtaining an exclusive lock on the inserted record. The example involves two clients, A and B.

Client A creates a table containing two index records (90 and 102) and then starts a transaction that places an exclusive lock on index records with an ID greater than 100. The exclusive lock includes a gap lock before record 102:

```
mysql> CREATE TABLE child (id int(11) NOT NULL, PRIMARY KEY(id)) ENGINE=InnoDB;
mysql> INSERT INTO child (id) values (90),(102);

mysql> START TRANSACTION;
mysql> SELECT * FROM child WHERE id > 100 FOR UPDATE;
+-----+
| id  |
+-----+
| 102 |
+-----+
```

Client B begins a transaction to insert a record into the gap. The transaction takes an insert intention lock while it waits to obtain an exclusive lock.

```
mysql> START TRANSACTION;
mysql> INSERT INTO child (id) VALUES (101);
```

Transaction data for an insert intention lock appears similar to the following in `SHOW ENGINE INNODB STATUS` and InnoDB monitor output:

```
RECORD LOCKS space id 31 page no 3 n bits 72 index `PRIMARY` of table `test`.`child`
trx id 8731 lock_mode X locks gap before rec insert intention waiting
Record lock, heap no 3 PHYSICAL RECORD: n_fields 3; compact format; info bits 0
 0: len 4; hex 80000066; asc    f;;
 1: len 6; hex 000000002215; asc     " ;;
 2: len 7; hex 9000000172011c; asc     r  ;;...
```

AUTO-INC Locks

An `AUTO-INC` lock is a special table-level lock taken by transactions inserting into tables with `AUTO_INCREMENT` columns. In the simplest case, if one transaction is inserting values into the table, any other transactions must wait to do their own inserts into that table, so that rows inserted by the first transaction receive consecutive primary key values.

The `innodb_autoinc_lock_mode` configuration option controls the algorithm used for auto-increment locking. It allows you to choose how to trade off between predictable sequences of auto-increment values and maximum concurrency for insert operations.

For more information, see Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”.

14.8.2 InnoDB Transaction Model

In the `InnoDB` transaction model, the goal is to combine the best properties of a multi-versioning database with traditional two-phase locking. `InnoDB` performs locking at the row level and runs queries as nonlocking consistent reads by default, in the style of Oracle. The lock information in `InnoDB` is stored space-efficiently so that lock escalation is not needed. Typically, several users are permitted to lock every row in `InnoDB` tables, or any random subset of the rows, without causing `InnoDB` memory exhaustion.

14.8.2.1 Transaction Isolation Levels

Transaction isolation is one of the foundations of database processing. Isolation is the I in the acronym ACID; the isolation level is the setting that fine-tunes the balance between performance and reliability, consistency, and reproducibility of results when multiple transactions are making changes and performing queries at the same time.

`InnoDB` offers all four transaction isolation levels described by the SQL:1992 standard: `READ UNCOMMITTED`, `READ COMMITTED`, `REPEATABLE READ`, and `SERIALIZABLE`. The default isolation level for `InnoDB` is `REPEATABLE READ`.

A user can change the isolation level for a single session or for all subsequent connections with the `SET TRANSACTION` statement. To set the server's default isolation level for all connections, use the `--transaction-isolation` option on the command line or in an option file. For detailed information about isolation levels and level-setting syntax, see Section 13.3.6, “SET TRANSACTION Syntax”.

`InnoDB` supports each of the transaction isolation levels described here using different locking strategies. You can enforce a high degree of consistency with the default `REPEATABLE READ` level, for operations on crucial data where ACID compliance is important. Or you can relax the consistency rules with `READ COMMITTED` or even `READ UNCOMMITTED`, in situations such as bulk reporting where precise consistency and repeatable results are less important than minimizing the amount of overhead for locking. `SERIALIZABLE` enforces even stricter rules than `REPEATABLE READ`, and is used mainly in specialized situations, such as with XA transactions and for troubleshooting issues with concurrency and deadlocks.

The following list describes how MySQL supports the different transaction levels. The list goes from the most commonly used level to the least used.

- `REPEATABLE READ`

  This is the default isolation level for `InnoDB`. Consistent reads within the same transaction read the snapshot established by the first read. This means that if you issue several plain (nonlocking) `SELECT` statements within the same transaction, these `SELECT` statements are consistent also with respect to each other. See Section 14.8.2.3, “Consistent Nonlocking Reads”.

  For locking reads (`SELECT` with `FOR UPDATE` or `LOCK IN SHARE MODE`), `UPDATE`, and `DELETE` statements, locking depends on whether the statement uses a unique index with a unique search condition, or a range-type search condition.

  - For a unique index with a unique search condition, `InnoDB` locks only the index record found, not the gap before it.
  - For other search conditions, `InnoDB` locks the index range scanned, using gap locks or next-key locks to block insertions by other sessions into the gaps covered by the range. For information about gap locks and next-key locks, see Section 14.8.1, “InnoDB Locking”.

- `READ COMMITTED`

  Each consistent read, even within the same transaction, sets and reads its own fresh snapshot. For information about consistent reads, see Section 14.8.2.3, “Consistent Nonlocking Reads”.

  For locking reads (`SELECT` with `FOR UPDATE` or `LOCK IN SHARE MODE`), `UPDATE` statements, and `DELETE` statements, `InnoDB` locks only index records, not the gaps before them, and thus permits the free insertion of new records next to locked records. Gap locking is only used for foreign-key constraint checking and duplicate-key checking.

  Because gap locking is disabled, phantom problems may occur, as other sessions can insert new rows into the gaps. For information about phantoms, see Section 14.8.4, “Phantom Rows”.

  If you use `READ COMMITTED`, you *must* use row-based binary logging.

Using `READ COMMITTED` has additional effects:

- For `UPDATE` or `DELETE` statements, `InnoDB` holds locks only for rows that it updates or deletes. Record locks for nonmatching rows are released after MySQL has evaluated the `WHERE` condition. This greatly reduces the probability of deadlocks, but they can still happen.
- For `UPDATE` statements, if a row is already locked, `InnoDB` performs a “semi-consistent” read, returning the latest committed version to MySQL so that MySQL can determine whether the row matches the `WHERE` condition of the `UPDATE`. If the row matches (must be updated), MySQL reads the row again and this time `InnoDB` either locks it or waits for a lock on it.

Consider the following example, beginning with this table:

```
CREATE TABLE t (a INT NOT NULL, b INT) ENGINE = InnoDB;
INSERT INTO t VALUES (1,2),(2,3),(3,2),(4,3),(5,2);
COMMIT;
```

In this case, table has no indexes, so searches and index scans use the hidden clustered index for record locking (see Section 14.11.2.1, “Clustered and Secondary Indexes”).

Suppose that one client performs an `UPDATE` using these statements:

```
SET autocommit = 0;
UPDATE t SET b = 5 WHERE b = 3;
```

Suppose also that a second client performs an `UPDATE` by executing these statements following those of the first client:

```
SET autocommit = 0;
UPDATE t SET b = 4 WHERE b = 2;
```

As `InnoDB` executes each `UPDATE`, it first acquires an exclusive lock for each row, and then determines whether to modify it. If `InnoDB` does not modify the row, it releases the lock. Otherwise, `InnoDB` retains the lock until the end of the transaction. This affects transaction processing as follows.

When using the default `REPEATABLE READ` isolation level, the first `UPDATE` acquires x-locks and does not release any of them:

```
x-lock(1,2); retain x-lock
x-lock(2,3); update(2,3) to (2,5); retain x-lock
x-lock(3,2); retain x-lock
x-lock(4,3); update(4,3) to (4,5); retain x-lock
x-lock(5,2); retain x-lock
```

The second `UPDATE` blocks as soon as it tries to acquire any locks (because first update has retained locks on all rows), and does not proceed until the first `UPDATE` commits or rolls back:

```
x-lock(1,2); block and wait for first UPDATE to commit or roll back
```

If `READ COMMITTED` is used instead, the first `UPDATE` acquires x-locks and releases those for rows that it does not modify:

```
x-lock(1,2); unlock(1,2)
x-lock(2,3); update(2,3) to (2,5); retain x-lock
x-lock(3,2); unlock(3,2)
x-lock(4,3); update(4,3) to (4,5); retain x-lock
x-lock(5,2); unlock(5,2)
```

For the second UPDATE, InnoDB does a “semi-consistent” read, returning the latest committed version of each row to MySQL so that MySQL can determine whether the row matches the WHERE condition of the UPDATE:

```
x-lock(1,2); update(1,2) to (1,4); retain x-lock
x-lock(2,3); unlock(2,3)
x-lock(3,2); update(3,2) to (3,4); retain x-lock
x-lock(4,3); unlock(4,3)
x-lock(5,2); update(5,2) to (5,4); retain x-lock
```

The effects of using the READ COMMITTED isolation level are the same as enabling the innodb_locks_unsafe_for_binlog configuration option, with these exceptions:

- Enabling innodb_locks_unsafe_for_binlog is a global setting and affects all sessions, whereas the isolation level can be set globally for all sessions, or individually per session.
- innodb_locks_unsafe_for_binlog can be set only at server startup, whereas the isolation level can be set at startup or changed at runtime.

READ COMMITTED therefore offers finer and more flexible control than innodb_locks_unsafe_for_binlog.

- READ UNCOMMITTED

  SELECT statements are performed in a nonlocking fashion, but a possible earlier version of a row might be used. Thus, using this isolation level, such reads are not consistent. This is also called a “dirty read.” Otherwise, this isolation level works like READ COMMITTED.

- SERIALIZABLE

  This level is like REPEATABLE READ, but InnoDB implicitly converts all plain SELECT statements to SELECT ... LOCK IN SHARE MODE if autocommit is disabled. If autocommit is enabled, the SELECT is its own transaction. It therefore is known to be read only and can be serialized if performed as a consistent (nonlocking) read and need not block for other transactions. (To force a plain SELECT to block if other transactions have modified the selected rows, disable autocommit.)

14.8.2.2 autocommit, Commit, and Rollback

In InnoDB, all user activity occurs inside a transaction. If autocommit mode is enabled, each SQL statement forms a single transaction on its own. By default, MySQL starts the session for each new connection with autocommit enabled, so MySQL does a commit after each SQL statement if that statement did not return an error. If a statement returns an error, the commit or rollback behavior depends on the error. See Section 14.23.4, “InnoDB Error Handling”.

A session that has autocommit enabled can perform a multiple-statement transaction by starting it with an explicit START TRANSACTION or BEGIN statement and ending it with a COMMIT or ROLLBACK statement. See Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”.

If autocommit mode is disabled within a session with SET autocommit = 0, the session always has a transaction open. A COMMIT or ROLLBACK statement ends the current transaction and a new one starts.

If a session that has autocommit disabled ends without explicitly committing the final transaction, MySQL rolls back that transaction.

Some statements implicitly end a transaction, as if you had done a COMMIT before executing the statement. For details, see Section 13.3.3, “Statements That Cause an Implicit Commit”.

A COMMIT means that the changes made in the current transaction are made permanent and become visible to other sessions. A ROLLBACK statement, on the other hand, cancels all modifications made by

the current transaction. Both COMMIT and ROLLBACK release all InnoDB locks that were set during the current transaction.

Grouping DML Operations with Transactions

By default, connection to the MySQL server begins with autocommit mode enabled, which automatically commits every SQL statement as you execute it. This mode of operation might be unfamiliar if you have experience with other database systems, where it is standard practice to issue a sequence of DML statements and commit them or roll them back all together.

To use multiple-statement transactions, switch autocommit off with the SQL statement SET autocommit = 0 and end each transaction with COMMIT or ROLLBACK as appropriate. To leave autocommit on, begin each transaction with START TRANSACTION and end it with COMMIT or ROLLBACK. The following example shows two transactions. The first is committed; the second is rolled back.

```
shell> mysql test

mysql> CREATE TABLE customer (a INT, b CHAR (20), INDEX (a))
    -> ENGINE=InnoDB;
Query OK, 0 rows affected (0.00 sec)
mysql> -- Do a transaction with autocommit turned on.
mysql> START TRANSACTION;
Query OK, 0 rows affected (0.00 sec)
mysql> INSERT INTO customer VALUES (10, 'Heikki');
Query OK, 1 row affected (0.00 sec)
mysql> COMMIT;
Query OK, 0 rows affected (0.00 sec)
mysql> -- Do another transaction with autocommit turned off.
mysql> SET autocommit=0;
Query OK, 0 rows affected (0.00 sec)
mysql> INSERT INTO customer VALUES (15, 'John');
Query OK, 1 row affected (0.00 sec)
mysql> INSERT INTO customer VALUES (20, 'Paul');
Query OK, 1 row affected (0.00 sec)
mysql> DELETE FROM customer WHERE b = 'Heikki';
Query OK, 1 row affected (0.00 sec)
mysql> -- Now we undo those last 2 inserts and the delete.
mysql> ROLLBACK;
Query OK, 0 rows affected (0.00 sec)
mysql> SELECT * FROM customer;
+------+--------+
| a    | b      |
+------+--------+
|   10 | Heikki |
+------+--------+
1 row in set (0.00 sec)
mysql>
```

Transactions in Client-Side Languages

In APIs such as PHP, Perl DBI, JDBC, ODBC, or the standard C call interface of MySQL, you can send transaction control statements such as COMMIT to the MySQL server as strings just like any other SQL statements such as SELECT or INSERT. Some APIs also offer separate special transaction commit and rollback functions or methods.

14.8.2.3 Consistent Nonlocking Reads

A consistent read means that InnoDB uses multi-versioning to present to a query a snapshot of the database at a point in time. The query sees the changes made by transactions that committed before that point of time, and no changes made by later or uncommitted transactions. The exception to this rule is that the query sees the changes made by earlier statements within the same transaction. This exception causes the following anomaly: If you update some rows in a table, a SELECT sees the latest version of the updated rows, but it might also see older versions of any rows. If other sessions

simultaneously update the same table, the anomaly means that you might see the table in a state that never existed in the database.

If the transaction isolation level is `REPEATABLE READ` (the default level), all consistent reads within the same transaction read the snapshot established by the first such read in that transaction. You can get a fresher snapshot for your queries by committing the current transaction and after that issuing new queries.

With `READ COMMITTED` isolation level, each consistent read within a transaction sets and reads its own fresh snapshot.

Consistent read is the default mode in which `InnoDB` processes `SELECT` statements in `READ COMMITTED` and `REPEATABLE READ` isolation levels. A consistent read does not set any locks on the tables it accesses, and therefore other sessions are free to modify those tables at the same time a consistent read is being performed on the table.

Suppose that you are running in the default `REPEATABLE READ` isolation level. When you issue a consistent read (that is, an ordinary `SELECT` statement), `InnoDB` gives your transaction a timepoint according to which your query sees the database. If another transaction deletes a row and commits after your timepoint was assigned, you do not see the row as having been deleted. Inserts and updates are treated similarly.

Note

The snapshot of the database state applies to `SELECT` statements within a transaction, not necessarily to DML statements. If you insert or modify some rows and then commit that transaction, a `DELETE` or `UPDATE` statement issued from another concurrent `REPEATABLE READ` transaction could affect those just-committed rows, even though the session could not query them. If a transaction does update or delete rows committed by a different transaction, those changes do become visible to the current transaction. For example, you might encounter a situation like the following:

```
SELECT COUNT(c1) FROM t1 WHERE c1 = 'xyz';
-- Returns 0: no rows match.
DELETE FROM t1 WHERE c1 = 'xyz';
-- Deletes several rows recently committed by other transaction.

SELECT COUNT(c2) FROM t1 WHERE c2 = 'abc';
-- Returns 0: no rows match.
UPDATE t1 SET c2 = 'cba' WHERE c2 = 'abc';
-- Affects 10 rows: another txn just committed 10 rows with 'abc' values.
SELECT COUNT(c2) FROM t1 WHERE c2 = 'cba';
-- Returns 10: this txn can now see the rows it just updated.
```

You can advance your timepoint by committing your transaction and then doing another `SELECT` or `START TRANSACTION WITH CONSISTENT SNAPSHOT`.

This is called *multi-versioned concurrency control*.

In the following example, session A sees the row inserted by B only when B has committed the insert and A has committed as well, so that the timepoint is advanced past the commit of B.

```
             Session A              Session B

           SET autocommit=0;      SET autocommit=0;
time
|          SELECT * FROM t;
|          empty set
|                                  INSERT INTO t VALUES (1, 2);
|
v          SELECT * FROM t;
           empty set
                                  COMMIT;
```

```
          SELECT * FROM t;
          empty set

          COMMIT;

          SELECT * FROM t;
          ---------------------
          |    1    |    2    |
          ---------------------
```

If you want to see the “freshest” state of the database, use either the `READ COMMITTED` isolation level or a locking read:

```
SELECT * FROM t LOCK IN SHARE MODE;
```

With `READ COMMITTED` isolation level, each consistent read within a transaction sets and reads its own fresh snapshot. With `LOCK IN SHARE MODE`, a locking read occurs instead: A `SELECT` blocks until the transaction containing the freshest rows ends (see Section 14.8.2.4, “Locking Reads”).

Consistent read does not work over certain DDL statements:

- Consistent read does not work over `DROP TABLE`, because MySQL cannot use a table that has been dropped and `InnoDB` destroys the table.
- Consistent read does not work over `ALTER TABLE`, because that statement makes a temporary copy of the original table and deletes the original table when the temporary copy is built. When you reissue a consistent read within a transaction, rows in the new table are not visible because those rows did not exist when the transaction's snapshot was taken.

The type of read varies for selects in clauses like `INSERT INTO ... SELECT`, `UPDATE ... (SELECT)`, and `CREATE TABLE ... SELECT` that do not specify `FOR UPDATE` or `LOCK IN SHARE MODE`:

- By default, `InnoDB` uses stronger locks and the `SELECT` part acts like `READ COMMITTED`, where each consistent read, even within the same transaction, sets and reads its own fresh snapshot.
- To use a consistent read in such cases, enable the `innodb_locks_unsafe_for_binlog` option and set the isolation level of the transaction to `READ UNCOMMITTED`, `READ COMMITTED`, or `REPEATABLE READ` (that is, anything other than `SERIALIZABLE`). In this case, no locks are set on rows read from the selected table.

14.8.2.4 Locking Reads

If you query data and then insert or update related data within the same transaction, the regular `SELECT` statement does not give enough protection. Other transactions can update or delete the same rows you just queried. `InnoDB` supports two types of locking reads that offer extra safety:

- `SELECT ... LOCK IN SHARE MODE`

  Sets a shared mode lock on any rows that are read. Other sessions can read the rows, but cannot modify them until your transaction commits. If any of these rows were changed by another transaction that has not yet committed, your query waits until that transaction ends and then uses the latest values.

- `SELECT ... FOR UPDATE`

  For index records the search encounters, locks the rows and any associated index entries, the same as if you issued an `UPDATE` statement for those rows. Other transactions are blocked from updating those rows, from doing `SELECT ... LOCK IN SHARE MODE`, or from reading the data in certain transaction isolation levels. Consistent reads ignore any locks set on the records that exist in the read view. (Old versions of a record cannot be locked; they are reconstructed by applying undo logs on an in-memory copy of the record.)

These clauses are primarily useful when dealing with tree-structured or graph-structured data, either in a single table or split across multiple tables. You traverse edges or tree branches from one place to another, while reserving the right to come back and change any of these “pointer” values.

All locks set by `LOCK IN SHARE MODE` and `FOR UPDATE` queries are released when the transaction is committed or rolled back.

Note

Locking of rows for update using `SELECT FOR UPDATE` only applies when autocommit is disabled (either by beginning transaction with `START TRANSACTION` or by setting `autocommit` to 0. If autocommit is enabled, the rows matching the specification are not locked.

Locking Read Examples

Suppose that you want to insert a new row into a table `child`, and make sure that the child row has a parent row in table `parent`. Your application code can ensure referential integrity throughout this sequence of operations.

First, use a consistent read to query the table `PARENT` and verify that the parent row exists. Can you safely insert the child row to table `CHILD`? No, because some other session could delete the parent row in the moment between your `SELECT` and your `INSERT`, without you being aware of it.

To avoid this potential issue, perform the `SELECT` using `LOCK IN SHARE MODE`:

```
SELECT * FROM parent WHERE NAME = 'Jones' LOCK IN SHARE MODE;
```

After the `LOCK IN SHARE MODE` query returns the parent `'Jones'`, you can safely add the child record to the `CHILD` table and commit the transaction. Any transaction that tries to acquire an exclusive lock in the applicable row in the `PARENT` table waits until you are finished, that is, until the data in all tables is in a consistent state.

For another example, consider an integer counter field in a table `CHILD_CODES`, used to assign a unique identifier to each child added to table `CHILD`. Do not use either consistent read or a shared mode read to read the present value of the counter, because two users of the database could see the same value for the counter, and a duplicate-key error occurs if two transactions attempt to add rows with the same identifier to the `CHILD` table.

Here, `LOCK IN SHARE MODE` is not a good solution because if two users read the counter at the same time, at least one of them ends up in deadlock when it attempts to update the counter.

To implement reading and incrementing the counter, first perform a locking read of the counter using `FOR UPDATE`, and then increment the counter. For example:

```
SELECT counter_field FROM child_codes FOR UPDATE;
UPDATE child_codes SET counter_field = counter_field + 1;
```

A `SELECT ... FOR UPDATE` reads the latest available data, setting exclusive locks on each row it reads. Thus, it sets the same locks a searched SQL `UPDATE` would set on the rows.

The preceding description is merely an example of how `SELECT ... FOR UPDATE` works. In MySQL, the specific task of generating a unique identifier actually can be accomplished using only a single access to the table:

```
UPDATE child_codes SET counter_field = LAST_INSERT_ID(counter_field + 1);
SELECT LAST_INSERT_ID();
```

The `SELECT` statement merely retrieves the identifier information (specific to the current connection). It does not access any table.

14.8.3 Locks Set by Different SQL Statements in InnoDB

A locking read, an `UPDATE`, or a `DELETE` generally set record locks on every index record that is scanned in the processing of the SQL statement. It does not matter whether there are `WHERE` conditions in the statement that would exclude the row. `InnoDB` does not remember the exact `WHERE` condition, but only knows which index ranges were scanned. The locks are normally next-key locks that also block inserts into the “gap” immediately before the record. However, gap locking can be disabled explicitly, which causes next-key locking not to be used. For more information, see Section 14.8.1, “InnoDB Locking”. The transaction isolation level also can affect which locks are set; see Section 14.8.2.1, “Transaction Isolation Levels”.

If a secondary index is used in a search and index record locks to be set are exclusive, `InnoDB` also retrieves the corresponding clustered index records and sets locks on them.

Differences between shared and exclusive locks are described in Section 14.8.1, “InnoDB Locking”.

If you have no indexes suitable for your statement and MySQL must scan the entire table to process the statement, every row of the table becomes locked, which in turn blocks all inserts by other users to the table. It is important to create good indexes so that your queries do not unnecessarily scan many rows.

For `SELECT ... FOR UPDATE` or `SELECT ... LOCK IN SHARE MODE`, locks are acquired for scanned rows, and expected to be released for rows that do not qualify for inclusion in the result set (for example, if they do not meet the criteria given in the `WHERE` clause). However, in some cases, rows might not be unlocked immediately because the relationship between a result row and its original source is lost during query execution. For example, in a `UNION`, scanned (and locked) rows from a table might be inserted into a temporary table before evaluation whether they qualify for the result set. In this circumstance, the relationship of the rows in the temporary table to the rows in the original table is lost and the latter rows are not unlocked until the end of query execution.

`InnoDB` sets specific types of locks as follows.

- `SELECT ... FROM` is a consistent read, reading a snapshot of the database and setting no locks unless the transaction isolation level is set to `SERIALIZABLE`. For `SERIALIZABLE` level, the search sets shared next-key locks on the index records it encounters. However, only an index record lock is required for statements that lock rows using a unique index to search for a unique row.

- `SELECT ... FROM ... LOCK IN SHARE MODE` sets shared next-key locks on all index records the search encounters. However, only an index record lock is required for statements that lock rows using a unique index to search for a unique row.

- `SELECT ... FROM ... FOR UPDATE` sets an exclusive next-key lock on every record the search encounters. However, only an index record lock is required for statements that lock rows using a unique index to search for a unique row.

  For index records the search encounters, `SELECT ... FROM ... FOR UPDATE` blocks other sessions from doing `SELECT ... FROM ... LOCK IN SHARE MODE` or from reading in certain transaction isolation levels. Consistent reads ignore any locks set on the records that exist in the read view.

- `UPDATE ... WHERE ...` sets an exclusive next-key lock on every record the search encounters. However, only an index record lock is required for statements that lock rows using a unique index to search for a unique row.

- When `UPDATE` modifies a clustered index record, implicit locks are taken on affected secondary index records. The `UPDATE` operation also takes shared locks on affected secondary index records when performing duplicate check scans prior to inserting new secondary index records, and when inserting new secondary index records.

- `DELETE FROM ... WHERE ...` sets an exclusive next-key lock on every record the search encounters. However, only an index record lock is required for statements that lock rows using a unique index to search for a unique row.

- `INSERT` sets an exclusive lock on the inserted row. This lock is an index-record lock, not a next-key lock (that is, there is no gap lock) and does not prevent other sessions from inserting into the gap before the inserted row.

  Prior to inserting the row, a type of gap lock called an insert intention gap lock is set. This lock signals the intent to insert in such a way that multiple transactions inserting into the same index gap need not wait for each other if they are not inserting at the same position within the gap. Suppose that there are index records with values of 4 and 7. Separate transactions that attempt to insert values of 5 and 6 each lock the gap between 4 and 7 with insert intention locks prior to obtaining the exclusive lock on the inserted row, but do not block each other because the rows are nonconflicting.

  If a duplicate-key error occurs, a shared lock on the duplicate index record is set. This use of a shared lock can result in deadlock should there be multiple sessions trying to insert the same row if another session already has an exclusive lock. This can occur if another session deletes the row. Suppose that an `InnoDB` table `t1` has the following structure:

```
CREATE TABLE t1 (i INT, PRIMARY KEY (i)) ENGINE = InnoDB;
```

  Now suppose that three sessions perform the following operations in order:

  Session 1:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

  Session 2:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

  Session 3:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

  Session 1:

```
ROLLBACK;
```

  The first operation by session 1 acquires an exclusive lock for the row. The operations by sessions 2 and 3 both result in a duplicate-key error and they both request a shared lock for the row. When session 1 rolls back, it releases its exclusive lock on the row and the queued shared lock requests for sessions 2 and 3 are granted. At this point, sessions 2 and 3 deadlock: Neither can acquire an exclusive lock for the row because of the shared lock held by the other.

  A similar situation occurs if the table already contains a row with key value 1 and three sessions perform the following operations in order:

  Session 1:

```
START TRANSACTION;
DELETE FROM t1 WHERE i = 1;
```

  Session 2:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

Session 3:

```
START TRANSACTION;
INSERT INTO t1 VALUES(1);
```

Session 1:

```
COMMIT;
```

The first operation by session 1 acquires an exclusive lock for the row. The operations by sessions 2 and 3 both result in a duplicate-key error and they both request a shared lock for the row. When session 1 commits, it releases its exclusive lock on the row and the queued shared lock requests for sessions 2 and 3 are granted. At this point, sessions 2 and 3 deadlock: Neither can acquire an exclusive lock for the row because of the shared lock held by the other.

- `INSERT ... ON DUPLICATE KEY UPDATE` differs from a simple `INSERT` in that an exclusive lock rather than a shared lock is placed on the row to be updated when a duplicate-key error occurs. An exclusive index-record lock is taken for a duplicate primary key value. An exclusive next-key lock is taken for a duplicate unique key value.

- `REPLACE` is done like an `INSERT` if there is no collision on a unique key. Otherwise, an exclusive next-key lock is placed on the row to be replaced.

- `INSERT INTO T SELECT ... FROM S WHERE ...` sets an exclusive index record lock (without a gap lock) on each row inserted into `T`. If the transaction isolation level is `READ COMMITTED`, or `innodb_locks_unsafe_for_binlog` is enabled and the transaction isolation level is not `SERIALIZABLE`, `InnoDB` does the search on `S` as a consistent read (no locks). Otherwise, `InnoDB` sets shared next-key locks on rows from `S`. `InnoDB` has to set locks in the latter case: In roll-forward recovery from a backup, every SQL statement must be executed in exactly the same way it was done originally.

  `CREATE TABLE ... SELECT ...` performs the `SELECT` with shared next-key locks or as a consistent read, as for `INSERT ... SELECT`.

  When a `SELECT` is used in the constructs `REPLACE INTO t SELECT ... FROM s WHERE ...` or `UPDATE t ... WHERE col IN (SELECT ... FROM s ...)`, `InnoDB` sets shared next-key locks on rows from table `s`.

- While initializing a previously specified `AUTO_INCREMENT` column on a table, `InnoDB` sets an exclusive lock on the end of the index associated with the `AUTO_INCREMENT` column. In accessing the auto-increment counter, `InnoDB` uses a specific `AUTO-INC` table lock mode where the lock lasts only to the end of the current SQL statement, not to the end of the entire transaction. Other sessions cannot insert into the table while the `AUTO-INC` table lock is held; see Section 14.8.2, “InnoDB Transaction Model”.

  `InnoDB` fetches the value of a previously initialized `AUTO_INCREMENT` column without setting any locks.

- If a `FOREIGN KEY` constraint is defined on a table, any insert, update, or delete that requires the constraint condition to be checked sets shared record-level locks on the records that it looks at to check the constraint. `InnoDB` also sets these locks in the case where the constraint fails.

- `LOCK TABLES` sets table locks, but it is the higher MySQL layer above the `InnoDB` layer that sets these locks. `InnoDB` is aware of table locks if `innodb_table_locks = 1` (the default) and `autocommit = 0`, and the MySQL layer above `InnoDB` knows about row-level locks.

Otherwise, InnoDB's automatic deadlock detection cannot detect deadlocks where such table locks are involved. Also, because in this case the higher MySQL layer does not know about row-level locks, it is possible to get a table lock on a table where another session currently has row-level locks. However, this does not endanger transaction integrity, as discussed in Section 14.8.5.2, “Deadlock Detection and Rollback”. See also Section 14.11.1.7, “Limits on InnoDB Tables”.

14.8.4 Phantom Rows

The so-called *phantom* problem occurs within a transaction when the same query produces different sets of rows at different times. For example, if a SELECT is executed twice, but returns a row the second time that was not returned the first time, the row is a “phantom” row.

Suppose that there is an index on the id column of the child table and that you want to read and lock all rows from the table having an identifier value larger than 100, with the intention of updating some column in the selected rows later:

```
SELECT * FROM child WHERE id > 100 FOR UPDATE;
```

The query scans the index starting from the first record where id is bigger than 100. Let the table contain rows having id values of 90 and 102. If the locks set on the index records in the scanned range do not lock out inserts made in the gaps (in this case, the gap between 90 and 102), another session can insert a new row into the table with an id of 101. If you were to execute the same SELECT within the same transaction, you would see a new row with an id of 101 (a “phantom”) in the result set returned by the query. If we regard a set of rows as a data item, the new phantom child would violate the isolation principle of transactions that a transaction should be able to run so that the data it has read does not change during the transaction.

To prevent phantoms, InnoDB uses an algorithm called *next-key locking* that combines index-row locking with gap locking. InnoDB performs row-level locking in such a way that when it searches or scans a table index, it sets shared or exclusive locks on the index records it encounters. Thus, the row-level locks are actually index-record locks. In addition, a next-key lock on an index record also affects the “gap” before that index record. That is, a next-key lock is an index-record lock plus a gap lock on the gap preceding the index record. If one session has a shared or exclusive lock on record R in an index, another session cannot insert a new index record in the gap immediately before R in the index order.

When InnoDB scans an index, it can also lock the gap after the last record in the index. Just that happens in the preceding example: To prevent any insert into the table where id would be bigger than 100, the locks set by InnoDB include a lock on the gap following id value 102.

You can use next-key locking to implement a uniqueness check in your application: If you read your data in share mode and do not see a duplicate for a row you are going to insert, then you can safely insert your row and know that the next-key lock set on the successor of your row during the read prevents anyone meanwhile inserting a duplicate for your row. Thus, the next-key locking enables you to “lock” the nonexistence of something in your table.

Gap locking can be disabled as discussed in Section 14.8.1, “InnoDB Locking”. This may cause phantom problems because other sessions can insert new rows into the gaps when gap locking is disabled.

14.8.5 Deadlocks in InnoDB

A deadlock is a situation where different transactions are unable to proceed because each holds a lock that the other needs. Because both transactions are waiting for a resource to become available, neither ever release the locks it holds.

A deadlock can occur when transactions lock rows in multiple tables (through statements such as UPDATE or SELECT ... FOR UPDATE), but in the opposite order. A deadlock can also occur when

such statements lock ranges of index records and gaps, with each transaction acquiring some locks but not others due to a timing issue. For a deadlock example, see Section 14.8.5.1, “An InnoDB Deadlock Example”.

To reduce the possibility of deadlocks, use transactions rather than `LOCK TABLES` statements; keep transactions that insert or update data small enough that they do not stay open for long periods of time; when different transactions update multiple tables or large ranges of rows, use the same order of operations (such as `SELECT ... FOR UPDATE`) in each transaction; create indexes on the columns used in `SELECT ... FOR UPDATE` and `UPDATE ... WHERE` statements. The possibility of deadlocks is not affected by the isolation level, because the isolation level changes the behavior of read operations, while deadlocks occur because of write operations. For more information about avoiding and recovering from deadlock conditions, see Section 14.8.5.3, “How to Minimize and Handle Deadlocks”.

If a deadlock does occur, `InnoDB` detects the condition and rolls back one of the transactions (the victim). Thus, even if your application logic is correct, you must still handle the case where a transaction must be retried. To see the last deadlock in an `InnoDB` user transaction, use the `SHOW ENGINE INNODB STATUS` command. If frequent deadlocks highlight a problem with transaction structure or application error handling, run with the `innodb_print_all_deadlocks` setting enabled to print information about all deadlocks to the `mysqld` error log. For more information about how deadlocks are automatically detected and handled, see Section 14.8.5.2, “Deadlock Detection and Rollback”.

14.8.5.1 An InnoDB Deadlock Example

The following example illustrates how an error can occur when a lock request would cause a deadlock. The example involves two clients, A and B.

First, client A creates a table containing one row, and then begins a transaction. Within the transaction, A obtains an *S* lock on the row by selecting it in share mode:

```
mysql> CREATE TABLE t (i INT) ENGINE = InnoDB;
Query OK, 0 rows affected (1.07 sec)

mysql> INSERT INTO t (i) VALUES(1);
Query OK, 1 row affected (0.09 sec)

mysql> START TRANSACTION;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT * FROM t WHERE i = 1 LOCK IN SHARE MODE;
+------+
| i    |
+------+
|    1 |
+------+
```

Next, client B begins a transaction and attempts to delete the row from the table:

```
mysql> START TRANSACTION;
Query OK, 0 rows affected (0.00 sec)

mysql> DELETE FROM t WHERE i = 1;
```

The delete operation requires an *X* lock. The lock cannot be granted because it is incompatible with the *S* lock that client A holds, so the request goes on the queue of lock requests for the row and client B blocks.

Finally, client A also attempts to delete the row from the table:

```
mysql> DELETE FROM t WHERE i = 1;
ERROR 1213 (40001): Deadlock found when trying to get lock;
```

```
try restarting transaction
```

Deadlock occurs here because client A needs an *X* lock to delete the row. However, that lock request cannot be granted because client B already has a request for an *X* lock and is waiting for client A to release its *S* lock. Nor can the *S* lock held by A be upgraded to an *X* lock because of the prior request by B for an *X* lock. As a result, `InnoDB` generates an error for one of the clients and releases its locks. The client returns this error:

```
ERROR 1213 (40001): Deadlock found when trying to get lock;
try restarting transaction
```

At that point, the lock request for the other client can be granted and it deletes the row from the table.

14.8.5.2 Deadlock Detection and Rollback

`InnoDB` automatically detects transaction deadlocks and rolls back a transaction or transactions to break the deadlock. `InnoDB` tries to pick small transactions to roll back, where the size of a transaction is determined by the number of rows inserted, updated, or deleted.

`InnoDB` is aware of table locks if `innodb_table_locks = 1` (the default) and `autocommit = 0`, and the MySQL layer above it knows about row-level locks. Otherwise, `InnoDB` cannot detect deadlocks where a table lock set by a MySQL `LOCK TABLES` statement or a lock set by a storage engine other than `InnoDB` is involved. Resolve these situations by setting the value of the `innodb_lock_wait_timeout` system variable.

When `InnoDB` performs a complete rollback of a transaction, all locks set by the transaction are released. However, if just a single SQL statement is rolled back as a result of an error, some of the locks set by the statement may be preserved. This happens because `InnoDB` stores row locks in a format such that it cannot know afterward which lock was set by which statement.

If a `SELECT` calls a stored function in a transaction, and a statement within the function fails, that statement rolls back. Furthermore, if `ROLLBACK` is executed after that, the entire transaction rolls back.

If the `LATEST DETECTED DEADLOCK` section of `InnoDB` Monitor output includes a message stating, "`TOO DEEP OR LONG SEARCH IN THE LOCK TABLE WAITS-FOR GRAPH, WE WILL ROLL BACK FOLLOWING TRANSACTION`," this indicates that the number of transactions on the wait-for list has reached a limit of 200. A wait-for list that exceeds 200 transactions is treated as a deadlock and the transaction attempting to check the wait-for list is rolled back. The same error may also occur if the locking thread must look at more than 1,000,000 locks owned by transactions on the wait-for list.

For techniques to organize database operations to avoid deadlocks, see Section 14.8.5, "Deadlocks in InnoDB".

14.8.5.3 How to Minimize and Handle Deadlocks

This section builds on the conceptual information about deadlocks in Section 14.8.5.2, "Deadlock Detection and Rollback". It explains how to organize database operations to minimize deadlocks and the subsequent error handling required in applications.

Deadlocks are a classic problem in transactional databases, but they are not dangerous unless they are so frequent that you cannot run certain transactions at all. Normally, you must write your applications so that they are always prepared to re-issue a transaction if it gets rolled back because of a deadlock.

`InnoDB` uses automatic row-level locking. You can get deadlocks even in the case of transactions that just insert or delete a single row. That is because these operations are not really "atomic"; they automatically set locks on the (possibly several) index records of the row inserted or deleted.

You can cope with deadlocks and reduce the likelihood of their occurrence with the following techniques:

- At any time, issue the `SHOW ENGINE INNODB STATUS` command to determine the cause of the most recent deadlock. That can help you to tune your application to avoid deadlocks.
- If frequent deadlock warnings cause concern, collect more extensive debugging information by enabling the `innodb_print_all_deadlocks` configuration option. Information about each deadlock, not just the latest one, is recorded in the MySQL error log. Disable this option when you are finished debugging.
- Always be prepared to re-issue a transaction if it fails due to deadlock. Deadlocks are not dangerous. Just try again.
- Keep transactions small and short in duration to make them less prone to collision.
- Commit transactions immediately after making a set of related changes to make them less prone to collision. In particular, do not leave an interactive `mysql` session open for a long time with an uncommitted transaction.
- If you use locking reads (`SELECT ... FOR UPDATE` or `SELECT ... LOCK IN SHARE MODE`), try using a lower isolation level such as `READ COMMITTED`.
- When modifying multiple tables within a transaction, or different sets of rows in the same table, do those operations in a consistent order each time. Then transactions form well-defined queues and do not deadlock. For example, organize database operations into functions within your application, or call stored routines, rather than coding multiple similar sequences of `INSERT`, `UPDATE`, and `DELETE` statements in different places.
- Add well-chosen indexes to your tables. Then your queries need to scan fewer index records and consequently set fewer locks. Use `EXPLAIN SELECT` to determine which indexes the MySQL server regards as the most appropriate for your queries.
- Use less locking. If you can afford to permit a `SELECT` to return data from an old snapshot, do not add the clause `FOR UPDATE` or `LOCK IN SHARE MODE` to it. Using the `READ COMMITTED` isolation level is good here, because each consistent read within the same transaction reads from its own fresh snapshot.
- If nothing else helps, serialize your transactions with table-level locks. The correct way to use `LOCK TABLES` with transactional tables, such as `InnoDB` tables, is to begin a transaction with `SET autocommit = 0` (not `START TRANSACTION`) followed by `LOCK TABLES`, and to not call `UNLOCK TABLES` until you commit the transaction explicitly. For example, if you need to write to table `t1` and read from table `t2`, you can do this:

  ```
  SET autocommit=0;
  LOCK TABLES t1 WRITE, t2 READ, ...;
  ... do something with tables t1 and t2 here ...
  COMMIT;
  UNLOCK TABLES;
  ```

  Table-level locks prevent concurrent updates to the table, avoiding deadlocks at the expense of less responsiveness for a busy system.
- Another way to serialize transactions is to create an auxiliary “semaphore” table that contains just a single row. Have each transaction update that row before accessing other tables. In that way, all transactions happen in a serial fashion. Note that the `InnoDB` instant deadlock detection algorithm also works in this case, because the serializing lock is a row-level lock. With MySQL table-level locks, the timeout method must be used to resolve deadlocks.

14.9 InnoDB Configuration

This section provides configuration information and procedures for `InnoDB` initialization, startup, and various components and features of the `InnoDB` storage engine. For information about optimizing database operations for `InnoDB` tables, see Section 8.5, “Optimizing for InnoDB Tables”.

14.9.1 InnoDB Startup Configuration

The first decisions to make about `InnoDB` configuration involve the configuration of data files, log files, and memory buffers. It is recommended that you define data file, log file, and page size configuration before creating the `InnoDB` instance. Modifying data file or log file configuration after the `InnoDB` instance is created may involve a non-trivial procedure.

In addition to these topics, this section provides information about specifying `InnoDB` options in a configuration file, viewing `InnoDB` initialization information, and important storage considerations.

- Specifying Options in a MySQL Configuration File
- Viewing InnoDB Initialization Information
- Important Storage Considerations
- System Tablespace Data File Configuration
- InnoDB Log File Configuration
- InnoDB Memory Configuration

Specifying Options in a MySQL Configuration File

Because MySQL uses data file and log file configuration settings to initialize the `InnoDB` instance, it is recommended that you define these settings in a configuration file that MySQL reads at startup, prior to initializing `InnoDB` for the first time. `InnoDB` is initialized when the MySQL server is started, and the first initialization of `InnoDB` normally occurs the first time you start the MySQL server.

You can place `InnoDB` options in the `[mysqld]` group of any option file that your server reads when it starts. The locations of MySQL option files are described in Section 4.2.6, “Using Option Files”.

To make sure that `mysqld` reads options only from a specific file, use the `--defaults-file` option as the first option on the command line when starting the server:

```
mysqld --defaults-file=path_to_configuration_file
```

Viewing InnoDB Initialization Information

To view `InnoDB` initialization information during startup, start `mysqld` from a command prompt. When `mysqld` is started from a command prompt, initialization information is printed to the console.

For example, on Windows, if `mysqld` is located in `C:\Program Files\MySQL\MySQL Server 5.5\bin`, start the MySQL server like this:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld" --console
```

On Unix-like systems, `mysqld` is located in the `bin` directory of your MySQL installation:

```
sell> bin/mysqld --user=mysql &
```

If you do not send server output to the console, check the error log after startup to see the initialization information `InnoDB` printed during the startup process.

For information about starting MySQL using other methods, see Section 2.10.5, “Starting and Stopping MySQL Automatically”.

Note

`InnoDB` does not open all user tables and associated data files at startup. However, `InnoDB` does check for the existence of tablespace files (`*.ibd`

files) that are referenced in the data dictionary. If a tablespace file is not found, `InnoDB` logs an error and continues the startup sequence. Tablespace files that are referenced in the redo log may be opened during crash recovery for redo application.

Important Storage Considerations

Review the following storage-related considerations before proceeding with your startup configuration.

- In some cases, database performance improves if the data is not all placed on the same physical disk. Putting log files on a different disk from data is very often beneficial for performance. For example, you can place system tablespace data files and log files on different disks. You can also use raw disk partitions (raw devices) for `InnoDB` data files, which may speed up I/O. See Section 14.10.3, “Using Raw Disk Partitions for the System Tablespace”.

- `InnoDB` is a transaction-safe (ACID compliant) storage engine for MySQL that has commit, rollback, and crash-recovery capabilities to protect user data. **However, it cannot do so** if the underlying operating system or hardware does not work as advertised. Many operating systems or disk subsystems may delay or reorder write operations to improve performance. On some operating systems, the very `fsync()` system call that should wait until all unwritten data for a file has been flushed might actually return before the data has been flushed to stable storage. Because of this, an operating system crash or a power outage may destroy recently committed data, or in the worst case, even corrupt the database because of write operations having been reordered. If data integrity is important to you, perform some “pull-the-plug” tests before using anything in production. On OS X 10.3 and higher, `InnoDB` uses a special `fcntl()` file flush method. Under Linux, it is advisable to **disable the write-back cache**.

  On ATA/SATA disk drives, a command such `hdparm -W0 /dev/hda` may work to disable the write-back cache. **Beware that some drives or disk controllers may be unable to disable the write-back cache.**

- With regard to `InnoDB` recovery capabilities that protect user data, `InnoDB` uses a file flush technique involving a structure called the doublewrite buffer, which is enabled by default (`innodb_doublewrite=ON`). The doublewrite buffer adds safety to recovery following a crash or power outage, and improves performance on most varieties of Unix by reducing the need for `fsync()` operations. It is recommended that the `innodb_doublewrite` option remains enabled if you are concerned with data integrity or possible failures. For additional information about the doublewrite buffer, see Section 14.15.1, “InnoDB Disk I/O”.

- Before using NFS with `InnoDB`, review potential issues outlined in Using NFS with MySQL.

- Running MySQL server on a 4K sector hard drive on Windows is not supported with `innodb_flush_method=async_unbuffered`, which is the default setting. The workaround is to use `innodb_flush_method=normal`.

System Tablespace Data File Configuration

The `innodb_data_file_path` configuration option defines the name, size, and attributes of `InnoDB` system tablespace data files. If you do not specify a value for `innodb_data_file_path`, the default behavior is to create a single auto-extending data file, slightly larger than 10MB, named `ibdata1`.

To specify more than one data file, separate them by semicolon (`;`) characters:

```
innodb_data_file_path=datafile_spec1[;datafile_spec2]...
```

The following setting configures a single 12MB data file named `ibdata1` that is auto-extending. No location for the file is given, so by default, `InnoDB` creates it in the MySQL data directory:

```
[mysqld]
innodb_data_file_path=ibdata1:12M:autoextend
```

File size is specified using `K`, `M`, or `G` suffix letters to indicate units of KB, MB, or GB. If specifying the data file size in kilobytes (KB), do so in multiples of 1024. Otherwise, KB values are rounded to nearest megabyte (MB) boundary. The sum of the sizes of the files must be at least slightly larger than 10MB.

A system tablespace with a fixed-size 50MB data file named `ibdata1` and a 50MB auto-extending file named `ibdata2` can be configured like this:

```
[mysqld]
innodb_data_file_path=ibdata1:50M;ibdata2:50M:autoextend
```

The full syntax for a data file specification includes the file name, file size, and optional `autoextend` and `max` attributes:

```
file_name:file_size[:autoextend[:max:max_file_size]]
```

The `autoextend` and `max` attributes can be used only for the data file that is specified last in the `innodb_data_file_path` setting.

If you specify the `autoextend` option for the last data file, `InnoDB` extends the data file if it runs out of free space in the tablespace. The `autoextend` increment is 64MB at a time by default. To modify the increment, change the `innodb_autoextend_increment` system variable.

If the disk becomes full, you might want to add another data file on another disk. For instructions, see Section 14.10.1, “Resizing the InnoDB System Tablespace”.

The size limit of individual files is determined by your operating system. You can set the file size to more than 4GB on operating systems that support large files. You can also use raw disk partitions as data files.

`InnoDB` is not aware of the file system maximum file size, so be cautious on file systems where the maximum file size is a small value such as 2GB. To specify a maximum size for an auto-extending data file, use the `max` attribute following the `autoextend` attribute. Use the `max` attribute only in cases where constraining disk usage is of critical importance, because exceeding the maximum size causes a fatal error, possibly causing the server to exit. The following configuration permits `ibdata1` to grow to a limit of 500MB:

```
[mysqld]
innodb_data_file_path=ibdata1:12M:autoextend:max:500M
```

`InnoDB` creates system tablespace files in the MySQL data directory by default (`datadir`). To specify a location explicitly, use the `innodb_data_home_dir` option. For example, to create two files named `ibdata1` and `ibdata2` in a directory named `myibdata`, configure `InnoDB` like this:

```
[mysqld]
innodb_data_home_dir = /path/to/myibdata/
innodb_data_file_path=ibdata1:50M;ibdata2:50M:autoextend
```

Note

A trailing slash is required when specifying a value for `innodb_data_home_dir`.

`InnoDB` does not create directories, so make sure that the `myibdata` directory exists before you start the server. Use the Unix or DOS `mkdir` command to create directories.

Make sure that the MySQL server has the proper access rights to create files in the data directory. More generally, the server must have access rights in any directory where it needs to create data files.

InnoDB forms the directory path for each data file by textually concatenating the value of innodb_data_home_dir to the data file name. If the innodb_data_home_dir option is not specified, the default value is the “dot” directory ./, which means the MySQL data directory. (The MySQL server changes its current working directory to its data directory when it begins executing.)

If you specify innodb_data_home_dir as an empty string, you can specify absolute paths for data files listed in the innodb_data_file_path value. The following example is equivalent to the preceding one:

```
[mysqld]
innodb_data_home_dir =
innodb_data_file_path=/path/to/myibdata/ibdata1:50M;/path/to/myibdata/ibdata2:50M:autoextend
```

InnoDB Log File Configuration

By default, InnoDB creates two 5MB log files in the MySQL data directory (datadir) named ib_logfile0 and ib_logfile1.

The following options can be used to modify the default configuration:

- innodb_log_group_home_dir defines directory path to the InnoDB log files (the redo logs). If this option is not configured, InnoDB log files are created in the MySQL data directory (datadir).

  You might use this option to place InnoDB log files in a different physical storage location than InnoDB data files to avoid potential I/O resource conflicts. For example:

  ```
  [mysqld]
  innodb_log_group_home_dir = /dr3/iblogs
  ```

  Note

  InnoDB does not create directories, so make sure that the log directory exists before you start the server. Use the Unix or DOS mkdir command to create any necessary directories.

  Make sure that the MySQL server has the proper access rights to create files in the log directory. More generally, the server must have access rights in any directory where it needs to create log files.

- innodb_log_files_in_group defines the number of log files in the log group. The default and recommended value is 2.

- innodb_log_file_size defines the size in bytes of each log file in the log group. The combined size of log files (innodb_log_file_size * innodb_log_files_in_group) cannot exceed a maximum value that is slightly less than 4GB. A pair of 2047 MB log files, for example, approaches the limit but does not exceed it. The default log file size is 5MB. Generally, the combined size of the log files should be large enough that the server can smooth out peaks and troughs in workload activity, which often means that there is enough redo log space to handle more than an hour of write activity. The larger the value, the less checkpoint flush activity is needed in the buffer pool, saving disk I/O. For additional information, see Section 8.5.3, “Optimizing InnoDB Redo Logging”.

InnoDB Memory Configuration

MySQL allocates memory to various caches and buffers to improve performance of database operations. When allocating memory for InnoDB, always consider memory required by the operating system, memory allocated to other applications, and memory allocated for other MySQL buffers and caches. For example, if you use MyISAM tables, consider the amount of memory allocated for the key buffer (key_buffer_size). For an overview of MySQL buffers and caches, see Section 8.12.4.1, “How MySQL Uses Memory”.

Buffers specific to `InnoDB` are configured using the following parameters:

- `innodb_buffer_pool_size` defines size of the buffer pool, which is the memory area that holds cached data for `InnoDB` tables, indexes, and other auxiliary buffers. The size of the buffer pool is important for system performance, and it is typically recommended that `innodb_buffer_pool_size` is configured to 50 to 75 percent of system memory. The default buffer pool size is 128MB. For additional guidance, see Section 8.12.4.1, “How MySQL Uses Memory”. For information about how to configure `InnoDB` buffer pool size, see Configuring InnoDB Buffer Pool Size. Buffer pool size can be configured at startup.

  On systems with a large amount of memory, you can improve concurrency by dividing the buffer pool into multiple buffer pool instances. The number of buffer pool instances is controlled by the by `innodb_buffer_pool_instances` option. By default, `InnoDB` creates one buffer pool instance. The number of buffer pool instances can be configured at startup. For more information, see Section 14.9.2.2, “Configuring Multiple Buffer Pool Instances”.

- `innodb_additional_mem_pool_size` defines size in bytes of a memory pool `InnoDB` uses to store data dictionary information and other internal data structures. The more tables you have in your application, the more memory you allocate here. If `InnoDB` runs out of memory in this pool, it starts to allocate memory from the operating system and writes warning messages to the MySQL error log. The default value is 8MB.

- `innodb_log_buffer_size` defines the size in bytes of the buffer that `InnoDB` uses to write to the log files on disk. The default size is 8MB. A large log buffer enables large transactions to run without a need to write the log to disk before the transactions commit. If you have transactions that update, insert, or delete many rows, you might consider increasing the size of the log buffer to save disk I/O. `innodb_log_buffer_size` can be configured at startup. For related information, see Section 8.5.3, “Optimizing InnoDB Redo Logging”.

Warning

On 32-bit GNU/Linux x86, be careful not to set memory usage too high. `glibc` may permit the process heap to grow over thread stacks, which crashes your server. It is a risk if the memory allocated to the `mysqld` process for global and per-thread buffers and caches is close to or exceeds 2GB.

A formula similar to the following that calculates global and per-thread memory allocation for MySQL can be used to estimate MySQL memory usage. You may need to modify the formula to account for buffers and caches in your MySQL version and configuration. For an overview of MySQL buffers and caches, see Section 8.12.4.1, “How MySQL Uses Memory”.

```
innodb_buffer_pool_size
+ key_buffer_size
+ max_connections*(sort_buffer_size+read_buffer_size+binlog_cache_size)
+ max_connections*2MB
```

Each thread uses a stack (often 2MB, but only 256KB in MySQL binaries provided by Oracle Corporation.) and in the worst case also uses `sort_buffer_size + read_buffer_size` additional memory.

On Linux, if the kernel is enabled for large page support, `InnoDB` can use large pages to allocate memory for its buffer pool and additional memory pool. See Section 8.12.4.2, “Enabling Large Page Support”.

14.9.2 InnoDB Buffer Pool Configuration

This section provides configuration and tuning information for the `InnoDB` buffer pool.

14.9.2.1 The InnoDB Buffer Pool

`InnoDB` maintains a storage area called the buffer pool for caching data and indexes in memory. Knowing how the `InnoDB` buffer pool works, and taking advantage of it to keep frequently accessed data in memory, is an important aspect of MySQL tuning. For information about how the `InnoDB` buffer pool works, see InnoDB Buffer Pool LRU Algorithm.

You can configure the various aspects of the `InnoDB` buffer pool to improve performance.

- Ideally, you set the size of the buffer pool to as large a value as practical, leaving enough memory for other processes on the server to run without excessive paging. The larger the buffer pool, the more `InnoDB` acts like an in-memory database, reading data from disk once and then accessing the data from memory during subsequent reads. Buffer pool size is configured using the `innodb_buffer_pool_size` configuration option.
- With 64-bit systems with large memory sizes, you can split the buffer pool into multiple parts, to minimize contention for the memory structures among concurrent operations. For details, see Section 14.9.2.2, “Configuring Multiple Buffer Pool Instances”.
- You can keep frequently accessed data in memory despite sudden spikes of activity for operations such as backups or reporting. For details, see Section 14.9.2.3, “Making the Buffer Pool Scan Resistant”.
- You can control when and how `InnoDB` performs read-ahead requests to prefetch pages into the buffer pool asynchronously, in anticipation that the pages will be needed soon. For details, see Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”.
- You can control when background flushing of dirty pages occurs and whether or not `InnoDB` dynamically adjusts the rate of flushing based on workload. For details, see Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing”.

InnoDB Buffer Pool LRU Algorithm

`InnoDB` manages the buffer pool as a list, using a variation of the least recently used (LRU) algorithm. When room is needed to add a new page to the pool, `InnoDB` evicts the least recently used page and adds the new page to the middle of the list. This “midpoint insertion strategy” treats the list as two sublists:

- At the head, a sublist of “new” (or “young”) pages that were accessed recently.
- At the tail, a sublist of “old” pages that were accessed less recently.

This algorithm keeps pages that are heavily used by queries in the new sublist. The old sublist contains less-used pages; these pages are candidates for eviction.

The LRU algorithm operates as follows by default:

- 3/8 of the buffer pool is devoted to the old sublist.
- The midpoint of the list is the boundary where the tail of the new sublist meets the head of the old sublist.
- When `InnoDB` reads a page into the buffer pool, it initially inserts it at the midpoint (the head of the old sublist). A page can be read in because it is required for a user-specified operation such as an SQL query, or as part of a read-ahead operation performed automatically by `InnoDB`.
- Accessing a page in the old sublist makes it “young”, moving it to the head of the buffer pool (the head of the new sublist). If the page was read in because it was required, the first access occurs immediately and the page is made young. If the page was read in due to read-ahead, the first access does not occur immediately (and might not occur at all before the page is evicted).
- As the database operates, pages in the buffer pool that are not accessed “age” by moving toward the tail of the list. Pages in both the new and old sublists age as other pages are made new. Pages in the old sublist also age as pages are inserted at the midpoint. Eventually, a page that remains unused for long enough reaches the tail of the old sublist and is evicted.

By default, pages read by queries immediately move into the new sublist, meaning they stay in the buffer pool longer. A table scan (such as performed for a `mysqldump` operation, or a `SELECT` statement with no `WHERE` clause) can bring a large amount of data into the buffer pool and evict an equivalent amount of older data, even if the new data is never used again. Similarly, pages that are loaded by the read-ahead background thread and then accessed only once move to the head of the new list. These situations can push frequently used pages to the old sublist, where they become subject to eviction. For information about optimizing this behavior, see Section 14.9.2.3, “Making the Buffer Pool Scan Resistant”, and Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”.

`InnoDB` Standard Monitor output contains several fields in the `BUFFER POOL AND MEMORY` section that pertain to operation of the buffer pool LRU algorithm. For details, see Section 14.9.2.6, “Monitoring the Buffer Pool Using the InnoDB Standard Monitor”.

InnoDB Buffer Pool Configuration Options

Several configuration options affect different aspects of the `InnoDB` buffer pool.

- `innodb_buffer_pool_size`

  Specifies the size of the buffer pool. If the buffer pool is small and you have sufficient memory, making the buffer pool larger can improve performance by reducing the amount of disk I/O needed as queries access `InnoDB` tables.

- `innodb_buffer_pool_instances`

  Divides the buffer pool into a user-specified number of separate regions, each with its own LRU list and related data structures, to reduce contention during concurrent memory read and write operations. This option only takes effect when you set `innodb_buffer_pool_size` to a value of 1GB or more. The total size you specify is divided among all the buffer pools. For best efficiency, specify a combination of `innodb_buffer_pool_instances` and `innodb_buffer_pool_size` so that each buffer pool instance is at least 1 gigabyte. See Section 14.9.2.2, “Configuring Multiple Buffer Pool Instances” for more information.

- `innodb_old_blocks_pct`

  Specifies the approximate percentage of the buffer pool that `InnoDB` uses for the old block sublist. The range of values is 5 to 95. The default value is 37 (that is, 3/8 of the pool). See Section 14.9.2.3, “Making the Buffer Pool Scan Resistant” for more information.

- `innodb_old_blocks_time`

  Specifies how long in milliseconds (ms) a page inserted into the old sublist must stay there after its first access before it can be moved to the new sublist. If the value is 0, a page inserted into the old sublist moves immediately to the new sublist the first time it is accessed, no matter how soon after insertion the access occurs. If the value is greater than 0, pages remain in the old sublist until an access occurs at least that many milliseconds after the first access. For example, a value of 1000 causes pages to stay in the old sublist for 1 second after the first access before they become eligible to move to the new sublist.

  Setting `innodb_old_blocks_time` greater than 0 prevents one-time table scans from flooding the new sublist with pages used only for the scan. Rows in a page read in for a scan are accessed many times in rapid succession, but the page is unused after that. If `innodb_old_blocks_time` is set to a value greater than time to process the page, the page remains in the “old” sublist and ages to the tail of the list to be evicted quickly. This way, pages used only for a one-time scan do not act to the detriment of heavily used pages in the new sublist.

  `innodb_old_blocks_time` can be set at runtime, so you can change it temporarily while performing operations such as table scans and dumps:

```
SET GLOBAL innodb_old_blocks_time = 1000;
... perform queries that scan tables ...
SET GLOBAL innodb_old_blocks_time = 0;
```

This strategy does not apply if your intent is to “warm up” the buffer pool by filling it with a table's content. For example, benchmark tests often perform a table or index scan at server startup, because that data would normally be in the buffer pool after a period of normal use. In this case, leave `innodb_old_blocks_time` set to 0, at least until the warmup phase is complete.

See Section 14.9.2.3, “Making the Buffer Pool Scan Resistant” for more information.

- `innodb_read_ahead_threshold`

  Controls the sensitivity of linear read-ahead that `InnoDB` uses to prefetch pages into the buffer pool.

  See Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)” for more information.

- `innodb_random_read_ahead`

  Enables random read-ahead technique for prefetching pages into the buffer pool. Random read-ahead is a technique that predicts when pages might be needed soon based on pages already in the buffer pool, regardless of the order in which those pages were read. `innodb_random_read_ahead` is disabled by default.

  See Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)” for more information.

- `innodb_adaptive_flushing`

  Specifies whether to dynamically adjust the rate of flushing dirty pages in the buffer pool based on workload. Adjusting the flush rate dynamically is intended to avoid bursts of I/O activity. This setting is enabled by default.

  See Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing” for more information.

- `innodb_max_dirty_pages_pct`

  `InnoDB` tries to flush data from the buffer pool so that the percentage of dirty pages does not exceed this value. Specify an integer in the range from 0 to 99. The default value is 75.

  See Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing” for more information.

14.9.2.2 Configuring Multiple Buffer Pool Instances

For systems with buffer pools in the multi-gigabyte range, dividing the buffer pool into separate instances can improve concurrency, by reducing contention as different threads read and write to cached pages. This feature is typically intended for systems with a buffer pool size in the multi-gigabyte range. Multiple buffer pool instances are configured using the `innodb_buffer_pool_instances` configuration option, and you might also adjust the `innodb_buffer_pool_size` value.

When the `InnoDB` buffer pool is large, many data requests can be satisfied by retrieving from memory. You might encounter bottlenecks from multiple threads trying to access the buffer pool at once. You can enable multiple buffer pools to minimize this contention. Each page that is stored in or read from the buffer pool is assigned to one of the buffer pools randomly, using a hashing function. Each buffer pool manages its own free lists, flush lists, LRUs, and all other data structures connected to a buffer pool, and is protected by its own buffer pool mutex.

To enable multiple buffer pool instances, set the `innodb_buffer_pool_instances` configuration option to a value greater than 1 (the default) up to 64 (the maximum). This option takes effect only when you set `innodb_buffer_pool_size` to a size of 1GB or more. The total size

you specify is divided among all the buffer pools. For best efficiency, specify a combination of `innodb_buffer_pool_instances` and `innodb_buffer_pool_size` so that each buffer pool instance is at least 1GB.

14.9.2.3 Making the Buffer Pool Scan Resistant

Rather than using a strict LRU algorithm, `InnoDB` uses a technique to minimize the amount of data that is brought into the buffer pool and never accessed again. The goal is to make sure that frequently accessed ("hot") pages remain in the buffer pool, even as read-ahead and full table scans bring in new blocks that might or might not be accessed afterward.

Newly read blocks are inserted into the middle of the LRU list. All newly read pages are inserted at a location that by default is `3/8` from the tail of the LRU list. The pages are moved to the front of the list (the most-recently used end) when they are accessed in the buffer pool for the first time. Thus, pages that are never accessed never make it to the front portion of the LRU list, and "age out" sooner than with a strict LRU approach. This arrangement divides the LRU list into two segments, where the pages downstream of the insertion point are considered "old" and are desirable victims for LRU eviction.

For an explanation of the inner workings of the `InnoDB` buffer pool and specifics about the LRU algorithm, see Section 14.9.2.1, "The InnoDB Buffer Pool".

You can control the insertion point in the LRU list and choose whether `InnoDB` applies the same optimization to blocks brought into the buffer pool by table or index scans. The configuration parameter `innodb_old_blocks_pct` controls the percentage of "old" blocks in the LRU list. The default value of `innodb_old_blocks_pct` is `37`, corresponding to the original fixed ratio of 3/8. The value range is `5` (new pages in the buffer pool age out very quickly) to `95` (only 5% of the buffer pool is reserved for hot pages, making the algorithm close to the familiar LRU strategy).

The optimization that keeps the buffer pool from being churned by read-ahead can avoid similar problems due to table or index scans. In these scans, a data page is typically accessed a few times in quick succession and is never touched again. The configuration parameter `innodb_old_blocks_time` specifies the time window (in milliseconds) after the first access to a page during which it can be accessed without being moved to the front (most-recently used end) of the LRU list. The default value of `innodb_old_blocks_time` is `0`, corresponding to the original behavior of moving a page to the most-recently used end of the buffer pool list when it is first accessed in the buffer pool. Increasing this value makes more and more blocks likely to age out faster from the buffer pool.

Both `innodb_old_blocks_pct` and `innodb_old_blocks_time` are dynamic, global and can be specified in the MySQL option file (`my.cnf` or `my.ini`) or changed at runtime with the `SET GLOBAL` command. Changing the setting requires the `SUPER` privilege.

To help you gauge the effect of setting these parameters, the `SHOW ENGINE INNODB STATUS` command reports buffer pool statistics. For details, see Section 14.9.2.6, "Monitoring the Buffer Pool Using the InnoDB Standard Monitor".

Because the effects of these parameters can vary widely based on your hardware configuration, your data, and the details of your workload, always benchmark to verify the effectiveness before changing these settings in any performance-critical or production environment.

In mixed workloads where most of the activity is OLTP type with periodic batch reporting queries which result in large scans, setting the value of `innodb_old_blocks_time` during the batch runs can help keep the working set of the normal workload in the buffer pool.

When scanning large tables that cannot fit entirely in the buffer pool, setting `innodb_old_blocks_pct` to a small value keeps the data that is only read once from consuming a significant portion of the buffer pool. For example, setting `innodb_old_blocks_pct=5` restricts this data that is only read once to 5% of the buffer pool.

When scanning small tables that do fit into memory, there is less overhead for moving pages around within the buffer pool, so you can leave `innodb_old_blocks_pct` at its default value, or even higher, such as `innodb_old_blocks_pct=50`.

The effect of the `innodb_old_blocks_time` parameter is harder to predict than the `innodb_old_blocks_pct` parameter, is relatively small, and varies more with the workload. To arrive at an optimal value, conduct your own benchmarks if the performance improvement from adjusting `innodb_old_blocks_pct` is not sufficient.

14.9.2.4 Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)

A read-ahead request is an I/O request to prefetch multiple pages in the buffer pool asynchronously, in anticipation that these pages will be needed soon. The requests bring in all the pages in one extent. `InnoDB` uses two read-ahead algorithms to improve I/O performance:

Linear read-ahead is a technique that predicts what pages might be needed soon based on pages in the buffer pool being accessed sequentially. You control when `InnoDB` performs a read-ahead operation by adjusting the number of sequential page accesses required to trigger an asynchronous read request, using the configuration parameter `innodb_read_ahead_threshold`. Before this parameter was added, `InnoDB` would only calculate whether to issue an asynchronous prefetch request for the entire next extent when it read in the last page of the current extent.

The configuration parameter `innodb_read_ahead_threshold` controls how sensitive `InnoDB` is in detecting patterns of sequential page access. If the number of pages read sequentially from an extent is greater than or equal to `innodb_read_ahead_threshold`, `InnoDB` initiates an asynchronous read-ahead operation of the entire following extent. `innodb_read_ahead_threshold` can be set to any value from 0-64. The default value is 56. The higher the value, the more strict the access pattern check. For example, if you set the value to 48, `InnoDB` triggers a linear read-ahead request only when 48 pages in the current extent have been accessed sequentially. If the value is 8, `InnoDB` triggers an asynchronous read-ahead even if as few as 8 pages in the extent are accessed sequentially. You can set the value of this parameter in the MySQL configuration file, or change it dynamically with the `SET GLOBAL` command, which requires the `SUPER` privilege.

Random read-ahead is a technique that predicts when pages might be needed soon based on pages already in the buffer pool, regardless of the order in which those pages were read. If 13 consecutive pages from the same extent are found in the buffer pool, `InnoDB` asynchronously issues a request to prefetch the remaining pages of the extent. To enable this feature, set the configuration variable `innodb_random_read_ahead` to `ON`.

Random read-ahead functionality was removed from the `InnoDB Plugin` (version 1.0.4) and was therefore not included in MySQL 5.5.0 when `InnoDB Plugin` became the “built-in” version of `InnoDB`. Random read-ahead was reintroduced in MySQL 5.1.59 and 5.5.16 and higher along with the `innodb_random_read_ahead` configuration option, which is disabled by default. To enable this feature, set the configuration variable `innodb_random_read_ahead` to `ON`.

The `SHOW ENGINE INNODB STATUS` command displays statistics to help you evaluate the effectiveness of the read-ahead algorithm. Statistics include counter information for the following global status variables:

- `Innodb_buffer_pool_read_ahead`
- `Innodb_buffer_pool_read_ahead_evicted`
- `Innodb_buffer_pool_read_ahead_rnd`

This information can be useful when fine-tuning the `innodb_random_read_ahead` setting.

For more information about I/O performance, see Section 8.5.7, “Optimizing InnoDB Disk I/O” and Section 8.12.2, “Optimizing Disk I/O”.

14.9.2.5 Configuring InnoDB Buffer Pool Flushing

InnoDB performs certain tasks in the background, including flushing of dirty pages (those pages that have been changed but are not yet written to the database files) from the buffer pool, a task performed by the master thread. InnoDB aggressively flushes buffer pool pages if the percentage of dirty pages in the buffer pool exceeds innodb_max_dirty_pages_pct.

InnoDB uses an algorithm to estimate the required rate of flushing, based on the speed of redo log generation and the current rate of flushing. The intent is to smooth overall performance by ensuring that buffer flush activity keeps up with the need to keep the buffer pool "clean". Automatically adjusting the rate of flushing can help to avoid sudden dips in throughput, when excessive buffer pool flushing limits the I/O capacity available for ordinary read and write activity.

InnoDB uses its log files in a circular fashion. Before reusing a portion of a log file, InnoDB flushes to disk all dirty buffer pool pages whose redo entries are contained in that portion of the log file, a process known as a sharp checkpoint. If a workload is write-intensive, it generates a lot of redo information, all written to the log file. If all available space in the log files is used up, a sharp checkpoint occurs, causing a temporary reduction in throughput. This situation can happen even if innodb_max_dirty_pages_pct is not reached.

InnoDB uses a heuristic-based algorithm to avoid such a scenario, by measuring the number of dirty pages in the buffer pool and the rate at which redo is being generated. Based on these numbers, InnoDB decides how many dirty pages to flush from the buffer pool each second. This self-adapting algorithm is able to deal with sudden changes in workload.

Internal benchmarking has shown that this algorithm not only maintains throughput over time, but can also improve overall throughput significantly.

Because adaptive flushing can significantly affect the I/O pattern of a workload, the innodb_adaptive_flushing configuration parameter lets you turn off this feature. The default value for innodb_adaptive_flushing is ON, enabling the adaptive flushing algorithm. You can set the value of this parameter in the MySQL option file (my.cnf or my.ini) or change it dynamically with the SET GLOBAL command, which requires the SUPER privilege.

For more information about InnoDB I/O performance, see Section 8.5.7, "Optimizing InnoDB Disk I/O".

14.9.2.6 Monitoring the Buffer Pool Using the InnoDB Standard Monitor

InnoDB Standard Monitor output, which can be accessed using SHOW ENGINE INNODB STATUS, provides metrics that pertain to operation of the InnoDB buffer pool. Buffer pool metrics are located in the BUFFER POOL AND MEMORY section of InnoDB Standard Monitor output and appear similar to the following:

```
----------------------
BUFFER POOL AND MEMORY
----------------------
Total memory allocated 2217738240; in additional pool allocated 0
Dictionary memory allocated 121719
Buffer pool size   131072
Free buffers       129937
Database pages     1134
Old database pages 211
Modified db pages  187
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 0, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 426, created 708, written 768
0.00 reads/s, 40.99 creates/s, 50.49 writes/s
Buffer pool hit rate 1000 / 1000, young-making rate 0 / 1000 not 0 / 1000
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead
0.00/s
LRU len: 1134, unzip_LRU len: 0
```

```
I/O sum[0]:cur[0], unzip sum[0]:cur[0]
```

The following table describes InnoDB buffer pool metrics reported by the InnoDB Standard Monitor.

Note

Per second averages provided in InnoDB Standard Monitor output are based on the elapsed time since InnoDB Standard Monitor output was last printed.

Table 14.2 InnoDB Buffer Pool Metrics

Name	Description
Total memory allocated	The total memory allocated for the buffer pool in bytes.
additional pool allocated	The total memory allocated for the additional pool in bytes.
Dictionary memory allocated	The total memory allocated for the InnoDB data dictionary in bytes.
Buffer pool size	The total size in pages allocated to the buffer pool.
Free buffers	The total size in pages of the buffer pool free list.
Database pages	The total size in pages of the buffer pool LRU list.
Old database pages	The total size in pages of the buffer pool old LRU sublist.
Modified db pages	The current number of pages modified in the buffer pool.
Pending reads	The number of buffer pool pages waiting to be read in to the buffer pool.
Pending writes LRU	The number of old dirty pages within the buffer pool to be written from the bottom of the LRU list.
Pending writes flush list	The number of buffer pool pages to be flushed during checkpointing.
Pending writes single page	The number of pending independent page writes within the buffer pool.
Pages made young	The total number of pages made young in the buffer pool LRU list (moved to the head of sublist of “new” pages).
Pages made not young	The total number of pages not made young in the buffer pool LRU list (pages that have remained in the “old” sublist without being made young).
youngs/s	The per second average of accesses to old pages in the buffer pool LRU list that have resulted in making pages young. See the notes that follow this table for more information.
non-youngs/s	The per second average of accesses to old pages in the buffer pool LRU list that have resulted in not making pages young. See the notes that follow this table for more information.
Pages read	The total number of pages read from the buffer pool.
Pages created	The total number of pages created within the buffer pool.
Pages written	The total number of pages written from the buffer pool.
reads/s	The per second average number of buffer pool page reads per second.
creates/s	The per second average number of buffer pool pages created per second.
writes/s	The per second average number of buffer pool page writes per second.
Buffer pool hit rate	The buffer pool page hit rate for pages read from the buffer pool memory vs from disk storage.

Name	Description
young-making rate	The average hit rate at which page accesses have resulted in making pages young. See the notes that follow this table for more information.
not (young-making rate)	The average hit rate at which page accesses have not resulted in making pages young. See the notes that follow this table for more information.
Pages read ahead	The per second average of read ahead operations.
Pages evicted without access	The per second average of the pages evicted without being accessed from the buffer pool.
Random read ahead	The per second average of random read ahead operations.
LRU len	The total size in pages of the buffer pool LRU list.
unzip_LRU len	The total size in pages of the buffer pool unzip_LRU list.
I/O sum	The total number of buffer pool LRU list pages accessed, for the last 50 seconds.
I/O cur	The total number of buffer pool LRU list pages accessed.
I/O unzip sum	The total number of buffer pool unzip_LRU list pages accessed.
I/O unzip cur	The total number of buffer pool unzip_LRU list pages accessed.

Notes:

- The `youngs/s` metric only relates to old pages. It is based on the number of accesses to pages and not the number of pages. There can be multiple accesses to a given page, all of which are counted. If you see very low `youngs/s` values when there are no large scans occurring, you might need to reduce the delay time or increase the percentage of the buffer pool used for the old sublist. Increasing the percentage makes the old sublist larger, so pages in that sublist take longer to move to the tail and to be evicted. This increases the likelihood that the pages will be accessed again and be made young.

- The `non-youngs/s` metric only relates to old pages. It is based on the number of accesses to pages and not the number of pages. There can be multiple accesses to a given page, all of which are counted. If you do not see a lot of `non-youngs/s` when you are doing large table scans (and lots of `youngs/s`), increase the delay value.

- The `young-making` rate accounts for accesses to all buffer pool pages, not just accesses to pages in the old sublist. The `young-making` rate and `not` rate do not normally add up to the overall buffer pool hit rate. Page hits in the old sublist cause pages to move to the new sublist, but page hits in the new sublist cause pages to move to the head of the list only if they are a certain distance from the head.

- `not (young-making rate)` is the average hit rate at which page accesses have not resulted in making pages young due to the delay defined by `innodb_old_blocks_time` not being met, or due to page hits in the new sublist that did not result in pages being moved to the head. This rate accounts for accesses to all buffer pool pages, not just accesses to pages in the old sublist.

`InnoDB` buffer pool server status variables and the `INNODB_BUFFER_POOL_STATS` table provide many of the same buffer pool metrics found in `InnoDB` Standard Monitor output. For more information about the `INNODB_BUFFER_POOL_STATS` table, see Example 14.6, “Querying the INNODB_BUFFER_POOL_STATS Table”.

14.9.3 Configuring the Memory Allocator for InnoDB

When `InnoDB` was developed, the memory allocators supplied with operating systems and run-time libraries were often lacking in performance and scalability. At that time, there were no memory allocator libraries tuned for multi-core CPUs. Therefore, `InnoDB` implemented its own memory allocator in the

mem subsystem. This allocator is guarded by a single mutex, which may become a bottleneck. InnoDB also implements a wrapper interface around the system allocator (malloc and free) that is likewise guarded by a single mutex.

Today, as multi-core systems have become more widely available, and as operating systems have matured, significant improvements have been made in the memory allocators provided with operating systems. These new memory allocators perform better and are more scalable than they were in the past. Most workloads, especially those where memory is frequently allocated and released (such as multi-table joins), benefit from using a more highly tuned memory allocator as opposed to the internal, InnoDB-specific memory allocator.

You can control whether InnoDB uses its own memory allocator or an allocator of the operating system, by setting the value of the system configuration parameter innodb_use_sys_malloc in the MySQL option file (my.cnf or my.ini). If set to ON or 1 (the default), InnoDB uses the malloc and free functions of the underlying system rather than manage memory pools itself. This parameter is not dynamic, and takes effect only when the system is started. To continue to use the InnoDB memory allocator, set innodb_use_sys_malloc to 0.

Note

When the InnoDB memory allocator is disabled, InnoDB ignores the value of the parameter innodb_additional_mem_pool_size. The InnoDB memory allocator uses an additional memory pool for satisfying allocation requests without having to fall back to the system memory allocator. When the InnoDB memory allocator is disabled, all such allocation requests are fulfilled by the system memory allocator.

On Unix-like systems that use dynamic linking, replacing the memory allocator may be as easy as making the environment variable LD_PRELOAD or LD_LIBRARY_PATH point to the dynamic library that implements the allocator. On other systems, some relinking may be necessary. Please refer to the documentation of the memory allocator library of your choice.

Since InnoDB cannot track all memory use when the system memory allocator is used (innodb_use_sys_malloc is ON), the section "BUFFER POOL AND MEMORY" in the output of the SHOW ENGINE INNODB STATUS command only includes the buffer pool statistics in the "Total memory allocated". Any memory allocated using the mem subsystem or using ut_malloc is excluded.

For more information about the performance implications of InnoDB memory usage, see Section 8.10, "Buffering and Caching".

14.9.4 Configuring InnoDB Change Buffering

When INSERT, UPDATE, and DELETE operations are performed on a table, the values of indexed columns (particularly the values of secondary keys) are often in an unsorted order, requiring substantial I/O to bring secondary indexes up to date. InnoDB has a change buffer that caches changes to secondary index entries when the relevant page is not in the buffer pool, thus avoiding expensive I/O operations by not immediately reading in the page from disk. The buffered changes are merged when the page is loaded to the buffer pool, and the updated page is later flushed to disk. The InnoDB main thread merges buffered changes when the server is nearly idle, and during a slow shutdown.

Because it can result in fewer disk reads and writes, the change buffer feature is most valuable for workloads that are I/O-bound, for example applications with a high volume of DML operations such as bulk inserts.

However, the change buffer occupies a part of the buffer pool, reducing the memory available to cache data pages. If the working set almost fits in the buffer pool, or if your tables have relatively few secondary indexes, it may be useful to disable change buffering. If the working set fits entirely within

the buffer, change buffering does not impose extra overhead, because it only applies to pages that are not in the buffer pool.

You can control the extent to which InnoDB performs change buffering using the innodb_change_buffering configuration parameter. You can enable or disable buffering for inserts, delete operations (when index records are initially marked for deletion) and purge operations (when index records are physically deleted). An update operation is a combination of an insert and a delete. In MySQL 5.5 and higher, the default innodb_change_buffering value is changed from inserts to all.

Permitted innodb_change_buffering values include:

- **all**

  The default value: buffer inserts, delete-marking operations, and purges.

- **none**

  Do not buffer any operations.

- **inserts**

  Buffer insert operations.

- **deletes**

  Buffer delete-marking operations.

- **changes**

  Buffer both inserts and delete-marking operations.

- **purges**

  Buffer the physical deletion operations that happen in the background.

You can set the innodb_change_buffering parameter in the MySQL option file (my.cnf or my.ini) or change it dynamically with the SET GLOBAL command, which requires the SUPER privilege. Changing the setting affects the buffering of new operations; the merging of existing buffered entries is not affected.

For related information, see Section 14.7.2, “Change Buffer”.

14.9.5 Configuring Thread Concurrency for InnoDB

InnoDB uses operating system threads to process requests from user transactions. (Transactions may issue many requests to InnoDB before they commit or roll back.) On modern operating systems and servers with multi-core processors, where context switching is efficient, most workloads run well without any limit on the number of concurrent threads. Scalability improvements in MySQL 5.5 and up reduce the need to limit the number of concurrently executing threads inside InnoDB.

In situations where it is helpful to minimize context switching between threads, InnoDB can use a number of techniques to limit the number of concurrently executing operating system threads (and thus the number of requests that are processed at any one time). When InnoDB receives a new request from a user session, if the number of threads concurrently executing is at a pre-defined limit, the new request sleeps for a short time before it tries again. A request that cannot be rescheduled after the sleep is put in a first-in/first-out queue and eventually is processed. Threads waiting for locks are not counted in the number of concurrently executing threads.

You can limit the number of concurrent threads by setting the configuration parameter innodb_thread_concurrency. Once the number of executing threads reaches this limit,

additional threads sleep for a number of microseconds, set by the configuration parameter `innodb_thread_sleep_delay`, before being placed into the queue.

The default value for `innodb_thread_concurrency` and the implied default limit on the number of concurrent threads has been changed in various releases of MySQL and `InnoDB`. The default value of `innodb_thread_concurrency` is `0`, so that by default there is no limit on the number of concurrently executing threads, as shown in Table 14.3, “Changes to innodb_thread_concurrency”.

Table 14.3 Changes to innodb_thread_concurrency

InnoDB Version	MySQL Version	Default value	Default limit of concurrent threads	Value to allow unlimited threads
Built-in	Earlier than 5.1.11	20	No limit	20 or higher
Built-in	5.1.11 and newer	8	8	0
InnoDB before 1.0.3	(corresponding to Plugin)	8	8	0
InnoDB 1.0.3 and newer	(corresponding to Plugin)	0	No limit	0

`InnoDB` causes threads to sleep only when the number of concurrent threads is limited. When there is no limit on the number of threads, all contend equally to be scheduled. That is, if `innodb_thread_concurrency` is `0`, the value of `innodb_thread_sleep_delay` is ignored.

When there is a limit on the number of threads (when `innodb_thread_concurrency` is > 0), `InnoDB` reduces context switching overhead by permitting multiple requests made during the execution of a *single SQL statement* to enter `InnoDB` without observing the limit set by `innodb_thread_concurrency`. Since an SQL statement (such as a join) may comprise multiple row operations within `InnoDB`, `InnoDB` assigns a specified number of “tickets” that allow a thread to be scheduled repeatedly with minimal overhead.

When a new SQL statement starts, a thread has no tickets, and it must observe `innodb_thread_concurrency`. Once the thread is entitled to enter `InnoDB`, it is assigned a number of tickets that it can use for subsequently entering `InnoDB` to perform row operations. If the tickets run out, the thread is evicted, and `innodb_thread_concurrency` is observed again which may place the thread back into the first-in/first-out queue of waiting threads. When the thread is once again entitled to enter `InnoDB`, tickets are assigned again. The number of tickets assigned is specified by the global option `innodb_concurrency_tickets`, which is 500 by default. A thread that is waiting for a lock is given one ticket once the lock becomes available.

The correct values of these variables depend on your environment and workload. Try a range of different values to determine what value works for your applications. Before limiting the number of concurrently executing threads, review configuration options that may improve the performance of InnoDB on multi-core and multi-processor computers, such as `innodb_use_sys_malloc` and `innodb_adaptive_hash_index`.

For general performance information about MySQL thread handling, see Section 8.12.5.1, “How MySQL Uses Threads for Client Connections”.

14.9.6 Configuring the Number of Background InnoDB I/O Threads

`InnoDB` uses background threads to service various types of I/O requests. You can configure the number of background threads that service read and write I/O on data pages using the `innodb_read_io_threads` and `innodb_write_io_threads` configuration parameters. These parameters signify the number of background threads used for read and write requests, respectively. They are effective on all supported platforms. You can set values for these parameters in the MySQL

option file (`my.cnf` or `my.ini`); you cannot change values dynamically. The default value for these parameters is `4` and permissible values range from `1-64`.

These parameters replace `innodb_file_io_threads` from earlier versions of MySQL. If you try to set a value for this obsolete parameter, a warning is written to the log file and the value is ignored. This parameter only applied to Windows platforms. (On non-Windows platforms, there was only one thread each for read and write.)

The purpose of these configuration options to make `InnoDB` more scalable on high end systems. Each background thread can handle up to 256 pending I/O requests. A major source of background I/O is read-ahead requests. `InnoDB` tries to balance the load of incoming requests in such way that most background threads share work equally. `InnoDB` also attempts to allocate read requests from the same extent to the same thread, to increase the chances of coalescing the requests. If you have a high end I/O subsystem and you see more than 64 × `innodb_read_io_threads` pending read requests in `SHOW ENGINE INNODB STATUS` output, you might improve performance by increasing the value of `innodb_read_io_threads`.

On Linux systems, `InnoDB` uses the asynchronous I/O subsystem by default to perform read-ahead and write requests for data file pages, which changes the way that `InnoDB` background threads service these types of I/O requests. For more information, see Section 14.9.7, “Using Asynchronous I/O on Linux”.

For more information about `InnoDB` I/O performance, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

14.9.7 Using Asynchronous I/O on Linux

`InnoDB` uses the asynchronous I/O subsystem (native AIO) on Linux to perform readahead and write requests for data file pages. This behavior is controlled by the `innodb_use_native_aio` configuration option, which applies to Linux systems only and is enabled by default. On other Unix-like systems, `InnoDB` uses synchronous I/O only. Historically, `InnoDB` only used asynchronous I/O on Windows systems. Using the asynchronous I/O subsystem on Linux requires the `libaio` library.

With synchronous I/O, query threads queue I/O requests, and `InnoDB` background threads retrieve the queued requests one at a time, issuing a synchronous I/O call for each. When an I/O request is completed and the I/O call returns, the `InnoDB` background thread that is handling the request calls an I/O completion routine and returns to process the next request. The number of requests that can be processed in parallel is *n*, where *n* is the number of `InnoDB` background threads. The number of `InnoDB` background threads is controlled by `innodb_read_io_threads` and `innodb_write_io_threads`. See Section 14.9.6, “Configuring the Number of Background InnoDB I/O Threads”.

With native AIO, query threads dispatch I/O requests directly to the operating system, thereby removing the limit imposed by the number of background threads. `InnoDB` background threads wait for I/O events to signal completed requests. When a request is completed, a background thread calls an I/O completion routine and resumes waiting for I/O events.

The advantage of native AIO is scalability for heavily I/O-bound systems that typically show many pending reads/writes in `SHOW ENGINE INNODB STATUS\G` output. The increase in parallel processing when using native AIO means that the type of I/O scheduler or properties of the disk array controller have a greater influence on I/O performance.

A potential disadvantage of native AIO for heavily I/O-bound systems is lack of control over the number of I/O write requests dispatched to the operating system at once. Too many I/O write requests dispatched to the operating system for parallel processing could, in some cases, result in I/O read starvation, depending on the amount of I/O activity and system capabilities.

If a problem with the asynchronous I/O subsystem in the OS prevents `InnoDB` from starting, you can start the server with `innodb_use_native_aio=0`. This option may also be disabled automatically during startup if `InnoDB` detects a potential problem such as a combination of `tmpdir` location, `tmpfs` file system, and Linux kernel that does not support asynchronous I/O on `tmpfs`.

14.9.8 Configuring the InnoDB Master Thread I/O Rate

The master thread in InnoDB is a thread that performs various tasks in the background. Most of these tasks are I/O related, such as flushing dirty pages from the buffer pool or writing changes from the insert buffer to the appropriate secondary indexes. The master thread attempts to perform these tasks in a way that does not adversely affect the normal working of the server. It tries to estimate the free I/O bandwidth available and tune its activities to take advantage of this free capacity. Historically, InnoDB has used a hard coded value of 100 IOPs (input/output operations per second) as the total I/O capacity of the server.

The parameter `innodb_io_capacity` indicates the overall I/O capacity available to InnoDB. This parameter should be set to approximately the number of I/O operations that the system can perform per second. The value depends on your system configuration. When `innodb_io_capacity` is set, the master threads estimates the I/O bandwidth available for background tasks based on the set value. Setting the value to `100` reverts to the old behavior.

You can set the value of `innodb_io_capacity` to any number 100 or greater. The default value is `200`, reflecting that the performance of typical modern I/O devices is higher than in the early days of MySQL. Typically, values around the previous default of 100 are appropriate for consumer-level storage devices, such as hard drives up to 7200 RPMs. Faster hard drives, RAID configurations, and SSDs benefit from higher values.

The `innodb_io_capacity` setting is a total limit for all buffer pool instances. When dirty pages are flushed, the `innodb_io_capacity` limit is divided equally among buffer pool instances. For more information, see the `innodb_io_capacity` system variable description.

You can set the value of this parameter in the MySQL option file (`my.cnf` or `my.ini`) or change it dynamically with the `SET GLOBAL` command, which requires the `SUPER` privilege.

For more information about InnoDB I/O performance, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

14.9.9 Configuring Spin Lock Polling

Many InnoDB mutexes and rw-locks are reserved for a short time. On a multi-core system, it can be more efficient for a thread to continuously check if it can acquire a mutex or rw-lock for a while before sleeping. If the mutex or rw-lock becomes available during this polling period, the thread can continue immediately, in the same time slice. However, too-frequent polling by multiple threads of a shared object can cause “cache ping pong”, different processors invalidating portions of each others' cache. InnoDB minimizes this issue by waiting a random time between subsequent polls. The delay is implemented as a busy loop.

You can control the maximum delay between testing a mutex or rw-lock using the parameter `innodb_spin_wait_delay`. The duration of the delay loop depends on the C compiler and the target processor. (In the 100MHz Pentium era, the unit of delay was one microsecond.) On a system where all processor cores share a fast cache memory, you might reduce the maximum delay or disable the busy loop altogether by setting `innodb_spin_wait_delay=0`. On a system with multiple processor chips, the effect of cache invalidation can be more significant and you might increase the maximum delay.

The default value of `innodb_spin_wait_delay` is `6`. The spin wait delay is a dynamic, global parameter that you can specify in the MySQL option file (`my.cnf` or `my.ini`) or change at runtime with the command `SET GLOBAL innodb_spin_wait_delay=`*`delay`*, where *`delay`* is the desired maximum delay. Changing the setting requires the `SUPER` privilege.

For performance considerations for InnoDB locking operations, see Section 8.11, “Optimizing Locking Operations”.

14.9.10 Configuring InnoDB Purge Scheduling

Starting in MySQL 5.5, the purge operations (a type of garbage collection) that InnoDB performs automatically can be done in a separate thread rather than as part of the master thread. This change improves scalability by allowing the main database operations to run independently from maintenance work happening in the background.

To enable this feature, set the configuration option `innodb_purge_threads` to `1`, as opposed to the default of 0, which combines the purge operation into the master thread. `innodb_purge_threads` is a non-dynamic configuration option, which means it cannot be configured at runtime.

You might not notice a significant speedup, because the purge thread might encounter new types of contention; the single purge thread really lays the groundwork for further tuning and possibly multiple purge threads in the future. There is another new configuration option, `innodb_purge_batch_size` with a default value of 20 and maximum value of 5000. This option is mainly intended for experimentation and tuning of purge operations, and should not be interesting to typical users.

For more information about InnoDB I/O performance, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

14.9.11 Configuring Optimizer Statistics for InnoDB

The MySQL query optimizer uses estimated statistics about key distributions to choose the indexes for an execution plan, based on the relative selectivity of the index. Certain operations cause InnoDB to sample random pages from each index on a table to estimate the cardinality of the index. (This technique is known as random dives.) These operations include the `ANALYZE TABLE` statement, the `SHOW TABLE STATUS` statement, and accessing the table for the first time after a restart.

To give you control over the quality of the statistics estimate (and thus better information for the query optimizer), you can now change the number of sampled pages using the parameter `innodb_stats_sample_pages`. Previously, the number of sampled pages was always 8, which could be insufficient to produce an accurate estimate, leading to poor index choices by the query optimizer. This technique is especially important for large tables and tables used in joins. Unnecessary full table scans for such tables can be a substantial performance issue.

You can set the global parameter `innodb_stats_sample_pages`, at runtime. The default value for this parameter is 8, preserving the same behavior as in past releases.

Note

The value of `innodb_stats_sample_pages` affects the index sampling for *all* tables and indexes. There are the following potentially significant impacts when you change the index sample size:

- Small values like 1 or 2 can result in very inaccurate estimates of cardinality.
- Increasing the `innodb_stats_sample_pages` value might require more disk reads. Values much larger than 8 (say, 100), can cause a big slowdown in the time it takes to open a table or execute `SHOW TABLE STATUS`.
- The optimizer might choose very different query plans based on different estimates of index selectivity.

To disable the cardinality estimation for metadata statements such as `SHOW TABLE STATUS` or `SHOW INDEX`, or when accessing the `INFORMATION_SCHEMA.TABLES` or `INFORMATION_SCHEMA.STATISTICS` tables, execute the statement `SET GLOBAL innodb_stats_on_metadata=OFF`. The ability to set this option dynamically is also relatively new.

All `InnoDB` tables are opened, and the statistics are re-estimated for all associated indexes, when the `mysql` client starts with the `--auto-rehash` setting on (the default). To improve the start up time of the `mysql` client, you can turn auto-rehash off using the `--disable-auto-rehash` option. The `auto-rehash` feature enables automatic name completion of database, table, and column names for interactive users.

Whatever value of `innodb_stats_sample_pages` works best for a system, set the option and leave it at that value. Choose a value that results in reasonably accurate estimates for all tables in your database without requiring excessive I/O. Because the statistics are automatically recalculated at various times other than on execution of `ANALYZE TABLE`, it does not make sense to increase the index sample size, run `ANALYZE TABLE`, then decrease sample size again. The more accurate statistics calculated by `ANALYZE` running with a high value of `innodb_stats_sample_pages` can be wiped away later.

Although it is not possible to specify the sample size on a per-table basis, smaller tables generally require fewer index samples than larger tables do. If your database has many large tables, consider using a higher value for `innodb_stats_sample_pages` than if you have mostly smaller tables.

14.9.11.1 Estimating ANALYZE TABLE Complexity for InnoDB Tables

`ANALYZE TABLE` complexity for `InnoDB` tables is dependent on:

- The number of pages sampled, as defined by `innodb_stats_sample_pages`.
- The number of indexed columns in a table
- The number of partitions. If a table has no partitions, the number of partitions is considered to be 1.

Using these parameters, an approximate formula for estimating `ANALYZE TABLE` complexity would be:

`innodb_stats_sample_pages` * number of indexed columns in a table * number of partitions

Typically, the greater the resulting value, the greater the execution time for `ANALYZE TABLE`.

For more information about the `innodb_stats_sample_pages` configuration parameter, see Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”.

14.10 InnoDB Tablespaces

This section covers topics related to `InnoDB` tablespaces.

14.10.1 Resizing the InnoDB System Tablespace

This section describes how to increase or decrease the size of the `InnoDB` system tablespace.

Increasing the Size of the InnoDB System Tablespace

The easiest way to increase the size of the `InnoDB` system tablespace is to configure it from the beginning to be auto-extending. Specify the `autoextend` attribute for the last data file in the tablespace definition. Then `InnoDB` increases the size of that file automatically in 8MB increments when it runs out of space. The increment size can be changed by setting the value of the `innodb_autoextend_increment` system variable, which is measured in megabytes.

You can expand the system tablespace by a defined amount by adding another data file:

1. Shut down the MySQL server.
2. If the previous last data file is defined with the keyword `autoextend`, change its definition to use a fixed size, based on how large it has actually grown. Check the size of the data file, round it down to the closest multiple of 1024 × 1024 bytes (= 1MB), and specify this rounded size explicitly in `innodb_data_file_path`.
3. Add a new data file to the end of `innodb_data_file_path`, optionally making that file auto-extending. Only the last data file in the `innodb_data_file_path` can be specified as auto-extending.

4. Start the MySQL server again.

For example, this tablespace has just one auto-extending data file `ibdata1`:

```
innodb_data_home_dir =
innodb_data_file_path = /ibdata/ibdata1:10M:autoextend
```

Suppose that this data file, over time, has grown to 988MB. Here is the configuration line after modifying the original data file to use a fixed size and adding a new auto-extending data file:

```
innodb_data_home_dir =
innodb_data_file_path = /ibdata/ibdata1:988M;/disk2/ibdata2:50M:autoextend
```

When you add a new data file to the system tablespace configuration, make sure that the filename does not refer to an existing file. `InnoDB` creates and initializes the file when you restart the server.

Decreasing the Size of the InnoDB System Tablespace

You cannot remove a data file from the system tablespace. To decrease the system tablespace size, use this procedure:

1. Use `mysqldump` to dump all your `InnoDB` tables.
2. Stop the server.
3. Remove all the existing tablespace files, including the `ibdata` and `ib_log` files. If you want to keep a backup copy of the information, then copy all the `ib*` files to another location before the removing the files in your MySQL installation.
4. Remove any `.frm` files for `InnoDB` tables.
5. Configure a new tablespace.
6. Restart the server.
7. Import the dump files.

14.10.2 Changing the Number or Size of InnoDB Redo Log Files

To change the number or the size of your `InnoDB` redo log files, perform the following steps:

1. If `innodb_fast_shutdown` is set to 2, set `innodb_fast_shutdown` to 1:

   ```
   mysql> SET GLOBAL innodb_fast_shutdown = 1;
   ```

2. After ensuring that `innodb_fast_shutdown` is not set to 2, stop the MySQL server and make sure that it shuts down without errors (to ensure that there is no information for outstanding transactions in the log).
3. Copy the old log files into a safe place in case something went wrong during the shutdown and you need them to recover the tablespace.
4. Delete the old log files from the log file directory.
5. Edit `my.cnf` to change the log file configuration.
6. Start the MySQL server again. `mysqld` sees that no `InnoDB` log files exist at startup and creates new ones.

14.10.3 Using Raw Disk Partitions for the System Tablespace

You can use raw disk partitions as data files in the InnoDB system tablespace. This technique enables nonbuffered I/O on Windows and on some Linux and Unix systems without file system overhead. Perform tests with and without raw partitions to verify whether this change actually improves performance on your system.

When you use a raw disk partition, ensure that the user ID that runs the MySQL server has read and write privileges for that partition. For example, if you run the server as the `mysql` user, the partition must be readable and writeable by `mysql`. If you run the server with the `--memlock` option, the server must be run as `root`, so the partition must be readable and writeable by `root`.

The procedures described below involve option file modification. For additional information, see Section 4.2.6, “Using Option Files”.

Allocating a Raw Disk Partition on Linux and Unix Systems

1. When you create a new data file, specify the keyword `newraw` immediately after the data file size for the `innodb_data_file_path` option. The partition must be at least as large as the size that you specify. Note that 1MB in `InnoDB` is 1024 × 1024 bytes, whereas 1MB in disk specifications usually means 1,000,000 bytes.

   ```
   [mysqld]
   innodb_data_home_dir=
   innodb_data_file_path=/dev/hdd1:3Gnewraw;/dev/hdd2:2Gnewraw
   ```

2. Restart the server. `InnoDB` notices the `newraw` keyword and initializes the new partition. However, do not create or change any `InnoDB` tables yet. Otherwise, when you next restart the server, `InnoDB` reinitializes the partition and your changes are lost. (As a safety measure `InnoDB` prevents users from modifying data when any partition with `newraw` is specified.)

3. After `InnoDB` has initialized the new partition, stop the server, change `newraw` in the data file specification to `raw`:

   ```
   [mysqld]
   innodb_data_home_dir=
   innodb_data_file_path=/dev/hdd1:3Graw;/dev/hdd2:2Graw
   ```

4. Restart the server. `InnoDB` now permits changes to be made.

Allocating a Raw Disk Partition on Windows

On Windows systems, the same steps and accompanying guidelines described for Linux and Unix systems apply except that the `innodb_data_file_path` setting differs slightly on Windows.

1. When you create a new data file, specify the keyword `newraw` immediately after the data file size for the `innodb_data_file_path` option:

   ```
   [mysqld]
   innodb_data_home_dir=
   innodb_data_file_path=//./D::10Gnewraw
   ```

   The `//./` corresponds to the Windows syntax of `\\.\` for accessing physical drives. In the example above, `D:` is the drive letter of the partition.

2. Restart the server. `InnoDB` notices the `newraw` keyword and initializes the new partition.

3. After `InnoDB` has initialized the new partition, stop the server, change `newraw` in the data file specification to `raw`:

   ```
   [mysqld]
   innodb_data_home_dir=
   ```

```
innodb_data_file_path=//./D::10Graw
```

4. Restart the server. InnoDB now permits changes to be made.

14.10.4 InnoDB File-Per-Table Tablespaces

By default, all InnoDB tables and indexes are stored in the system tablespace. As an alternative, you can store each InnoDB table and associated indexes in its own data file. This feature is called "file-per-table tablespaces" because each table has its own tablespace, and each tablespace has its own .ibd data file. This feature is controlled by the innodb_file_per_table configuration option.

Advantages of File-Per-Table Tablespaces

- You can reclaim disk space when truncating or dropping a table stored in a file-per-table tablepace. Truncating or dropping tables stored in the shared system tablespace creates free space internally in the system tablespace data files (ibdata files) which can only be used for new InnoDB data.

  Similarly, a table-copying ALTER TABLE operation on table that resides in a shared tablespace can increase the amount of space used by the tablespace. Such operations may require as much additional space as the data in the table plus indexes. The additional space required for the table-copying ALTER TABLE operation is not released back to the operating system as it is for file-per-table tablespaces.

- The TRUNCATE TABLE operation is faster when run on tables stored in file-per-table tablepaces.

- You can store specific tables on separate storage devices, for I/O optimization, space management, or backup purposes.

- You can run OPTIMIZE TABLE to compact or recreate a file-per-table tablespace. When you run an OPTIMIZE TABLE, InnoDB creates a new .ibd file with a temporary name, using only the space required to store actual data. When the optimization is complete, InnoDB removes the old .ibd file and replaces it with the new one. If the previous .ibd file grew significantly but the actual data only accounted for a portion of its size, running OPTIMIZE TABLE can reclaim the unused space.

- You can move individual InnoDB tables rather than entire databases.

- Tables created in file-per-table tablespaces use the Barracuda file format. The Barracuda file format enables features such as compressed and dynamic row formats. Tables created in the system tablespace cannot use these features. To take advantage of these features for an existing table, enable the innodb_file_per_table setting and run ALTER TABLE *t* ENGINE=INNODB to place the table in a file-per-table tablespace. Before converting tables, refer to Section 14.11.1.4, "Converting Tables from MyISAM to InnoDB".

- You can enable more efficient storage for tables with large BLOB or TEXT columns using the dynamic row format.

- File-per-table tablespaces may improve chances for a successful recovery and save time when a corruption occurs, when a server cannot be restarted, or when backup and binary logs are unavailable.

- You can back up or restore individual tables quickly using the MySQL Enterprise Backup product, without interrupting the use of other InnoDB tables. This is beneficial if you have tables that require backup less frequently or on a different backup schedule. See Partial Backup and Restore Options for details.

- File-per-table tablespaces are convenient for per-table status reporting when copying or backing up tables.

- You can monitor table size at a file system level, without accessing MySQL.

- Common Linux file systems do not permit concurrent writes to a single file when innodb_flush_method is set to O_DIRECT. As a result, there are possible

performance improvements when using `innodb_file_per_table` in conjunction with `innodb_flush_method`.

- The system tablespace stores the `InnoDB` data dictionary and undo logs, and has a 64TB size limit. By comparison, each file-per-table tablespace has a 64TB size limit, which provides room for growth. See Section 14.11.1.7, “Limits on InnoDB Tables” for related information.

Potential Disadvantages of File-Per-Table Tablespaces

- With file-per-table tablespaces, each table may have unused space, which can only be utilized by rows of the same table. This could lead to wasted space if not properly managed.
- `fsync` operations must run on each open table rather than on a single file. Because there is a separate `fsync` operation for each file, write operations on multiple tables cannot be combined into a single I/O operation. This may require `InnoDB` to perform a higher total number of `fsync` operations.
- `mysqld` must keep one open file handle per table, which may impact performance if you have numerous tables in file-per-table tablespaces.
- More file descriptors are used.
- If backward compatibility with MySQL 5.1 is a concern, be aware that enabling `innodb_file_per_table` means that an `ALTER TABLE` operation can move an `InnoDB` table from the system tablespace to an individual `.ibd` file in cases where `ALTER TABLE` recreates the table (`ALTER OFFLINE`).

  For example, when restructuring the clustered index for an `InnoDB` table, the table is re-created using the current setting for `innodb_file_per_table`. This behavior does not apply when adding or dropping `InnoDB` secondary indexes. When a secondary index is created without rebuilding the table, the index is stored in the same file as the table data, regardless of the current `innodb_file_per_table` setting.
- If many tables are growing there is potential for more fragmentation which can impede `DROP TABLE` and table scan performance. However, when fragmentation is managed, having files in their own tablespace can improve performance.
- The buffer pool is scanned when dropping a file-per-table tablespace, which can take several seconds for buffer pools that are tens of gigabytes in size. The scan is performed with a broad internal lock, which may delay other operations. Tables in the system tablespace are not affected.
- The `innodb_autoextend_increment` variable, which defines increment size (in MB) for extending the size of an auto-extending shared tablespace file when it becomes full, does not apply to file-per-table tablespace files, which are auto-extending regardless of the `innodb_autoextend_increment` setting. The initial extensions are by small amounts, after which extensions occur in increments of 4MB.

Enabling and Disabling File-Per-Table Tablespaces

To enable file-per-table tablespaces, start the server with the `--innodb_file_per_table` option. For example, add a line to the `[mysqld]` section of `my.cnf`:

```
[mysqld]
innodb_file_per_table=1
```

With `innodb_file_per_table` enabled, `InnoDB` stores each newly created table into its own *`tbl_name`*`.ibd` file in the database directory where the table belongs. This is similar to what the `MyISAM` storage engine does, but `MyISAM` divides the table into a *`tbl_name`*`.MYD` data file and an *`tbl_name`*`.MYI` index file. For `InnoDB`, the data and the indexes are stored together in the `.ibd` file. The *`tbl_name`*`.frm` file is still created as usual.

If you remove the `innodb_file_per_table` line from `my.cnf` and restart the server, newly created `InnoDB` tables are created inside the shared tablespace files again.

To move a table from the system tablespace to its own tablespace, change the `innodb_file_per_table` setting and rebuild the table:

```
SET GLOBAL innodb_file_per_table=1;
ALTER TABLE table_name ENGINE=InnoDB;
```

Note

`InnoDB` requires the shared tablespace to store its internal data dictionary and undo logs. The `.ibd` files alone are not sufficient for `InnoDB` to operate.

When a table is moved out of the system tablespace into its own `.ibd` file, the data files that make up the system tablespace remain the same size. The space formerly occupied by the table can be reused for new `InnoDB` data, but is not reclaimed for use by the operating system. When moving large `InnoDB` tables out of the system tablespace, where disk space is limited, you might prefer to turn on `innodb_file_per_table` and then recreate the entire instance using the `mysqldump` command.

Portability Considerations for .ibd Files

You cannot freely move `.ibd` files between database directories as you can with `MyISAM` table files. The table definition stored in the `InnoDB` shared tablespace includes the database name. The transaction IDs and log sequence numbers stored in the tablespace files also differ between databases.

To move an `.ibd` file and the associated table from one database to another, use a `RENAME TABLE` statement:

```
RENAME TABLE db1.tbl_name TO db2.tbl_name;
```

If you have a “clean” backup of an `.ibd` file, you can restore it to the MySQL installation from which it originated as follows:

1. The table must not have been dropped or truncated since you copied the `.ibd` file, because doing so changes the table ID stored inside the tablespace.
2. Issue this `ALTER TABLE` statement to delete the current `.ibd` file:

   ```
   ALTER TABLE tbl_name DISCARD TABLESPACE;
   ```

3. Copy the backup `.ibd` file to the proper database directory.
4. Issue this `ALTER TABLE` statement to tell `InnoDB` to use the new `.ibd` file for the table:

   ```
   ALTER TABLE tbl_name IMPORT TABLESPACE;
   ```

In this context, a “clean” `.ibd` file backup is one for which the following requirements are satisfied:

- There are no uncommitted modifications by transactions in the `.ibd` file.
- There are no unmerged change buffer entries in the `.ibd` file.
- Purge has removed all delete-marked index records from the `.ibd` file.
- `mysqld` has flushed all modified pages of the `.ibd` file from the buffer pool to the file.

You can make a clean backup `.ibd` file using the following method:

1. Stop all activity from the `mysqld` server and commit all transactions.
2. Wait until `SHOW ENGINE INNODB STATUS` shows that there are no active transactions in the database, and the main thread status of `InnoDB` is `Waiting for server activity`. Then you can make a copy of the `.ibd` file.

Another method for making a clean copy of an `.ibd` file is to use the MySQL Enterprise Backup product:

1. Use MySQL Enterprise Backup to back up the `InnoDB` installation.
2. Start a second `mysqld` server on the backup and let it clean up the `.ibd` files in the backup.

14.10.4.1 Enabling and Disabling File-Per-Table Tablespaces

To make file-per-table tablespaces the default for a MySQL server, start the server with the `--innodb_file_per_table` command-line option, or add this line to the `[mysqld]` section of `my.cnf`:

```
[mysqld]
innodb_file_per_table
```

You can also issue the command while the server is running:

```
mysql> SET GLOBAL innodb_file_per_table=1;
```

With `innodb-file-per-table` enabled, `InnoDB` stores each newly created table in its own *`tbl_name`*`.ibd` file in the appropriate database directory. Unlike the `MyISAM` storage engine, with its separate *`tbl_name`*`.MYD` and *`tbl_name`*`.MYI` files for indexes and data, `InnoDB` stores the data and the indexes together in a single `.ibd` file. The *`tbl_name`*`.frm` file is still created as usual.

If you remove `innodb_file_per_table` from your startup options and restart the server, or turn it off with the `SET GLOBAL` command, `InnoDB` creates any new tables inside the system tablespace.

You can always read and write any `InnoDB` tables, regardless of the file-per-table setting.

To move a table from the system tablespace to its own tablespace, change the `innodb_file_per_table` setting and rebuild the table:

```
mysql> SET GLOBAL innodb_file_per_table=1;
mysql> ALTER TABLE table_name ENGINE=InnoDB;
```

Note

`InnoDB` always needs the system tablespace because it puts its internal data dictionary and undo logs there. The `.ibd` files are not sufficient for `InnoDB` to operate.

When a table is moved out of the system tablespace into its own `.ibd` file, the data files that make up the system tablespace remain the same size. The space formerly occupied by the table can be reused for new `InnoDB` data, but is not reclaimed for use by the operating system. When moving large `InnoDB` tables out of the system tablespace, where disk space is limited, you might prefer to turn on `innodb_file_per_table` and then recreate the entire instance using the `mysqldump` command.

14.11 InnoDB Tables and Indexes

This section covers topics related to `InnoDB` tables and indexes.

14.11.1 InnoDB Tables

This section covers topics related to InnoDB tables.

14.11.1.1 Creating InnoDB Tables

To create an InnoDB table, use the CREATE TABLE statement.

```
CREATE TABLE t1 (a INT, b CHAR (20), PRIMARY KEY (a)) ENGINE=InnoDB;
```

You do not need to specify the ENGINE=InnoDB clause if InnoDB is defined as the default storage engine, which it is by default. To check the default storage engine, issue the following statement:

```
mysql> SELECT @@default_storage_engine;
+--------------------------+
| @@default_storage_engine |
+--------------------------+
| InnoDB                   |
+--------------------------+
```

You might still use ENGINE=InnoDB clause if you plan to use mysqldump or replication to replay the CREATE TABLE statement on a server where the default storage engine is not InnoDB.

An InnoDB table and its indexes can be created in the system tablespace or in a file-per-table tablespace. When innodb_file_per_table is enabled, an InnoDB table is implicitly created in an individual file-per-table tablespace. Conversely, when innodb_file_per_table is disabled, an InnoDB table is implicitly created in the InnoDB system tablespace.

When you create an InnoDB table, MySQL creates a .frm file in the database directory under the MySQL data directory. For more information about .frm files, see InnoDB Tables and .frm Files. For a table created in a file-per-table tablespace, MySQL also creates an .ibd tablespace file in the database directory. A table created in the InnoDBsystem tablespace is created in an existing ibdata file, which resides in the MySQL data directory.

Internally, InnoDB adds an entry for each table to the InnoDB data dictionary. The entry includes the database name. For example, if table t1 is created in the test database, the data dictionary entry for the database name is 'test/t1'. This means you can create a table of the same name (t1) in a different database, and the table names do not collide inside InnoDB.

InnoDB Tables and .frm Files

MySQL stores data dictionary information for tables in .frm files in database directories. Unlike other MySQL storage engines, InnoDB also encodes information about the table in its own internal data dictionary inside the system tablespace. When MySQL drops a table or a database, it deletes one or more .frm files as well as the corresponding entries inside the InnoDB data dictionary. You cannot move InnoDB tables between databases simply by moving the .frm files. For information about moving InnoDB tables, see Section 14.11.1.3, “Moving or Copying InnoDB Tables”.

InnoDB Tables and Row Formats

The default row format of an InnoDB table is Compact. Although this row format is fine for basic experimentation, consider using the Dynamic or Compressed row format to take advantage of InnoDB features such as table compression and efficient off-page storage of long column values. Using these row formats requires that innodb_file_per_table is enabled and that innodb_file_format is set to Barracuda:

```
SET GLOBAL innodb_file_per_table=1;
SET GLOBAL innodb_file_format=barracuda;
CREATE TABLE t3 (a INT, b CHAR (20), PRIMARY KEY (a)) ROW_FORMAT=DYNAMIC;
CREATE TABLE t4 (a INT, b CHAR (20), PRIMARY KEY (a)) ROW_FORMAT=COMPRESSED;
```

For more information about InnoDB row formats, see Section 14.14, “InnoDB Row Storage and Row Formats”. For how to determine the row format of an InnoDB table and the physical characteristics of InnoDB row formats, see Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table”.

InnoDB Tables and Primary Keys

Always define a primary key for an InnoDB table, specifying the column or columns that:

- Are referenced by the most important queries.
- Are never left blank.
- Never have duplicate values.
- Rarely if ever change value once inserted.

For example, in a table containing information about people, you would not create a primary key on (firstname, lastname) because more than one person can have the same name, some people have blank last names, and sometimes people change their names. With so many constraints, often there is not an obvious set of columns to use as a primary key, so you create a new column with a numeric ID to serve as all or part of the primary key. You can declare an auto-increment column so that ascending values are filled in automatically as rows are inserted:

```
-- The value of ID can act like a pointer between related items in different tables.
CREATE TABLE t5 (id INT AUTO_INCREMENT, b CHAR (20), PRIMARY KEY (id));

-- The primary key can consist of more than one column. Any autoinc column must come first.
CREATE TABLE t6 (id INT AUTO_INCREMENT, a INT, b CHAR (20), PRIMARY KEY (id,a));
```

Although the table works correctly without defining a primary key, the primary key is involved with many aspects of performance and is a crucial design aspect for any large or frequently used table. It is recommended that you always specify a primary key in the CREATE TABLE statement. If you create the table, load data, and then run ALTER TABLE to add a primary key later, that operation is much slower than defining the primary key when creating the table.

Viewing InnoDB Table Properties

To view the properties of an InnoDB table, issue a SHOW TABLE STATUS statement:

```
mysql> SHOW TABLE STATUS FROM test LIKE 't%' \G;
*************************** 1. row ***************************
           Name: t1
         Engine: InnoDB
        Version: 10
     Row_format: Compact
           Rows: 0
 Avg_row_length: 0
    Data_length: 16384
Max_data_length: 0
   Index_length: 0
      Data_free: 41943040
 Auto_increment: NULL
    Create_time: 2015-03-16 16:42:17
    Update_time: NULL
     Check_time: NULL
      Collation: latin1_swedish_ci
       Checksum: NULL
 Create_options:
        Comment:
1 row in set (0.00 sec)
```

For information about SHOW TABLE STATUS output, see Section 13.7.5.37, “SHOW TABLE STATUS Syntax”.

14.11.1.2 The Physical Row Structure of an InnoDB Table

The physical row structure of an InnoDB table depends on the row format specified when the table is created. If a row format is not specified, the default row format is used. The default InnoDB row format is COMPACT. When innodb_file_per_table is enabled and innodb_file_format is set to Barracuda, you can use DYNAMIC and COMPRESSED row formats. For more information, see Section 14.14, “InnoDB Row Storage and Row Formats”.

The following sections describe the characteristics of InnoDB row formats.

- Determining the Row Format of an InnoDB Table
- Redundant Row Format Characteristics
- COMPACT Row Format Characteristics
- DYNAMIC and COMPRESSED Row Format Characteristics

For more information about InnoDB row formats, see Section 14.14, “InnoDB Row Storage and Row Formats”.

Determining the Row Format of an InnoDB Table

To check the row format of an InnoDB table, use SHOW TABLE STATUS. For example:

```
mysql> SHOW TABLE STATUS IN test1\G
*************************** 1. row ***************************
           Name: t1
         Engine: InnoDB
        Version: 10
     Row_format: Compact
           Rows: 0
 Avg_row_length: 0
    Data_length: 16384
Max_data_length: 0
   Index_length: 16384
      Data_free: 0
 Auto_increment: 1
    Create_time: 2014-10-31 16:02:01
    Update_time: NULL
     Check_time: NULL
      Collation: latin1_swedish_ci
       Checksum: NULL
 Create_options:
        Comment:
```

Redundant Row Format Characteristics

The REDUNDANT format is available to retain compatibility with older versions of MySQL.

Rows in InnoDB tables that use REDUNDANT row format have the following characteristics:

- Each index record contains a 6-byte header. The header is used to link together consecutive records, and also in row-level locking.
- Records in the clustered index contain fields for all user-defined columns. In addition, there is a 6-byte transaction ID field and a 7-byte roll pointer field.
- If no primary key was defined for a table, each clustered index record also contains a 6-byte row ID field.
- Each secondary index record also contains all the primary key fields defined for the clustered index key that are not in the secondary index.
- A record contains a pointer to each field of the record. If the total length of the fields in a record is less than 128 bytes, the pointer is one byte; otherwise, two bytes. The array of these pointers is called the record directory. The area where these pointers point is called the data part of the record.

- Internally, `InnoDB` stores fixed-length character columns such as `CHAR(10)` in a fixed-length format. `InnoDB` does not truncate trailing spaces from `VARCHAR` columns.
- `InnoDB` encodes fixed-length fields greater than or equal to 768 bytes in length as variable-length fields, which can be stored off-page. For example, a `CHAR(255)` column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with `utf8mb4`.
- An SQL `NULL` value reserves one or two bytes in the record directory. Besides that, an SQL `NULL` value reserves zero bytes in the data part of the record if stored in a variable length column. In a fixed-length column, it reserves the fixed length of the column in the data part of the record. Reserving the fixed space for `NULL` values enables an update of the column from `NULL` to a non-`NULL` value to be done in place without causing fragmentation of the index page.

COMPACT Row Format Characteristics

The `COMPACT` row format decreases row storage space by about 20% compared to the `REDUNDANT` format at the cost of increasing CPU use for some operations. If your workload is a typical one that is limited by cache hit rates and disk speed, `COMPACT` format is likely to be faster. If the workload is a rare case that is limited by CPU speed, compact format might be slower.

Rows in `InnoDB` tables that use `COMPACT` row format have the following characteristics:

- Each index record contains a 5-byte header that may be preceded by a variable-length header. The header is used to link together consecutive records, and also in row-level locking.
- The variable-length part of the record header contains a bit vector for indicating `NULL` columns. If the number of columns in the index that can be `NULL` is *`N`*, the bit vector occupies `CEILING(`*`N`*`/8)` bytes. (For example, if there are anywhere from 9 to 15 columns that can be `NULL`, the bit vector uses two bytes.) Columns that are `NULL` do not occupy space other than the bit in this vector. The variable-length part of the header also contains the lengths of variable-length columns. Each length takes one or two bytes, depending on the maximum length of the column. If all columns in the index are `NOT NULL` and have a fixed length, the record header has no variable-length part.
- For each non-`NULL` variable-length field, the record header contains the length of the column in one or two bytes. Two bytes are only needed if part of the column is stored externally in overflow pages or the maximum length exceeds 255 bytes and the actual length exceeds 127 bytes. For an externally stored column, the 2-byte length indicates the length of the internally stored part plus the 20-byte pointer to the externally stored part. The internal part is 768 bytes, so the length is 768+20. The 20-byte pointer stores the true length of the column.
- The record header is followed by the data contents of the non-`NULL` columns.
- Records in the clustered index contain fields for all user-defined columns. In addition, there is a 6-byte transaction ID field and a 7-byte roll pointer field.
- If no primary key was defined for a table, each clustered index record also contains a 6-byte row ID field.
- Each secondary index record also contains all the primary key fields defined for the clustered index key that are not in the secondary index. If any of these primary key fields are variable length, the record header for each secondary index has a variable-length part to record their lengths, even if the secondary index is defined on fixed-length columns.
- Internally, for nonvariable-length character sets, `InnoDB` stores fixed-length character columns such as `CHAR(10)` in a fixed-length format.

  `InnoDB` does not truncate trailing spaces from `VARCHAR` columns.
- Internally, for variable-length character sets such as `utf8mb3` and `utf8mb4`, `InnoDB` attempts to store `CHAR(`*`N`*`)` in *`N`* bytes by trimming trailing spaces. If the byte length of a `CHAR(`*`N`*`)` column value exceeds *`N`* bytes, `InnoDB` trims trailing spaces to a minimum of the column value byte length. The maximum length of a `CHAR(`*`N`*`)` column is the maximum character byte length × *`N`*.

`InnoDB` reserves a minimum of *`N`* bytes for `CHAR(N)`. Reserving the minimum space *`N`* in many cases enables column updates to be done in place without causing fragmentation of the index page. By comparison, for `ROW_FORMAT=REDUNDANT`, `CHAR(N)` columns occupy the maximum character byte length × *`N`*.

`InnoDB` encodes fixed-length fields greater than or equal to 768 bytes in length as variable-length fields, which can be stored off-page. For example, a `CHAR(255)` column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with `utf8mb4`.

`ROW_FORMAT=DYNAMIC` and `ROW_FORMAT=COMPRESSED` handle `CHAR` storage in the same way as `ROW_FORMAT=COMPACT`.

DYNAMIC and COMPRESSED Row Format Characteristics

`DYNAMIC` and `COMPRESSED` row formats are variations of the `COMPACT` row format. For information about these row formats, see Section 14.14.3, “DYNAMIC and COMPRESSED Row Formats”.

14.11.1.3 Moving or Copying InnoDB Tables

This section describes techniques for moving or copying some or all `InnoDB` tables to a different server or instance. For example, you might move an entire MySQL instance to a larger, faster server; you might clone an entire MySQL instance to a new replication slave server; you might copy individual tables to another instance to develop and test an application, or to a data warehouse server to produce reports.

On Windows, `InnoDB` always stores database and table names internally in lowercase. To move databases in a binary format from Unix to Windows or from Windows to Unix, create all databases and tables using lowercase names. A convenient way to accomplish this is to add the following line to the `[mysqld]` section of your `my.cnf` or `my.ini` file before creating any databases or tables:

```
[mysqld]
lower_case_table_names=1
```

Techniques for moving or copying `InnoDB` tables include:

- Copying Data Files (Cold Backup Method)
- Export and Import (mysqldump)

Copying Data Files (Cold Backup Method)

You can move an `InnoDB` database simply by copying all the relevant files listed under "Cold Backups" in Section 14.21.1, “InnoDB Backup”.

`InnoDB` data and log files are binary-compatible on all platforms having the same floating-point number format. If the floating-point formats differ but you have not used `FLOAT` or `DOUBLE` data types in your tables, then the procedure is the same: simply copy the relevant files.

Export and Import (mysqldump)

You can use `mysqldump` to dump your tables on one machine and then import the dump files on the other machine. Using this method, it does not matter whether the formats differ or if your tables contain floating-point data.

One way to increase the performance of this method is to switch off autocommit mode when importing data, assuming that the tablespace has enough space for the big rollback segment that the import transactions generate. Do the commit only after importing a whole table or a segment of a table.

14.11.1.4 Converting Tables from MyISAM to InnoDB

If you have MyISAM tables that you want to convert to InnoDB for better reliability and scalability, review the following guidelines and tips before converting.

- Adjusting Memory Usage for MyISAM and InnoDB
- Handling Too-Long Or Too-Short Transactions
- Handling Deadlocks
- Planning the Storage Layout
- Converting an Existing Table
- Cloning the Structure of a Table
- Transferring Existing Data
- Storage Requirements
- Defining a PRIMARY KEY for Each Table
- Application Performance Considerations
- Understanding Files Associated with InnoDB Tables

Adjusting Memory Usage for MyISAM and InnoDB

As you transition away from MyISAM tables, lower the value of the key_buffer_size configuration option to free memory no longer needed for caching results. Increase the value of the innodb_buffer_pool_size configuration option, which performs a similar role of allocating cache memory for InnoDB tables. The InnoDB buffer pool caches both table data and index data, speeding up lookups for queries and keeping query results in memory for reuse. For guidance regarding buffer pool size configuration, see Section 8.12.4.1, “How MySQL Uses Memory”.

On a busy server, run benchmarks with the query cache turned off. The InnoDB buffer pool provides similar benefits, so the query cache might be tying up memory unnecessarily. For information about the query cache, see Section 8.10.3, “The MySQL Query Cache”.

Handling Too-Long Or Too-Short Transactions

Because MyISAM tables do not support transactions, you might not have paid much attention to the autocommit configuration option and the COMMIT and ROLLBACK statements. These keywords are important to allow multiple sessions to read and write InnoDB tables concurrently, providing substantial scalability benefits in write-heavy workloads.

While a transaction is open, the system keeps a snapshot of the data as seen at the beginning of the transaction, which can cause substantial overhead if the system inserts, updates, and deletes millions of rows while a stray transaction keeps running. Thus, take care to avoid transactions that run for too long:

- If you are using a mysql session for interactive experiments, always COMMIT (to finalize the changes) or ROLLBACK (to undo the changes) when finished. Close down interactive sessions rather than leave them open for long periods, to avoid keeping transactions open for long periods by accident.
- Make sure that any error handlers in your application also ROLLBACK incomplete changes or COMMIT completed changes.
- ROLLBACK is a relatively expensive operation, because INSERT, UPDATE, and DELETE operations are written to InnoDB tables prior to the COMMIT, with the expectation that most changes are

committed successfully and rollbacks are rare. When experimenting with large volumes of data, avoid making changes to large numbers of rows and then rolling back those changes.

- When loading large volumes of data with a sequence of `INSERT` statements, periodically `COMMIT` the results to avoid having transactions that last for hours. In typical load operations for data warehousing, if something goes wrong, you truncate the table (using `TRUNCATE TABLE`) and start over from the beginning rather than doing a `ROLLBACK`.

The preceding tips save memory and disk space that can be wasted during too-long transactions. When transactions are shorter than they should be, the problem is excessive I/O. With each `COMMIT`, MySQL makes sure each change is safely recorded to disk, which involves some I/O.

- For most operations on `InnoDB` tables, you should use the setting `autocommit=0`. From an efficiency perspective, this avoids unnecessary I/O when you issue large numbers of consecutive `INSERT`, `UPDATE`, or `DELETE` statements. From a safety perspective, this allows you to issue a `ROLLBACK` statement to recover lost or garbled data if you make a mistake on the `mysql` command line, or in an exception handler in your application.
- The time when `autocommit=1` is suitable for `InnoDB` tables is when running a sequence of queries for generating reports or analyzing statistics. In this situation, there is no I/O penalty related to `COMMIT` or `ROLLBACK`, and `InnoDB` can automatically optimize the read-only workload.
- If you make a series of related changes, finalize all the changes at once with a single `COMMIT` at the end. For example, if you insert related pieces of information into several tables, do a single `COMMIT` after making all the changes. Or if you run many consecutive `INSERT` statements, do a single `COMMIT` after all the data is loaded; if you are doing millions of `INSERT` statements, perhaps split up the huge transaction by issuing a `COMMIT` every ten thousand or hundred thousand records, so the transaction does not grow too large.
- Remember that even a `SELECT` statement opens a transaction, so after running some report or debugging queries in an interactive `mysql` session, either issue a `COMMIT` or close the `mysql` session.

Handling Deadlocks

You might see warning messages referring to “deadlocks” in the MySQL error log, or the output of `SHOW ENGINE INNODB STATUS`. Despite the scary-sounding name, a deadlock is not a serious issue for `InnoDB` tables, and often does not require any corrective action. When two transactions start modifying multiple tables, accessing the tables in a different order, they can reach a state where each transaction is waiting for the other and neither can proceed. MySQL immediately detects this condition and cancels (rolls back) the “smaller” transaction, allowing the other to proceed.

Your applications do need error-handling logic to restart a transaction that is forcibly cancelled like this. When you re-issue the same SQL statements as before, the original timing issue no longer applies. Either the other transaction has already finished and yours can proceed, or the other transaction is still in progress and your transaction waits until it finishes.

If deadlock warnings occur constantly, you might review the application code to reorder the SQL operations in a consistent way, or to shorten the transactions.

For more information, see Section 14.8.5, “Deadlocks in InnoDB”.

Planning the Storage Layout

To get the best performance from `InnoDB` tables, you can adjust a number of parameters related to storage layout.

When you convert `MyISAM` tables that are large, frequently accessed, and hold vital data, investigate and consider the `innodb_file_per_table` and `innodb_file_format` configuration options, and the `ROW_FORMAT` and `KEY_BLOCK_SIZE` clauses of the `CREATE TABLE` statement.

During your initial experiments, the most important setting is `innodb_file_per_table`. When this setting is enabled, new `InnoDB` tables are implicitly created in file-per-table tablespaces. In contrast with the `InnoDB` system tablespace, file-per-table tablespaces allow disk space to be reclaimed by the operating system when a table is truncated or dropped. File-per-table tablespaces also support the Barracuda file format and associated features such as table compression and efficient off-page storage for long variable-length columns. For more information, see Section 14.10.4, “InnoDB File-Per-Table Tablespaces”.

Converting an Existing Table

To convert a non-`InnoDB` table to use `InnoDB` use `ALTER TABLE`:

```
ALTER TABLE table_name ENGINE=InnoDB;
```

Important

Do not convert MySQL system tables in the `mysql` database (such as `user` or `host`) to the `InnoDB` type. This is an unsupported operation. The system tables must always be of the `MyISAM` type.

Cloning the Structure of a Table

You might make an `InnoDB` table that is a clone of a MyISAM table, rather than using `ALTER TABLE` to perform conversion, to test the old and new table side-by-side before switching.

Create an empty `InnoDB` table with identical column and index definitions. Use `SHOW CREATE TABLE table_name\G` to see the full `CREATE TABLE` statement to use. Change the `ENGINE` clause to `ENGINE=INNODB`.

Transferring Existing Data

To transfer a large volume of data into an empty `InnoDB` table created as shown in the previous section, insert the rows with `INSERT INTO innodb_table SELECT * FROM myisam_table ORDER BY primary_key_columns`.

You can also create the indexes for the `InnoDB` table after inserting the data. Historically, creating new secondary indexes was a slow operation for InnoDB, but now you can create the indexes after the data is loaded with relatively little overhead from the index creation step.

If you have `UNIQUE` constraints on secondary keys, you can speed up a table import by turning off the uniqueness checks temporarily during the import operation:

```
SET unique_checks=0;
... import operation ...
SET unique_checks=1;
```

For big tables, this saves disk I/O because `InnoDB` can use its change buffer to write secondary index records as a batch. Be certain that the data contains no duplicate keys. `unique_checks` permits but does not require storage engines to ignore duplicate keys.

For better control over the insertion process, you can insert big tables in pieces:

```
INSERT INTO newtable SELECT * FROM oldtable
   WHERE yourkey > something AND yourkey <= somethingelse;
```

After all records are inserted, you can rename the tables.

During the conversion of big tables, increase the size of the `InnoDB` buffer pool to reduce disk I/O, to a maximum of 80% of physical memory. You can also increase the size of `InnoDB` log files.

Storage Requirements

If you intend to make several temporary copies of your data in `InnoDB` tables during the conversion process, it is recommended that you create the tables in file-per-table tablespaces so that you can reclaim the disk space when you drop the tables. When the `innodb_file_per_table` configuration option is enabled (the default), newly created `InnoDB` tables are implicitly created in file-per-table tablespaces.

Whether you convert the `MyISAM` table directly or create a cloned `InnoDB` table, make sure that you have sufficient disk space to hold both the old and new tables during the process. **`InnoDB` tables require more disk space than `MyISAM` tables.** If an `ALTER TABLE` operation runs out of space, it starts a rollback, and that can take hours if it is disk-bound. For inserts, `InnoDB` uses the insert buffer to merge secondary index records to indexes in batches. That saves a lot of disk I/O. For rollback, no such mechanism is used, and the rollback can take 30 times longer than the insertion.

In the case of a runaway rollback, if you do not have valuable data in your database, it may be advisable to kill the database process rather than wait for millions of disk I/O operations to complete. For the complete procedure, see Section 14.23.2, “Forcing InnoDB Recovery”.

Defining a PRIMARY KEY for Each Table

The `PRIMARY KEY` clause is a critical factor affecting the performance of MySQL queries and the space usage for tables and indexes. The primary key uniquely identifies a row in a table. Every row in the table must have a primary key value, and no two rows can have the same primary key value.

These are guidelines for the primary key, followed by more detailed explanations.

- Declare a `PRIMARY KEY` for each table. Typically, it is the most important column that you refer to in `WHERE` clauses when looking up a single row.
- Declare the `PRIMARY KEY` clause in the original `CREATE TABLE` statement, rather than adding it later through an `ALTER TABLE` statement.
- Choose the column and its data type carefully. Prefer numeric columns over character or string ones.
- Consider using an auto-increment column if there is not another stable, unique, non-null, numeric column to use.
- An auto-increment column is also a good choice if there is any doubt whether the value of the primary key column could ever change. Changing the value of a primary key column is an expensive operation, possibly involving rearranging data within the table and within each secondary index.

Consider adding a primary key to any table that does not already have one. Use the smallest practical numeric type based on the maximum projected size of the table. This can make each row slightly more compact, which can yield substantial space savings for large tables. The space savings are multiplied if the table has any secondary indexes, because the primary key value is repeated in each secondary index entry. In addition to reducing data size on disk, a small primary key also lets more data fit into the buffer pool, speeding up all kinds of operations and improving concurrency.

If the table already has a primary key on some longer column, such as a `VARCHAR`, consider adding a new unsigned `AUTO_INCREMENT` column and switching the primary key to that, even if that column is not referenced in queries. This design change can produce substantial space savings in the secondary indexes. You can designate the former primary key columns as `UNIQUE NOT NULL` to enforce the same constraints as the `PRIMARY KEY` clause, that is, to prevent duplicate or null values across all those columns.

If you spread related information across multiple tables, typically each table uses the same column for its primary key. For example, a personnel database might have several tables, each with a primary key of employee number. A sales database might have some tables with a primary key of customer number, and other tables with a primary key of order number. Because lookups using the primary key are very fast, you can construct efficient join queries for such tables.

If you leave the `PRIMARY KEY` clause out entirely, MySQL creates an invisible one for you. It is a 6-byte value that might be longer than you need, thus wasting space. Because it is hidden, you cannot refer to it in queries.

Application Performance Considerations

The reliability and scalability features of `InnoDB` require more disk storage than equivalent `MyISAM` tables. You might change the column and index definitions slightly, for better space utilization, reduced I/O and memory consumption when processing result sets, and better query optimization plans making efficient use of index lookups.

If you do set up a numeric ID column for the primary key, use that value to cross-reference with related values in any other tables, particularly for join queries. For example, rather than accepting a country name as input and doing queries searching for the same name, do one lookup to determine the country ID, then do other queries (or a single join query) to look up relevant information across several tables. Rather than storing a customer or catalog item number as a string of digits, potentially using up several bytes, convert it to a numeric ID for storing and querying. A 4-byte unsigned `INT` column can index over 4 billion items (with the US meaning of billion: 1000 million). For the ranges of the different integer types, see Section 11.2.1, “Integer Types (Exact Value) - INTEGER, INT, SMALLINT, TINYINT, MEDIUMINT, BIGINT”.

Understanding Files Associated with InnoDB Tables

`InnoDB` files require more care and planning than `MyISAM` files do.

- You must not delete the ibdata files that represent the `InnoDB` system tablespace.
- Methods of moving or copying `InnoDB` tables to a different server are described in Section 14.11.1.3, “Moving or Copying InnoDB Tables”.

14.11.1.5 AUTO_INCREMENT Handling in InnoDB

`InnoDB` provides a configurable locking mechanism that can significantly improve scalability and performance of SQL statements that add rows to tables with `AUTO_INCREMENT` columns. To use the `AUTO_INCREMENT` mechanism with an `InnoDB` table, an `AUTO_INCREMENT` column must be defined as part of an index such that it is possible to perform the equivalent of an indexed `SELECT MAX(ai_col)` lookup on the table to obtain the maximum column value. Typically, this is achieved by making the column the first column of some table index.

This section describes the behavior of `AUTO_INCREMENT` lock modes, usage implications for different `AUTO_INCREMENT` lock mode settings, and how `InnoDB` initializes the `AUTO_INCREMENT` counter.

- InnoDB AUTO_INCREMENT Lock Modes
- InnoDB AUTO_INCREMENT Lock Mode Usage Implications
- InnoDB AUTO_INCREMENT Counter Initialization

InnoDB AUTO_INCREMENT Lock Modes

This section describes the behavior of `AUTO_INCREMENT` lock modes used to generate auto-increment values, and how each lock mode affects replication. Auto-increment lock modes are configured at startup using the `innodb_autoinc_lock_mode` configuration parameter.

The following terms are used in describing `innodb_autoinc_lock_mode` settings:

- “`INSERT`-like” statements

  All statements that generate new rows in a table, including `INSERT`, `INSERT ... SELECT`, `REPLACE`, `REPLACE ... SELECT`, and `LOAD DATA`. Includes “simple-inserts”, “bulk-inserts”, and “mixed-mode” inserts.

- “Simple inserts”

Statements for which the number of rows to be inserted can be determined in advance (when the statement is initially processed). This includes single-row and multiple-row `INSERT` and `REPLACE` statements that do not have a nested subquery, but not `INSERT ... ON DUPLICATE KEY UPDATE`.

- “Bulk inserts”

  Statements for which the number of rows to be inserted (and the number of required auto-increment values) is not known in advance. This includes `INSERT ... SELECT`, `REPLACE ... SELECT`, and `LOAD DATA` statements, but not plain `INSERT`. `InnoDB` assigns new values for the `AUTO_INCREMENT` column one at a time as each row is processed.

- “Mixed-mode inserts”

  These are “simple insert” statements that specify the auto-increment value for some (but not all) of the new rows. An example follows, where `c1` is an `AUTO_INCREMENT` column of table `t1`:

```
INSERT INTO t1 (c1,c2) VALUES (1,'a'), (NULL,'b'), (5,'c'), (NULL,'d');
```

  Another type of “mixed-mode insert” is `INSERT ... ON DUPLICATE KEY UPDATE`, which in the worst case is in effect an `INSERT` followed by a `UPDATE`, where the allocated value for the `AUTO_INCREMENT` column may or may not be used during the update phase.

There are three possible settings for the `innodb_autoinc_lock_mode` configuration parameter. The settings are 0, 1, or 2, for “traditional”, “consecutive”, or “interleaved” lock mode, respectively.

- `innodb_autoinc_lock_mode = 0` (“traditional” lock mode)

  The traditional lock mode provides the same behavior that existed before the `innodb_autoinc_lock_mode` configuration parameter was introduced in MySQL 5.1. The traditional lock mode option is provided for backward compatibility, performance testing, and working around issues with “mixed-mode inserts”, due to possible differences in semantics.

  In this lock mode, all “INSERT-like” statements obtain a special table-level `AUTO-INC` lock for inserts into tables with `AUTO_INCREMENT` columns. This lock is normally held to the end of the statement (not to the end of the transaction) to ensure that auto-increment values are assigned in a predictable and repeatable order for a given sequence of `INSERT` statements, and to ensure that auto-increment values assigned by any given statement are consecutive.

  In the case of statement-based replication, this means that when an SQL statement is replicated on a slave server, the same values are used for the auto-increment column as on the master server. The result of execution of multiple `INSERT` statements is deterministic, and the slave reproduces the same data as on the master. If auto-increment values generated by multiple `INSERT` statements were interleaved, the result of two concurrent `INSERT` statements would be nondeterministic, and could not reliably be propagated to a slave server using statement-based replication.

  To make this clear, consider an example that uses this table:

```
CREATE TABLE t1 (
  c1 INT(11) NOT NULL AUTO_INCREMENT,
  c2 VARCHAR(10) DEFAULT NULL,
  PRIMARY KEY (c1)
) ENGINE=InnoDB;
```

  Suppose that there are two transactions running, each inserting rows into a table with an `AUTO_INCREMENT` column. One transaction is using an `INSERT ... SELECT` statement that inserts 1000 rows, and another is using a simple `INSERT` statement that inserts one row:

```
Tx1: INSERT INTO t1 (c2) SELECT 1000 rows from another table ...
```

```
Tx2: INSERT INTO t1 (c2) VALUES ('xxx');
```

InnoDB cannot tell in advance how many rows are retrieved from the SELECT in the INSERT statement in Tx1, and it assigns the auto-increment values one at a time as the statement proceeds. With a table-level lock, held to the end of the statement, only one INSERT statement referring to table t1 can execute at a time, and the generation of auto-increment numbers by different statements is not interleaved. The auto-increment value generated by the Tx1 INSERT ... SELECT statement is consecutive, and the (single) auto-increment value used by the INSERT statement in Tx2 is either be smaller or larger than all those used for Tx1, depending on which statement executes first.

As long as the SQL statements execute in the same order when replayed from the binary log (when using statement-based replication, or in recovery scenarios), the results are the same as they were when Tx1 and Tx2 first ran. Thus, table-level locks held until the end of a statement make INSERT statements using auto-increment safe for use with statement-based replication. However, those table-level locks limit concurrency and scalability when multiple transactions are executing insert statements at the same time.

In the preceding example, if there were no table-level lock, the value of the auto-increment column used for the INSERT in Tx2 depends on precisely when the statement executes. If the INSERT of Tx2 executes while the INSERT of Tx1 is running (rather than before it starts or after it completes), the specific auto-increment values assigned by the two INSERT statements are nondeterministic, and may vary from run to run.

Under the consecutive lock mode, InnoDB can avoid using table-level AUTO-INC locks for “simple insert” statements where the number of rows is known in advance, and still preserve deterministic execution and safety for statement-based replication.

If you are not using the binary log to replay SQL statements as part of recovery or replication, the interleaved lock mode can be used to eliminate all use of table-level AUTO-INC locks for even greater concurrency and performance, at the cost of permitting gaps in auto-increment numbers assigned by a statement and potentially having the numbers assigned by concurrently executing statements interleaved.

- innodb_autoinc_lock_mode = 1 (“consecutive” lock mode)

  This is the default lock mode. In this mode, “bulk inserts” use the special AUTO-INC table-level lock and hold it until the end of the statement. This applies to all INSERT ... SELECT, REPLACE ... SELECT, and LOAD DATA statements. Only one statement holding the AUTO-INC lock can execute at a time. If the source table of the bulk insert operation is different from the target table, the AUTO-INC lock on the target table is taken after a shared lock is taken on the first row selected from the source table. If the source and target of the bulk insert operation are the same table, the AUTO-INC lock is taken after shared locks are taken on all selected rows.

  “Simple inserts” (for which the number of rows to be inserted is known in advance) avoid table-level AUTO-INC locks by obtaining the required number of auto-increment values under the control of a mutex (a light-weight lock) that is only held for the duration of the allocation process, *not* until the statement completes. No table-level AUTO-INC lock is used unless an AUTO-INC lock is held by another transaction. If another transaction holds an AUTO-INC lock, a “simple insert” waits for the AUTO-INC lock, as if it were a “bulk insert”.

  This lock mode ensures that, in the presence of INSERT statements where the number of rows is not known in advance (and where auto-increment numbers are assigned as the statement progresses), all auto-increment values assigned by any “INSERT-like” statement are consecutive, and operations are safe for statement-based replication.

  Simply put, this lock mode significantly improves scalability while being safe for use with statement-based replication. Further, as with “traditional” lock mode, auto-increment numbers assigned by any given statement are *consecutive*. There is *no change* in semantics compared to “traditional” mode for any statement that uses auto-increment, with one important exception.

The exception is for “mixed-mode inserts”, where the user provides explicit values for an `AUTO_INCREMENT` column for some, but not all, rows in a multiple-row “simple insert”. For such inserts, `InnoDB` allocates more auto-increment values than the number of rows to be inserted. However, all values automatically assigned are consecutively generated (and thus higher than) the auto-increment value generated by the most recently executed previous statement. “Excess” numbers are lost.

- `innodb_autoinc_lock_mode = 2` (“interleaved” lock mode)

  In this lock mode, no “`INSERT`-like” statements use the table-level `AUTO-INC` lock, and multiple statements can execute at the same time. This is the fastest and most scalable lock mode, but it is *not safe* when using statement-based replication or recovery scenarios when SQL statements are replayed from the binary log.

  In this lock mode, auto-increment values are guaranteed to be unique and monotonically increasing across all concurrently executing “`INSERT`-like” statements. However, because multiple statements can be generating numbers at the same time (that is, allocation of numbers is *interleaved* across statements), the values generated for the rows inserted by any given statement may not be consecutive.

  If the only statements executing are “simple inserts” where the number of rows to be inserted is known ahead of time, there are no gaps in the numbers generated for a single statement, except for “mixed-mode inserts”. However, when “bulk inserts” are executed, there may be gaps in the auto-increment values assigned by any given statement.

InnoDB AUTO_INCREMENT Lock Mode Usage Implications

- Using auto-increment with replication

  If you are using statement-based replication, set `innodb_autoinc_lock_mode` to 0 or 1 and use the same value on the master and its slaves. Auto-increment values are not ensured to be the same on the slaves as on the master if you use `innodb_autoinc_lock_mode` = 2 (“interleaved”) or configurations where the master and slaves do not use the same lock mode.

  If you are using row-based or mixed-format replication, all of the auto-increment lock modes are safe, since row-based replication is not sensitive to the order of execution of the SQL statements (and the mixed format uses row-based replication for any statements that are unsafe for statement-based replication).

- “Lost” auto-increment values and sequence gaps

  In all lock modes (0, 1, and 2), if a transaction that generated auto-increment values rolls back, those auto-increment values are “lost”. Once a value is generated for an auto-increment column, it cannot be rolled back, whether or not the “`INSERT`-like” statement is completed, and whether or not the containing transaction is rolled back. Such lost values are not reused. Thus, there may be gaps in the values stored in an `AUTO_INCREMENT` column of a table.

- Specifying NULL or 0 for the `AUTO_INCREMENT` column

  In all lock modes (0, 1, and 2), if a user specifies NULL or 0 for the `AUTO_INCREMENT` column in an `INSERT`, `InnoDB` treats the row as if the value was not specified and generates a new value for it.

- Assigning a negative value to the `AUTO_INCREMENT` column

  In all lock modes (0, 1, and 2), the behavior of the auto-increment mechanism is not defined if you assign a negative value to the `AUTO_INCREMENT` column.

- If the `AUTO_INCREMENT` value becomes larger than the maximum integer for the specified integer type

In all lock modes (0, 1, and 2), the behavior of the auto-increment mechanism is not defined if the value becomes larger than the maximum integer that can be stored in the specified integer type.

- Gaps in auto-increment values for “bulk inserts”

  With `innodb_autoinc_lock_mode` set to 0 (“traditional”) or 1 (“consecutive”), the auto-increment values generated by any given statement are consecutive, without gaps, because the table-level `AUTO-INC` lock is held until the end of the statement, and only one such statement can execute at a time.

  With `innodb_autoinc_lock_mode` set to 2 (“interleaved”), there may be gaps in the auto-increment values generated by “bulk inserts,” but only if there are concurrently executing “`INSERT`-like” statements.

  For lock modes 1 or 2, gaps may occur between successive statements because for bulk inserts the exact number of auto-increment values required by each statement may not be known and overestimation is possible.

- Auto-increment values assigned by “mixed-mode inserts”

  Consider a “mixed-mode insert,” where a “simple insert” specifies the auto-increment value for some (but not all) resulting rows. Such a statement behaves differently in lock modes 0, 1, and 2. For example, assume `c1` is an `AUTO_INCREMENT` column of table `t1`, and that the most recent automatically generated sequence number is 100.

```
mysql> CREATE TABLE t1 (
    -> c1 INT UNSIGNED NOT NULL AUTO_INCREMENT PRIMARY KEY,
    -> c2 CHAR(1)
    -> ) ENGINE = INNODB;
```

  Now, consider the following “mixed-mode insert” statement:

```
mysql> INSERT INTO t1 (c1,c2) VALUES (1,'a'), (NULL,'b'), (5,'c'), (NULL,'d');
```

  With `innodb_autoinc_lock_mode` set to 0 (“traditional”), the four new rows are:

```
mysql> SELECT c1, c2 FROM t1 ORDER BY c2;
+-----+------+
| c1  | c2   |
+-----+------+
|   1 | a    |
| 101 | b    |
|   5 | c    |
| 102 | d    |
+-----+------+
```

  The next available auto-increment value is 103 because the auto-increment values are allocated one at a time, not all at once at the beginning of statement execution. This result is true whether or not there are concurrently executing “`INSERT`-like” statements (of any type).

  With `innodb_autoinc_lock_mode` set to 1 (“consecutive”), the four new rows are also:

```
mysql> SELECT c1, c2 FROM t1 ORDER BY c2;
+-----+------+
| c1  | c2   |
+-----+------+
|   1 | a    |
| 101 | b    |
|   5 | c    |
| 102 | d    |
+-----+------+
```

However, in this case, the next available auto-increment value is 105, not 103 because four auto-increment values are allocated at the time the statement is processed, but only two are used. This result is true whether or not there are concurrently executing "`INSERT`-like" statements (of any type).

With `innodb_autoinc_lock_mode` set to mode 2 ("interleaved"), the four new rows are:

```
mysql> SELECT c1, c2 FROM t1 ORDER BY c2;
+-----+------+
| c1  | c2   |
+-----+------+
|   1 | a    |
|   x | b    |
|   5 | c    |
|   y | d    |
+-----+------+
```

The values of *x* and *y* are unique and larger than any previously generated rows. However, the specific values of *x* and *y* depend on the number of auto-increment values generated by concurrently executing statements.

Finally, consider the following statement, issued when the most-recently generated sequence number is 100:

```
mysql> INSERT INTO t1 (c1,c2) VALUES (1,'a'), (NULL,'b'), (101,'c'), (NULL,'d');
```

With any `innodb_autoinc_lock_mode` setting, this statement generates a duplicate-key error 23000 (`Can't write; duplicate key in table`) because 101 is allocated for the row `(NULL, 'b')` and insertion of the row `(101, 'c')` fails.

- Modifying `AUTO_INCREMENT` column values in the middle of a sequence of `INSERT` statements

  In all lock modes (0, 1, and 2), modifying an `AUTO_INCREMENT` column value in the middle of a sequence of `INSERT` statements could lead to "Duplicate entry" errors. For example, if you perform an `UPDATE` operation that changes an `AUTO_INCREMENT` column value to a value larger than the current maximum auto-increment value, subsequent `INSERT` operations that do not specify an unused auto-increment value could encounter "Duplicate entry" errors. This behavior is demonstrated in the following example.

```
mysql> CREATE TABLE t1 (
    -> c1 INT NOT NULL AUTO_INCREMENT,
    -> PRIMARY KEY (c1)
    ->  ) ENGINE = InnoDB;

mysql> INSERT INTO t1 VALUES(0), (0), (3);

mysql> SELECT c1 FROM t1;
+----+
| c1 |
+----+
|  1 |
|  2 |
|  3 |
+----+

mysql> UPDATE t1 SET c1 = 4 WHERE c1 = 1;

mysql> SELECT c1 FROM t1;
+----+
| c1 |
+----+
|  2 |
|  3 |
|  4 |
+----+
```

```
mysql> INSERT INTO t1 VALUES(0);
ERROR 1062 (23000): Duplicate entry '4' for key 'PRIMARY'
```

InnoDB AUTO_INCREMENT Counter Initialization

This section describes how InnoDB initializes AUTO_INCREMENT counters.

If you specify an AUTO_INCREMENT column for an InnoDB table, the table handle in the InnoDB data dictionary contains a special counter called the auto-increment counter that is used in assigning new values for the column. This counter is stored only in main memory, not on disk.

To initialize an auto-increment counter after a server restart, InnoDB executes the equivalent of the following statement on the first insert into a table containing an AUTO_INCREMENT column.

```
SELECT MAX(ai_col) FROM table_name FOR UPDATE;
```

InnoDB increments the value retrieved by the statement and assigns it to the column and to the auto-increment counter for the table. By default, the value is incremented by 1. This default can be overridden by the auto_increment_increment configuration setting.

If the table is empty, InnoDB uses the value 1. This default can be overridden by the auto_increment_offset configuration setting.

If a SHOW TABLE STATUS statement examines the table before the auto-increment counter is initialized, InnoDB initializes but does not increment the value. The value is stored for use by later inserts. This initialization uses a normal exclusive-locking read on the table and the lock lasts to the end of the transaction. InnoDB follows the same procedure for initializing the auto-increment counter for a newly created table.

After the auto-increment counter has been initialized, if you do not explicitly specify a value for an AUTO_INCREMENT column, InnoDB increments the counter and assigns the new value to the column. If you insert a row that explicitly specifies the column value, and the value is greater than the current counter value, the counter is set to the specified column value.

InnoDB uses the in-memory auto-increment counter as long as the server runs. When the server is stopped and restarted, InnoDB reinitializes the counter for each table for the first INSERT to the table, as described earlier.

A server restart also cancels the effect of the AUTO_INCREMENT = *N* table option in CREATE TABLE and ALTER TABLE statements, which you can use with InnoDB tables to set the initial counter value or alter the current counter value.

14.11.1.6 InnoDB and FOREIGN KEY Constraints

How the InnoDB storage engine handles foreign key constraints is described under the following topics in this section:

- Foreign Key Definitions
- Referential Actions
- Foreign Key Usage and Error Information

For foreign key usage information and examples, see Section 13.1.17.6, “Using FOREIGN KEY Constraints”.

Foreign Key Definitions

Foreign key definitions for InnoDB tables are subject to the following conditions:

- InnoDB permits a foreign key to reference any index column or group of columns. However, in the referenced table, there must be an index where the referenced columns are listed as the *first* columns in the same order.
- InnoDB does not currently support foreign keys for tables with user-defined partitioning. This means that no user-partitioned InnoDB table may contain foreign key references or columns referenced by foreign keys.
- InnoDB allows a foreign key constraint to reference a non-unique key. *This is an InnoDB extension to standard SQL.*

Referential Actions

Referential actions for foreign keys of InnoDB tables are subject to the following conditions:

- While SET DEFAULT is allowed by the MySQL Server, it is rejected as invalid by InnoDB. CREATE TABLE and ALTER TABLE statements using this clause are not allowed for InnoDB tables.
- If there are several rows in the parent table that have the same referenced key value, InnoDB acts in foreign key checks as if the other parent rows with the same key value do not exist. For example, if you have defined a RESTRICT type constraint, and there is a child row with several parent rows, InnoDB does not permit the deletion of any of those parent rows.
- InnoDB performs cascading operations through a depth-first algorithm, based on records in the indexes corresponding to the foreign key constraints.
- If ON UPDATE CASCADE or ON UPDATE SET NULL recurses to update the *same table* it has previously updated during the cascade, it acts like RESTRICT. This means that you cannot use self-referential ON UPDATE CASCADE or ON UPDATE SET NULL operations. This is to prevent infinite loops resulting from cascaded updates. A self-referential ON DELETE SET NULL, on the other hand, is possible, as is a self-referential ON DELETE CASCADE. Cascading operations may not be nested more than 15 levels deep.
- Like MySQL in general, in an SQL statement that inserts, deletes, or updates many rows, InnoDB checks UNIQUE and FOREIGN KEY constraints row-by-row. When performing foreign key checks, InnoDB sets shared row-level locks on child or parent records it has to look at. InnoDB checks foreign key constraints immediately; the check is not deferred to transaction commit. According to the SQL standard, the default behavior should be deferred checking. That is, constraints are only checked after the *entire SQL statement* has been processed. Until InnoDB implements deferred constraint checking, some things are impossible, such as deleting a record that refers to itself using a foreign key.

Foreign Key Usage and Error Information

You can obtain general information about foreign keys and their usage from querying the INFORMATION_SCHEMA.KEY_COLUMN_USAGE table.

In addition to SHOW ERRORS, in the event of a foreign key error involving InnoDB tables (usually Error 150 in the MySQL Server), you can obtain a detailed explanation of the most recent InnoDB foreign key error by checking the output of SHOW ENGINE INNODB STATUS.

14.11.1.7 Limits on InnoDB Tables

Limits on InnoDB tables are described under the following topics in this section:

- Maximums and Minimums
- Restrictions on InnoDB Tables
- Locking and Transactions

Warning

Do *not* convert MySQL system tables in the `mysql` database from `MyISAM` to `InnoDB` tables. This is an unsupported operation. If you do this, MySQL does not restart until you restore the old system tables from a backup or regenerate them by reinitializing the data directory (see Section 2.10.1, “Initializing the Data Directory”).

Warning

Before using NFS with `InnoDB`, review potential issues outlined in Using NFS with MySQL.

Maximums and Minimums

- A table can contain a maximum of 1000 columns.
- A table can contain a maximum of 64 secondary indexes.
- By default, the index key prefix length limit is 767 bytes. See Section 13.1.13, “CREATE INDEX Syntax”. For example, you might hit this limit with a column prefix index of more than 255 characters on a `TEXT` or `VARCHAR` column, assuming a `utf8mb3` character set and the maximum of 3 bytes for each character. When the `innodb_large_prefix` configuration option is enabled, the index key prefix length limit is raised to 3072 bytes for `InnoDB` tables that use `DYNAMIC` or `COMPRESSED` row format.

  If you specify an index key prefix length that exceeds the limit, the length is silently reduced to the maximum length.

  When `innodb_large_prefix` is enabled, attempting to create an index key prefix with a length greater than 3072 bytes for a `DYNAMIC` or `COMPRESSED` table causes an `ER_INDEX_COLUMN_TOO_LONG` error.

  The limits that apply to index key prefixes also apply to full-column index keys.
- A maximum of 16 columns is permitted for multicolumn indexes. Exceeding the limit returns an error.

```
ERROR 1070 (42000): Too many key parts specified; max 16 parts allowed
```

- The maximum row length, except for variable-length columns (`VARBINARY`, `VARCHAR`, `BLOB` and `TEXT`), is slightly less than half of a page. That is, the maximum row length is about 8000 bytes. `LONGBLOB` and `LONGTEXT` columns must be less than 4GB, and the total row length, including `BLOB` and `TEXT` columns, must be less than 4GB.

  If a row is less than half a page long, all of it is stored locally within the page. If it exceeds half a page, variable-length columns are chosen for external off-page storage until the row fits within half a page, as described in Section 14.15.2, “File Space Management”.

  The row size for `BLOB` columns that are chosen for external off-page storage should not exceed 10% of the combined redo log file size. If the row size exceeds 10% of the combined redo log file size, `InnoDB` could overwrite the most recent checkpoint which may result in lost data during crash recovery. (Bug#69477).
- Although `InnoDB` supports row sizes larger than 65,535 bytes internally, MySQL itself imposes a row-size limit of 65,535 for the combined size of all columns:

```
mysql> CREATE TABLE t (a VARCHAR(8000), b VARCHAR(10000),
    -> c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
    -> f VARCHAR(10000), g VARCHAR(10000)) ENGINE=InnoDB;
ERROR 1118 (42000): Row size too large. The maximum row size for the
used table type, not counting BLOBs, is 65535. You have to change some
columns to TEXT or BLOBs
```

See Section C.10.4, “Limits on Table Column Count and Row Size”.

- On some older operating systems, files must be less than 2GB. This is not a limitation of `InnoDB` itself, but if you require a large tablespace, configure it using several smaller data files rather than one large data file.
- The combined size of the `InnoDB` log files must be less than 4GB.
- The minimum tablespace size is slightly larger than 10MB. The maximum tablespace size is four billion pages (64TB). This is also the maximum size for a table.
- The default page size in `InnoDB` is 16KB.

  Changing the page size is not a supported operation and there is no guarantee that `InnoDB` functions normally with a page size other than 16KB. Problems compiling or running `InnoDB` may occur. In particular, `ROW_FORMAT=COMPRESSED` in the Barracuda file format assumes that the page size is at most 16KB and uses 14-bit pointers.

  A version of `InnoDB` built for one page size cannot use data files or log files from a version built for a different page size. This limitation could affect restore or downgrade operations using data from MySQL 5.6, which does support page sizes other than 16KB.
- `InnoDB` tables do not support `FULLTEXT` indexes.
- `InnoDB` tables support spatial data types, but not indexes on them.

Restrictions on InnoDB Tables

- `ANALYZE TABLE` determines index cardinality (as displayed in the `Cardinality` column of `SHOW INDEX` output) by performing random dives on each of the index trees and updating index cardinality estimates accordingly. Because these are only estimates, repeated runs of `ANALYZE TABLE` could produce different numbers. This makes `ANALYZE TABLE` fast on `InnoDB` tables but not 100% accurate because it does not take all rows into account.

  You can change the number of random dives by modifying the `innodb_stats_sample_pages` system variable.

  MySQL uses index cardinality estimates in join optimization. If a join is not optimized in the right way, try using `ANALYZE TABLE`. In the few cases that `ANALYZE TABLE` does not produce values good enough for your particular tables, you can use `FORCE INDEX` with your queries to force the use of a particular index, or set the `max_seeks_for_key` system variable to ensure that MySQL prefers index lookups over table scans. See Section B.5.5, “Optimizer-Related Issues”.
- If statements or transactions are running on a table, and `ANALYZE TABLE` is run on the same table followed by a second `ANALYZE TABLE` operation, the second `ANALYZE TABLE` operation is blocked until the statements or transactions are completed. This behavior occurs because `ANALYZE TABLE` marks the currently loaded table definition as obsolete when `ANALYZE TABLE` is finished running. New statements or transactions (including a second `ANALYZE TABLE` statement) must load the new table definition into the table cache, which cannot occur until currently running statements or transactions are completed and the old table definition is purged. Loading multiple concurrent table definitions is not supported.
- `SHOW TABLE STATUS` does not give accurate statistics on `InnoDB` tables except for the physical size reserved by the table. The row count is only a rough estimate used in SQL optimization.
- `InnoDB` does not keep an internal count of rows in a table because concurrent transactions might “see” different numbers of rows at the same time. Consequently, `SELECT COUNT(*)` statements only count rows visible to the current transaction.

  To process a `SELECT COUNT(*)` statement, `InnoDB` scans an index of the table, which takes some time if the index is not entirely in the buffer pool. For a faster count, you can create a counter table

and let your application update it according to the inserts and deletes it does. However, this method may not scale well in situations where thousands of concurrent transactions are initiating updates to the same counter table. If an approximate row count is sufficient, `SHOW TABLE STATUS` can be used.

`InnoDB` handles `SELECT COUNT(*)` and `SELECT COUNT(1)` operations in the same way. There is no performance difference.

- On Windows, `InnoDB` always stores database and table names internally in lowercase. To move databases in a binary format from Unix to Windows or from Windows to Unix, create all databases and tables using lowercase names.
- An `AUTO_INCREMENT` column *`ai_col`* must be defined as part of an index such that it is possible to perform the equivalent of an indexed `SELECT MAX(ai_col)` lookup on the table to obtain the maximum column value. Typically, this is achieved by making the column the first column of some table index.
- `InnoDB` sets an exclusive lock on the end of the index associated with the `AUTO_INCREMENT` column while initializing a previously specified `AUTO_INCREMENT` column on a table.

  With `innodb_autoinc_lock_mode=0`, `InnoDB` uses a special `AUTO-INC` table lock mode where the lock is obtained and held to the end of the current SQL statement while accessing the auto-increment counter. Other clients cannot insert into the table while the `AUTO-INC` table lock is held. The same behavior occurs for "bulk inserts" with `innodb_autoinc_lock_mode=1`. Table-level `AUTO-INC` locks are not used with `innodb_autoinc_lock_mode=2`. For more information, See Section 14.11.1.5, "AUTO_INCREMENT Handling in InnoDB".
- When you restart the MySQL server, `InnoDB` may reuse an old value that was generated for an `AUTO_INCREMENT` column but never stored (that is, a value that was generated during an old transaction that was rolled back).
- When an `AUTO_INCREMENT` integer column runs out of values, a subsequent `INSERT` operation returns a duplicate-key error. This is general MySQL behavior.
- `DELETE FROM tbl_name` does not regenerate the table but instead deletes all rows, one by one.
- Under some conditions, `TRUNCATE tbl_name` for an `InnoDB` table is mapped to `DELETE FROM tbl_name`. See Section 13.1.33, "TRUNCATE TABLE Syntax".
- Cascaded foreign key actions do not activate triggers.
- You cannot create a table with a column name that matches the name of an internal `InnoDB` column (including `DB_ROW_ID`, `DB_TRX_ID`, `DB_ROLL_PTR`, and `DB_MIX_ID`). This restriction applies to use of the names in any letter case.

```
mysql> CREATE TABLE t1 (c1 INT, db_row_id INT) ENGINE=INNODB;
ERROR 1166 (42000): Incorrect column name 'db_row_id'
```

Locking and Transactions

- `LOCK TABLES` acquires two locks on each table if `innodb_table_locks=1` (the default). In addition to a table lock on the MySQL layer, it also acquires an `InnoDB` table lock. Versions of MySQL before 4.1.2 did not acquire `InnoDB` table locks; the old behavior can be selected by setting `innodb_table_locks=0`. If no `InnoDB` table lock is acquired, `LOCK TABLES` completes even if some records of the tables are being locked by other transactions.

  As of MySQL 5.5.3, `innodb_table_locks=0` has no effect for tables locked explicitly with `LOCK TABLES ... WRITE`. It still has an effect for tables locked for read or write by `LOCK TABLES ... WRITE` implicitly (for example, through triggers) or by `LOCK TABLES ... READ`.

- All InnoDB locks held by a transaction are released when the transaction is committed or aborted. Thus, it does not make much sense to invoke LOCK TABLES on InnoDB tables in autocommit=1 mode because the acquired InnoDB table locks would be released immediately.
- You cannot lock additional tables in the middle of a transaction because LOCK TABLES performs an implicit COMMIT and UNLOCK TABLES.
- The limit of 1023 concurrent data-modifying transactions has been raised in MySQL 5.5 and above. The limit is now 128 * 1023 concurrent transactions that generate undo records. You can remove any workarounds that require changing the proper structure of your transactions, such as committing more frequently.

14.11.2 InnoDB Indexes

This section covers topics related to InnoDB indexes.

14.11.2.1 Clustered and Secondary Indexes

Every InnoDB table has a special index called the clustered index where the data for the rows is stored. Typically, the clustered index is synonymous with the primary key. To get the best performance from queries, inserts, and other database operations, you must understand how InnoDB uses the clustered index to optimize the most common lookup and DML operations for each table.

- When you define a PRIMARY KEY on your table, InnoDB uses it as the clustered index. Define a primary key for each table that you create. If there is no logical unique and non-null column or set of columns, add a new auto-increment column, whose values are filled in automatically.
- If you do not define a PRIMARY KEY for your table, MySQL locates the first UNIQUE index where all the key columns are NOT NULL and InnoDB uses it as the clustered index.
- If the table has no PRIMARY KEY or suitable UNIQUE index, InnoDB internally generates a hidden clustered index on a synthetic column containing row ID values. The rows are ordered by the ID that InnoDB assigns to the rows in such a table. The row ID is a 6-byte field that increases monotonically as new rows are inserted. Thus, the rows ordered by the row ID are physically in insertion order.

How the Clustered Index Speeds Up Queries

Accessing a row through the clustered index is fast because the index search leads directly to the page with all the row data. If a table is large, the clustered index architecture often saves a disk I/O operation when compared to storage organizations that store row data using a different page from the index record.

How Secondary Indexes Relate to the Clustered Index

All indexes other than the clustered index are known as secondary indexes. In InnoDB, each record in a secondary index contains the primary key columns for the row, as well as the columns specified for the secondary index. InnoDB uses this primary key value to search for the row in the clustered index.

If the primary key is long, the secondary indexes use more space, so it is advantageous to have a short primary key.

For guidelines to take advantage of InnoDB clustered and secondary indexes, see Section 8.3, “Optimization and Indexes”.

14.11.2.2 The Physical Structure of an InnoDB Index

All InnoDB indexes are B-trees where the index records are stored in the leaf pages of the tree. The default size of an index page is 16KB.

When new records are inserted into an InnoDB clustered index, InnoDB tries to leave 1/16 of the page free for future insertions and updates of the index records. If index records are inserted in a sequential

order (ascending or descending), the resulting index pages are about 15/16 full. If records are inserted in a random order, the pages are from 1/2 to 15/16 full. If the fill factor of an index page drops below 1/2, `InnoDB` tries to contract the index tree to free the page.

Changing the `InnoDB` page size is not a supported operation and there is no guarantee that `InnoDB` functions normally with a page size other than 16KB. Problems compiling or running `InnoDB` may occur. In particular, `ROW_FORMAT=COMPRESSED` in the Barracuda file format assumes that the page size is at most 16KB and uses 14-bit pointers.

An instance using a particular `InnoDB` page size cannot use data files or log files from an instance that uses a different page size.

14.12 InnoDB Table Compression

By using the SQL syntax and InnoDB configuration options for compression, you can create tables where the data is stored in compressed form. Compression can help to improve both raw performance and scalability. The compression means less data is transferred between disk and memory, and takes up less space on disk and in memory. The benefits are amplified for tables with secondary indexes, because index data is compressed also. Compression can be especially important for SSD storage devices, because they tend to have lower capacity than HDD devices.

14.12.1 Overview of Table Compression

Because processors and cache memories have increased in speed more than disk storage devices, many workloads are disk-bound. Data compression enables smaller database size, reduced I/O, and improved throughput, at the small cost of increased CPU utilization. Compression is especially valuable for read-intensive applications, on systems with enough RAM to keep frequently used data in memory.

An InnoDB table created with `ROW_FORMAT=COMPRESSED` can use a smaller page size on disk than the usual 16KB default. Smaller pages require less I/O to read from and write to disk, which is especially valuable for SSD devices.

The page size is specified through the `KEY_BLOCK_SIZE` parameter. The different page size means the table must be in its own `.ibd` file rather than in the system tablespace, which requires enabling the `innodb_file_per_table` option. The level of compression is the same regardless of the `KEY_BLOCK_SIZE` value. As you specify smaller values for `KEY_BLOCK_SIZE`, you get the I/O benefits of increasingly smaller pages. But if you specify a value that is too small, there is additional overhead to reorganize the pages when data values cannot be compressed enough to fit multiple rows in each page. There is a hard limit on how small `KEY_BLOCK_SIZE` can be for a table, based on the lengths of the key columns for each of its indexes. Specify a value that is too small, and the `CREATE TABLE` or `ALTER TABLE` statement fails.

In the buffer pool, the compressed data is held in small pages, with a page size based on the `KEY_BLOCK_SIZE` value. For extracting or updating the column values, MySQL also creates a 16KB page in the buffer pool with the uncompressed data. Within the buffer pool, any updates to the uncompressed page are also re-written back to the equivalent compressed page. You might need to size your buffer pool to accommodate the additional data of both compressed and uncompressed pages, although the uncompressed pages are evicted from the buffer pool when space is needed, and then uncompressed again on the next access.

14.12.2 Enabling Compression for a Table

Before creating a compressed table, make sure the `innodb_file_per_table` configuration option is enabled, and `innodb_file_format` is set to `Barracuda`. You can set these parameters in the MySQL configuration file `my.cnf` or `my.ini`, or with the `SET` statement without shutting down the MySQL server.

To enable compression for a table, you use the clauses `ROW_FORMAT=COMPRESSED`, `KEY_BLOCK_SIZE`, or both in a `CREATE TABLE` or `ALTER TABLE` statement.

To create a compressed table, you might use statements like these:

```
SET GLOBAL innodb_file_per_table=1;
SET GLOBAL innodb_file_format=Barracuda;
CREATE TABLE t1
 (c1 INT PRIMARY KEY)
 ROW_FORMAT=COMPRESSED
 KEY_BLOCK_SIZE=8;
```

- If you specify `ROW_FORMAT=COMPRESSED`, you can omit `KEY_BLOCK_SIZE`; the default compressed page size of 8KB is used.
- If you specify `KEY_BLOCK_SIZE`, you can omit `ROW_FORMAT=COMPRESSED`; compression is enabled automatically.
- To determine the best value for `KEY_BLOCK_SIZE`, typically you create several copies of the same table with different values for this clause, then measure the size of the resulting `.ibd` files and see how well each performs with a realistic workload.
- For additional performance-related configuration options, see Section 14.12.3, “Tuning Compression for InnoDB Tables”.

The default uncompressed size of InnoDB data pages is 16KB. Depending on the combination of option values, MySQL uses a page size of 1KB, 2KB, 4KB, 8KB, or 16KB for the `.ibd` file of the table. The actual compression algorithm is not affected by the `KEY_BLOCK_SIZE` value; the value determines how large each compressed chunk is, which in turn affects how many rows can be packed into each compressed page.

Setting `KEY_BLOCK_SIZE=16` typically does not result in much compression, since the normal InnoDB page size is 16KB. This setting may still be useful for tables with many long `BLOB`, `VARCHAR` or `TEXT` columns, because such values often do compress well, and might therefore require fewer overflow pages as described in Section 14.12.5, “How Compression Works for InnoDB Tables”.

All indexes of a table (including the clustered index) are compressed using the same page size, as specified in the `CREATE TABLE` or `ALTER TABLE` statement. Table attributes such as `ROW_FORMAT` and `KEY_BLOCK_SIZE` are not part of the `CREATE INDEX` syntax, and are ignored if they are specified (although you see them in the output of the `SHOW CREATE TABLE` statement).

Restrictions on Compressed Tables

Because MySQL versions prior to 5.1 cannot process compressed tables, using compression requires specifying the configuration parameter `innodb_file_format=Barracuda`, to avoid accidentally introducing compatibility issues.

Table compression is also not available for the InnoDB system tablespace. The system tablespace (space 0, the `ibdata*` files) can contain user data, but it also contains internal system information, and therefore is never compressed. Thus, compression applies only to tables (and indexes) stored in their own tablespaces, that is, created with the `innodb_file_per_table` option enabled.

Compression applies to an entire table and all its associated indexes, not to individual rows, despite the clause name `ROW_FORMAT`.

14.12.3 Tuning Compression for InnoDB Tables

Most often, the internal optimizations described in InnoDB Data Storage and Compression ensure that the system runs well with compressed data. However, because the efficiency of compression depends on the nature of your data, you can make decisions that affect the performance of compressed tables:

- Which tables to compress.
- What compressed page size to use.

- Whether to adjust the size of the buffer pool based on run-time performance characteristics, such as the amount of time the system spends compressing and uncompressing data. Whether the workload is more like a data warehouse (primarily queries) or an OLTP system (mix of queries and DML).
- If the system performs DML operations on compressed tables, and the way the data is distributed leads to expensive compression failures at runtime, you might adjust additional advanced configuration options.

Use the guidelines in this section to help make those architectural and configuration choices. When you are ready to conduct long-term testing and put compressed tables into production, see Section 14.12.4, “Monitoring InnoDB Table Compression at Runtime” for ways to verify the effectiveness of those choices under real-world conditions.

When to Use Compression

In general, compression works best on tables that include a reasonable number of character string columns and where the data is read far more often than it is written. Because there are no guaranteed ways to predict whether or not compression benefits a particular situation, always test with a specific workload and data set running on a representative configuration. Consider the following factors when deciding which tables to compress.

Data Characteristics and Compression

A key determinant of the efficiency of compression in reducing the size of data files is the nature of the data itself. Recall that compression works by identifying repeated strings of bytes in a block of data. Completely randomized data is the worst case. Typical data often has repeated values, and so compresses effectively. Character strings often compress well, whether defined in `CHAR`, `VARCHAR`, `TEXT` or `BLOB` columns. On the other hand, tables containing mostly binary data (integers or floating point numbers) or data that is previously compressed (for example JPEG or PNG images) may not generally compress well, significantly or at all.

You choose whether to turn on compression for each InnoDB table. A table and all of its indexes use the same (compressed) page size. It might be that the primary key (clustered) index, which contains the data for all columns of a table, compresses more effectively than the secondary indexes. For those cases where there are long rows, the use of compression might result in long column values being stored “off-page”, as discussed in Section 14.14.3, “DYNAMIC and COMPRESSED Row Formats”. Those overflow pages may compress well. Given these considerations, for many applications, some tables compress more effectively than others, and you might find that your workload performs best only with a subset of tables compressed.

To determine whether or not to compress a particular table, conduct experiments. You can get a rough estimate of how efficiently your data can be compressed by using a utility that implements LZ77 compression (such as `gzip` or WinZip) on a copy of the .ibd file for an uncompressed table. You can expect less compression from a MySQL compressed table than from file-based compression tools, because MySQL compresses data in chunks based on the page size, 16KB by default. In addition to user data, the page format includes some internal system data that is not compressed. File-based compression utilities can examine much larger chunks of data, and so might find more repeated strings in a huge file than MySQL can find in an individual page.

Another way to test compression on a specific table is to copy some data from your uncompressed table to a similar, compressed table (having all the same indexes) and look at the size of the resulting `.ibd` file. For example:

```
USE test;
SET GLOBAL innodb_file_per_table=1;
SET GLOBAL innodb_file_format=Barracuda;
SET GLOBAL autocommit=0;

-- Create an uncompressed table with a million or two rows.
CREATE TABLE big_table AS SELECT * FROM information_schema.columns;
INSERT INTO big_table SELECT * FROM big_table;
```

```
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
INSERT INTO big_table SELECT * FROM big_table;
COMMIT;
ALTER TABLE big_table ADD id int unsigned NOT NULL PRIMARY KEY auto_increment;

SHOW CREATE TABLE big_table\G

select count(id) from big_table;

-- Check how much space is needed for the uncompressed table.
\! ls -l data/test/big_table.ibd

CREATE TABLE key_block_size_4 LIKE big_table;
ALTER TABLE key_block_size_4 key_block_size=4 row_format=compressed;

INSERT INTO key_block_size_4 SELECT * FROM big_table;
commit;

-- Check how much space is needed for a compressed table
-- with particular compression settings.
\! ls -l data/test/key_block_size_4.ibd
```

This experiment produced the following numbers, which of course could vary considerably depending on your table structure and data:

```
-rw-rw----  1 cirrus  staff  310378496 Jan  9 13:44 data/test/big_table.ibd
-rw-rw----  1 cirrus  staff  83886080 Jan  9 15:10 data/test/key_block_size_4.ibd
```

To see whether compression is efficient for your particular workload, use a MySQL instance with no other compressed tables and run queries against the `INFORMATION_SCHEMA.INNODB_CMP` table. For exmaple, you examine the ratio of successful compression operations to overall compression operations. (In the `INNODB_CMP` table, compare `COMPRESS_OPS` to `COMPRESS_OPS_OK`. See `INNODB_CMP` for more information.) If a high percentage of compression operations complete successfully, the table might be a good candidate for compression.

Compression and Application and Schema Design

Decide whether to compress data in your application or in the table; do not use both types of compression for the same data. When you compress the data in the application and store the results in a compressed table, extra space savings are extremely unlikely, and the double compression just wastes CPU cycles.

Compressing in the Database

The InnoDB table compression is automatic and applies to all columns and index values. The columns can still be tested with operators such as `LIKE`, and sort operations can still use indexes even when the index values are compressed. Because indexes are often a significant fraction of the total size of a database, compression could result in significant savings in storage, I/O or processor time. The compression and decompression operations happen on the database server, which likely is a powerful system that is sized to handle the expected load.

Compressing in the Application

If you compress data such as text in your application, before it is inserted into the database, You might save overhead for data that does not compress well by compressing some columns and not others. This approach uses CPU cycles for compression and uncompression on the client machine rather than the database server, which might be appropriate for a distributed application with many clients, or where the client machine has spare CPU cycles.

Hybrid Approach

Of course, it is possible to combine these approaches. For some applications, it may be appropriate to use some compressed tables and some uncompressed tables. It may be best to externally compress some data (and store it in uncompressed InnoDB tables) and allow InnoDB to compress (some of) the other tables in the application. As always, up-front design and real-life testing are valuable in reaching the right decision.

Workload Characteristics and Compression

In addition to choosing which tables to compress (and the page size), the workload is another key determinant of performance. If the application is dominated by reads, rather than updates, fewer pages need to be reorganized and recompressed after the index page runs out of room for the per-page "modification log" that InnoDB maintains for compressed data. If the updates predominantly change non-indexed columns or those containing `BLOB`s or large strings that happen to be stored "off-page", the overhead of compression may be acceptable. If the only changes to a table are `INSERT`s that use a monotonically increasing primary key, and there are few secondary indexes, there is little need to reorganize and recompress index pages. Since InnoDB can "delete-mark" and delete rows on compressed pages "in place" by modifying uncompressed data, `DELETE` operations on a table are relatively efficient.

For some environments, the time it takes to load data can be as important as run-time retrieval. Especially in data warehouse environments, many tables may be read-only or read-mostly. In those cases, it might or might not be acceptable to pay the price of compression in terms of increased load time, unless the resulting savings in fewer disk reads or in storage cost is significant.

Fundamentally, compression works best when the CPU time is available for compressing and uncompressing data. Thus, if your workload is I/O bound, rather than CPU-bound, you might find that compression can improve overall performance. When you test your application performance with different compression configurations, test on a platform similar to the planned configuration of the production system.

Configuration Characteristics and Compression

Reading and writing database pages from and to disk is the slowest aspect of system performance. Compression attempts to reduce I/O by using CPU time to compress and uncompress data, and is most effective when I/O is a relatively scarce resource compared to processor cycles.

This is often especially the case when running in a multi-user environment with fast, multi-core CPUs. When a page of a compressed table is in memory, InnoDB often uses an additional 16K in the buffer pool for an uncompressed copy of the page. The adaptive LRU algorithm in the InnoDB storage engine attempts to balance the use of memory between compressed and uncompressed pages to take into account whether the workload is running in an I/O-bound or CPU-bound manner. Still, a configuration with more memory dedicated to the InnoDB buffer pool tends to run better when using compressed tables than a configuration where memory is highly constrained.

Choosing the Compressed Page Size

The optimal setting of the compressed page size depends on the type and distribution of data that the table and its indexes contain. The compressed page size should always be bigger than the maximum record size, or operations may fail as noted in Compression of B-Tree Pages.

Setting the compressed page size too large wastes some space, but the pages do not have to be compressed as often. If the compressed page size is set too small, inserts or updates may require time-consuming recompression, and the B-tree nodes may have to be split more frequently, leading to bigger data files and less efficient indexing.

Typically, you set the compressed page size to 8K or 4K bytes. Given that the maximum row size for an InnoDB table is around 8K, `KEY_BLOCK_SIZE=8` is usually a safe choice.

14.12.4 Monitoring InnoDB Table Compression at Runtime

Overall application performance, CPU and I/O utilization and the size of disk files are good indicators of how effective compression is for your application. This section builds on the performance tuning advice from Section 14.12.3, “Tuning Compression for InnoDB Tables”, and shows how to find problems that might not turn up during initial testing.

To dig deeper into performance considerations for compressed tables, you can monitor compression performance at runtime using the Information Schema tables described in Example 14.1, “Using the Compression Information Schema Tables”. These tables reflect the internal use of memory and the rates of compression used overall.

The `INNODB_CMP` table reports information about compression activity for each compressed page size (`KEY_BLOCK_SIZE`) in use. The information in these tables is system-wide: it summarizes the compression statistics across all compressed tables in your database. You can use this data to help decide whether or not to compress a table by examining these tables when no other compressed tables are being accessed. It involves relatively low overhead on the server, so you might query it periodically on a production server to check the overall efficiency of the compression feature.

The key statistics to consider are the number of, and amount of time spent performing, compression and uncompression operations. Since InnoDB must split B-tree nodes when they are too full to contain the compressed data following a modification, compare the number of “successful” compression operations with the number of such operations overall. Based on the information in the `INNODB_CMP` tables and overall application performance and hardware resource utilization, you might make changes in your hardware configuration, adjust the size of the InnoDB buffer pool, choose a different page size, or select a different set of tables to compress.

If the amount of CPU time required for compressing and uncompressing is high, changing to faster CPUs, or those with more cores, can help improve performance with the same data, application workload and set of compressed tables. Increasing the size of the InnoDB buffer pool might also help performance, so that more uncompressed pages can stay in memory, reducing the need to uncompress pages that exist in memory only in compressed form.

A large number of compression operations overall (compared to the number of `INSERT`, `UPDATE` and `DELETE` operations in your application and the size of the database) could indicate that some of your compressed tables are being updated too heavily for effective compression. If so, choose a larger page size, or be more selective about which tables you compress.

If the number of “successful” compression operations (`COMPRESS_OPS_OK`) is a high percentage of the total number of compression operations (`COMPRESS_OPS`), then the system is likely performing well. If the ratio is low, then InnoDB is reorganizing, recompressing, and splitting B-tree nodes more often than is desirable. In this case, avoid compressing some tables, or increase `KEY_BLOCK_SIZE` for some of the compressed tables. You might turn off compression for tables that cause the number of “compression failures” in your application to be more than 1% or 2% of the total. (Such a failure ratio might be acceptable during a temporary operation such as a data load).

14.12.5 How Compression Works for InnoDB Tables

This section describes some internal implementation details about compression for InnoDB tables. The information presented here may be helpful in tuning for performance, but is not necessary to know for basic use of compression.

Compression Algorithms

Some operating systems implement compression at the file system level. Files are typically divided into fixed-size blocks that are compressed into variable-size blocks, which easily leads into fragmentation. Every time something inside a block is modified, the whole block is recompressed before it is written to disk. These properties make this compression technique unsuitable for use in an update-intensive database system.

InnoDB implements compression with the help of the well-known zlib library, which implements the LZ77 compression algorithm. This compression algorithm is mature, robust, and efficient in both CPU utilization and in reduction of data size. The algorithm is “lossless”, so that the original uncompressed

data can always be reconstructed from the compressed form. LZ77 compression works by finding sequences of data that are repeated within the data to be compressed. The patterns of values in your data determine how well it compresses, but typical user data often compresses by 50% or more.

Note

InnoDB supports the `zlib` library only up to version 1.2.3.

Unlike compression performed by an application, or compression features of some other database management systems, InnoDB compression applies both to user data and to indexes. In many cases, indexes can constitute 40-50% or more of the total database size, so this difference is significant. When compression is working well for a data set, the size of the InnoDB data files (the `.idb` files) is 25% to 50% of the uncompressed size or possibly smaller. Depending on the workload, this smaller database can in turn lead to a reduction in I/O, and an increase in throughput, at a modest cost in terms of increased CPU utilization.

InnoDB Data Storage and Compression

All user data in InnoDB tables is stored in pages comprising a B-tree index (the clustered index). In some other database systems, this type of index is called an “index-organized table”. Each row in the index node contains the values of the (user-specified or system-generated) primary key and all the other columns of the table.

Secondary indexes in InnoDB tables are also B-trees, containing pairs of values: the index key and a pointer to a row in the clustered index. The pointer is in fact the value of the primary key of the table, which is used to access the clustered index if columns other than the index key and primary key are required. Secondary index records must always fit on a single B-tree page.

The compression of B-tree nodes (of both clustered and secondary indexes) is handled differently from compression of overflow pages used to store long `VARCHAR`, `BLOB`, or `TEXT` columns, as explained in the following sections.

Compression of B-Tree Pages

Because they are frequently updated, B-tree pages require special treatment. It is important to minimize the number of times B-tree nodes are split, as well as to minimize the need to uncompress and recompress their content.

One technique InnoDB uses is to maintain some system information in the B-tree node in uncompressed form, thus facilitating certain in-place updates. For example, this allows rows to be delete-marked and deleted without any compression operation.

In addition, InnoDB attempts to avoid unnecessary uncompression and recompression of index pages when they are changed. Within each B-tree page, the system keeps an uncompressed “modification log” to record changes made to the page. Updates and inserts of small records may be written to this modification log without requiring the entire page to be completely reconstructed.

When the space for the modification log runs out, InnoDB uncompresses the page, applies the changes and recompresses the page. If recompression fails (a situation known as a compression failure), the B-tree nodes are split and the process is repeated until the update or insert succeeds.

Generally, InnoDB requires that each B-tree page can accommodate at least two records. For compressed tables, this requirement has been relaxed. Leaf pages of B-tree nodes (whether of the primary key or secondary indexes) only need to accommodate one record, but that record must fit in uncompressed form, in the per-page modification log. Starting with InnoDB storage engine version 1.0.2, and if `innodb_strict_mode` is `ON`, the InnoDB storage engine checks the maximum row size during `CREATE TABLE` or `CREATE INDEX`. If the row does not fit, the following error message is issued: `ERROR HY000: Too big row`.

If you create a table when `innodb_strict_mode` is OFF, and a subsequent `INSERT` or `UPDATE` statement attempts to create an index entry that does not fit in the size of the compressed page, the

operation fails with `ERROR 42000: Row size too large`. (This error message does not name the index for which the record is too large, or mention the length of the index record or the maximum record size on that particular index page.) To solve this problem, rebuild the table with `ALTER TABLE` and select a larger compressed page size (`KEY_BLOCK_SIZE`), shorten any column prefix indexes, or disable compression entirely with `ROW_FORMAT=DYNAMIC` or `ROW_FORMAT=COMPACT`.

Compressing BLOB, VARCHAR, and TEXT Columns

In an InnoDB table, `BLOB`, `VARCHAR`, and `TEXT` columns that are not part of the primary key may be stored on separately allocated overflow pages. We refer to these columns as off-page columns. Their values are stored on singly-linked lists of overflow pages.

For tables created in `ROW_FORMAT=DYNAMIC` or `ROW_FORMAT=COMPRESSED`, the values of `BLOB`, `TEXT`, or `VARCHAR` columns may be stored fully off-page, depending on their length and the length of the entire row. For columns that are stored off-page, the clustered index record only contains 20-byte pointers to the overflow pages, one per column. Whether any columns are stored off-page depends on the page size and the total size of the row. When the row is too long to fit entirely within the page of the clustered index, MySQL chooses the longest columns for off-page storage until the row fits on the clustered index page. As noted above, if a row does not fit by itself on a compressed page, an error occurs.

Note

For tables created in `ROW_FORMAT=DYNAMIC` or `ROW_FORMAT=COMPRESSED`, `TEXT` and `BLOB` columns that are less than or equal to 40 bytes are always stored in-line.

Tables created in older versions of InnoDB use the Antelope file format, which supports only `ROW_FORMAT=REDUNDANT` and `ROW_FORMAT=COMPACT`. In these formats, MySQL stores the first 768 bytes of `BLOB`, `VARCHAR`, and `TEXT` columns in the clustered index record along with the primary key. The 768-byte prefix is followed by a 20-byte pointer to the overflow pages that contain the rest of the column value.

When a table is in `COMPRESSED` format, all data written to overflow pages is compressed “as is”; that is, InnoDB applies the zlib compression algorithm to the entire data item. Other than the data, compressed overflow pages contain an uncompressed header and trailer comprising a page checksum and a link to the next overflow page, among other things. Therefore, very significant storage savings can be obtained for longer `BLOB`, `TEXT`, or `VARCHAR` columns if the data is highly compressible, as is often the case with text data. Image data, such as `JPEG`, is typically already compressed and so does not benefit much from being stored in a compressed table; the double compression can waste CPU cycles for little or no space savings.

The overflow pages are of the same size as other pages. A row containing ten columns stored off-page occupies ten overflow pages, even if the total length of the columns is only 8K bytes. In an uncompressed table, ten uncompressed overflow pages occupy 160K bytes. In a compressed table with an 8K page size, they occupy only 80K bytes. Thus, it is often more efficient to use compressed table format for tables with long column values.

Using a 16K compressed page size can reduce storage and I/O costs for `BLOB`, `VARCHAR`, or `TEXT` columns, because such data often compress well, and might therefore require fewer overflow pages, even though the B-tree nodes themselves take as many pages as in the uncompressed form.

Compression and the InnoDB Buffer Pool

In a compressed InnoDB table, every compressed page (whether 1K, 2K, 4K or 8K) corresponds to an uncompressed page of 16K bytes. To access the data in a page, InnoDB reads the compressed page from disk if it is not already in the buffer pool, then uncompresses the page to its original form. This section describes how InnoDB manages the buffer pool with respect to pages of compressed tables.

To minimize I/O and to reduce the need to uncompress a page, at times the buffer pool contains both the compressed and uncompressed form of a database page. To make room for other required

database pages, InnoDB may evict from the buffer pool an uncompressed page, while leaving the compressed page in memory. Or, if a page has not been accessed in a while, the compressed form of the page might be written to disk, to free space for other data. Thus, at any given time, the buffer pool might contain both the compressed and uncompressed forms of the page, or only the compressed form of the page, or neither.

InnoDB keeps track of which pages to keep in memory and which to evict using a least-recently-used (LRU) list, so that hot (frequently accessed) data tends to stay in memory. When compressed tables are accessed, MySQL uses an adaptive LRU algorithm to achieve an appropriate balance of compressed and uncompressed pages in memory. This adaptive algorithm is sensitive to whether the system is running in an I/O-bound or CPU-bound manner. The goal is to avoid spending too much processing time uncompressing pages when the CPU is busy, and to avoid doing excess I/O when the CPU has spare cycles that can be used for uncompressing compressed pages (that may already be in memory). When the system is I/O-bound, the algorithm prefers to evict the uncompressed copy of a page rather than both copies, to make more room for other disk pages to become memory resident. When the system is CPU-bound, MySQL prefers to evict both the compressed and uncompressed page, so that more memory can be used for “hot” pages and reducing the need to uncompress data in memory only in compressed form.

Compression and the InnoDB Redo Log Files

Before a compressed page is written to a data file, MySQL writes a copy of the page to the redo log (if it has been recompressed since the last time it was written to the database). This is done to ensure that redo logs are usable for crash recovery, even in the unlikely case that the `zlib` library is upgraded and that change introduces a compatibility problem with the compressed data. Therefore, some increase in the size of log files, or a need for more frequent checkpoints, can be expected when using compression. The amount of increase in the log file size or checkpoint frequency depends on the number of times compressed pages are modified in a way that requires reorganization and recompression.

Note that compressed tables use a different file format for the redo log and the per-table tablespaces than in MySQL 5.1 and earlier. The MySQL Enterprise Backup product supports this latest Barracuda file format for compressed InnoDB tables.

14.12.6 SQL Compression Syntax Warnings and Errors

Specifying `ROW_FORMAT=COMPRESSED` or `KEY_BLOCK_SIZE` in `CREATE TABLE` or `ALTER TABLE` statements produces the following warnings if the Barracuda file format is not enabled. You can view them with the `SHOW WARNINGS` statement.

Level	Code	Message
Warning	1478	`InnoDB: KEY_BLOCK_SIZE requires innodb_file_per_table.`
Warning	1478	`InnoDB: KEY_BLOCK_SIZE requires innodb_file_format=1`
Warning	1478	`InnoDB: ignoring KEY_BLOCK_SIZE=4.`
Warning	1478	`InnoDB: ROW_FORMAT=COMPRESSED requires innodb_file_per_table.`
Warning	1478	`InnoDB: assuming ROW_FORMAT=COMPACT.`

Notes:

- By default, these messages are only warnings, not errors, and the table is created without compression, as if the options were not specified.
- When `innodb_strict_mode` is enabled, MySQL generates an error, not a warning, for these cases. The table is not created if the current configuration does not permit using compressed tables.

The “non-strict” behavior lets you import a `mysqldump` file into a database that does not support compressed tables, even if the source database contained compressed tables. In that case, MySQL creates the table in `ROW_FORMAT=COMPACT` instead of preventing the operation.

To import the dump file into a new database, and have the tables re-created as they exist in the original database, ensure the server has the proper settings for the configuration parameters `innodb_file_format` and `innodb_file_per_table`.

The attribute `KEY_BLOCK_SIZE` is permitted only when `ROW_FORMAT` is specified as `COMPRESSED` or is omitted. Specifying a `KEY_BLOCK_SIZE` with any other `ROW_FORMAT` generates a warning that you can view with `SHOW WARNINGS`. However, the table is non-compressed; the specified `KEY_BLOCK_SIZE` is ignored).

Level	Code	Message
Warning	1478	`InnoDB: ignoring KEY_BLOCK_SIZE=`*n*` unless ROW_FORMAT=COMPRESSED.`

If you are running with `innodb_strict_mode` enabled, the combination of a `KEY_BLOCK_SIZE` with any `ROW_FORMAT` other than `COMPRESSED` generates an error, not a warning, and the table is not created.

Table 14.4, "ROW_FORMAT and KEY_BLOCK_SIZE Options" provides an overview the `ROW_FORMAT` and `KEY_BLOCK_SIZE` options that are used with `CREATE TABLE` or `ALTER TABLE`.

Table 14.4 ROW_FORMAT and KEY_BLOCK_SIZE Options

Option	Usage Notes	Description
`ROW_FORMAT=REDUNDANT`	Storage format used prior to MySQL 5.0.3	Less efficient than `ROW_FORMAT=COMPACT`; for backward compatibility
`ROW_FORMAT=COMPACT`	Default storage format since MySQL 5.0.3	Stores a prefix of 768 bytes of long column values in the clustered index page, with the remaining bytes stored in an overflow page
`ROW_FORMAT=DYNAMIC`	Available only with `innodb_file_format=Barracuda`	Store values within the clustered index page if they fit; if not, stores only a 20-byte pointer to an overflow page (no prefix)
`ROW_FORMAT=COMPRESSED`	Available only with `innodb_file_format=Barracuda`	Compresses the table and indexes using zlib to default compressed page size of 8K bytes
`KEY_BLOCK_SIZE=`*n*	Available only with `innodb_file_format=Barracuda`	Specifies compressed page size of 1, 2, 4, 8 or 16 kilobytes; implies `ROW_FORMAT=COMPRESSED`

Table 14.5, "CREATE/ALTER TABLE Warnings and Errors when InnoDB Strict Mode is OFF" summarizes error conditions that occur with certain combinations of configuration parameters and options on the `CREATE TABLE` or `ALTER TABLE` statements, and how the options appear in the output of `SHOW TABLE STATUS`.

When `innodb_strict_mode` is `OFF`, InnoDB creates or alters the table, but ignores certain settings as shown below. You can see the warning messages in the MySQL error log. When `innodb_strict_mode` is `ON`, these specified combinations of options generate errors, and the table is not created or altered. To see the full description of the error condition, issue the `SHOW ERRORS` statement: example:

```
mysql> CREATE TABLE x (id INT PRIMARY KEY, c INT)

-> ENGINE=INNODB KEY_BLOCK_SIZE=33333;

ERROR 1005 (HY000): Can't create table 'test.x' (errno: 1478)

mysql> SHOW ERRORS;
+-------+------+-----------------------------------------+
| Level | Code | Message                                 |
+-------+------+-----------------------------------------+
```

```
| Error | 1478 | InnoDB: invalid KEY_BLOCK_SIZE=33333.     |
| Error | 1005 | Can't create table 'test.x' (errno: 1478) |
+-------+------+-------------------------------------------+
```

Table 14.5 CREATE/ALTER TABLE Warnings and Errors when InnoDB Strict Mode is OFF

Syntax	Warning or Error Condition	Resulting `ROW_FORMAT`, as shown in `SHOW TABLE STATUS`
`ROW_FORMAT=REDUNDANT`	None	`REDUNDANT`
`ROW_FORMAT=COMPACT`	None	`COMPACT`
`ROW_FORMAT=COMPRESSED` or `ROW_FORMAT=DYNAMIC` or `KEY_BLOCK_SIZE` is specified	Ignored unless both `innodb_file_format=Barracuda` and `innodb_file_per_table` are enabled	`COMPACT`
Invalid `KEY_BLOCK_SIZE` is specified (not 1, 2, 4, 8 or 16)	`KEY_BLOCK_SIZE` is ignored	the specified row format, or `COMPACT` by default
`ROW_FORMAT=COMPRESSED` and valid `KEY_BLOCK_SIZE` are specified	None; `KEY_BLOCK_SIZE` specified is used, not the 8K default	`COMPRESSED`
`KEY_BLOCK_SIZE` is specified with `REDUNDANT`, `COMPACT` or `DYNAMIC` row format	`KEY_BLOCK_SIZE` is ignored	`REDUNDANT`, `COMPACT` or `DYNAMIC`
`ROW_FORMAT` is not one of `REDUNDANT`, `COMPACT`, `DYNAMIC` or `COMPRESSED`	Ignored if recognized by the MySQL parser. Otherwise, an error is issued.	`COMPACT` or N/A

When `innodb_strict_mode` is `ON`, the InnoDB storage engine rejects invalid `ROW_FORMAT` or `KEY_BLOCK_SIZE` parameters. For compatibility with earlier versions of MySQL, strict mode is not enabled by default; instead, MySQL issues warnings (not errors) for ignored invalid parameters.

Note that it is not possible to see the chosen `KEY_BLOCK_SIZE` using `SHOW TABLE STATUS`. The statement `SHOW CREATE TABLE` displays the `KEY_BLOCK_SIZE` (even if it was ignored when creating the table). The real compressed page size of the table cannot be displayed by MySQL.

14.13 InnoDB File-Format Management

As `InnoDB` evolves, data file formats that are not compatible with prior versions of `InnoDB` are sometimes required to support new features. To help manage compatibility in upgrade and downgrade situations, and systems that run different versions of MySQL, `InnoDB` uses named file formats. `InnoDB` currently supports two named file formats, Antelope and Barracuda.

- Antelope is the original `InnoDB` file format, which previously did not have a name. It supports COMPACT and REDUNDANT row formats for `InnoDB` tables and is the default file format in MySQL 5.5 to ensure maximum compatibility with earlier MySQL versions that do not support the Barracuda file format.
- Barracuda is the newest file format. It supports all `InnoDB` row formats including the newer COMPRESSED and DYNAMIC row formats. The features associated with COMPRESSED and DYNAMIC row formats include compressed tables and efficient storage of off-page columns. See Section 14.14, “InnoDB Row Storage and Row Formats”.

This section discusses enabling `InnoDB` file formats, verifying compatibility of different file formats between MySQL releases, identifying the file format in use, and downgrading the file format.

14.13.1 Enabling File Formats

The `innodb_file_format` configuration option enables an `InnoDB` file format for file-per-table tablespaces.

`Antelope` is the default `innodb_file_format`.

To preclude the use of features supported by the Barracuda file that make your database inaccessible to the built-in `InnoDB` in MySQL 5.1 and prior releases, set `innodb_file_format` to `Antelope`. Alternatively, you can disable `innodb_file_per_table` to have new tables created in the system tablespace. The system tablespace is stored in the original Antelope file format.

You can set the value of `innodb_file_format` on the command line when you start `mysqld`, or in the option file (`my.cnf` on Unix, `my.ini` on Windows). You can also change it dynamically with a `SET GLOBAL` statement.

```
SET GLOBAL innodb_file_format=Barracuda;
```

Although Oracle recommends using the Barracuda format for new tables where practical, in MySQL 5.5 the default file format is Antelope, for maximum compatibility with replication configurations containing earlier MySQL releases.

14.13.2 Verifying File Format Compatibility

InnoDB incorporates several checks to guard against the possible crashes and data corruptions that might occur if you run an old release of the MySQL server on InnoDB data files that use a newer file format. These checks take place when the server is started, and when you first access a table. This section describes these checks, how you can control them, and error and warning conditions that might arise.

Backward Compatibility

You only need to consider backward file format compatibility when using a recent version of InnoDB (the InnoDB Plugin, or MySQL 5.5 and higher with InnoDB) alongside an older version (MySQL 5.1 or earlier, with the built-in InnoDB rather than the InnoDB Plugin). To minimize the chance of compatibility issues, you can standardize on the InnoDB Plugin for all your MySQL 5.1 and earlier database servers.

In general, a newer version of InnoDB may create a table or index that cannot safely be read or written with an older version of InnoDB without risk of crashes, hangs, wrong results or corruptions. MySQL 5.5 and higher with InnoDB includes a mechanism to guard against these conditions, and to help preserve compatibility among database files and versions of InnoDB. This mechanism lets you take advantage of some new features of an InnoDB release (such as performance improvements and bug fixes), and still preserve the option of using your database with a prior version of InnoDB, by preventing accidental use of new features that create downward-incompatible disk files.

If a version of InnoDB supports a particular file format (whether or not that format is the default), you can query and update any table that requires that format or an earlier format. Only the creation of new tables using new features is limited based on the particular file format enabled. Conversely, if a tablespace contains a table or index that uses a file format that is not supported, it cannot be accessed at all, even for read access.

The only way to “downgrade” an InnoDB tablespace to the earlier Antelope file format is to copy the data to a new table, in a tablespace that uses the earlier format. This can be done with the `ALTER TABLE` statement, as described in Section 14.13.4, “Downgrading the File Format”.

The easiest way to determine the file format of an existing InnoDB tablespace is to examine the properties of the table it contains, using the `SHOW TABLE STATUS` command or querying the table `INFORMATION_SCHEMA.TABLES`. If the `Row_format` of the table is reported as `'Compressed'` or `'Dynamic'`, the tablespace containing the table uses the Barracuda format. Otherwise, it uses the prior InnoDB file format, Antelope.

Internal Details

Every InnoDB file-per-table tablespace (represented by a `*.ibd` file) file is labeled with a file format identifier. The system tablespace (represented by the `ibdata` files) is tagged with the "highest" file format in use in a group of InnoDB database files, and this tag is checked when the files are opened.

Creating a compressed table, or a table with `ROW_FORMAT=DYNAMIC`, updates the file header of the corresponding file-per-table `.ibd` file and the table type in the InnoDB data dictionary with the identifier for the Barracuda file format. From that point forward, the table cannot be used with a version of InnoDB that does not support the Barracuda file format. To protect against anomalous behavior, InnoDB version 5.0.21 and later performs a compatibility check when the table is opened. (In many cases, the `ALTER TABLE` statement recreates a table and thus changes its properties. The special case of adding or dropping indexes without rebuilding the table is described in Section 14.16, "InnoDB Fast Index Creation".)

Definition of ib-file set

To avoid confusion, for the purposes of this discussion we define the term "ib-file set" to mean the set of operating system files that InnoDB manages as a unit. The ib-file set includes the following files:

- The system tablespace (one or more `ibdata` files) that contain internal system information (including internal catalogs and undo information) and may include user data and indexes.
- Zero or more single-table tablespaces (also called "file per table" files, named `*.ibd` files).
- InnoDB log files; usually two, `ib_logfile0` and `ib_logfile1`. Used for crash recovery and in backups.

An "ib-file set" does not include the corresponding `.frm` files that contain metadata about InnoDB tables. The `.frm` files are created and managed by MySQL, and can sometimes get out of sync with the internal metadata in InnoDB.

Multiple tables, even from more than one database, can be stored in a single "ib-file set". (In MySQL, a "database" is a logical collection of tables, what other systems refer to as a "schema" or "catalog".)

14.13.2.1 Compatibility Check When InnoDB Is Started

To prevent possible crashes or data corruptions when InnoDB opens an ib-file set, it checks that it can fully support the file formats in use within the ib-file set. If the system is restarted following a crash, or a "fast shutdown" (i.e., `innodb_fast_shutdown` is greater than zero), there may be on-disk data structures (such as redo or undo entries, or doublewrite pages) that are in a "too-new" format for the current software. During the recovery process, serious damage can be done to your data files if these data structures are accessed. The startup check of the file format occurs before any recovery process begins, thereby preventing consistency issues with the new tables or startup problems for the MySQL server.

Beginning with version InnoDB 1.0.1, the system tablespace records an identifier or tag for the "highest" file format used by any table in any of the tablespaces that is part of the ib-file set. Checks against this file format tag are controlled by the configuration parameter `innodb_file_format_check`, which is `ON` by default.

If the file format tag in the system tablespace is newer or higher than the highest version supported by the particular currently executing software and if `innodb_file_format_check` is `ON`, the following error is issued when the server is started:

```
InnoDB: Error: the system tablespace is in a
file format that this version doesn't support
```

You can also set `innodb_file_format` to a file format name. Doing so prevents InnoDB from starting if the current software does not support the file format specified. It also sets the "high water mark" to the value you specify. The ability to set `innodb_file_format_check` is useful (with future

releases) if you manually “downgrade” all of the tables in an ib-file set (as described in Section 14.4, “Downgrading the InnoDB Storage Engine”). You can then rely on the file format check at startup if you subsequently use an older version of InnoDB to access the ib-file set.

In some limited circumstances, you might want to start the server and use an ib-file set that is in a new file format that is not supported by the software you are using. If you set the configuration parameter `innodb_file_format_check` to `OFF`, InnoDB opens the database, but issues this warning message in the error log:

```
InnoDB: Warning: the system tablespace is in a
file format that this version doesn't support
```

Note

This is a dangerous setting, as it permits the recovery process to run, possibly corrupting your database if the previous shutdown was a crash or “fast shutdown”. You should only set `innodb_file_format_check` to `OFF` if you are sure that the previous shutdown was done with `innodb_fast_shutdown=0`, so that essentially no recovery process occurs.

The parameter `innodb_file_format_check` affects only what happens when a database is opened, not subsequently. Conversely, the parameter `innodb_file_format` (which enables a specific format) only determines whether or not a new table can be created in the enabled format and has no effect on whether or not a database can be opened.

The file format tag is a “high water mark”, and as such it is increased after the server is started, if a table in a “higher” format is created or an existing table is accessed for read or write (assuming its format is supported). If you access an existing table in a format higher than the format the running software supports, the system tablespace tag is not updated, but table-level compatibility checking applies (and an error is issued), as described in Section 14.13.2.2, “Compatibility Check When a Table Is Opened”. Any time the high water mark is updated, the value of `innodb_file_format_check` is updated as well, so the command `SELECT @@innodb_file_format_check;` displays the name of the latest file format known to be used by tables in the currently open ib-file set and supported by the currently executing software.

14.13.2.2 Compatibility Check When a Table Is Opened

When a table is first accessed, InnoDB (including some releases prior to InnoDB 1.0) checks that the file format of the tablespace in which the table is stored is fully supported. This check prevents crashes or corruptions that would otherwise occur when tables using a “too new” data structure are encountered.

All tables using any file format supported by a release can be read or written (assuming the user has sufficient privileges). The setting of the system configuration parameter `innodb_file_format` can prevent creating a new table that uses a specific file format, even if the file format is supported by a given release. Such a setting might be used to preserve backward compatibility, but it does not prevent accessing any table that uses a supported format.

Versions of MySQL older than 5.0.21 cannot reliably use database files created by newer versions if a new file format was used when a table was created. To prevent various error conditions or corruptions, InnoDB checks file format compatibility when it opens a file (for example, upon first access to a table). If the currently running version of InnoDB does not support the file format identified by the table type in the InnoDB data dictionary, MySQL reports the following error:

```
ERROR 1146 (42S02): Table 'test.t1' doesn't exist
```

InnoDB also writes a message to the error log:

```
InnoDB: table test/t1: unknown table type 33
```

The table type should be equal to the tablespace flags, which contains the file format version as discussed in Section 14.13.3, “Identifying the File Format in Use”.

Versions of InnoDB prior to MySQL 4.1 did not include table format identifiers in the database files, and versions prior to MySQL 5.0.21 did not include a table format compatibility check. Therefore, there is no way to ensure proper operations if a table in a newer file format is used with versions of InnoDB prior to 5.0.21.

The file format management capability in InnoDB 1.0 and higher (tablespace tagging and run-time checks) allows InnoDB to verify as soon as possible that the running version of software can properly process the tables existing in the database.

If you permit InnoDB to open a database containing files in a format it does not support (by setting the parameter `innodb_file_format_check` to `OFF`), the table-level checking described in this section still applies.

Users are *strongly* urged not to use database files that contain Barracuda file format tables with releases of InnoDB older than the MySQL 5.1 with the InnoDB Plugin. It is possible to “downgrade” such tables to the Antelope format with the procedure described in Section 14.13.4, “Downgrading the File Format”.

14.13.3 Identifying the File Format in Use

If you enable a different file format using the `innodb_file_format` configuration option, the change only applies to newly created tables. Also, when you create a new table, the tablespace containing the table is tagged with the “earliest” or “simplest” file format that is required to support the table's features. For example, if you enable the `Barracuda` file format, and create a new table that does not use the Dynamic or Compressed row format, the new tablespace that contains the table is tagged as using the `Antelope` file format .

It is easy to identify the file format used by a given table. The table uses the `Antelope` file format if the row format reported by `SHOW TABLE STATUS` is either `Compact` or `Redundant`. The table uses the `Barracuda` file format if the row format reported by `SHOW TABLE STATUS` is either `Compressed` or `Dynamic`.

```
mysql> SHOW TABLE STATUS\G
*************************** 1. row ***************************
           Name: t1
         Engine: InnoDB
        Version: 10
     Row_format: Compact
           Rows: 0
 Avg_row_length: 0
    Data_length: 16384
Max_data_length: 0
   Index_length: 16384
      Data_free: 0
 Auto_increment: 1
    Create_time: 2014-11-03 13:32:10
    Update_time: NULL
     Check_time: NULL
      Collation: latin1_swedish_ci
       Checksum: NULL
 Create_options:
        Comment:
```

14.13.4 Downgrading the File Format

Each InnoDB tablespace file (with a name matching `*.ibd`) is tagged with the file format used to create its table and indexes. The way to downgrade the tablespace is to re-create the table and its indexes. The easiest way to recreate a table and its indexes is to use the command:

```
ALTER TABLE t ROW_FORMAT=COMPACT;
```

on each table that you want to downgrade. The `COMPACT` row format uses the file format Antelope. It was introduced in MySQL 5.0.3.

14.14 InnoDB Row Storage and Row Formats

This section discusses how InnoDB features such as table compression and off-page storage of long variable-length column values are controlled by the `ROW_FORMAT` clause of the `CREATE TABLE` statement. It also discusses considerations for choosing the right row format, and compatibility of row formats between MySQL releases.

14.14.1 Overview of InnoDB Row Storage

The storage for rows and associated columns affects performance for queries and DML operations. As more rows fit into a single disk page, queries and index lookups can work faster, less cache memory is required in the InnoDB buffer pool, and less I/O is required to write out updated values for the numeric and short string columns.

The data in each InnoDB table is divided into pages. The pages that make up each table are arranged in a tree data structure called a B-tree index. Table data and secondary indexes both use this type of structure. The B-tree index that represents an entire table is known as the clustered index, which is organized according to the primary key columns. The nodes of the index data structure contain the values of all the columns in that row (for the clustered index) or the index columns and the primary key columns (for secondary indexes).

Variable-length columns are an exception to this rule. Columns such as `BLOB` and `VARCHAR` that are too long to fit on a B-tree page are stored on separately allocated disk pages called overflow pages. We call such columns off-page columns. The values of these columns are stored in singly-linked lists of overflow pages, and each such column has its own list of one or more overflow pages. In some cases, all or a prefix of the long column value is stored in the B-tree, to avoid wasting storage and eliminating the need to read a separate page.

The Barracuda file format provides a new option (`KEY_BLOCK_SIZE`) to control how much column data is stored in the clustered index, and how much is placed on overflow pages.

The following sections describe how to configure the row format of `InnoDB` tables to control how variable-length columns values are stored. Row format configuration also determines the availability of the table compression feature.

14.14.2 Specifying the Row Format for a Table

You specify the row format for a table with the `ROW_FORMAT` clause of the `CREATE TABLE` and `ALTER TABLE` statements. For example:

```
CREATE TABLE t1 (f1 int unsigned) ROW_FORMAT=DYNAMIC ENGINE=INNODB;
```

`InnoDB` `ROW_FORMAT` options include COMPACT, REDUNDANT, DYNAMIC, and COMPRESSED. For `InnoDB` tables, rows are stored in `COMPACT` format (`ROW_FORMAT=COMPACT`) by default. Refer to the `CREATE TABLE` documentation for additional information about the `ROW_FORMAT` table option.

The physical row structure of an `InnoDB` table is dependant on the row format. See Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table” for more information.

14.14.3 DYNAMIC and COMPRESSED Row Formats

This section discusses the `DYNAMIC` and `COMPRESSED` row formats for `InnoDB` tables. To create tables that use these row formats, `innodb_file_format` must be set to `Barracuda`, and `innodb_file_per_table` must be enabled. (The Barracuda file format also allows the `COMPACT` and `REDUNDANT` row formats.)

When a table is created with ROW_FORMAT=DYNAMIC or ROW_FORMAT=COMPRESSED, InnoDB can store long variable-length column values (for VARCHAR, VARBINARY, and BLOB and TEXT types) fully off-page, with the clustered index record containing only a 20-byte pointer to the overflow page. InnoDB also encodes fixed-length fields greater than or equal to 768 bytes in length as variable-length fields. For example, a CHAR(255) column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with utf8mb4.

Whether any columns are stored off-page depends on the page size and the total size of the row. When the row is too long, InnoDB chooses the longest columns for off-page storage until the clustered index record fits on the B-tree page. TEXT and BLOB columns that are less than or equal to 40 bytes are always stored in-line.

The DYNAMIC row format maintains the efficiency of storing the entire row in the index node if it fits (as do the COMPACT and REDUNDANT formats), but this new format avoids the problem of filling B-tree nodes with a large number of data bytes of long columns. The DYNAMIC format is based on the idea that if a portion of a long data value is stored off-page, it is usually most efficient to store all of the value off-page. With DYNAMIC format, shorter columns are likely to remain in the B-tree node, minimizing the number of overflow pages needed for any given row.

The COMPRESSED row format uses similar internal details for off-page storage as the DYNAMIC row format, with additional storage and performance considerations from the table and index data being compressed and using smaller page sizes. With the COMPRESSED row format, the option KEY_BLOCK_SIZE controls how much column data is stored in the clustered index, and how much is placed on overflow pages. For full details about the COMPRESSED row format, see Section 14.12, “InnoDB Table Compression”.

ROW_FORMAT=DYNAMIC and ROW_FORMAT=COMPRESSED are variations of ROW_FORMAT=COMPACT and therefore handle CHAR storage in the same way as ROW_FORMAT=COMPACT. For more information, see Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table”.

14.14.4 COMPACT and REDUNDANT Row Formats

Early versions of InnoDB used an unnamed file format (now called Antelope) for database files. With that file format, tables are defined with ROW_FORMAT=COMPACT or ROW_FORMAT=REDUNDANT. With these row formats, InnoDB stores up to the first 768 bytes of variable-length columns (VARCHAR, VARBINARY, and BLOB and TEXT types) in the index record within the B-tree node, with the remainder stored on the overflow pages. InnoDB also encodes fixed-length fields greater than or equal to 768 bytes in length as variable-length fields, which can be stored off-page. For example, a CHAR(255) column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with utf8mb4.

With the Antelope file format, if the value of a column is 768 bytes or less, no overflow page is needed, and some savings in I/O may result, since the value is in the B-tree node. This works well for relatively short BLOBs, but may cause B-tree nodes to fill with data rather than key values, reducing their efficiency. Tables with many BLOB columns could cause B-tree nodes to become too full of data, and contain too few rows, making the entire index less efficient than if the rows were shorter or if the column values were stored off-page.

To preserve compatibility with prior versions of InnoDB, InnoDB tables created in MySQL 5.5 default to the COMPACT row format rather than the newer DYNAMIC row format. See Section 14.14.3, “DYNAMIC and COMPRESSED Row Formats” for more information.

For information about the physical row structure of tables that use the REDUNDANT or COMPACT row format, see Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table”.

14.15 InnoDB Disk I/O and File Space Management

As a DBA, you must manage disk I/O to keep the I/O subsystem from becoming saturated, and manage disk space to avoid filling up storage devices. The ACID design model requires a certain amount of I/O that might seem redundant, but helps to ensure data reliability. Within these constraints,

InnoDB tries to optimize the database work and the organization of disk files to minimize the amount of disk I/O. Sometimes, I/O is postponed until the database is not busy, or until everything needs to be brought to a consistent state, such as during a database restart after a fast shutdown.

This section discusses the main considerations for I/O and disk space with the default kind of MySQL tables (also known as InnoDB tables):

- Controlling the amount of background I/O used to improve query performance.
- Enabling or disabling features that provide extra durability at the expense of additional I/O.
- Organizing tables into many small files, a few larger files, or a combination of both.
- Balancing the size of redo log files against the I/O activity that occurs when the log files become full.
- How to reorganize a table for optimal query performance.

14.15.1 InnoDB Disk I/O

InnoDB uses asynchronous disk I/O where possible, by creating a number of threads to handle I/O operations, while permitting other database operations to proceed while the I/O is still in progress. On Linux and Windows platforms, InnoDB uses the available OS and library functions to perform “native” asynchronous I/O. On other platforms, InnoDB still uses I/O threads, but the threads may actually wait for I/O requests to complete; this technique is known as “simulated” asynchronous I/O.

Read-Ahead

If InnoDB can determine there is a high probability that data might be needed soon, it performs read-ahead operations to bring that data into the buffer pool so that it is available in memory. Making a few large read requests for contiguous data can be more efficient than making several small, spread-out requests. There are two read-ahead heuristics in InnoDB:

- In sequential read-ahead, if InnoDB notices that the access pattern to a segment in the tablespace is sequential, it posts in advance a batch of reads of database pages to the I/O system.
- In random read-ahead, if InnoDB notices that some area in a tablespace seems to be in the process of being fully read into the buffer pool, it posts the remaining reads to the I/O system.

For information about configuring read-ahead heuristics, see Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”.

Doublewrite Buffer

InnoDB uses a novel file flush technique involving a structure called the doublewrite buffer, which is enabled by default (`innodb_doublewrite=ON`). It adds safety to recovery following a crash or power outage, and improves performance on most varieties of Unix by reducing the need for `fsync()` operations.

Before writing pages to a data file, InnoDB first writes them to a contiguous tablespace area called the doublewrite buffer. Only after the write and the flush to the doublewrite buffer has completed does InnoDB write the pages to their proper positions in the data file. If there is an operating system, storage subsystem, or `mysqld` process crash in the middle of a page write (causing a torn page condition), InnoDB can later find a good copy of the page from the doublewrite buffer during recovery.

14.15.2 File Space Management

The data files that you define in the configuration file using the `innodb_data_file_path` configuration option form the InnoDB system tablespace. The files are logically concatenated to form the system tablespace. There is no striping in use. You cannot define where within the system tablespace your tables are allocated. In a newly created system tablespace, InnoDB allocates space starting from the first data file.

To avoid the issues that come with storing all tables and indexes inside the system tablespace, you can enable the `innodb_file_per_table` configuration option, which stores each newly created table in a separate tablespace file (with extension `.ibd`). For tables stored this way, there is less fragmentation within the disk file, and when the table is truncated, the space is returned to the operating system rather than still being reserved by InnoDB within the system tablespace.

Pages, Extents, Segments, and Tablespaces

Each tablespace consists of database pages with a default size of 16KB. The pages are grouped into extents of size 1MB (64 consecutive pages). The "files" inside a tablespace are called segments in `InnoDB`. (These segments are different from the rollback segment, which actually contains many tablespace segments.)

When a segment grows inside the tablespace, `InnoDB` allocates the first 32 pages to it one at a time. After that, `InnoDB` starts to allocate whole extents to the segment. `InnoDB` can add up to 4 extents at a time to a large segment to ensure good sequentiality of data.

Two segments are allocated for each index in `InnoDB`. One is for nonleaf nodes of the B-tree, the other is for the leaf nodes. Keeping the leaf nodes contiguous on disk enables better sequential I/O operations, because these leaf nodes contain the actual table data.

Some pages in the tablespace contain bitmaps of other pages, and therefore a few extents in an `InnoDB` tablespace cannot be allocated to segments as a whole, but only as individual pages.

When you ask for available free space in the tablespace by issuing a `SHOW TABLE STATUS` statement, `InnoDB` reports the extents that are definitely free in the tablespace. `InnoDB` always reserves some extents for cleanup and other internal purposes; these reserved extents are not included in the free space.

When you delete data from a table, `InnoDB` contracts the corresponding B-tree indexes. Whether the freed space becomes available for other users depends on whether the pattern of deletes frees individual pages or extents to the tablespace. Dropping a table or deleting all rows from it is guaranteed to release the space to other users, but remember that deleted rows are physically removed only by the purge operation, which happens automatically some time after they are no longer needed for transaction rollbacks or consistent reads. (See Section 14.6, "InnoDB Multi-Versioning".)

To see information about the tablespace, use the Tablespace Monitor. See Section 14.20, "InnoDB Monitors".

How Pages Relate to Table Rows

The maximum row length is slightly less than half a database page. For example, the maximum row length is slightly less than 8KB for the 16KB `InnoDB` page size.

If a row does not exceed the half page limit, all of it is stored locally within the page. If a row exceeds the half page limit, variable-length columns are chosen for external off-page storage until the row fits within half a page. External off-page storage for variable-length columns differs by row format:

- *COMPACT and REDUNDANT Row Formats*

  When a variable-length column is chosen for external off-page storage, `InnoDB` stores the first 768 bytes locally in the row, and the rest externally into overflow pages. Each such column has its own list of overflow pages. The 768-byte prefix is accompanied by a 20-byte value that stores the true length of the column and points into the overflow list where the rest of the value is stored. See Section 14.14.4, "COMPACT and REDUNDANT Row Formats".

- *DYNAMIC and COMPRESSED Row Formats*

  When a variable-length column is chosen for external off-page storage, `InnoDB` stores a 20-byte pointer locally in the row, and the rest externally into overflow pages. See Section 14.14.3, "DYNAMIC and COMPRESSED Row Formats".

LONGBLOB and LONGTEXT columns must be less than 4GB, and the total row length, including BLOB and TEXT columns, must be less than 4GB.

14.15.3 InnoDB Checkpoints

Making your log files very large may reduce disk I/O during checkpointing. It often makes sense to set the total size of the log files as large as the buffer pool or even larger. Although in the past large log files could make crash recovery take excessive time, starting with MySQL 5.5, performance enhancements to crash recovery make it possible to use large log files with fast startup after a crash. (Strictly speaking, this performance improvement is available for MySQL 5.1 with the InnoDB Plugin 1.0.7 and higher. It is with MySQL 5.5 that this improvement is available in the default InnoDB storage engine.)

How Checkpoint Processing Works

InnoDB implements a checkpoint mechanism known as fuzzy checkpointing. InnoDB flushes modified database pages from the buffer pool in small batches. There is no need to flush the buffer pool in one single batch, which would disrupt processing of user SQL statements during the checkpointing process.

During crash recovery, InnoDB looks for a checkpoint label written to the log files. It knows that all modifications to the database before the label are present in the disk image of the database. Then InnoDB scans the log files forward from the checkpoint, applying the logged modifications to the database.

InnoDB writes to its log files on a rotating basis. It also writes checkpoint information to the first log file at each checkpoint. All committed modifications that make the database pages in the buffer pool different from the images on disk must be available in the log files in case InnoDB has to do a recovery. This means that when InnoDB starts to reuse a log file, it has to make sure that the database page images on disk contain the modifications logged in the log file that InnoDB is going to reuse. In other words, InnoDB must create a checkpoint and this often involves flushing of modified database pages to disk.

14.15.4 Defragmenting a Table

Random insertions into or deletions from a secondary index can cause the index to become fragmented. Fragmentation means that the physical ordering of the index pages on the disk is not close to the index ordering of the records on the pages, or that there are many unused pages in the 64-page blocks that were allocated to the index.

One symptom of fragmentation is that a table takes more space than it “should” take. How much that is exactly, is difficult to determine. All InnoDB data and indexes are stored in B-trees, and their fill factor may vary from 50% to 100%. Another symptom of fragmentation is that a table scan such as this takes more time than it “should” take:

```
SELECT COUNT(*) FROM t WHERE non_indexed_column <> 12345;
```

The preceding query requires MySQL to perform a full table scan, the slowest type of query for a large table.

To speed up index scans, you can periodically perform a “null” ALTER TABLE operation, which causes MySQL to rebuild the table:

```
ALTER TABLE tbl_name ENGINE=INNODB
```

Another way to perform a defragmentation operation is to use mysqldump to dump the table to a text file, drop the table, and reload it from the dump file.

If the insertions into an index are always ascending and records are deleted only from the end, the InnoDB filespace management algorithm guarantees that fragmentation in the index does not occur.

14.15.5 Reclaiming Disk Space with TRUNCATE TABLE

To reclaim operating system disk space when truncating an `InnoDB` table, the table must be stored in its own .ibd file. For a table to be stored in its own .ibd file, `innodb_file_per_table` must enabled when the table is created. Additionally, there cannot be a foreign key constraint between the table being truncated and other tables, otherwise the `TRUNCATE TABLE` operation fails. This is a change from previous behavior, which would transform the `TRUNCATE` operation to a `DELETE` operation that removes all rows and triggers `ON DELETE` operations on child tables. A foreign key constraint between two columns in the same table, however, is permitted.

When a table is truncated, it is dropped and re-created in a new `.ibd` file (previous versions of `InnoDB` would keep the existing `.idb` file), and the freed space is returned to the operating system. This is in contrast to truncating `InnoDB` tables that are stored within the `InnoDB` system tablespace (tables created when `innodb_file_per_table=OFF`), where only `InnoDB` can use the freed space after the table is truncated.

The ability to truncate tables and return disk space to the operating system also means that physical backups can be smaller. Truncating tables that are stored in the system tablespace (tables created when `innodb_file_per_table=OFF`) leaves blocks of unused space in the system tablespace.

14.16 InnoDB Fast Index Creation

In MySQL 5.5 and higher, or in MySQL 5.1 with the InnoDB Plugin, creating and dropping secondary indexes does not copy the contents of the entire table, making this operation much more efficient than with prior releases.

14.16.1 Overview of Fast Index Creation

With MySQL 5.5 and higher, or MySQL 5.1 with the InnoDB Plugin, creating and dropping secondary indexes for InnoDB tables is much faster than before. Historically, adding or dropping an index on a table with existing data could be very slow. The `CREATE INDEX` and `DROP INDEX` statements worked by creating a new, empty table defined with the requested set of indexes, then copying the existing rows to the new table one-by-one, updating the indexes as the rows are inserted. After all rows from the original table were copied, the old table was dropped and the copy was renamed with the name of the original table.

The performance speedup for fast index creation applies to secondary indexes, not to the primary key index. The rows of an InnoDB table are stored in a clustered index organized based on the primary key, forming what some database systems call an “index-organized table”. Because the table structure is so closely tied to the primary key, redefining the primary key still requires copying the data.

This new mechanism also means that you can generally speed the overall process of creating and loading an indexed table by creating the table with only the clustered index, and adding the secondary indexes after the data is loaded.

Although no syntax changes are required in the `CREATE INDEX` or `DROP INDEX` commands, some factors affect the performance, space usage, and semantics of this operation (see Section 14.16.6, “Limitations of Fast Index Creation”).

14.16.2 Examples of Fast Index Creation

It is possible to create multiple indexes on a table with one `ALTER TABLE` statement. This is relatively efficient, because the clustered index of the table needs to be scanned only once (although the data is sorted separately for each new index). For example:

```
CREATE TABLE T1(A INT PRIMARY KEY, B INT, C CHAR(1)) ENGINE=InnoDB;
INSERT INTO T1 VALUES (1,2,'a'), (2,3,'b'), (3,2,'c'), (4,3,'d'), (5,2,'e');
COMMIT;
ALTER TABLE T1 ADD INDEX (B), ADD UNIQUE INDEX (C);
```

The above statements create table `T1` with the clustered index (primary key) on column `A`, insert several rows, and then build two new indexes on columns `B` and `C`. If there were many rows inserted into `T1` before the `ALTER TABLE` statement, this approach is much more efficient than creating all the secondary indexes before loading the data.

You can also create the indexes one at a time, but then the clustered index of the table is scanned (as well as sorted) once for each `CREATE INDEX` statement. Thus, the following statements are not as efficient as the `ALTER TABLE` statement above, even though neither requires recreating the clustered index for table `T1`.

```
CREATE INDEX B ON T1 (B);
CREATE UNIQUE INDEX C ON T1 (C);
```

Dropping InnoDB secondary indexes also does not require any copying of table data. You can equally quickly drop multiple indexes with a single `ALTER TABLE` statement or multiple `DROP INDEX` statements:

```
ALTER TABLE T1 DROP INDEX B, DROP INDEX C;
```

or:

```
DROP INDEX B ON T1;
DROP INDEX C ON T1;
```

Restructuring the clustered index in InnoDB always requires copying the data in the table. For example, if you create a table without a primary key, InnoDB chooses one for you, which may be the first `UNIQUE` key defined on `NOT NULL` columns, or a system-generated key. Defining a `PRIMARY KEY` later causes the data to be copied, as in the following example:

```
CREATE TABLE T2 (A INT, B INT) ENGINE=InnoDB;
INSERT INTO T2 VALUES (NULL, 1);
ALTER TABLE T2 ADD PRIMARY KEY (B);
```

When you create a `UNIQUE` or `PRIMARY KEY` index, InnoDB must do some extra work. For `UNIQUE` indexes, InnoDB checks that the table contains no duplicate values for the key. For a `PRIMARY KEY` index, InnoDB also checks that none of the `PRIMARY KEY` columns contains a `NULL`. It is best to define the primary key when you create a table, so you need not rebuild the table later.

14.16.3 Implementation Details of Fast Index Creation

InnoDB has two types of indexes: the clustered index and secondary indexes. Since the clustered index contains the data values in its B-tree nodes, adding or dropping a clustered index does involve copying the data, and creating a new copy of the table. A secondary index, however, contains only the index key and the value of the primary key. This type of index can be created or dropped without copying the data in the clustered index. Because each secondary index contains copies of the primary key values (used to access the clustered index when needed), when you change the definition of the primary key, all secondary indexes are recreated as well.

Dropping a secondary index is simple. Only the internal InnoDB system tables and the MySQL data dictionary tables are updated to reflect the fact that the index no longer exists. InnoDB returns the storage used for the index to the tablespace that contained it, so that new indexes or additional table rows can use the space.

To add a secondary index to an existing table, InnoDB scans the table, and sorts the rows using memory buffers and temporary files in order by the values of the secondary index key columns. The B-tree is then built in key-value order, which is more efficient than inserting rows into an index in random order. Because the B-tree nodes are split when they fill, building the index in this way results in a higher fill-factor for the index, making it more efficient for subsequent access.

14.16.4 Concurrency Considerations for Fast Index Creation

While an InnoDB secondary index is being created or dropped, the table is locked in shared mode. Any writes to the table are blocked, but the data in the table can be read. When you alter the clustered index of a table, the table is locked in exclusive mode, because the data must be copied. Thus, during the creation of a new clustered index, all operations on the table are blocked.

A `CREATE INDEX` or `ALTER TABLE` statement for an InnoDB table always waits for currently executing transactions that are accessing the table to commit or roll back. `ALTER TABLE` statements that redefine an InnoDB primary key wait for all `SELECT` statements that access the table to complete, or their containing transactions to commit. No transactions whose execution spans the creation of the index can be accessing the table, because the original table is dropped when the clustered index is restructured.

Once a `CREATE INDEX` or `ALTER TABLE` statement that creates an InnoDB secondary index begins executing, queries can access the table for read access, but cannot update the table. If an `ALTER TABLE` statement is changing the clustered index for an InnoDB table, all queries wait until the operation completes.

A newly-created InnoDB secondary index contains only the committed data in the table at the time the `CREATE INDEX` or `ALTER TABLE` statement begins to execute. It does not contain any uncommitted values, old versions of values, or values marked for deletion but not yet removed from the old index.

Because a newly-created index contains only information about data current at the time the index was created, queries that need to see data that was deleted or changed before the index was created cannot use the index. The only queries that could be affected by this limitation are those executing in transactions that began before the creation of the index was begun. For such queries, unpredictable results could occur. Newer queries can use the index.

14.16.5 How Crash Recovery Works with Fast Index Creation

Although no data is lost if the server crashes while an `ALTER TABLE` statement is executing, the crash recovery process is different for clustered indexes and secondary indexes.

If the server crashes while creating an InnoDB secondary index, upon recovery, MySQL drops any partially created indexes. You must re-run the `ALTER TABLE` or `CREATE INDEX` statement.

When a crash occurs during the creation of an InnoDB clustered index, recovery is more complicated, because the data in the table must be copied to an entirely new clustered index. Remember that all InnoDB tables are stored as clustered indexes. In the following discussion, we use the word table and clustered index interchangeably.

MySQL creates the new clustered index by copying the existing data from the original InnoDB table to a temporary table that has the desired index structure. Once the data is completely copied to this temporary table, the original table is renamed with a different temporary table name. The temporary table comprising the new clustered index is renamed with the name of the original table, and the original table is dropped from the database.

If a system crash occurs while creating a new clustered index, no data is lost, but you must complete the recovery process using the temporary tables that exist during the process. Since it is rare to re-create a clustered index or re-define primary keys on large tables, or to encounter a system crash during this operation, this manual does not provide information on recovering from this scenario. Contact MySQL support.

14.16.6 Limitations of Fast Index Creation

Take the following considerations into account when creating or dropping InnoDB indexes:

- During index creation, files are written to the temporary directory (`$TMPDIR` on Unix, `%TEMP%` on Windows, or the value of the `--tmpdir` configuration variable). Each temporary file is large enough to hold one column that makes up the new index, and each one is removed as soon as it is merged into the final index.

- An `ALTER TABLE` statement that contains `DROP INDEX` and `ADD INDEX` clauses that both name the same index uses a table copy, not Fast Index Creation.
- The table is copied, rather than using Fast Index Creation when you create an index on a `TEMPORARY TABLE`. This has been reported as MySQL Bug #39833.
- To avoid consistency issues between the InnoDB data dictionary and the MySQL data dictionary, the table is copied rather than using Fast Index Creation when renaming a column using `ALTER TABLE ... CHANGE` syntax.
- The statement `ALTER IGNORE TABLE t ADD UNIQUE INDEX` does not delete duplicate rows. This has been reported as MySQL Bug #40344. The `IGNORE` keyword is ignored. If any duplicate rows exist, the operation fails with the following error message:

```
ERROR 23000: Duplicate entry '347' for key 'pl'
```

- As noted above, a newly-created index contains only information about data current at the time the index was created. Therefore, you should not run queries in a transaction that might use a secondary index that did not exist at the beginning of the transaction. There is no way for InnoDB to access "old" data that is consistent with the rest of the data read by the transaction. See the discussion of locking in Section 14.16.4, "Concurrency Considerations for Fast Index Creation".

  Prior to InnoDB storage engine 1.0.4, unexpected results could occur if a query attempts to use an index created after the start of the transaction containing the query. If an old transaction attempts to access a "too new" index, InnoDB storage engine 1.0.4 and later reports an error:

```
ERROR HY000: Table definition has changed, please retry transaction
```

  As the error message suggests, committing (or rolling back) the transaction, and restarting it, cures the problem.
- InnoDB storage engine 1.0.2 introduces some improvements in error handling when users attempt to drop indexes. See Section B.3, "Server Error Codes and Messages" for information related to errors `1025`, `1553`, and `1173`.
- MySQL 5.5 does not support efficient creation or dropping of `FOREIGN KEY` constraints. Therefore, if you use `ALTER TABLE` to add or remove a `REFERENCES` constraint, the child table is copied, rather than using Fast Index Creation.
- `OPTIMIZE TABLE` for an `InnoDB` table is mapped to an `ALTER TABLE` operation to rebuild the table and update index statistics and free unused space in the clustered index. This operation does not use fast index creation. Secondary indexes are not created as efficiently because keys are inserted in the order they appeared in the primary key.

14.17 InnoDB Startup Options and System Variables

This section describes the `InnoDB`-related command options and system variables.

- System variables that are true or false can be enabled at server startup by naming them, or disabled by using a `--skip-` prefix. For example, to enable or disable `InnoDB` checksums, you can use `--innodb_checksums` or `--skip-innodb_checksums` on the command line, or `innodb_checksums` or `skip-innodb_checksums` in an option file.
- System variables that take a numeric value can be specified as *`--var_name=value`* on the command line or as *`var_name=value`* in option files.
- Many system variables can be changed at runtime (see Section 5.1.6.2, "Dynamic System Variables").
- For information about `GLOBAL` and `SESSION` variable scope modifiers, refer to the `SET` statement documentation.

- Certain options control the locations and layout of the `InnoDB` data files. Section 14.9.1, “InnoDB Startup Configuration” explains how to use these options.
- Some options, which you might not use initially, help tune `InnoDB` performance characteristics based on machine capacity and your database workload.
- For more information on specifying options and system variables, see Section 4.2.3, “Specifying Program Options”.

Table 14.6 `InnoDB` Option and Variable Reference

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
foreign_key_checks			Yes		Varies	Yes
have_innodb			Yes		Global	No
ignore-builtin-innodb	Yes	Yes			Global	No
- *Variable*: ignore_builtin_innodb			Yes		Global	No
innodb	Yes	Yes				
innodb_adaptive_flushing	Yes	Yes	Yes		Global	Yes
innodb_adaptive_hash_index	Yes	Yes	Yes		Global	Yes
innodb_additional_mem_pool_size	Yes	Yes	Yes		Global	No
innodb_autoextend_increment	Yes	Yes	Yes		Global	Yes
innodb_autoinc_lock_mode	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_bytes_data				Yes	Global	No
Innodb_buffer_pool_bytes_dirty				Yes	Global	No
innodb_buffer_pool_instances	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_pages_data				Yes	Global	No
Innodb_buffer_pool_pages_dirty				Yes	Global	No
Innodb_buffer_pool_pages_flushed				Yes	Global	No
Innodb_buffer_pool_pages_free				Yes	Global	No
Innodb_buffer_pool_pages_latched				Yes	Global	No
Innodb_buffer_pool_pages_misc				Yes	Global	No
Innodb_buffer_pool_pages_total				Yes	Global	No
Innodb_buffer_pool_read_ahead				Yes	Global	No
Innodb_buffer_pool_read_ahead_evicted				Yes	Global	No
Innodb_buffer_pool_read_ahead_rnd				Yes	Global	No
Innodb_buffer_pool_read_requests				Yes	Global	No
Innodb_buffer_pool_reads				Yes	Global	No
innodb_buffer_pool_size	Yes	Yes	Yes		Global	No
Innodb_buffer_pool_wait_free				Yes	Global	No
Innodb_buffer_pool_write_requests				Yes	Global	No
innodb_change_buffering	Yes	Yes	Yes		Global	Yes
innodb_change_buffering_debug	Yes	Yes	Yes		Global	Yes
innodb_checksums	Yes	Yes	Yes		Global	No
innodb_commit_concurrency	Yes	Yes	Yes		Global	Yes
innodb_concurrency_tickets	Yes	Yes	Yes		Global	Yes

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
innodb_data_file_path	Yes	Yes	Yes		Global	No
Innodb_data_fsyncs				Yes	Global	No
innodb_data_home_dir	Yes	Yes	Yes		Global	No
Innodb_data_pending_fsyncs				Yes	Global	No
Innodb_data_pending_reads				Yes	Global	No
Innodb_data_pending_writes				Yes	Global	No
Innodb_data_read				Yes	Global	No
Innodb_data_reads				Yes	Global	No
Innodb_data_writes				Yes	Global	No
Innodb_data_written				Yes	Global	No
Innodb_dblwr_pages_written				Yes	Global	No
Innodb_dblwr_writes				Yes	Global	No
innodb_doublewrite	Yes	Yes	Yes		Global	No
innodb_fast_shutdown	Yes	Yes	Yes		Global	Yes
innodb_file_format	Yes	Yes	Yes		Global	Yes
innodb_file_format_check	Yes	Yes	Yes		Global	Varies
innodb_file_format_max	Yes	Yes	Yes		Global	Yes
innodb_file_per_table	Yes	Yes	Yes		Global	Yes
innodb_flush_log_at_trx_commit	Yes	Yes	Yes		Global	Yes
innodb_flush_method	Yes	Yes	Yes		Global	No
innodb_force_load_corrupted	Yes	Yes	Yes		Global	No
innodb_force_recovery	Yes	Yes	Yes		Global	No
Innodb_have_atomic_builtins				Yes	Global	No
innodb_io_capacity	Yes	Yes	Yes		Global	Yes
innodb_large_prefix	Yes	Yes	Yes		Global	Yes
innodb_limit_optimistic_insert_debug	Yes	Yes	Yes		Global	Yes
innodb_lock_wait_timeout	Yes	Yes	Yes		Both	Yes
innodb_locks_unsafe_for_binlog	Yes	Yes	Yes		Global	No
innodb_log_buffer_size	Yes	Yes	Yes		Global	No
innodb_log_file_size	Yes	Yes	Yes		Global	No
innodb_log_files_in_group	Yes	Yes	Yes		Global	No
innodb_log_group_home_dir	Yes	Yes	Yes		Global	No
Innodb_log_waits				Yes	Global	No
Innodb_log_write_requests				Yes	Global	No
Innodb_log_writes				Yes	Global	No
innodb_max_dirty_pages_pct	Yes	Yes	Yes		Global	Yes
innodb_max_purge_lag	Yes	Yes	Yes		Global	Yes
innodb_mirrored_log_groups	Yes	Yes	Yes		Global	No
innodb_old_blocks_pct	Yes	Yes	Yes		Global	Yes
innodb_old_blocks_time	Yes	Yes	Yes		Global	Yes
innodb_open_files	Yes	Yes	Yes		Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
Innodb_os_log_fsyncs				Yes	Global	No
Innodb_os_log_pending_fsyncs				Yes	Global	No
Innodb_os_log_pending_writes				Yes	Global	No
Innodb_os_log_written				Yes	Global	No
Innodb_page_size				Yes	Global	No
Innodb_pages_created				Yes	Global	No
Innodb_pages_read				Yes	Global	No
Innodb_pages_written				Yes	Global	No
innodb_print_all_deadlocks	Yes	Yes	Yes		Global	Yes
innodb_purge_batch_size	Yes	Yes	Yes		Global	Yes
innodb_purge_threads	Yes	Yes	Yes		Global	No
innodb_random_read_ahead	Yes	Yes	Yes		Global	Yes
innodb_read_ahead_threshold	Yes	Yes	Yes		Global	Yes
innodb_read_io_threads	Yes	Yes	Yes		Global	No
innodb_replication_delay	Yes	Yes	Yes		Global	Yes
innodb_rollback_on_timeout	Yes	Yes	Yes		Global	No
innodb_rollback_segments	Yes	Yes	Yes		Global	Yes
Innodb_row_lock_current_waits				Yes	Global	No
Innodb_row_lock_time				Yes	Global	No
Innodb_row_lock_time_avg				Yes	Global	No
Innodb_row_lock_time_max				Yes	Global	No
Innodb_row_lock_waits				Yes	Global	No
Innodb_rows_deleted				Yes	Global	No
Innodb_rows_inserted				Yes	Global	No
Innodb_rows_read				Yes	Global	No
Innodb_rows_updated				Yes	Global	No
innodb_spin_wait_delay	Yes	Yes	Yes		Global	Yes
innodb_stats_method	Yes	Yes	Yes		Global	Yes
innodb_stats_on_metadata	Yes	Yes	Yes		Global	Yes
innodb_stats_sample_pages	Yes	Yes	Yes		Global	Yes
innodb-status-file	Yes	Yes				
innodb_strict_mode	Yes	Yes	Yes		Both	Yes
innodb_support_xa	Yes	Yes	Yes		Both	Yes
innodb_sync_spin_loops	Yes	Yes	Yes		Global	Yes
innodb_table_locks	Yes	Yes	Yes		Both	Yes
innodb_thread_concurrency	Yes	Yes	Yes		Global	Yes
innodb_thread_sleep_delay	Yes	Yes	Yes		Global	Yes
Innodb_truncated_status_writes				Yes	Global	No
innodb_trx_purge_view_update_only_debug	Yes	Yes	Yes		Global	Yes
innodb_trx_rseg_n_slots_debug	Yes	Yes	Yes		Global	Yes
innodb_use_native_aio	Yes	Yes	Yes		Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
innodb_use_sys_malloc	Yes	Yes	Yes		Global	No
innodb_version			Yes		Global	No
innodb_write_io_threads	Yes	Yes	Yes		Global	No
timed_mutexes	Yes	Yes	Yes		Global	Yes
unique_checks			Yes		Varies	Yes

InnoDB Command Options

- `--ignore-builtin-innodb`

Deprecated	5.5.22	
Command-Line Format	`--ignore-builtin-innodb`	
System Variable	**Name**	`ignore_builtin_innodb`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	boolean

In MySQL 5.1, this option caused the server to behave as if the built-in `InnoDB` were not present, which enabled the `InnoDB Plugin` to be used instead. In MySQL 5.5, `InnoDB` is the default storage engine and `InnoDB Plugin` is not used, so this option has no effect. As of MySQL 5.5.22, it is deprecated and its use results in a warning.

- `--innodb[=value]`

Command-Line Format	`--innodb[=value]`	
Permitted Values	**Type**	enumeration
	Default	`ON`
	Valid Values	`OFF`
		`ON`
		`FORCE`

Controls loading of the `InnoDB` storage engine, if the server was compiled with `InnoDB` support. This option has a tristate format, with possible values of `OFF`, `ON`, or `FORCE`. See Section 5.5.1, “Installing and Uninstalling Plugins”.

To disable `InnoDB`, use `--innodb=OFF` or `--skip-innodb`. In this case, because the default storage engine is `InnoDB`, the server does not start unless you also use `--default-storage-engine` to set the default to some other engine.

- `--innodb-status-file`

Command-Line Format	`--innodb-status-file`	
Permitted Values	**Type**	boolean
	Default	`OFF`

Controls whether `InnoDB` creates a file named `innodb_status.pid` in the MySQL data directory. If enabled, `InnoDB` periodically writes the output of `SHOW ENGINE INNODB STATUS` to this file.

By default, the file is not created. To create it, start `mysqld` with the `--innodb-status-file=1` option. The file is deleted during normal shutdown.

- `--skip-innodb`

  Disable the `InnoDB` storage engine. See the description of `--innodb`.

InnoDB System Variables

- `ignore_builtin_innodb`

Deprecated	5.5.22	
Command-Line Format	`--ignore-builtin-innodb`	
System Variable	**Name**	`ignore_builtin_innodb`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	boolean

See the description of `--ignore-builtin-innodb` under “InnoDB Command Options” earlier in this section.

- `innodb_adaptive_flushing`

Command-Line Format	`--innodb-adaptive-flushing=#`	
System Variable	**Name**	`innodb_adaptive_flushing`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`ON`

Specifies whether to dynamically adjust the rate of flushing dirty pages in the `InnoDB` buffer pool based on the workload. Adjusting the flush rate dynamically is intended to avoid bursts of I/O activity. This setting is enabled by default. See Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing” for more information. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- `innodb_adaptive_hash_index`

Command-Line Format	`--innodb-adaptive-hash-index=#`	
System Variable	**Name**	`innodb_adaptive_hash_index`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`ON`

Whether the `InnoDB` adaptive hash index is enabled or disabled. It may be desirable, depending on your workload, to dynamically enable or disable adaptive hash indexing to improve query performance. Because the adaptive hash index may not be useful for all workloads, conduct benchmarks with it both enabled and disabled, using realistic workloads. See Section 14.7.3, “Adaptive Hash Index” for details.

This variable is enabled by default. As of MySQL 5.5, You can modify this parameter using the `SET GLOBAL` statement, without restarting the server. Changing the setting requires the `SUPER` privilege. You can also use `--skip-innodb_adaptive_hash_index` at server startup to disable it.

Disabling the adaptive hash index empties the hash table immediately. Normal operations can continue while the hash table is emptied, and executing queries that were using the hash table

access the index B-trees directly instead. When the adaptive hash index is re-enabled, the hash table is populated again during normal operation.

- `innodb_additional_mem_pool_size`

Command-Line Format	`--innodb-additional-mem-pool-size=#`	
System Variable	Name	`innodb_additional_mem_pool_size`
	Scope	Global
	Dynamic	No
Permitted Values	Type	integer
	Default	`8388608`
	Minimum	`2097152`
	Maximum	`4294967295`

The size in bytes of a memory pool `InnoDB` uses to store data dictionary information and other internal data structures. The more tables you have in your application, the more memory you need to allocate here. If `InnoDB` runs out of memory in this pool, it starts to allocate memory from the operating system and writes warning messages to the MySQL error log. The default value is 8MB.

This variable relates to the `InnoDB` internal memory allocator, which is unused if `innodb_use_sys_malloc` is enabled. For more information, see Section 14.9.3, “Configuring the Memory Allocator for InnoDB”.

- `innodb_autoextend_increment`

Command-Line Format	`--innodb-autoextend-increment=#`	
System Variable	Name	`innodb_autoextend_increment`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`8`
	Minimum	`1`
	Maximum	`1000`

The increment size (in megabytes) for extending the size of an auto-extending system tablespace file when it becomes full. The default value is 8. For related information, see System Tablespace Data File Configuration, and Section 14.10.1, “Resizing the InnoDB System Tablespace”.

The `innodb_autoextend_increment` setting does not affect file-per-table tablespace files. These files are auto-extending regardless of the `innodb_autoextend_increment` setting. The initial extensions are by small amounts, after which extensions occur in increments of 4MB.

- `innodb_autoinc_lock_mode`

Command-Line Format	`--innodb-autoinc-lock-mode=#`	
System Variable	Name	`innodb_autoinc_lock_mode`
	Scope	Global
	Dynamic	No
Permitted Values	Type	integer
	Default	`1`

	Valid Values	`0`
		`1`
		`2`

The lock mode to use for generating auto-increment values. Permissible values are 0, 1, or 2, for traditional, consecutive, or interleaved, respectively. The default setting is 1 (consecutive). For the characteristics of each lock mode, see InnoDB AUTO_INCREMENT Lock Modes.

- `innodb_buffer_pool_instances`

Introduced	5.5.4	
Command-Line Format	`--innodb-buffer-pool-instances=#`	
System Variable	**Name**	`innodb_buffer_pool_instances`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`1`
	Minimum	`1`
	Maximum	`64`

The number of regions that the `InnoDB` buffer pool is divided into. For systems with buffer pools in the multi-gigabyte range, dividing the buffer pool into separate instances can improve concurrency, by reducing contention as different threads read and write to cached pages. Each page that is stored in or read from the buffer pool is assigned to one of the buffer pool instances randomly, using a hashing function. Each buffer pool manages its own free lists, flush lists, LRUs, and all other data structures connected to a buffer pool, and is protected by its own buffer pool mutex.

This option only takes effect when setting `innodb_buffer_pool_size` to a size of 1GB or more. The total size you specify is divided among all the buffer pools. For best efficiency, specify a combination of `innodb_buffer_pool_instances` and `innodb_buffer_pool_size` so that each buffer pool instance is at least 1GB.

- `innodb_buffer_pool_size`

Command-Line Format	`--innodb-buffer-pool-size=#`	
System Variable	**Name**	`innodb_buffer_pool_size`
	Scope	Global
	Dynamic	No
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`134217728`
	Minimum	`5242880`
	Maximum	`2**32-1`
Permitted Values (64-bit platforms)	**Type**	integer
	Default	`134217728`
	Minimum	`5242880`
	Maximum	`2**64-1`

The size in bytes of the buffer pool, the memory area where `InnoDB` caches table and index data. The default value is 134217728 bytes (128MB). The maximum value depends on the CPU architecture; the maximum is 4294967295 (2^{32}-1) on 32-bit systems and 18446744073709551615

(2^{64}-1) on 64-bit systems. On 32-bit systems, the CPU architecture and operating system may impose a lower practical maximum size than the stated maximum. When the size of the buffer pool is greater than 1GB, setting `innodb_buffer_pool_instances` to a value greater than 1 can improve the scalability on a busy server.

A larger buffer pool requires less disk I/O to access the same table data more than once. On a dedicated database server, you might set the buffer pool size to 80% of the machine's physical memory size. Be aware of the following potential issues when configuring buffer pool size, and be prepared to scale back the size of the buffer pool if necessary.

- Competition for physical memory can cause paging in the operating system.
- `InnoDB` reserves additional memory for buffers and control structures, so that the total allocated space is approximately 10% greater than the specified buffer pool size.
- Address space for the buffer pool must be contiguous, which can be an issue on Windows systems with DLLs that load at specific addresses.
- The time to initialize the buffer pool is roughly proportional to its size. On instances with large buffer pools, initialization time might be significant.

- `innodb_change_buffering`

Command-Line Format	`--innodb-change-buffering=#`	
System Variable	**Name**	`innodb_change_buffering`
	Scope	Global
	Dynamic	Yes
Permitted Values (<= 5.5.3)	**Type**	enumeration
	Default	`inserts`
	Valid Values	`inserts`
		`none`
Permitted Values (>= 5.5.4)	**Type**	enumeration
	Default	`all`
	Valid Values	`none`
		`inserts`
		`deletes`
		`changes`
		`purges`
		`all`

Whether `InnoDB` performs change buffering, an optimization that delays write operations to secondary indexes so that the I/O operations can be performed sequentially. Permitted values are described in the following table.

Table 14.7 Permitted Values for innodb_change_buffering

Value	Description
`none`	Do not buffer any operations.
`inserts`	Buffer insert operations.
`deletes`	Buffer delete marking operations; strictly speaking, the writes that mark index records for later deletion during a purge operation.
`changes`	Buffer inserts and delete-marking operations.

Value	Description
purges	Buffer the physical deletion operations that happen in the background.
all	The default. Buffer inserts, delete-marking operations, and purges.

For more information, see Section 14.7.2, “Change Buffer”, and Section 14.9.4, “Configuring InnoDB Change Buffering”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- innodb_change_buffering_debug

Command-Line Format	--innodb-change-buffering-debug=#	
System Variable	Name	innodb_change_buffering_debug
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	0
	Maximum	2

Sets a debug flag for InnoDB change buffering. A value of 1 forces all changes to the change buffer. A value of 2 causes a crash at merge. A default value of 0 indicates that the change buffering debug flag is not set. This option is only available when debugging support is compiled in using the WITH_DEBUG CMake option.

- innodb_checksums

Command-Line Format	--innodb-checksums	
System Variable	Name	innodb_checksums
	Scope	Global
	Dynamic	No
Permitted Values	Type	boolean
	Default	ON

InnoDB can use checksum validation on all pages read from disk to ensure extra fault tolerance against broken hardware or data files. This validation is enabled by default. Under specialized circumstances (such as when running benchmarks) this safety feature can be disabled with --skip-innodb-checksums.

- innodb_commit_concurrency

Command-Line Format	--innodb-commit-concurrency=#	
System Variable	Name	innodb_commit_concurrency
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	0
	Minimum	0
	Maximum	1000

The number of threads that can commit at the same time. A value of 0 (the default) permits any number of transactions to commit simultaneously.

The value of `innodb_commit_concurrency` cannot be changed at runtime from zero to nonzero or vice versa. The value can be changed from one nonzero value to another.

- `innodb_concurrency_tickets`

Command-Line Format	`--innodb-concurrency-tickets=#`	
System Variable	Name	`innodb_concurrency_tickets`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`500`
	Minimum	`1`
	Maximum	`4294967295`

Determines the number of threads that can enter `InnoDB` concurrently. A thread is placed in a queue when it tries to enter `InnoDB` if the number of threads has already reached the concurrency limit. When a thread is permitted to enter `InnoDB`, it is given a number of " tickets" equal to the value of `innodb_concurrency_tickets`, and the thread can enter and leave `InnoDB` freely until it has used up its tickets. After that point, the thread again becomes subject to the concurrency check (and possible queuing) the next time it tries to enter `InnoDB`. The default value is 500.

With a small `innodb_concurrency_tickets` value, small transactions that only need to process a few rows compete fairly with larger transactions that process many rows. The disadvantage of a small `innodb_concurrency_tickets` value is that large transactions must loop through the queue many times before they can complete, which extends the amount of time required to complete their task.

With a large `innodb_concurrency_tickets` value, large transactions spend less time waiting for a position at the end of the queue (controlled by `innodb_thread_concurrency`) and more time retrieving rows. Large transactions also require fewer trips through the queue to complete their task. The disadvantage of a large `innodb_concurrency_tickets` value is that too many large transactions running at the same time can starve smaller transactions by making them wait a longer time before executing.

With a non-zero `innodb_thread_concurrency` value, you may need to adjust the `innodb_concurrency_tickets` value up or down to find the optimal balance between larger and smaller transactions. The `SHOW ENGINE INNODB STATUS` report shows the number of tickets remaining for an executing transaction in its current pass through the queue. This data may also be obtained from the `TRX_CONCURRENCY_TICKETS` column of the `INFORMATION_SCHEMA.INNODB_TRX` table.

For more information, see Section 14.9.5, "Configuring Thread Concurrency for InnoDB".

- `innodb_data_file_path`

Command-Line Format	`--innodb-data-file-path=name`	
System Variable	Name	`innodb_data_file_path`
	Scope	Global
	Dynamic	No
Permitted Values	Type	string
	Default	`ibdata1:10M:autoextend`

Defines the name, size, and attributes of InnoDB system tablespace data files. If you do not specify a value for innodb_data_file_path, the default behavior is to create a single auto-extending data file, slightly larger than 10MB, named ibdata1.

The full syntax for a data file specification includes the file name, file size, and autoextend and max attributes:

```
file_name:file_size[:autoextend[:max:max_file_size]]
```

File sizes are specified KB, MB or GB (1024MB) by appending K, M or G to the size value. If specifying the data file size in kilobytes (KB), do so in multiples of 1024. Otherwise, KB values are rounded to nearest megabyte (MB) boundary. The sum of the sizes of the files must be at least slightly larger than 10MB.

The size limit of individual files is determined by your operating system. You can set the file size to more than 4GB on operating systems that support large files. You can also use raw disk partitions as data files.

The autoextend and max attributes can be used only for the data file that is specified last in the innodb_data_file_path setting. For example:

```
[mysqld]
innodb_data_file_path=ibdata1:50M;ibdata2:12M:autoextend:max:500MB
```

If you specify the autoextend option, InnoDB extends the data file if it runs out of free space. The autoextend increment is 8MB by default. To modify the increment, change the innodb_autoextend_increment system variable.

The full directory path for system tablespace data files is formed by concatenating the paths defined by innodb_data_home_dir and innodb_data_file_path.

For more information about configuring system tablespace data files, see Section 14.9.1, “InnoDB Startup Configuration”.

- innodb_data_home_dir

Command-Line Format	--innodb-data-home-dir=dir_name	
System Variable	Name	innodb_data_home_dir
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The common part of the directory path for InnoDB system tablespace data files. This setting does not affect the location of file-per-table tablespaces when innodb_file_per_table is enabled. The default value is the MySQL data directory. If you specify the value as an empty string, you can specify an absolute file paths for innodb_data_file_path.

A trailing slash is required when specifying a value for innodb_data_home_dir. For example:

```
[mysqld]
innodb_data_home_dir = /path/to/myibdata/
```

For related information, see Section 14.9.1, “InnoDB Startup Configuration”.

- innodb_doublewrite

Command-Line Format	--innodb-doublewrite	
System Variable	Name	innodb_doublewrite
	Scope	Global
	Dynamic	No
Permitted Values	Type	boolean
	Default	ON

When enabled (the default), InnoDB stores all data twice, first to the doublewrite buffer, and then to the actual data files. This variable can be turned off with --skip-innodb_doublewrite for benchmarks or cases when top performance is needed rather than concern for data integrity or possible failures.

For related information, see Section 14.7.7, “Doublewrite Buffer”.

- innodb_fast_shutdown

Command-Line Format	--innodb-fast-shutdown[=#]	
System Variable	Name	innodb_fast_shutdown
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	1
	Valid Values	0
		1
		2

The InnoDB shutdown mode. If the value is 0, InnoDB does a slow shutdown, a full purge and a change buffer merge before shutting down. If the value is 1 (the default), InnoDB skips these operations at shutdown, a process known as a fast shutdown. If the value is 2, InnoDB flushes its logs and shuts down cold, as if MySQL had crashed; no committed transactions are lost, but the crash recovery operation makes the next startup take longer.

The slow shutdown can take minutes, or even hours in extreme cases where substantial amounts of data are still buffered. Use the slow shutdown technique before upgrading or downgrading between MySQL major releases, so that all data files are fully prepared in case the upgrade process updates the file format.

Use innodb_fast_shutdown=2 in emergency or troubleshooting situations, to get the absolute fastest shutdown if data is at risk of corruption.

- innodb_file_format

Command-Line Format	--innodb-file-format=#	
System Variable	Name	innodb_file_format
	Scope	Global
	Dynamic	Yes
Permitted Values (<= 5.5.6)	Type	string
	Default	Barracuda
	Valid Values	Antelope
		Barracuda

Permitted Values (>= 5.5.7)	**Type**	string
	Default	`Antelope`
	Valid Values	`Antelope`
		`Barracuda`

Enables an `InnoDB` file format for file-per-table tablespaces. Supported file formats are `Antelope` and `Barracuda`. `Antelope` is the original `InnoDB` file format, which supports `REDUNDANT` and `COMPACT` row formats for `InnoDB` tables. `Barracuda` is the newer file format, which supports `COMPRESSED` and `DYNAMIC` row formats.

`COMPRESSED` and `DYNAMIC` row formats enable important storage features for `InnoDB` tables. See Section 14.14, “InnoDB Row Storage and Row Formats”.

To create tables that use `COMPRESSED` or `DYNAMIC` row format, the `Barracuda` file format and `innodb_file_per_table` must be enabled.

Changing the `innodb_file_format` setting does not affect the file format of existing `InnoDB` tablespace files.

For more information, see Section 14.13, “InnoDB File-Format Management”.

- `innodb_file_format_check`

Command-Line Format	`--innodb-file-format-check=#`	
System Variable (<= 5.5.4)	**Name**	`innodb_file_format_check`
	Scope	Global
	Dynamic	Yes
System Variable (>= 5.5.5)	**Name**	`innodb_file_format_check`
	Scope	Global
	Dynamic	No
Permitted Values (5.5.0)	**Type**	string
	Default	`Antelope`
Permitted Values (>= 5.5.1, <= 5.5.4)	**Type**	string
	Default	`Barracuda`
Permitted Values (>= 5.5.5)	**Type**	boolean
	Default	`ON`

As of MySQL 5.5.5, this variable can be set to 1 or 0 at server startup to enable or disable whether `InnoDB` checks the file format tag in the system tablespace (for example, `Antelope` or `Barracuda`). If the tag is checked and is higher than that supported by the current version of `InnoDB`, an error occurs and `InnoDB` does not start. If the tag is not higher, `InnoDB` sets the value of `innodb_file_format_max` to the file format tag.

Before MySQL 5.5.5, this variable can be set to 1 or 0 at server startup to enable or disable whether `InnoDB` checks the file format tag in the shared tablespace. If the tag is checked and is higher than that supported by the current version of `InnoDB`, an error occurs and `InnoDB` does not start. If the tag is not higher, `InnoDB` sets the value of `innodb_file_format_check` to the file format tag, which is the value seen at runtime.

Note

Despite the default value sometimes being displayed as `ON` or `OFF`, always use the numeric values 1 or 0 to turn this option on or off in your configuration file or command line string.

For more information, see Section 14.13.2.1, “Compatibility Check When InnoDB Is Started”.

- `innodb_file_format_max`

Introduced	5.5.5	
Command-Line Format	`--innodb-file-format-max=#`	
System Variable	**Name**	`innodb_file_format_max`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	string
	Default	`Antelope`
	Valid Values	`Antelope`
		`Barracuda`

At server startup, `InnoDB` sets the value of this variable to the file format tag in the system tablespace (for example, `Antelope` or `Barracuda`). If the server creates or opens a table with a “higher” file format, it sets the value of `innodb_file_format_max` to that format.

For related information, see Section 14.13, “InnoDB File-Format Management”.

- `innodb_file_per_table`

Command-Line Format	`--innodb-file-per-table`	
System Variable	**Name**	`innodb_file_per_table`
	Scope	Global
	Dynamic	Yes
Permitted Values (<= 5.5.6)	**Type**	boolean
	Default	`ON`
Permitted Values (>= 5.5.7)	**Type**	boolean
	Default	`OFF`

When `innodb_file_per_table` is disabled, `InnoDB` stores the data for tables and indexes in the ibdata files that make up the system tablespace. This setting reduces the performance overhead of file system operations for operations such as `DROP TABLE` or `TRUNCATE TABLE`. It is most appropriate for a server environment where entire storage devices are devoted to MySQL data. Because the system tablespace never shrinks, and is shared across all databases in an instance, avoid loading huge amounts of temporary data on a space-constrained system when `innodb_file_per_table` is disabled. Set up a separate instance in such cases, so that you can drop the entire instance to reclaim the space.

When `innodb_file_per_table` is enabled, `InnoDB` stores data and indexes for each newly created table in a separate `.ibd` file instead of the system tablespace. The storage for these tables is reclaimed when the tables are dropped or truncated. This setting enables `InnoDB`features such as table compression. See Section 14.10.4, “InnoDB File-Per-Table Tablespaces” for more information.

Enabling `innodb_file_per_table` also means that an `ALTER TABLE` operation moves an `InnoDB` table from the system tablespace to an individual `.ibd` file in cases where `ALTER TABLE` rebuilds the table (`ALTER OFFLINE`).

`innodb_file_per_table` is dynamic and can be set `ON` or `OFF` using `SET GLOBAL`.

Dynamically changing the value requires the `SUPER` privilege and immediately affects the operation of all connections.

- `innodb_flush_log_at_trx_commit`

Command-Line Format	`--innodb-flush-log-at-trx-commit[=#]`	
System Variable	**Name**	`innodb_flush_log_at_trx_commit`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`1`
	Valid Values	`0`
		`1`
		`2`

Controls the balance between strict ACID compliance for commit operations and higher performance that is possible when commit-related I/O operations are rearranged and done in batches. You can achieve better performance by changing the default value but then you can lose up to a second of transactions in a crash.

- The default value of 1 is required for full ACID compliance. With this value, the contents of the `InnoDB` log buffer are written out to the log file at each transaction commit and the log file is flushed to disk.
- With a value of 0, the contents of the `InnoDB` log buffer are written to the log file approximately once per second and the log file is flushed to disk. No writes from the log buffer to the log file are performed at transaction commit. Once-per-second flushing is not guaranteed to happen every second due to process scheduling issues. Because the flush to disk operation only occurs approximately once per second, you can lose up to a second of transactions with any `mysqld` process crash.
- With a value of 2, the contents of the `InnoDB` log buffer are written to the log file after each transaction commit and the log file is flushed to disk approximately once per second. Once-per-second flushing is not 100% guaranteed to happen every second, due to process scheduling issues. Because the flush to disk operation only occurs approximately once per second, you can lose up to a second of transactions in an operating system crash or a power outage.
- `InnoDB` crash recovery works regardless of the value. Transactions are either applied entirely or erased entirely.

For the greatest possible durability and consistency in a replication setup using `InnoDB` with transactions, use `innodb_flush_log_at_trx_commit=1` and `sync_binlog=1` in your master server `my.cnf` file.

Caution

Many operating systems and some disk hardware fool the flush-to-disk operation. They may tell `mysqld` that the flush has taken place, even though it has not. In this case, the durability of transactions is not guaranteed even with the setting 1, and in the worst case, a power outage can corrupt `InnoDB`

data. Using a battery-backed disk cache in the SCSI disk controller or in the disk itself speeds up file flushes, and makes the operation safer. You can also try to disable the caching of disk writes in hardware caches.

- `innodb_flush_method`

Command-Line Format	`--innodb-flush-method=name`	
System Variable	**Name**	`innodb_flush_method`
	Scope	Global
	Dynamic	No
Permitted Values (Unix)	**Type**	string
	Default	`NULL`
	Valid Values	`fsync`
		`littlesync`
		`nosync`
		`O_DSYNC`
		`O_DIRECT`
Permitted Values (Windows)	**Type**	string
	Default	`NULL`
	Valid Values	`async_unbuffered`
		`normal`
		`unbuffered`

Defines the method used to flush data to `InnoDB` data files and log files, which can affect I/O throughput.

If `innodb_flush_method` is set to `NULL` on a Unix-like system, the `fsync` option is used by default. If `innodb_flush_method` is set to `NULL` on Windows, the `async_unbuffered` option is used by default.

The `innodb_flush_method` options for Unix-like systems include:

- `fsync`: `InnoDB` uses the `fsync()` system call to flush both the data and log files. `fsync` is the default setting.
- `O_DSYNC`: `InnoDB` uses `O_SYNC` to open and flush the log files, and `fsync()` to flush the data files. `InnoDB` does not use `O_DSYNC` directly because there have been problems with it on many varieties of Unix.
- `littlesync`: This option is used for internal performance testing and is currently unsupported. Use at your own risk.
- `nosync`: This option is used for internal performance testing and is currently unsupported. Use at your own risk.
- `O_DIRECT`: `InnoDB` uses `O_DIRECT` (or `directio()` on Solaris) to open the data files, and uses `fsync()` to flush both the data and log files. This option is available on some GNU/Linux versions, FreeBSD, and Solaris.

The `innodb_flush_method` options for Windows systems include:

- `async_unbuffered`: `InnoDB` uses Windows asynchronous I/O and non-buffered I/O. `async_unbuffered` is the default setting on Windows systems.

Running MySQL server on a 4K sector hard drive on Windows is not supported with `async_unbuffered`. The workaround is to use `innodb_flush_method=normal`.

- `normal`: `InnoDB` uses simulated asynchronous I/O and buffered I/O. This option is used for internal performance testing and is currently unsupported. Use at your own risk.
- `unbuffered`: `InnoDB` uses simulated asynchronous I/O and non-buffered I/O. This option is used for internal performance testing and is currently unsupported. Use at your own risk.

How each setting affects performance depends on hardware configuration and workload. Benchmark your particular configuration to decide which setting to use, or whether to keep the default setting. Examine the `Innodb_data_fsyncs` status variable to see the overall number of `fsync()` calls for each setting. The mix of read and write operations in your workload can affect how a setting performs. For example, on a system with a hardware RAID controller and battery-backed write cache, `O_DIRECT` can help to avoid double buffering between the `InnoDB` buffer pool and the operating system file system cache. On some systems where `InnoDB` data and log files are located on a SAN, the default value or `O_DSYNC` might be faster for a read-heavy workload with mostly `SELECT` statements. Always test this parameter with hardware and workload that reflect your production environment. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

Prior to MySQL 5.1.24, the default `innodb_flush_method` option was named `fdatasync`. When `fdatasync` was specified, `InnoDB` used the `fsync()` system call to flush both the data and log files. To avoid confusing the `fdatasync` option name with the `fdatasync()` system call, the option name was changed to `fsync` in MySQL 5.1.24.

- `innodb_force_load_corrupted`

Introduced	5.5.18	
Command-Line Format	`--innodb-force-load-corrupted`	
System Variable	**Name**	`innodb_force_load_corrupted`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	boolean
	Default	`OFF`

Permits `InnoDB` to load tables at startup that are marked as corrupted. Use only during troubleshooting, to recover data that is otherwise inaccessible. When troubleshooting is complete, disable this setting and restart the server.

- `innodb_force_recovery`

Command-Line Format	`--innodb-force-recovery=#`	
System Variable	**Name**	`innodb_force_recovery`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`6`

The crash recovery mode, typically only changed in serious troubleshooting situations. Possible values are from 0 to 6. For the meanings of these values and important information about `innodb_force_recovery`, see Section 14.23.2, “Forcing InnoDB Recovery”.

Warning

Only set this variable to a value greater than 0 in an emergency situation so that you can start `InnoDB` and dump your tables. As a safety measure, `InnoDB` prevents `INSERT`, `UPDATE`, or `DELETE` operations when `innodb_force_recovery` is greater than 0.

- `innodb_io_capacity`

Command-Line Format	`--innodb-io-capacity=#`	
System Variable	**Name**	`innodb_io_capacity`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`200`
	Minimum	`100`
	Maximum	`2**32-1`
Permitted Values (64-bit platforms)	**Type**	integer
	Default	`200`
	Minimum	`100`
	Maximum	`2**64-1`

The `innodb_io_capacity` parameter sets an upper limit on the number of I/O operations performed per second by `InnoDB` background tasks, such as flushing pages from the buffer pool and merging data from the change buffer.

The `innodb_io_capacity` limit is a total limit for all buffer pool instances. When dirty pages are flushed, the limit is divided equally among buffer pool instances.

`innodb_io_capacity` should be set to approximately the number of I/O operations that the system can perform per second. Ideally, keep the setting as low as practical, but not so low that background activities fall behind. If the value is too high, data is removed from the buffer pool and insert buffer too quickly for caching to provide a significant benefit.

The default value is 200. For busy systems capable of higher I/O rates, you can set a higher value to help the server handle the background maintenance work associated with a high rate of row changes.

In general, you can increase the value as a function of the number of drives used for `InnoDB` I/O. For example, you can increase the value on systems that use multiple disks or solid-state disks (SSD).

The default setting of 200 is generally sufficient for a lower-end SSD. For a higher-end, bus-attached SSD, consider a higher setting such as 1000, for example. For systems with individual 5400 RPM or 7200 RPM drives, you might lower the value to the former default of `100`, which represents an estimated proportion of the I/O operations per second (IOPS) available to older-generation disk drives that can perform about 100 IOPS.

Although you can specify a very high value such as one million, in practice such large values have little if any benefit. Generally, a value of 20000 or higher is not recommended unless you have proven that lower values are insufficient for your workload.

Consider write workload when tuning `innodb_io_capacity`. Systems with large write workloads are likely to benefit from a higher setting. A lower setting may be sufficient for systems with a small write workload.

You can set `innodb_io_capacity` in the MySQL option file (`my.cnf` or `my.ini`) or change it dynamically using a `SET GLOBAL` statement, which requires the `SUPER` privilege.

See Section 14.9.8, "Configuring the InnoDB Master Thread I/O Rate" for more information. For general information about `InnoDB` I/O performance, see Section 8.5.7, "Optimizing InnoDB Disk I/O".

- `innodb_large_prefix`

Introduced	5.5.14	
Command-Line Format	`--innodb-large-prefix`	
System Variable	**Name**	`innodb_large_prefix`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Enable this option to allow index key prefixes longer than 767 bytes (up to 3072 bytes), for `InnoDB` tables that use `DYNAMIC` or `COMPRESSED` row format. (Creating such tables also requires the option values `innodb_file_format=barracuda` and `innodb_file_per_table=true`.) See Section 14.11.1.7, "Limits on InnoDB Tables" for maximums associated with index key prefixes under various settings.

For tables that use `REDUNDANT` or `COMPACT` row format, this option does not affect the permitted index key prefix length. When this setting is enabled, attempting to create an index prefix with a key length greater than 3072 for a `REDUNDANT` or `COMPACT` table causes an `ER_INDEX_COLUMN_TOO_LONG` error.

- `innodb_limit_optimistic_insert_debug`

Command-Line Format	`--innodb-limit-optimistic-insert-debug=#`	
System Variable	**Name**	`innodb_limit_optimistic_insert_debug`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`2**32-1`

Limits the number of records per B-tree page. A default value of 0 means that no limit is imposed. This option is only available if debugging support is compiled in using the `WITH_DEBUG CMake` option.

- `innodb_lock_wait_timeout`

Command-Line Format	`--innodb-lock-wait-timeout=#`

System Variable	Name	innodb_lock_wait_timeout
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	50
	Minimum	1
	Maximum	1073741824

The length of time in seconds an InnoDB transaction waits for a row lock before giving up. The default value is 50 seconds. A transaction that tries to access a row that is locked by another InnoDB transaction waits at most this many seconds for write access to the row before issuing the following error:

```
ERROR 1205 (HY000): Lock wait timeout exceeded; try restarting transaction
```

When a lock wait timeout occurs, the current statement is rolled back (not the entire transaction). To have the entire transaction roll back, start the server with the --innodb_rollback_on_timeout option. See also Section 14.23.4, “InnoDB Error Handling”.

You might decrease this value for highly interactive applications or OLTP systems, to display user feedback quickly or put the update into a queue for processing later. You might increase this value for long-running back-end operations, such as a transform step in a data warehouse that waits for other large insert or update operations to finish.

innodb_lock_wait_timeout applies to InnoDB row locks only. A MySQL table lock does not happen inside InnoDB and this timeout does not apply to waits for table locks.

The lock wait timeout value does not apply to deadlocks, because InnoDB detects them immediately and rolls back one of the deadlocked transactions. See Section 14.8.5.2, “Deadlock Detection and Rollback”.

innodb_lock_wait_timeout can be set at runtime with the SET GLOBAL or SET SESSION statement. Changing the GLOBAL setting requires the SUPER privilege and affects the operation of all clients that subsequently connect. Any client can change the SESSION setting for innodb_lock_wait_timeout, which affects only that client.

- innodb_locks_unsafe_for_binlog

Command-Line Format	--innodb-locks-unsafe-for-binlog	
System Variable	Name	innodb_locks_unsafe_for_binlog
	Scope	Global
	Dynamic	No
Permitted Values	Type	boolean
	Default	OFF

This variable affects how InnoDB uses gap locking for searches and index scans. Normally, InnoDB uses an algorithm called *next-key locking* that combines index-row locking with gap locking. InnoDB performs row-level locking in such a way that when it searches or scans a table index, it sets shared or exclusive locks on the index records it encounters. Thus, row-level locks are actually index-record locks. In addition, a next-key lock on an index record also affects the gap before the index record. That is, a next-key lock is an index-record lock plus a gap lock on the gap preceding the index record. If one session has a shared or exclusive lock on record R in an index, another session cannot

insert a new index record in the gap immediately before `R` in the index order. See Section 14.8.1, “InnoDB Locking”.

By default, the value of `innodb_locks_unsafe_for_binlog` is 0 (disabled), which means that gap locking is enabled: `InnoDB` uses next-key locks for searches and index scans. To enable the variable, set it to 1. This causes gap locking to be disabled: `InnoDB` uses only index-record locks for searches and index scans.

Enabling `innodb_locks_unsafe_for_binlog` does not disable the use of gap locking for foreign-key constraint checking or duplicate-key checking.

The effects of enabling `innodb_locks_unsafe_for_binlog` are the same as setting the transaction isolation level to `READ COMMITTED`, with these exceptions:

- Enabling `innodb_locks_unsafe_for_binlog` is a global setting and affects all sessions, whereas the isolation level can be set globally for all sessions, or individually per session.
- `innodb_locks_unsafe_for_binlog` can be set only at server startup, whereas the isolation level can be set at startup or changed at runtime.

`READ COMMITTED` therefore offers finer and more flexible control than `innodb_locks_unsafe_for_binlog`. For more information about the effect of isolation level on gap locking, see Section 14.8.2.1, “Transaction Isolation Levels”.

Enabling `innodb_locks_unsafe_for_binlog` may cause phantom problems because other sessions can insert new rows into the gaps when gap locking is disabled. Suppose that there is an index on the `id` column of the `child` table and that you want to read and lock all rows from the table having an identifier value larger than 100, with the intention of updating some column in the selected rows later:

```
SELECT * FROM child WHERE id > 100 FOR UPDATE;
```

The query scans the index starting from the first record where the `id` is greater than 100. If the locks set on the index records in that range do not lock out inserts made in the gaps, another session can insert a new row into the table. Consequently, if you were to execute the same `SELECT` again within the same transaction, you would see a new row in the result set returned by the query. This also means that if new items are added to the database, `InnoDB` does not guarantee serializability. Therefore, if `innodb_locks_unsafe_for_binlog` is enabled, `InnoDB` guarantees at most an isolation level of `READ COMMITTED`. (Conflict serializability is still guaranteed.) For more information about phantoms, see Section 14.8.4, “Phantom Rows”.

Enabling `innodb_locks_unsafe_for_binlog` has additional effects:

- For `UPDATE` or `DELETE` statements, `InnoDB` holds locks only for rows that it updates or deletes. Record locks for nonmatching rows are released after MySQL has evaluated the `WHERE` condition. This greatly reduces the probability of deadlocks, but they can still happen.
- For `UPDATE` statements, if a row is already locked, `InnoDB` performs a “semi-consistent” read, returning the latest committed version to MySQL so that MySQL can determine whether the row matches the `WHERE` condition of the `UPDATE`. If the row matches (must be updated), MySQL reads the row again and this time `InnoDB` either locks it or waits for a lock on it.

Consider the following example, beginning with this table:

```
CREATE TABLE t (a INT NOT NULL, b INT) ENGINE = InnoDB;
INSERT INTO t VALUES (1,2),(2,3),(3,2),(4,3),(5,2);
COMMIT;
```

In this case, table has no indexes, so searches and index scans use the hidden clustered index for record locking (see Section 14.11.2.1, “Clustered and Secondary Indexes”).

Suppose that one client performs an UPDATE using these statements:

```
SET autocommit = 0;
UPDATE t SET b = 5 WHERE b = 3;
```

Suppose also that a second client performs an UPDATE by executing these statements following those of the first client:

```
SET autocommit = 0;
UPDATE t SET b = 4 WHERE b = 2;
```

As InnoDB executes each UPDATE, it first acquires an exclusive lock for each row, and then determines whether to modify it. If InnoDB does not modify the row and innodb_locks_unsafe_for_binlog is enabled, it releases the lock. Otherwise, InnoDB retains the lock until the end of the transaction. This affects transaction processing as follows.

If innodb_locks_unsafe_for_binlog is disabled, the first UPDATE acquires x-locks and does not release any of them:

```
x-lock(1,2); retain x-lock
x-lock(2,3); update(2,3) to (2,5); retain x-lock
x-lock(3,2); retain x-lock
x-lock(4,3); update(4,3) to (4,5); retain x-lock
x-lock(5,2); retain x-lock
```

The second UPDATE blocks as soon as it tries to acquire any locks (because the first update has retained locks on all rows), and does not proceed until the first UPDATE commits or rolls back:

```
x-lock(1,2); block and wait for first UPDATE to commit or roll back
```

If innodb_locks_unsafe_for_binlog is enabled, the first UPDATE acquires x-locks and releases those for rows that it does not modify:

```
x-lock(1,2); unlock(1,2)
x-lock(2,3); update(2,3) to (2,5); retain x-lock
x-lock(3,2); unlock(3,2)
x-lock(4,3); update(4,3) to (4,5); retain x-lock
x-lock(5,2); unlock(5,2)
```

For the second UPDATE, InnoDB does a “semi-consistent” read, returning the latest committed version of each row to MySQL so that MySQL can determine whether the row matches the WHERE condition of the UPDATE:

```
x-lock(1,2); update(1,2) to (1,4); retain x-lock
x-lock(2,3); unlock(2,3)
x-lock(3,2); update(3,2) to (3,4); retain x-lock
x-lock(4,3); unlock(4,3)
x-lock(5,2); update(5,2) to (5,4); retain x-lock
```

- innodb_log_buffer_size

Command-Line Format	--innodb-log-buffer-size=#	
System Variable	**Name**	innodb_log_buffer_size
	Scope	Global

	Dynamic	No
Permitted Values	**Type**	integer
	Default	`8388608`
	Minimum	`262144`
	Maximum	`4294967295`

The size in bytes of the buffer that `InnoDB` uses to write to the log files on disk. The default value is 8MB. A large log buffer enables large transactions to run without the need to write the log to disk before the transactions commit. Thus, if you have transactions that update, insert, or delete many rows, making the log buffer larger saves disk I/O. For related information, see InnoDB Memory Configuration, and Section 8.5.3, “Optimizing InnoDB Redo Logging”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- `innodb_log_file_size`

Command-Line Format	`--innodb-log-file-size=#`	
System Variable	**Name**	`innodb_log_file_size`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`5242880`
	Minimum	`1048576`
	Maximum	`4GB / innodb_log_files_in_group`

The size in bytes of each log file in a log group. The combined size of log files (`innodb_log_file_size` * `innodb_log_files_in_group`) cannot exceed a maximum value that is slightly less than 4GB. A pair of 2047 MB log files, for example, approaches the limit but does not exceed it. The default value is 5MB.

Generally, the combined size of the log files should be large enough that the server can smooth out peaks and troughs in workload activity, which often means that there is enough redo log space to handle more than an hour of write activity. The larger the value, the less checkpoint flush activity is required in the buffer pool, saving disk I/O. Larger log files also make crash recovery slower, although improvements to recovery performance in MySQL 5.5 and higher make the log file size less of a consideration.

For related information, see InnoDB Log File Configuration. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- `innodb_log_files_in_group`

Command-Line Format	`--innodb-log-files-in-group=#`	
System Variable	**Name**	`innodb_log_files_in_group`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`2`
	Minimum	`2`
	Maximum	`100`

The number of log files in the log group. `InnoDB` writes to the files in a circular fashion. The default (and recommended) value is 2. The location of the files is specified by `innodb_log_group_home_dir`.

For related information, see InnoDB Log File Configuration.

- `innodb_log_group_home_dir`

Command-Line Format	`--innodb-log-group-home-dir=dir_name`	
System Variable	Name	`innodb_log_group_home_dir`
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name

The directory path to the `InnoDB` redo log files, whose number is specified by `innodb_log_files_in_group`. If you do not specify any `InnoDB` log variables, the default is to create two files named `ib_logfile0` and `ib_logfile1` in the MySQL data directory. Log file size is given by the `innodb_log_file_size` system variable.

For related information, see InnoDB Log File Configuration.

- `innodb_max_dirty_pages_pct`

Command-Line Format	`--innodb-max-dirty-pages-pct=#`	
System Variable	Name	`innodb_max_dirty_pages_pct`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	numeric
	Default	`75`
	Minimum	`0`
	Maximum	`99`

`InnoDB` tries to flush data from the buffer pool so that the percentage of dirty pages does not exceed this value. Specify an integer in the range from 0 to 99. The default value is 75.

For additional information about this variable, see Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- `innodb_max_purge_lag`

Command-Line Format	`--innodb-max-purge-lag=#`	
System Variable	Name	`innodb_max_purge_lag`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4294967295`

Controls how to delay `INSERT`, `UPDATE`, and `DELETE` operations when purge operations are lagging (see Section 14.6, “InnoDB Multi-Versioning”). The unit value is microseconds. The default value is 0 (no delays).

The `InnoDB` transaction system maintains a list of transactions that have index records delete-marked by `UPDATE` or `DELETE` operations. The length of the list represents the *`purge_lag`* value. When *`purge_lag`* exceeds `innodb_max_purge_lag`, `INSERT`, `UPDATE`, and `DELETE` operations are delayed by ((*`purge_lag`*/`innodb_max_purge_lag`)×10)−5 milliseconds. The delay is computed in the beginning of a purge batch, every ten seconds. The operations are not delayed if purge cannot run because of an old consistent read view that could see the rows to be purged.

A typical setting for a problematic workload might be 1 million, assuming that transactions are small, only 100 bytes in size, and it is permissible to have 100MB of unpurged `InnoDB` table rows.

The lag value is displayed as the history list length in the `TRANSACTIONS` section of InnoDB Monitor output . For example, if the output includes the following lines, the lag value is 20:

```
------------
TRANSACTIONS
------------
Trx id counter 0 290328385
Purge done for trx's n:o < 0 290315608 undo n:o < 0 17
History list length 20
```

For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

- `innodb_mirrored_log_groups`

  Has no effect.

- `innodb_old_blocks_pct`

Command-Line Format	`--innodb-old-blocks-pct=#`	
System Variable	Name	`innodb_old_blocks_pct`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`37`
	Minimum	`5`
	Maximum	`95`

Specifies the approximate percentage of the `InnoDB` buffer pool used for the old block sublist. The range of values is 5 to 95. The default value is 37 (that is, 3/8 of the pool).

For more information, see Section 14.9.2.3, “Making the Buffer Pool Scan Resistant”. For information about buffer pool management, the LRU algorithm, and eviction policies, see Section 14.9.2.1, “The InnoDB Buffer Pool”.

- `innodb_old_blocks_time`

Command-Line Format	`--innodb-old-blocks-time=#`	
System Variable	Name	`innodb_old_blocks_time`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer

	Default	`0`
	Minimum	`0`
	Maximum	`2**32-1`

Non-zero values protect against the buffer pool being filled by data that is referenced only for a brief period, such as during a full table scan. Increasing this value offers more protection against full table scans interfering with data cached in the buffer pool.

Specifies how long in milliseconds a block inserted into the old sublist must stay there after its first access before it can be moved to the new sublist. If the value is 0, a block inserted into the old sublist moves immediately to the new sublist the first time it is accessed, no matter how soon after insertion the access occurs. If the value is greater than 0, blocks remain in the old sublist until an access occurs at least that many milliseconds after the first access. For example, a value of 1000 causes blocks to stay in the old sublist for 1 second after the first access before they become eligible to move to the new sublist.

This configuration option is often used in combination with `innodb_old_blocks_pct`. For more information, see Section 14.9.2.3, “Making the Buffer Pool Scan Resistant”. For information about buffer pool management, the LRU algorithm, and eviction policies, see Section 14.9.2.1, “The InnoDB Buffer Pool”.

- `innodb_open_files`

Command-Line Format	`--innodb-open-files=#`	
System Variable	**Name**	`innodb_open_files`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`300`
	Minimum	`10`
	Maximum	`4294967295`

This configuration option is only relevant if you use multiple `InnoDB` tablespaces. It specifies the maximum number of `.ibd` files that MySQL can keep open at one time. The minimum value is 10. The default value is 300.

The file descriptors used for `.ibd` files are for `InnoDB` tables only. They are independent of those specified by the `--open-files-limit` server option, and do not affect the operation of the table cache.

- `innodb_print_all_deadlocks`

Introduced	5.5.30	
Command-Line Format	`--innodb-print-all-deadlocks=#`	
System Variable	**Name**	`innodb_print_all_deadlocks`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

When this option is enabled, information about all deadlocks in `InnoDB` user transactions is recorded in the `mysqld` error log. Otherwise, you see information about only the last deadlock, using the

`SHOW ENGINE INNODB STATUS` command. An occasional `InnoDB` deadlock is not necessarily an issue, because `InnoDB` detects the condition immediately and rolls back one of the transactions automatically. You might use this option to troubleshoot why deadlocks are occurring if an application does not have appropriate error-handling logic to detect the rollback and retry its operation. A large number of deadlocks might indicate the need to restructure transactions that issue DML or `SELECT ... FOR UPDATE` statements for multiple tables, so that each transaction accesses the tables in the same order, thus avoiding the deadlock condition.

For related information, see Section 14.8.5, “Deadlocks in InnoDB”.

- `innodb_purge_batch_size`

Introduced	5.5.4	
Command-Line Format	`--innodb-purge-batch-size=#`	
System Variable	**Name**	`innodb_purge_batch_size`
	Scope	Global
	Dynamic	Yes
Permitted Values (>= 5.5.4)	**Type**	integer
	Default	`20`
	Minimum	`1`
	Maximum	`5000`

Defines the number of undo log pages that purge parses and processes in one batch from the history list. The `innodb_purge_batch_size` option also defines the number of undo log pages that purge frees after every 128 iterations through the undo logs.

The `innodb_purge_batch_size` option is intended for advanced performance tuning in combination with the `innodb_purge_threads` setting. Most MySQL users need not change `innodb_purge_batch_size` from its default value.

For related information, see Section 14.9.10, “Configuring InnoDB Purge Scheduling”.

- `innodb_purge_threads`

Introduced	5.5.4	
Command-Line Format	`--innodb-purge-threads=#`	
System Variable	**Name**	`innodb_purge_threads`
	Scope	Global
	Dynamic	No
Permitted Values (>= 5.5.4)	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`1`

The number of background threads devoted to the `InnoDB` purge operation. Currently, can only be 0 (the default) or 1. The default value of 0 signifies that the purge operation is performed as part of the master thread. Running the purge operation in its own thread can reduce internal contention within `InnoDB`, improving scalability. Currently, the performance gain might be minimal because the background thread might encounter different kinds of contention than before. This feature primarily lays the groundwork for future performance work.

For related information, see Section 14.9.10, “Configuring InnoDB Purge Scheduling”.

- `innodb_random_read_ahead`

Introduced	5.5.16	
Command-Line Format	`--innodb-random-read-ahead=#`	
System Variable	**Name**	`innodb_random_read_ahead`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Enables the random read-ahead technique for optimizing `InnoDB` I/O. Random read-ahead functionality was removed from the `InnoDB Plugin` (version 1.0.4) and was therefore not included in MySQL 5.5.0 when `InnoDB Plugin` became the "built-in" version of `InnoDB`. Random read-ahead was reintroduced in MySQL 5.1.59 and 5.5.16 and higher along with the `innodb_random_read_ahead` configuration option, which is disabled by default.

For details about performance considerations for different types of read-ahead requests, see Section 14.9.2.4, "Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)". For general I/O tuning advice, see Section 8.5.7, "Optimizing InnoDB Disk I/O".

- `innodb_read_ahead_threshold`

Command-Line Format	`--innodb-read-ahead-threshold=#`	
System Variable	**Name**	`innodb_read_ahead_threshold`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`56`
	Minimum	`0`
	Maximum	`64`

Controls the sensitivity of linear read-ahead that `InnoDB` uses to prefetch pages into the buffer pool. If `InnoDB` reads at least `innodb_read_ahead_threshold` pages sequentially from an extent (64 pages), it initiates an asynchronous read for the entire following extent. The permissible range of values is 0 to 64. The default is 56: `InnoDB` must read at least 56 pages sequentially from an extent to initiate an asynchronous read for the following extent.

Knowing how many pages are read through the read-ahead mechanism, and how many of these pages are evicted from the buffer pool without ever being accessed, can be useful when fine-tuning the `innodb_read_ahead_threshold` setting. As of MySQL 5.5, `SHOW ENGINE INNODB STATUS` output displays counter information from the `Innodb_buffer_pool_read_ahead` and `Innodb_buffer_pool_read_ahead_evicted` global status variables, which report the number of pages brought into the buffer pool by read-ahead requests, and the number of such pages evicted from the buffer pool without ever being accessed, respectively. The status variables report global values since the last server restart.

`SHOW ENGINE INNODB STATUS` also shows the rate at which the read-ahead pages are read in and the rate at which such pages are evicted without being accessed. The per-second averages are based on the statistics collected since the last invocation of `SHOW ENGINE INNODB STATUS` and are displayed in the `BUFFER POOL AND MEMORY` section of the `SHOW ENGINE INNODB STATUS` output.

For more information, see Section 14.9.2.4, "Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)". For general I/O tuning advice, see Section 8.5.7, "Optimizing InnoDB Disk I/O".

- `innodb_read_io_threads`

Command-Line Format	`--innodb-read-io-threads=#`	
System Variable	Name	`innodb_read_io_threads`
	Scope	Global
	Dynamic	No
Permitted Values	Type	integer
	Default	`4`
	Minimum	`1`
	Maximum	`64`

The number of I/O threads for read operations in `InnoDB`. Its counterpart for write threads is `innodb_write_io_threads`. For more information, see Section 14.9.6, “Configuring the Number of Background InnoDB I/O Threads”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

Note

On Linux systems, running multiple MySQL servers (typically more than 12) with default settings for `innodb_read_io_threads`, `innodb_write_io_threads`, and the Linux `aio-max-nr` setting can exceed system limits. Ideally, increase the `aio-max-nr` setting; as a workaround, you might reduce the settings for one or both of the MySQL configuration options.

- `innodb_replication_delay`

Command-Line Format	`--innodb-replication-delay=#`	
System Variable	Name	`innodb_replication_delay`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4294967295`

The replication thread delay in milliseconds on a slave server if `innodb_thread_concurrency` is reached.

- `innodb_rollback_on_timeout`

Command-Line Format	`--innodb-rollback-on-timeout`	
System Variable	Name	`innodb_rollback_on_timeout`
	Scope	Global
	Dynamic	No
Permitted Values	Type	boolean
	Default	`OFF`

`InnoDB` rolls back only the last statement on a transaction timeout by default. If `--innodb_rollback_on_timeout` is specified, a transaction timeout causes `InnoDB` to abort and roll back the entire transaction (the same behavior as in MySQL 4.1).

Note

If the start-transaction statement was `START TRANSACTION` or `BEGIN` statement, rollback does not cancel that statement. Further SQL statements become part of the transaction until the occurrence of `COMMIT`, `ROLLBACK`, or some SQL statement that causes an implicit commit.

For more information, see Section 14.23.4, “InnoDB Error Handling”.

- `innodb_rollback_segments`

Introduced	5.5.11	
Command-Line Format	`--innodb-rollback-segments=#`	
System Variable	**Name**	`innodb_rollback_segments`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`128`
	Minimum	`1`
	Maximum	`128`

Defines the number of rollback segments used by `InnoDB` for data-modifying transactions that generate undo records. Each rollback segment can support a maximum of 1023 data-modifying transactions.

This setting is appropriate for tuning performance if you observe mutex contention related to the undo logs.

Although you can increase or decrease the number of rollback segments used by `InnoDB`, the number of rollback segments physically present in the system never decreases. Thus, you might start with a low value for this parameter and gradually increase it, to avoid allocating rollback segments that are not required. The `innodb_rollback_segments` default value is 128, which is also the maximum value.

For more information about rollback segments, see Section 14.6, “InnoDB Multi-Versioning”.

- `innodb_spin_wait_delay`

Command-Line Format	`--innodb-spin-wait-delay=#`	
System Variable	**Name**	`innodb_spin_wait_delay`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`6`
	Minimum	`0`
	Maximum	`2**32-1`
Permitted Values (64-bit platforms)	**Type**	integer
	Default	`6`
	Minimum	`0`
	Maximum	`2**64-1`

The maximum delay between polls for a spin lock. The low-level implementation of this mechanism varies depending on the combination of hardware and operating system, so the delay does not correspond to a fixed time interval. For more information, see Section 14.9.9, “Configuring Spin Lock Polling”.

- `innodb_stats_method`

Introduced	5.5.10	
Command-Line Format	`--innodb-stats-method=name`	
System Variable	**Name**	`innodb_stats_method`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`nulls_equal`
	Valid Values	`nulls_equal`
		`nulls_unequal`
		`nulls_ignored`

How the server treats `NULL` values when collecting statistics about the distribution of index values for `InnoDB` tables. Permitted values are `nulls_equal`, `nulls_unequal`, and `nulls_ignored`. For `nulls_equal`, all `NULL` index values are considered equal and form a single value group with a size equal to the number of `NULL` values. For `nulls_unequal`, `NULL` values are considered unequal, and each `NULL` forms a distinct value group of size 1. For `nulls_ignored`, `NULL` values are ignored.

The method used to generate table statistics influences how the optimizer chooses indexes for query execution, as described in Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”.

- `innodb_stats_on_metadata`

Introduced	5.5.4	
Command-Line Format	`--innodb-stats-on-metadata`	
System Variable	**Name**	`innodb_stats_on_metadata`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`ON`

When this option is enabled (the default), `InnoDB` updates statistics when metadata statements such as `SHOW TABLE STATUS` or `SHOW INDEX` are run, or when accessing the `INFORMATION_SCHEMA.TABLES` or `INFORMATION_SCHEMA.STATISTICS` tables. (These updates are similar to what happens for `ANALYZE TABLE`.) When disabled, `InnoDB` does not update statistics during these operations. Disabling this variable can improve access speed for schemas that have a large number of tables or indexes. It can also improve the stability of execution plans for queries that involve `InnoDB` tables.

To change the setting, issue the statement `SET GLOBAL innodb_stats_on_metadata=`*`mode`*, where *`mode`* is either `ON` or `OFF` (or `1` or `0`). Changing the setting requires the `SUPER` privilege and immediately affects the operation of all connections.

- `innodb_stats_sample_pages`

Command-Line Format	--innodb-stats-sample-pages=#	
System Variable	Name	innodb_stats_sample_pages
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	8
	Minimum	1
	Maximum	2**64-1

The number of index pages to sample for index distribution statistics such as are calculated by ANALYZE TABLE. The default value is 8. For more information, see Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”.

Setting a high value for innodb_stats_sample_pages could result in lengthy ANALYZE TABLE execution time. To estimate the number of database pages accessed by ANALYZE TABLE, see Section 14.9.11.1, “Estimating ANALYZE TABLE Complexity for InnoDB Tables”.

- innodb_strict_mode

Command-Line Format	--innodb-strict-mode=#	
System Variable	Name	innodb_strict_mode
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	OFF

When innodb_strict_mode is enabled, InnoDB returns errors rather than warnings for certain conditions.

Strict mode helps guard against ignored typos and syntax errors in SQL, or other unintended consequences of various combinations of operational modes and SQL statements. When innodb_strict_mode is enabled, InnoDB raises error conditions in certain cases, rather than issuing a warning and processing the specified statement (perhaps with unintended behavior). This is analogous to sql_mode in MySQL, which controls what SQL syntax MySQL accepts, and determines whether it silently ignores errors, or validates input syntax and data values.

The innodb_strict_mode setting affects the handling of syntax errors for CREATE TABLE, ALTER TABLE and CREATE INDEX statements. innodb_strict_mode also enables a record size check, so that an INSERT or UPDATE never fails due to the record being too large for the selected page size.

Oracle recommends enabling innodb_strict_mode when using ROW_FORMAT and KEY_BLOCK_SIZE clauses in CREATE TABLE, ALTER TABLE, and CREATE INDEX statements. When innodb_strict_mode is disabled, InnoDB ignores conflicting clauses and creates the table or index with only a warning in the message log. The resulting table might have different characteristics than intended, such as lack of compression support when attempting to create a compressed table. When innodb_strict_mode is enabled, such problems generate an immediate error and the table or index is not created.

You can enable or disable innodb_strict_mode on the command line when starting mysqld, or in a MySQL configuration file. You can also enable or disable innodb_strict_mode at runtime with the statement SET [GLOBAL|SESSION] innodb_strict_mode=*mode*, where *mode* is either ON or OFF. Changing the GLOBAL setting requires the SUPER privilege and affects the

operation of all clients that subsequently connect. Any client can change the `SESSION` setting for `innodb_strict_mode`, and the setting affects only that client.

- `innodb_support_xa`

Command-Line Format	`--innodb-support-xa`	
System Variable	Name	`innodb_support_xa`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	`TRUE`

Enables `InnoDB` support for two-phase commit in XA transactions, causing an extra disk flush for transaction preparation. The XA mechanism is used internally and is essential for any server that has its binary log turned on and is accepting changes to its data from more than one thread. If you disable `innodb_support_xa`, transactions can be written to the binary log in a different order than the live database is committing them, which can produce different data when the binary log is replayed in disaster recovery or on a replication slave. Do not disable `innodb_support_xa` on a replication master server unless you have an unusual setup where only one thread is able to change data.

For a server that is accepting data changes from only one thread, it is safe and recommended to disable this option to improve performance for `InnoDB` tables. For example, you can turn it off on replication slaves where only the replication SQL thread is changing data.

You can also disable this option if you do not need it for safe binary logging or replication, and you also do not use an external XA transaction manager.

- `innodb_sync_spin_loops`

Command-Line Format	`--innodb-sync-spin-loops=#`	
System Variable	Name	`innodb_sync_spin_loops`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`30`
	Minimum	`0`
	Maximum	`4294967295`

The number of times a thread waits for an `InnoDB` mutex to be freed before the thread is suspended.

- `innodb_table_locks`

Command-Line Format	`--innodb-table-locks`	
System Variable	Name	`innodb_table_locks`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	`TRUE`

If `autocommit = 0`, `InnoDB` honors `LOCK TABLES`; MySQL does not return from `LOCK TABLES ... WRITE` until all other threads have released all their locks to the table. The default value of `innodb_table_locks` is 1, which means that `LOCK TABLES` causes `InnoDB` to lock a table internally if `autocommit = 0`.

As of MySQL 5.5.3, `innodb_table_locks = 0` has no effect for tables locked explicitly with `LOCK TABLES ... WRITE`. It still has an effect for tables locked for read or write by `LOCK TABLES ... WRITE` implicitly (for example, through triggers) or by `LOCK TABLES ... READ`.

For related information, see Section 14.8, “InnoDB Locking and Transaction Model”.

- `innodb_thread_concurrency`

Command-Line Format	`--innodb-thread-concurrency=#`	
System Variable	Name	`innodb_thread_concurrency`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`1000`

`InnoDB` tries to keep the number of operating system threads concurrently inside `InnoDB` less than or equal to the limit given by this variable (`InnoDB` uses operating system threads to process user transactions). Once the number of threads reaches this limit, additional threads are placed into a wait state within a “First In, First Out” (FIFO) queue for execution. Threads waiting for locks are not counted in the number of concurrently executing threads.

The range of this variable is 0 to 1000. A value of 0 (the default) is interpreted as infinite concurrency (no concurrency checking). Disabling thread concurrency checking enables `InnoDB` to create as many threads as it needs. A value of 0 also disables the `queries inside InnoDB` and `queries in queue counters` in the `ROW OPERATIONS` section of `SHOW ENGINE INNODB STATUS` output.

Consider setting this variable if your MySQL instance shares CPU resources with other applications, or if your workload or number of concurrent users is growing. The correct setting depends on workload, computing environment, and the version of MySQL that you are running. You will need to test a range of values to determine the setting that provides the best performance. `innodb_thread_concurrency` is a dynamic variable, which allows you to experiment with different settings on a live test system. If a particular setting performs poorly, you can quickly set `innodb_thread_concurrency` back to 0.

Use the following guidelines to help find and maintain an appropriate setting:

- If the number of concurrent user threads for a workload is less than 64, set `innodb_thread_concurrency=0`.
- If your workload is consistently heavy or occasionally spikes, start by setting `innodb_thread_concurrency=128` and then lowering the value to 96, 80, 64, and so on, until you find the number of threads that provides the best performance. For example, suppose your system typically has 40 to 50 users, but periodically the number increases to 60, 70, or even 200. You find that performance is stable at 80 concurrent users but starts to show a regression above this number. In this case, you would set `innodb_thread_concurrency=80` to avoid impacting performance.

- If you do not want `InnoDB` to use more than a certain number of vCPUs for user threads (20 vCPUs, for example), set `innodb_thread_concurrency` to this number (or possibly lower, depending on performance results). If your goal is to isolate MySQL from other applications, you may consider binding the `mysqld` process exclusively to the vCPUs. Be aware, however, that exclusive binding could result in non-optimal hardware usage if the `mysqld` process is not consistently busy. In this case, you might bind the `mysqld` process to the vCPUs but also allow other applications to use some or all of the vCPUs.

  Note

  From an operating system perspective, using a resource management solution to manage how CPU time is shared among applications may be preferable to binding the `mysqld` process. For example, you could assign 90% of vCPU time to a given application while other critical process *are not* running, and scale that value back to 40% when other critical processes *are* running.

- `innodb_thread_concurrency` values that are too high can cause performance regression due to increased contention on system internals and resources.
- In some cases, the optimal `innodb_thread_concurrency` setting can be smaller than the number of vCPUs.
- Monitor and analyze your system regularly. Changes to workload, number of users, or computing environment may require that you adjust the `innodb_thread_concurrency` setting.

For related information, see Section 14.9.5, “Configuring Thread Concurrency for InnoDB”.

- `innodb_thread_sleep_delay`

Command-Line Format	`--innodb-thread-sleep-delay=#`	
System Variable	**Name**	`innodb_thread_sleep_delay`
	Scope	Global
	Dynamic	Yes
Permitted Values (>= 5.5.37)	**Type**	integer
	Default	`10000`
	Minimum	`0`
	Maximum	`1000000`
Permitted Values (32-bit platforms, <= 5.5.36)	**Type**	integer
	Default	`10000`
	Minimum	`0`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.36)	**Type**	integer
	Default	`10000`
	Minimum	`0`
	Maximum	`18446744073709551615`

Defines how long `InnoDB` threads sleep before joining the `InnoDB` queue, in microseconds. The default value is 10000. A value of 0 disables sleep.

For more information, see Section 14.9.5, “Configuring Thread Concurrency for InnoDB”.

- `innodb_use_native_aio`

Introduced	5.5.4	
Command-Line Format	`--innodb-use-native-aio=#`	
System Variable	**Name**	`innodb_use_native_aio`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	boolean
	Default	`ON`

Specifies whether to use the Linux asynchronous I/O subsystem. This variable applies to Linux systems only, and cannot be changed while the server is running. Normally, you do not need to configure this option, because it is enabled by default.

As of MySQL 5.5, the asynchronous I/O capability that `InnoDB` has on Windows systems is available on Linux systems. (Other Unix-like systems continue to use synchronous I/O calls.) This feature improves the scalability of heavily I/O-bound systems, which typically show many pending reads/writes in `SHOW ENGINE INNODB STATUS\G` output.

Running with a large number of `InnoDB` I/O threads, and especially running multiple such instances on the same server machine, can exceed capacity limits on Linux systems. In this case, you may receive the following error:

```
EAGAIN: The specified maxevents exceeds the user's limit of available events.
```

You can typically address this error by writing a higher limit to `/proc/sys/fs/aio-max-nr`.

However, if a problem with the asynchronous I/O subsystem in the OS prevents `InnoDB` from starting, you can start the server with `innodb_use_native_aio=0`. This option may also be disabled automatically during startup if `InnoDB` detects a potential problem such as a combination of `tmpdir` location, `tmpfs` file system, and Linux kernel that does not support AIO on `tmpfs`.

For more information, see Section 14.9.7, “Using Asynchronous I/O on Linux”.

- `innodb_trx_purge_view_update_only_debug`

Command-Line Format	`--innodb-trx-purge-view-update-only-debug=#`	
System Variable	**Name**	`innodb_trx_purge_view_update_only_debug`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Pauses purging of delete-marked records while allowing the purge view to be updated. This option artificially creates a situation in which the purge view is updated but purges have not yet been performed. This option is only available if debugging support is compiled in using the `WITH_DEBUG CMake` option.

- `innodb_trx_rseg_n_slots_debug`

Command-Line Format	`--innodb-trx-rseg-n-slots-debug=#`	
System Variable	**Name**	`innodb_trx_rseg_n_slots_debug`
	Scope	Global
	Dynamic	Yes

Permitted Values	**Type**	integer
	Default	`0`
	Maximum	`1024`

Sets a debug flag that limits `TRX_RSEG_N_SLOTS` to a given value for the `trx_rsegf_undo_find_free` function that looks for free slots for undo log segments. This option is only available if debugging support is compiled in using the `WITH_DEBUG CMake` option.

- `innodb_use_sys_malloc`

Command-Line Format	`--innodb-use-sys-malloc=#`	
System Variable	**Name**	`innodb_use_sys_malloc`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	boolean
	Default	`ON`

Enables the operating system memory allocator. If disabled, `InnoDB` uses its own allocator. The default value is `ON`. For more information, see Section 14.9.3, “Configuring the Memory Allocator for InnoDB”.

- `innodb_version`

The `InnoDB` version number. Starting in MySQL 5.5.30, separate version numbering for `InnoDB` is discontinued and this value is the same the `version` number of the server.

- `innodb_write_io_threads`

Command-Line Format	`--innodb-write-io-threads=#`	
System Variable	**Name**	`innodb_write_io_threads`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`4`
	Minimum	`1`
	Maximum	`64`

The number of I/O threads for write operations in `InnoDB`. The default value is 4. Its counterpart for read threads is `innodb_read_io_threads`. For more information, see Section 14.9.6, “Configuring the Number of Background InnoDB I/O Threads”. For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

Note

On Linux systems, running multiple MySQL servers (typically more than 12) with default settings for `innodb_read_io_threads`, `innodb_write_io_threads`, and the Linux `aio-max-nr` setting can exceed system limits. Ideally, increase the `aio-max-nr` setting; as a workaround, you might reduce the settings for one or both of the MySQL configuration options.

Also take into consideration the value of `sync_binlog`, which controls synchronization of the binary log to disk.

For general I/O tuning advice, see Section 8.5.7, “Optimizing InnoDB Disk I/O”.

14.18 InnoDB INFORMATION_SCHEMA Tables

This section provides information and usage examples for `InnoDB INFORMATION_SCHEMA` tables.

`InnoDB INFORMATION_SCHEMA` tables provide metadata, status information, and statistics about various aspects of the `InnoDB` storage engine. You can view a list of `InnoDB INFORMATION_SCHEMA` tables by issuing a `SHOW TABLES` statement on the `INFORMATION_SCHEMA` database:

```
mysql> SHOW TABLES FROM INFORMATION_SCHEMA LIKE 'INNODB%';
```

For table definitions, see Section 21.28, “InnoDB INFORMATION_SCHEMA Tables”. For general information regarding the `MySQL INFORMATION_SCHEMA` database, see Chapter 21, *INFORMATION_SCHEMA Tables*.

The `InnoDB INFORMATION_SCHEMA` tables are themselves plugins to the MySQL server. To see what plugins are installed, use the `SHOW PLUGINS` statement or query the `INFORMATION_SCHEMA.PLUGINS` table. Use `INSTALL PLUGIN` syntax to install an `INFORMATION_SCHEMA` table plugin. If `INFORMATION_SCHEMA` table plugins are installed, but the `InnoDB` storage engine plugin is not installed, the tables appear empty.

14.18.1 InnoDB INFORMATION_SCHEMA Tables about Compression

There are two pairs of `InnoDB INFORMATION_SCHEMA` tables about compression that can provide insight into how well compression is working overall:

- `INNODB_CMP` and `INNODB_CMP_RESET` contain information about the number of compression operations and the amount of time spent performing compression.
- `INNODB_CMPMEM` and `INNODB_CMP_RESET` contain information about the way memory is allocated for compression.

14.18.1.1 INNODB_CMP and INNODB_CMP_RESET

The `INNODB_CMP` and `INNODB_CMP_RESET` tables contain status information about operations related to compressed tables, which are described in Section 14.12, “InnoDB Table Compression”. The `PAGE_SIZE` column reports the compressed page size.

These two tables have identical contents, but reading from `INNODB_CMP_RESET` resets the statistics on compression and uncompression operations. For example, if you archive the output of `INNODB_CMP_RESET` every 60 minutes, you see the statistics for each hourly period. If you monitor the output of `INNODB_CMP` (making sure never to read `INNODB_CMP_RESET`), you see the cumulated statistics since `InnoDB` was started.

For the table definition, see Section 21.28.4, “The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables”.

14.18.1.2 INNODB_CMPMEM and INNODB_CMPMEM_RESET

The `INNODB_CMPMEM` and `INNODB_CMPMEM_RESET` tables contain status information about compressed pages that reside in the buffer pool. Please consult Section 14.12, “InnoDB Table Compression” for further information on compressed tables and the use of the buffer pool. The `INNODB_CMP` and `INNODB_CMP_RESET` tables should provide more useful statistics on compression.

Internal Details

`InnoDB` uses a buddy allocator system to manage memory allocated to pages of various sizes, from 1KB to 16KB. Each row of the two tables described here corresponds to a single page size.

The INNODB_CMPMEM and INNODB_CMPMEM_RESET tables have identical contents, but reading from INNODB_CMPMEM_RESET resets the statistics on relocation operations. For example, if every 60 minutes you archived the output of INNODB_CMPMEM_RESET, it would show the hourly statistics. If you never read INNODB_CMPMEM_RESET and monitored the output of INNODB_CMPMEM instead, it would show the cumulated statistics since InnoDB was started.

For the table definition, see Section 21.28.5, "The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables".

14.18.1.3 Using the Compression Information Schema Tables

Example 14.1 Using the Compression Information Schema Tables

The following is sample output from a database that contains compressed tables (see Section 14.12, "InnoDB Table Compression", INNODB_CMP, and INNODB_CMPMEM).

The following table shows the contents of INFORMATION_SCHEMA.INNODB_CMP under a light workload. The only compressed page size that the buffer pool contains is 8K. Compressing or uncompressing pages has consumed less than a second since the time the statistics were reset, because the columns COMPRESS_TIME and UNCOMPRESS_TIME are zero.

page size	compress ops	compress ops ok	compress time	uncompress ops	uncompress time
1024	0	0	0	0	0
2048	0	0	0	0	0
4096	0	0	0	0	0
8192	1048	921	0	61	0
16384	0	0	0	0	0

According to INNODB_CMPMEM, there are 6169 compressed 8KB pages in the buffer pool.

The following table shows the contents of INFORMATION_SCHEMA.INNODB_CMPMEM under a light workload. Some memory is unusable due to fragmentation of the InnoDB memory allocator for compressed pages: SUM(PAGE_SIZE*PAGES_FREE)=6784. This is because small memory allocation requests are fulfilled by splitting bigger blocks, starting from the 16K blocks that are allocated from the main buffer pool, using the buddy allocation system. The fragmentation is this low because some allocated blocks have been relocated (copied) to form bigger adjacent free blocks. This copying of SUM(PAGE_SIZE*RELOCATION_OPS) bytes has consumed less than a second (SUM(RELOCATION_TIME)=0).

page size	pages used	pages free	relocation ops	relocation time
1024	0	0	0	0
2048	0	1	0	0
4096	0	1	0	0
8192	6169	0	5	0
16384	0	0	0	0

14.18.2 InnoDB INFORMATION_SCHEMA Transaction and Locking Information

Three InnoDB INFORMATION_SCHEMA tables enable you to monitor transactions and diagnose potential locking problems:

- `INNODB_TRX`: Contains information about every transaction currently executing inside `InnoDB`, including the transaction state (for example, whether it is running or waiting for a lock), when the transaction started, and the particular SQL statement the transaction is executing.
- `INNODB_LOCKS`: Each transaction in InnoDB that is waiting for another transaction to release a lock (`INNODB_TRX.TRX_STATE` is `LOCK WAIT`) is blocked by exactly one blocking lock request. That blocking lock request is for a row or table lock held by another transaction in an incompatible mode. A lock that blocks a transaction is always held in a mode incompatible with the mode of requested lock (read vs. write, shared vs. exclusive). The blocked transaction cannot proceed until the other transaction commits or rolls back, thereby releasing the requested lock. For every blocked transaction, `INNODB_LOCKS` contains one row that describes each lock the transaction has requested, and for which it is waiting. `INNODB_LOCKS` also contains one row for each lock that is blocking another transaction, whatever the state of the transaction that holds the lock (`INNODB_TRX.TRX_STATE` is `RUNNING`, `LOCK WAIT`, `ROLLING BACK` or `COMMITTING`).
- `INNODB_LOCK_WAITS`: This table indicates which transactions are waiting for a given lock, or for which lock a given transaction is waiting. This table contains one or more rows for each blocked transaction, indicating the lock it has requested and any locks that are blocking that request. The `REQUESTED_LOCK_ID` value refers to the lock requested by a transaction, and the `BLOCKING_LOCK_ID` value refers to the lock (held by another transaction) that prevents the first transaction from proceeding. For any given blocked transaction, all rows in `INNODB_LOCK_WAITS` have the same value for `REQUESTED_LOCK_ID` and different values for `BLOCKING_LOCK_ID`.

For more information about the preceding tables, see Section 21.28.8, “The INFORMATION_SCHEMA INNODB_TRX Table”, Section 21.28.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”, and Section 21.28.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”.

14.18.2.1 Using InnoDB Transaction and Locking Information

Identifying Blocking Transactions

It is sometimes helpful to identify which transaction blocks another. The tables that contain information about `InnoDB` transactions and data locks enable you to determine which transaction is waiting for another, and which resource is being requested. (For descriptions of these tables, see Section 14.18.2, “InnoDB INFORMATION_SCHEMA Transaction and Locking Information”.)

Suppose that three sessions are running concurrently. Each session corresponds to a MySQL thread, and executes one transaction after another. Consider the state of the system when these sessions have issued the following statements, but none has yet committed its transaction:

- Session A:

```
BEGIN;
SELECT a FROM t FOR UPDATE;
SELECT SLEEP(100);
```

- Session B:

```
SELECT b FROM t FOR UPDATE;
```

- Session C:

```
SELECT c FROM t FOR UPDATE;
```

In this scenario, use the following query to see which transactions are waiting and which transactions are blocking them:

```
SELECT
  r.trx_id waiting_trx_id,
```

```
  r.trx_mysql_thread_id waiting_thread,
  r.trx_query waiting_query,
  b.trx_id blocking_trx_id,
  b.trx_mysql_thread_id blocking_thread,
  b.trx_query blocking_query
FROM       information_schema.innodb_lock_waits w
INNER JOIN information_schema.innodb_trx b
  ON b.trx_id = w.blocking_trx_id
INNER JOIN information_schema.innodb_trx r
  ON r.trx_id = w.requesting_trx_id;
```

waiting trx id	waiting thread	waiting query	blocking trx id	blocking thread	blocking query
A4	6	SELECT b FROM t FOR UPDATE	A3	5	SELECT SLEEP(100)
A5	7	SELECT c FROM t FOR UPDATE	A3	5	SELECT SLEEP(100)
A5	7	SELECT c FROM t FOR UPDATE	A4	6	SELECT b FROM t FOR UPDATE

In the preceding table, you can identify sessions by the “waiting query” or “blocking query” columns. As you can see:

- Session B (trx id A4, thread 6) and Session C (trx id A5, thread 7) are both waiting for Session A (trx id A3, thread 5).
- Session C is waiting for Session B as well as Session A.

You can see the underlying data in the tables INNODB_TRX, INNODB_LOCKS, and INNODB_LOCK_WAITS.

The following table shows some sample contents of INFORMATION_SCHEMA.INNODB_TRX.

trx id	trx state	trx started	trx requested lock id	trx wait started	trx weight	trx mysql thread id	trx query
A3	RUNNING	2008-01-15 16:44:54	NULL	NULL	2	5	SELECT SLEEP(100)
A4	LOCK WAIT	2008-01-15 16:45:09	A4:1:3:2	2008-01-15 16:45:09	2	6	SELECT b FROM t FOR UPDATE
A5	LOCK WAIT	2008-01-15 16:45:14	A5:1:3:2	2008-01-15 16:45:14	2	7	SELECT c FROM t FOR UPDATE

The following table shows some sample contents of INFORMATION_SCHEMA.INNODB_LOCKS.

lock id	lock trx id	lock mode	lock type	lock table	lock index	lock data
A3:1:3:2	A3	X	RECORD	test.t	PRIMARY	0x0200
A4:1:3:2	A4	X	RECORD	test.t	PRIMARY	0x0200
A5:1:3:2	A5	X	RECORD	test.t	PRIMARY	0x0200

The following table shows some sample contents of INFORMATION_SCHEMA.INNODB_LOCK_WAITS.

requesting trx id	requested lock id	blocking trx id	blocking lock id
A4	A4:1:3:2	A3	A3:1:3:2
A5	A5:1:3:2	A3	A3:1:3:2

requesting trx id	requested lock id	blocking trx id	blocking lock id
A5	A5:1:3:2	A4	A4:1:3:2

Correlating InnoDB Transactions with MySQL Sessions

Sometimes it is useful to correlate internal InnoDB locking information with the session-level information maintained by MySQL. For example, you might like to know, for a given InnoDB transaction ID, the corresponding MySQL session ID and name of the session that may be holding a lock, and thus blocking other transactions.

The following output from the INFORMATION_SCHEMA tables is taken from a somewhat loaded system. As can be seen, there are several transactions running.

The following INNODB_LOCKS and INNODB_LOCK_WAITS tables show that:

- Transaction 77F (executing an INSERT) is waiting for transactions 77E, 77D, and 77B to commit.
- Transaction 77E (executing an INSERT) is waiting for transactions 77D and 77B to commit.
- Transaction 77D (executing an INSERT) is waiting for transaction 77B to commit.
- Transaction 77B (executing an INSERT) is waiting for transaction 77A to commit.
- Transaction 77A is running, currently executing SELECT.
- Transaction E56 (executing an INSERT) is waiting for transaction E55 to commit.
- Transaction E55 (executing an INSERT) is waiting for transaction 19C to commit.
- Transaction 19C is running, currently executing an INSERT.

Note

There may be inconsistencies between queries shown in the INFORMATION_SCHEMA PROCESSLIST and INNODB_TRX tables. For an explanation, see Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”.

The following table shows the contents of INFORMATION_SCHEMA.PROCESSLIST for a system running a heavy workload.

ID	USER	HOST	DB	COMMAND	TIME	STATE	INFO
384	root	localhost	test	Query	10	update	INSERT INTO t2 VALUES …
257	root	localhost	test	Query	3	update	INSERT INTO t2 VALUES …
130	root	localhost	test	Query	0	update	INSERT INTO t2 VALUES …
61	root	localhost	test	Query	1	update	INSERT INTO t2 VALUES …
8	root	localhost	test	Query	1	update	INSERT INTO t2 VALUES …
4	root	localhost	test	Query	0	preparing	SELECT * FROM PROCESSLIST
2	root	localhost	test	Sleep	566		NULL

The following table shows the contents of INFORMATION_SCHEMA.INNODB_TRX for a system running a heavy workload.

trx id	trx state	trx started	trx requested lock id	trx wait started	trx weight	trx mysql thread id	trx query
77F	LOCK WAIT	2008-01-15 13:10:16	77F	2008-01-15 13:10:16	1	876	INSERT INTO t09 (D, B, C) VALUES …
77E	LOCK WAIT	2008-01-15 13:10:16	77E	2008-01-15 13:10:16	1	875	INSERT INTO t09 (D, B, C) VALUES …
77D	LOCK WAIT	2008-01-15 13:10:16	77D	2008-01-15 13:10:16	1	874	INSERT INTO t09 (D, B, C) VALUES …
77B	LOCK WAIT	2008-01-15 13:10:16	77B:733:12:1	2008-01-15 13:10:16	4	873	INSERT INTO t09 (D, B, C) VALUES …
77A	RUN-NING	2008-01-15 13:10:16	NULL	NULL	4	872	SELECT b, c FROM t09 WHERE …
E56	LOCK WAIT	2008-01-15 13:10:06	E56:743:6:2	2008-01-15 13:10:06	5	384	INSERT INTO t2 VALUES …
E55	LOCK WAIT	2008-01-15 13:10:06	E55:743:38:2	2008-01-15 13:10:13	965	257	INSERT INTO t2 VALUES …
19C	RUN-NING	2008-01-15 13:09:10	NULL	NULL	2900	130	INSERT INTO t2 VALUES …
E15	RUN-NING	2008-01-15 13:08:59	NULL	NULL	5395	61	INSERT INTO t2 VALUES …
51D	RUN-NING	2008-01-15 13:08:47	NULL	NULL	9807	8	INSERT INTO t2 VALUES …

The following table shows the contents of `INFORMATION_SCHEMA.INNODB_LOCK_WAITS` for a system running a heavy workload.

requesting trx id	requested lock id	blocking trx id	blocking lock id
77F	77F:806	77E	77E:806
77F	77F:806	77D	77D:806
77F	77F:806	77B	77B:806
77E	77E:806	77D	77D:806
77E	77E:806	77B	77B:806
77D	77D:806	77B	77B:806
77B	77B:733:12:1	77A	77A:733:12:1
E56	E56:743:6:2	E55	E55:743:6:2
E55	E55:743:38:2	19C	19C:743:38:2

The following table shows the contents of `INFORMATION_SCHEMA.INNODB_LOCKS` for a system running a heavy workload.

lock id	lock trx id	lock mode	lock type	lock table	lock index	lock data
77F:806	77F	AUTO_INC	TABLE	test.t09	NULL	NULL

lock id	lock trx id	lock mode	lock type	lock table	lock index	lock data
77E:806	77E	AUTO_INC	TABLE	test.t09	NULL	NULL
77D:806	77D	AUTO_INC	TABLE	test.t09	NULL	NULL
77B:806	77B	AUTO_INC	TABLE	test.t09	NULL	NULL
77B:733:12:1	77B	X	RECORD	test.t09	PRIMARY	supremum pseudo-record
77A:733:12:1	77A	X	RECORD	test.t09	PRIMARY	supremum pseudo-record
E56:743:6:2	E56	S	RECORD	test.t2	PRIMARY	0, 0
E55:743:6:2	E55	X	RECORD	test.t2	PRIMARY	0, 0
E55:743:38:2	E55	S	RECORD	test.t2	PRIMARY	1922, 1922
19C:743:38:2	19C	X	RECORD	test.t2	PRIMARY	1922, 1922

14.18.2.2 InnoDB Lock and Lock-Wait Information

When a transaction updates a row in a table, or locks it with `SELECT FOR UPDATE`, `InnoDB` establishes a list or queue of locks on that row. Similarly, `InnoDB` maintains a list of locks on a table for table-level locks. If a second transaction wants to update a row or lock a table already locked by a prior transaction in an incompatible mode, `InnoDB` adds a lock request for the row to the corresponding queue. For a lock to be acquired by a transaction, all incompatible lock requests previously entered into the lock queue for that row or table must be removed (which occurs when the transactions holding or requesting those locks either commit or roll back).

A transaction may have any number of lock requests for different rows or tables. At any given time, a transaction may request a lock that is held by another transaction, in which case it is blocked by that other transaction. The requesting transaction must wait for the transaction that holds the blocking lock to commit or roll back. If a transaction is not waiting for a lock, it is in a `RUNNING` state. If a transaction is waiting for a lock, it is in a `LOCK WAIT` state. (The `INFORMATION_SCHEMA INNODB_TRX` table indicates transaction state values.)

The `INNODB_LOCKS` table holds one or more rows for each `LOCK WAIT` transaction, indicating any lock requests that prevent its progress. This table also contains one row describing each lock in a queue of locks pending for a given row or table. The `INNODB_LOCK_WAITS` table shows which locks already held by a transaction are blocking locks requested by other transactions.

14.18.2.3 Persistence and Consistency of InnoDB Transaction and Locking Information

The data exposed by the transaction and locking tables (`INNODB_TRX`, `INNODB_LOCKS`, and `INNODB_LOCK_WAITS`) represents a glimpse into fast-changing data. This is not like user tables, where the data changes only when application-initiated updates occur. The underlying data is internal system-managed data, and can change very quickly.

For performance reasons, and to minimize the chance of misleading joins between the transaction and locking tables, `InnoDB` collects the required transaction and locking information into an intermediate buffer whenever a `SELECT` on any of the tables is issued. This buffer is refreshed only if more than 0.1 seconds has elapsed since the last time the buffer was read. The data needed to fill the three tables is fetched atomically and consistently and is saved in this global internal buffer, forming a point-in-time “snapshot”. If multiple table accesses occur within 0.1 seconds (as they almost certainly do when MySQL processes a join among these tables), then the same snapshot is used to satisfy the query.

A correct result is returned when you join any of these tables together in a single query, because the data for the three tables comes from the same snapshot. Because the buffer is not refreshed with

every query of any of these tables, if you issue separate queries against these tables within a tenth of a second, the results are the same from query to query. On the other hand, two separate queries of the same or different tables issued more than a tenth of a second apart may see different results, since the data come from different snapshots.

Because `InnoDB` must temporarily stall while the transaction and locking data is collected, too frequent queries of these tables can negatively impact performance as seen by other users.

As these tables contain sensitive information (at least `INNODB_LOCKS.LOCK_DATA` and `INNODB_TRX.TRX_QUERY`), for security reasons, only the users with the `PROCESS` privilege are allowed to `SELECT` from them.

As described previously, the data that fills the transaction and locking tables (`INNODB_TRX`, `INNODB_LOCKS` and `INNODB_LOCK_WAITS`) is fetched automatically and saved to an intermediate buffer that provides a “point-in-time” snapshot. The data across all three tables is consistent when queried from the same snapshot. However, the underlying data changes so fast that similar glimpses at other, similarly fast-changing data, may not be in synchrony. Thus, you should be careful when comparing data in the `InnoDB` transaction and locking tables with data in the `PROCESSLIST` table. The data from the `PROCESSLIST` table does not come from the same snapshot as the data about locking and transactions. Even if you issue a single `SELECT` (joining `INNODB_TRX` and `PROCESSLIST`, for example), the content of those tables is generally not consistent. `INNODB_TRX` may reference rows that are not present in `PROCESSLIST` or the currently executing SQL query of a transaction shown in `INNODB_TRX.TRX_QUERY` may differ from the one in `PROCESSLIST.INFO`.

14.18.3 InnoDB INFORMATION_SCHEMA Buffer Pool Tables

The `InnoDB` `INFORMATION_SCHEMA` buffer pool tables provide buffer pool status information and metadata about the pages within the `InnoDB` buffer pool. The tables were introduced in MySQL 5.6.2 and later backported to MySQL 5.5 (in MySQL 5.5.28) and MySQL 5.1 (in MySQL 5.1.66).

The `InnoDB` `INFORMATION_SCHEMA` buffer pool tables include those listed below:

```
mysql> SHOW TABLES FROM INFORMATION_SCHEMA LIKE 'INNODB_BUFFER%';
+-----------------------------------------------+
| Tables_in_INFORMATION_SCHEMA (INNODB_BUFFER%) |
+-----------------------------------------------+
| INNODB_BUFFER_PAGE_LRU                        |
| INNODB_BUFFER_PAGE                            |
| INNODB_BUFFER_POOL_STATS                      |
+-----------------------------------------------+
```

Table Overview

- `INNODB_BUFFER_PAGE`: Holds information about each page in the `InnoDB` buffer pool.
- `INNODB_BUFFER_PAGE_LRU`: Holds information about the pages in the `InnoDB` buffer pool, in particular how they are ordered in the LRU list that determines which pages to evict from the buffer pool when it becomes full. The `INNODB_BUFFER_PAGE_LRU` table has the same columns as the `INNODB_BUFFER_PAGE` table, except that the `INNODB_BUFFER_PAGE_LRU` table has an `LRU_POSITION` column instead of a `BLOCK_ID` column.
- `INNODB_BUFFER_POOL_STATS`: Provides buffer pool status information. Much of the same information is provided by `SHOW ENGINE INNODB STATUS` output, or may be obtained using `InnoDB` buffer pool server status variables.

Warning

Querying the `INNODB_BUFFER_PAGE` table or `INNODB_BUFFER_PAGE_LRU` table can introduce significant performance overhead. Do not query these tables on a production system unless you are aware of the performance impact

that your query may have, and have determined it to be acceptable. To avoid impacting performance, reproduce the issue you want to investigate on a test instance and run your queries on the test instance.

Example 14.2 Querying System Data in the INNODB_BUFFER_PAGE Table

This query provides an approximate count of pages that contain system data by excluding pages where the `TABLE_NAME` value is either `NULL` or includes a slash `/` or period `.` in the table name, which indicates a user-defined table.

```
SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE TABLE_NAME IS NULL OR (INSTR(TABLE_NAME, '/') = 0 AND INSTR(TABLE_NAME, '.') = 0);
+----------+
| COUNT(*) |
+----------+
|      381 |
+----------+
```

This query returns the approximate number of pages that contain system data, the total number of buffer pool pages, and an approximate percentage of pages that contain system data.

```
SELECT
(SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE TABLE_NAME IS NULL OR (INSTR(TABLE_NAME, '/') = 0 AND INSTR(TABLE_NAME, '.') = 0)
) AS system_pages,
(
SELECT COUNT(*)
FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
) AS total_pages,
(
SELECT ROUND((system_pages/total_pages) * 100)
) AS system_page_percentage;
+--------------+-------------+-----------------------+
| system_pages | total_pages | system_page_percentage |
+--------------+-------------+-----------------------+
|          381 |        8192 |                     5 |
+--------------+-------------+-----------------------+
```

The type of system data in the buffer pool can be determined by querying the `PAGE_TYPE` value. For example, the following query returns eight distinct `PAGE_TYPE` values among the pages that contain system data:

```
mysql> SELECT DISTINCT PAGE_TYPE FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE TABLE_NAME IS NULL OR (INSTR(TABLE_NAME, '/') = 0 AND INSTR(TABLE_NAME, '.') = 0);
+-------------------+
| PAGE_TYPE         |
+-------------------+
| IBUF_BITMAP       |
| SYSTEM            |
| INDEX             |
| UNDO_LOG          |
| FILE_SPACE_HEADER |
| UNKNOWN           |
| INODE             |
| EXTENT_DESCRIPTOR |
+-------------------+
```

Example 14.3 Querying User Data in the INNODB_BUFFER_PAGE Table

This query provides an approximate count of pages containing user data by counting pages where the `TABLE_NAME` value is `NOT NULL`.

```
mysql> SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE TABLE_NAME IS NOT NULL;
+----------+
| COUNT(*) |
```

```
+----------+
|     7811 |
+----------+
```

This query returns the approximate number of pages that contain user data, the total number of buffer pool pages, and an approximate percentage of pages that contain user data.

```
mysql> SELECT
(SELECT COUNT(*) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE TABLE_NAME IS NOT NULL AND (INSTR(TABLE_NAME, '/') > 0 OR INSTR(TABLE_NAME, '.') > 0)
) AS user_pages,
(
SELECT COUNT(*)
FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
) AS total_pages,
(
SELECT ROUND((user_pages/total_pages) * 100)
) AS user_page_percentage;
+------------+-------------+----------------------+
| user_pages | total_pages | user_page_percentage |
+------------+-------------+----------------------+
|       7811 |        8192 |                   95 |
+------------+-------------+----------------------+
```

This query identifies user-defined tables with pages in the buffer pool:

```
mysql> SELECT DISTINCT TABLE_NAME
FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE TABLE_NAME IS NOT NULL
AND (INSTR(TABLE_NAME, '/') > 0 OR INSTR(TABLE_NAME, '.') > 0);
+---------------------+
| TABLE_NAME          |
+---------------------+
| employees/salaries  |
| employees/employees |
+---------------------+
```

Example 14.4 Querying Index Data in the INNODB_BUFFER_PAGE Table

For information about index pages, query the `INDEX_NAME` column using the name of the index. For example, the following query returns the number of pages and total data size of pages for the `emp_no` index that is defined on the `employees.salaries` table:

```
mysql> SELECT INDEX_NAME, COUNT(*) AS Pages,
ROUND(SUM(IF(COMPRESSED_SIZE = 0, 16384, COMPRESSED_SIZE))/1024/1024)
AS 'Total Data (MB)'  FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE INDEX_NAME='emp_no' AND TABLE_NAME = 'employees/salaries';
+------------+-------+-----------------+
| INDEX_NAME | Pages | Total Data (MB) |
+------------+-------+-----------------+
| emp_no     |  1244 |              19 |
+------------+-------+-----------------+
```

This query returns the number of pages and total data size of pages for all indexes defined on the `employees.salaries` table:

```
mysql> SELECT INDEX_NAME, COUNT(*) AS Pages,
ROUND(SUM(IF(COMPRESSED_SIZE = 0, 16384, COMPRESSED_SIZE))/1024/1024)
AS 'Total Data (MB)'
FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE
WHERE TABLE_NAME = 'employees/salaries'
GROUP BY INDEX_NAME;
+------------+-------+-----------------+
| INDEX_NAME | Pages | Total Data (MB) |
+------------+-------+-----------------+
| emp_no     |  1244 |              19 |
| PRIMARY    |  6086 |              95 |
+------------+-------+-----------------+
```

Example 14.5 Querying LRU_POSITION Data in the INNODB_BUFFER_PAGE_LRU Table

The `INNODB_BUFFER_PAGE_LRU` table holds information about the pages in the `InnoDB` buffer pool, in particular how they are ordered that determines which pages to evict from the buffer pool when it becomes full. The definition for this page is the same as for `INNODB_BUFFER_PAGE`, except this table has an `LRU_POSITION` column instead of a `BLOCK_ID` column.

This query counts the number of positions at a specific location in the LRU list occupied by pages of the `employees.employees` table.

```
mysql> SELECT COUNT(LRU_POSITION) FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE_LRU
WHERE TABLE_NAME='employees/employees' AND LRU_POSITION < 3072;
+--------------------+
| COUNT(LRU_POSITION) |
+--------------------+
|                481 |
+--------------------+
```

Example 14.6 Querying the INNODB_BUFFER_POOL_STATS Table

The `INNODB_BUFFER_POOL_STATS` table provides information similar to `SHOW ENGINE INNODB STATUS` and `InnoDB` buffer pool status variables.

```
mysql> SELECT * FROM information_schema.INNODB_BUFFER_POOL_STATS \G
*************************** 1. row ***************************
                         POOL_ID: 0
                       POOL_SIZE: 8192
                    FREE_BUFFERS: 1
                  DATABASE_PAGES: 7942
              OLD_DATABASE_PAGES: 2911
         MODIFIED_DATABASE_PAGES: 0
              PENDING_DECOMPRESS: 0
                   PENDING_READS: 0
               PENDING_FLUSH_LRU: 0
              PENDING_FLUSH_LIST: 0
                PAGES_MADE_YOUNG: 8358
            PAGES_NOT_MADE_YOUNG: 0
           PAGES_MADE_YOUNG_RATE: 0
       PAGES_MADE_NOT_YOUNG_RATE: 0
              NUMBER_PAGES_READ: 7045
           NUMBER_PAGES_CREATED: 12382
           NUMBER_PAGES_WRITTEN: 15790
                PAGES_READ_RATE: 0
              PAGES_CREATE_RATE: 0
             PAGES_WRITTEN_RATE: 0
               NUMBER_PAGES_GET: 28731589
                       HIT_RATE: 0
    YOUNG_MAKE_PER_THOUSAND_GETS: 0
NOT_YOUNG_MAKE_PER_THOUSAND_GETS: 0
         NUMBER_PAGES_READ_AHEAD: 2934
       NUMBER_READ_AHEAD_EVICTED: 23
                READ_AHEAD_RATE: 0
        READ_AHEAD_EVICTED_RATE: 0
                   LRU_IO_TOTAL: 0
                 LRU_IO_CURRENT: 0
               UNCOMPRESS_TOTAL: 0
             UNCOMPRESS_CURRENT: 0
```

For comparison, `SHOW ENGINE INNODB STATUS` output and `InnoDB` buffer pool status variable output is shown below, based on the same data set.

For more information about `SHOW ENGINE INNODB STATUS` output, see Section 14.20.3, “InnoDB Standard Monitor and Lock Monitor Output”.

```
mysql> SHOW ENGINE INNODB STATUS \G
...
----------------------
BUFFER POOL AND MEMORY
```

```
---------------------
Total memory allocated 137363456; in additional pool allocated 0
Dictionary memory allocated 71426
Buffer pool size   8192
Free buffers       1
Database pages     7942
Old database pages 2911
Modified db pages  0
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 8358, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 7045, created 12382, written 15790
0.00 reads/s, 0.00 creates/s, 0.00 writes/s
No buffer pool page gets since the last printout
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead 0.00/s
LRU len: 7942, unzip_LRU len: 0
I/O sum[0]:cur[0], unzip sum[0]:cur[0]
...
```

For status variable descriptions, see Section 5.1.7, “Server Status Variables”.

```
mysql> SHOW STATUS LIKE 'Innodb_buffer%';
+---------------------------------------+-----------+
| Variable_name                         | Value     |
+---------------------------------------+-----------+
| Innodb_buffer_pool_pages_data         | 7942      |
| Innodb_buffer_pool_bytes_data         | 130121728 |
| Innodb_buffer_pool_pages_dirty        | 0         |
| Innodb_buffer_pool_bytes_dirty        | 0         |
| Innodb_buffer_pool_pages_flushed      | 15790     |
| Innodb_buffer_pool_pages_free         | 1         |
| Innodb_buffer_pool_pages_misc         | 249       |
| Innodb_buffer_pool_pages_total        | 8192      |
| Innodb_buffer_pool_read_ahead_rnd     | 0         |
| Innodb_buffer_pool_read_ahead         | 2934      |
| Innodb_buffer_pool_read_ahead_evicted | 23        |
| Innodb_buffer_pool_read_requests      | 28731589  |
| Innodb_buffer_pool_reads              | 4112      |
| Innodb_buffer_pool_wait_free          | 0         |
| Innodb_buffer_pool_write_requests     | 11965146  |
+---------------------------------------+-----------+
```

14.19 InnoDB Integration with MySQL Performance Schema

This section provides a brief introduction to `InnoDB` integration with Performance Schema. For comprehensive Performance Schema documentation, see Chapter 22, *MySQL Performance Schema*.

Starting with InnoDB 1.1 with MySQL 5.5, you can profile certain internal `InnoDB` operations using the MySQL Performance Schema feature. This type of tuning is primarily for expert users who evaluate optimization strategies to overcome performance bottlenecks. DBAs can also use this feature for capacity planning, to see whether their typical workload encounters any performance bottlenecks with a particular combination of CPU, RAM, and disk storage; and if so, to judge whether performance can be improved by increasing the capacity of some part of the system.

To use this feature to examine `InnoDB` performance:

- You must be running MySQL 5.5 or higher with the Performance Schema feature available and enabled, as described in Section 22.2, “Performance Schema Build Configuration”, and Section 22.3, “Performance Schema Startup Configuration”. Since the Performance Schema feature introduces some performance overhead, you should use it on a test or development system rather than on a production system.
- You must be running InnoDB 1.1 or higher.
- You must be generally familiar with how to use the Performance Schema feature. For example, you should know how enable instruments and consumers, and how to query `performance_schema`

tables to retrieve data. For an introductory overview, see Section 22.1, “Performance Schema Quick Start”.

- You should be familiar with Performance Schema instruments that are available for `InnoDB`. To view `InnoDB`-related instruments, you can query the `setup_instruments` table for instrument names that contain '`innodb`'.

```
mysql> SELECT * FROM setup_instruments WHERE NAME LIKE '%innodb%';
+---------------------------------------------------------+---------+-------+
| NAME                                                    | ENABLED | TIMED |
+---------------------------------------------------------+---------+-------+
| wait/synch/mutex/innodb/commit_cond_mutex               | YES     | YES   |
| wait/synch/mutex/innodb/innobase_share_mutex            | YES     | YES   |
| wait/synch/mutex/innodb/prepare_commit_mutex            | YES     | YES   |
| wait/synch/mutex/innodb/autoinc_mutex                   | YES     | YES   |
| wait/synch/mutex/innodb/btr_search_enabled_mutex        | YES     | YES   |
| wait/synch/mutex/innodb/buf_pool_mutex                  | YES     | YES   |
| wait/synch/mutex/innodb/buf_pool_zip_mutex              | YES     | YES   |
| wait/synch/mutex/innodb/cache_last_read_mutex           | YES     | YES   |
| wait/synch/mutex/innodb/dict_foreign_err_mutex          | YES     | YES   |
| wait/synch/mutex/innodb/dict_sys_mutex                  | YES     | YES   |
| wait/synch/mutex/innodb/file_format_max_mutex           | YES     | YES   |
...
| wait/synch/rwlock/innodb/btr_search_latch               | YES     | YES   |
| wait/synch/rwlock/innodb/dict_operation_lock            | YES     | YES   |
| wait/synch/rwlock/innodb/fil_space_latch                | YES     | YES   |
| wait/synch/rwlock/innodb/checkpoint_lock                | YES     | YES   |
| wait/synch/rwlock/innodb/trx_i_s_cache_lock             | YES     | YES   |
| wait/synch/rwlock/innodb/trx_purge_latch                | YES     | YES   |
| wait/synch/rwlock/innodb/index_tree_rw_lock             | YES     | YES   |
| wait/synch/rwlock/innodb/dict_table_stats               | YES     | YES   |
| wait/synch/cond/innodb/commit_cond                      | YES     | YES   |
| wait/io/file/innodb/innodb_data_file                    | YES     | YES   |
| wait/io/file/innodb/innodb_log_file                     | YES     | YES   |
| wait/io/file/innodb/innodb_temp_file                    | YES     | YES   |
+---------------------------------------------------------+---------+-------+
46 rows in set (0.00 sec)
```

For additional information about the instrumented `InnoDB` objects, you can query Performance Schema instances tables, which provide additional information about instrumented objects. Instance tables relevant to `InnoDB` include:

- The `mutex_instances` table
- The `rwlock_instances` table
- The `cond_instances` table
- The `file_instances` table

Note

Mutexes and RW-locks related to the `InnoDB` buffer pool are not included in this coverage; the same applies to the output of the `SHOW ENGINE INNODB MUTEX` command.

For example, to view information about instrumented `InnoDB` file objects seen by the Performance Schema when executing file I/O instrumentation, you might issue the following query:

```
mysql> SELECT * FROM file_instances WHERE EVENT_NAME LIKE '%innodb%'\G
*************************** 1. row ***************************
 FILE_NAME: /path/to/mysql-5.5/data/ibdata1
EVENT_NAME: wait/io/file/innodb/innodb_data_file
OPEN_COUNT: 1
*************************** 2. row ***************************
 FILE_NAME: /path/to/mysql-5.5/data/ib_logfile0
```

```
EVENT_NAME: wait/io/file/innodb/innodb_log_file
OPEN_COUNT: 1
*************************** 3. row ***************************
 FILE_NAME: /path/to/mysql-5.5/data/ib_logfile1
EVENT_NAME: wait/io/file/innodb/innodb_log_file
OPEN_COUNT: 1
```

- You should be familiar with `performance_schema` tables that store `InnoDB` event data. Tables relevant to `InnoDB`-related events include:

  - The Wait Event tables, which store wait events.

  - The Summary tables, which provide aggregated information for terminated events over time. Summary tables include file I/O summary tables, which aggregate information about I/O operations.

  If you are only interested in `InnoDB`-related objects, use the clause `WHERE EVENT_NAME LIKE '%innodb%'` or `WHERE NAME LIKE '%innodb%'` (as required) when querying these tables.

14.19.1 Monitoring InnoDB Mutex Waits Using Performance Schema

A mutex is a synchronization mechanism used in the code to enforce that only one thread at a given time can have access to a common resource. When two or more threads executing in the server need to access the same resource, the threads compete against each other. The first thread to obtain a lock on the mutex causes the other threads to wait until the lock is released.

For `InnoDB` mutexes that are instrumented, mutex waits can be monitored using Performance Schema. Wait event data collected in Performance Schema tables can help identify mutexes with the most waits or the greatest total wait time, for example.

The following example demonstrates how to view `InnoDB` mutex wait instruments, how to verify that associated consumers are enabled, and how to query wait event data. It is assumed that Performance Schema was enabled at server startup. For information about enabling Performance Schema, see Section 22.1, “Performance Schema Quick Start”.

1. To view available `InnoDB` mutex wait instruments, query the Performance Schema `setup_instruments` table, as shown below. Instruments are enabled by default.

```
mysql> SELECT * FROM performance_schema.setup_instruments
       WHERE NAME LIKE '%wait/synch/mutex/innodb%';
+-----------------------------------------------------+---------+-------+
| NAME                                                | ENABLED | TIMED |
+-----------------------------------------------------+---------+-------+
| wait/synch/mutex/innodb/commit_cond_mutex           | YES     | YES   |
| wait/synch/mutex/innodb/innobase_share_mutex        | YES     | YES   |
| wait/synch/mutex/innodb/prepare_commit_mutex        | YES     | YES   |
| wait/synch/mutex/innodb/autoinc_mutex               | YES     | YES   |
| wait/synch/mutex/innodb/btr_search_enabled_mutex    | YES     | YES   |
| wait/synch/mutex/innodb/buf_pool_mutex              | YES     | YES   |
| wait/synch/mutex/innodb/buf_pool_zip_mutex          | YES     | YES   |
| wait/synch/mutex/innodb/cache_last_read_mutex       | YES     | YES   |
| wait/synch/mutex/innodb/dict_foreign_err_mutex      | YES     | YES   |
| wait/synch/mutex/innodb/dict_sys_mutex              | YES     | YES   |
| wait/synch/mutex/innodb/file_format_max_mutex       | YES     | YES   |
| wait/synch/mutex/innodb/fil_system_mutex            | YES     | YES   |
| wait/synch/mutex/innodb/flush_list_mutex            | YES     | YES   |
| wait/synch/mutex/innodb/log_flush_order_mutex       | YES     | YES   |
| wait/synch/mutex/innodb/hash_table_mutex            | YES     | YES   |
| wait/synch/mutex/innodb/ibuf_bitmap_mutex           | YES     | YES   |
| wait/synch/mutex/innodb/ibuf_mutex                  | YES     | YES   |
| wait/synch/mutex/innodb/ibuf_pessimistic_insert_mutex | YES   | YES   |
| wait/synch/mutex/innodb/kernel_mutex                | YES     | YES   |
| wait/synch/mutex/innodb/log_sys_mutex               | YES     | YES   |
| wait/synch/mutex/innodb/mem_pool_mutex              | YES     | YES   |
| wait/synch/mutex/innodb/mutex_list_mutex            | YES     | YES   |
```

```
| wait/synch/mutex/innodb/purge_sys_bh_mutex            | YES     | YES   |
| wait/synch/mutex/innodb/recv_sys_mutex                | YES     | YES   |
| wait/synch/mutex/innodb/rseg_mutex                    | YES     | YES   |
| wait/synch/mutex/innodb/rw_lock_list_mutex            | YES     | YES   |
| wait/synch/mutex/innodb/rw_lock_mutex                 | YES     | YES   |
| wait/synch/mutex/innodb/srv_dict_tmpfile_mutex        | YES     | YES   |
| wait/synch/mutex/innodb/srv_innodb_monitor_mutex      | YES     | YES   |
| wait/synch/mutex/innodb/srv_misc_tmpfile_mutex        | YES     | YES   |
| wait/synch/mutex/innodb/srv_monitor_file_mutex        | YES     | YES   |
| wait/synch/mutex/innodb/syn_arr_mutex                 | YES     | YES   |
| wait/synch/mutex/innodb/trx_doublewrite_mutex         | YES     | YES   |
| wait/synch/mutex/innodb/trx_undo_mutex                | YES     | YES   |
+-------------------------------------------------------+---------+-------+
34 rows in set (0.00 sec)
```

2. Verify that wait event consumers are enabled by querying the `setup_consumers` table. The `events_waits_current`, `events_waits_history`, and `events_waits_history_long` consumers should be enabled by default.

```
mysql> SELECT * FROM performance_schema.setup_consumers;
+----------------------------------------------+---------+
| NAME                                         | ENABLED |
+----------------------------------------------+---------+
| events_waits_current                         | YES     |
| events_waits_history                         | YES     |
| events_waits_history_long                    | YES     |
| events_waits_summary_by_thread_by_event_name | YES     |
| events_waits_summary_by_event_name           | YES     |
| events_waits_summary_by_instance             | YES     |
| file_summary_by_event_name                   | YES     |
| file_summary_by_instance                     | YES     |
+----------------------------------------------+---------+
8 rows in set (0.00 sec)
```

3. Run the workload that you want to monitor. In this example, the `mysqlslap` load emulation client is used to simulate a workload.

```
shell> ./mysqlslap --auto-generate-sql --concurrency=100 --iterations=10
       --number-of-queries=1000 --number-char-cols=6 --number-int-cols=6;
```

4. Query the wait event data. In this example, wait event data is queried from the `events_waits_summary_global_by_event_name` table which aggregates data found in the `events_waits_current`, `events_waits_history`, and `events_waits_history_long` tables. Data is summarized by event name (`EVENT_NAME`), which is the name of the instrument that produced the event. Summarized data includes:

   - `COUNT_STAR`

     The number of summarized wait events.

   - `SUM_TIMER_WAIT`

     The total wait time of the summarized timed wait events.

   - `MIN_TIMER_WAIT`

     The minimum wait time of the summarized timed wait events.

   - `AVG_TIMER_WAIT`

     The average wait time of the summarized timed wait events.

   - `MAX_TIMER_WAIT`

     The maximum wait time of the summarized timed wait events.

The following query returns the instrument name (EVENT_NAME), the number of wait events (COUNT_STAR), and the total wait time for the events for that instrument (SUM_TIMER_WAIT). Because waits are timed in picoseconds (trillionths of a second) by default, wait times are divided by 1000000000 to show wait times in milliseconds. Data is presented in descending order, by the number of summarized wait events (COUNT_STAR). You can adjust the ORDER BY clause to order the data by total wait time.

```
mysql> SELECT EVENT_NAME, COUNT_STAR, SUM_TIMER_WAIT/1000000000 SUM_TIMER_WAIT_MS
       FROM performance_schema.events_waits_summary_global_by_event_name
       WHERE SUM_TIMER_WAIT > 0 AND EVENT_NAME LIKE 'wait/synch/mutex/innodb/%'
       ORDER BY COUNT_STAR DESC;
+-----------------------------------------------------+------------+--------------------+
| EVENT_NAME                                          | COUNT_STAR | SUM_TIMER_WAIT_MS |
+-----------------------------------------------------+------------+--------------------+
| wait/synch/mutex/innodb/buf_pool_mutex              |     154477 |          6258.6407 |
| wait/synch/mutex/innodb/kernel_mutex                |      54294 |          1747.1980 |
| wait/synch/mutex/innodb/log_sys_mutex               |      40578 |          3167.6126 |
| wait/synch/mutex/innodb/dict_sys_mutex              |      34261 |            26.4183 |
| wait/synch/mutex/innodb/log_flush_order_mutex       |      24463 |             0.5867 |
| wait/synch/mutex/innodb/rseg_mutex                  |      18204 |             0.4750 |
| wait/synch/mutex/innodb/flush_list_mutex            |      15949 |             0.7182 |
| wait/synch/mutex/innodb/mutex_list_mutex            |      10439 |             0.2299 |
| wait/synch/mutex/innodb/fil_system_mutex            |       9815 |             0.5027 |
| wait/synch/mutex/innodb/rw_lock_list_mutex          |       8292 |             0.1763 |
| wait/synch/mutex/innodb/trx_undo_mutex              |       6070 |             0.2339 |
| wait/synch/mutex/innodb/innobase_share_mutex        |       1994 |             0.0761 |
| wait/synch/mutex/innodb/file_format_max_mutex       |       1007 |             0.0245 |
| wait/synch/mutex/innodb/trx_doublewrite_mutex       |        387 |             0.0214 |
| wait/synch/mutex/innodb/recv_sys_mutex              |        186 |             0.0047 |
| wait/synch/mutex/innodb/ibuf_mutex                  |        121 |             0.0030 |
| wait/synch/mutex/innodb/purge_sys_bh_mutex          |         99 |             0.0033 |
| wait/synch/mutex/innodb/ibuf_pessimistic_insert_mutex |         40 |             0.0011 |
| wait/synch/mutex/innodb/srv_innodb_monitor_mutex    |          3 |             0.0003 |
+-----------------------------------------------------+------------+--------------------+
19 rows in set (0.00 sec)
```

Note

The preceding result set includes wait event data produced during the startup process. To exclude this data, you can truncate the events_waits_summary_global_by_event_name table immediately after startup and before running your workload. However, the truncate operation itself may produce a negligible amount wait event data.

```
mysql> TRUNCATE performance_schema.events_waits_summary_global_by_event_name;
```

14.20 InnoDB Monitors

InnoDB monitors provide information about the InnoDB internal state. This information is useful for performance tuning.

14.20.1 InnoDB Monitor Types

There are four types of InnoDB monitors:

- The standard InnoDB Monitor displays the following types of information:
  - Work done by the main background thread
  - Semaphore waits
  - Data about the most recent foreign key and deadlock errors

- Lock waits for transactions
- Table and record locks held by active transactions
- Pending I/O operations and related statistics
- Insert buffer and adaptive hash index statistics
- Redo log data
- Buffer pool statistics
- Row operation data

- The `InnoDB` Lock Monitor prints additional lock information as part of the standard `InnoDB` Monitor output.
- The `InnoDB` Tablespace Monitor prints a list of file segments in the shared tablespace and validates the tablespace allocation data structures.
- The `InnoDB` Table Monitor prints the contents of the `InnoDB` internal data dictionary.

For additional information about `InnoDB` table and tablespace monitors, see Mark Leith: InnoDB Table and Tablespace Monitors.

14.20.2 Enabling InnoDB Monitors

When `InnoDB` monitors are enabled for periodic output, `InnoDB` writes the output to the `mysqld` server standard error output (`stderr`). `InnoDB` sends diagnostic output to `stderr` rather than to `stdout` or fixed-size memory buffers to avoid potential buffer overflows.

On Windows, `stderr` is directed to the default log file unless configured otherwise. If you want to direct the output to the console window rather than to the error log, start the server from a command prompt in a console window with the `--console` option. For more information, see Section 5.4.2.1, “Error Logging on Windows”.

On Unix and Unix-like systems, `stderr` is typically directed to the terminal unless configured otherwise. For more information, see Section 5.4.2.2, “Error Logging on Unix and Unix-Like Systems”.

When enabled, `InnoDB` monitors print data about every 15 seconds. This data is useful in performance tuning. As a side effect, the output of `SHOW ENGINE INNODB STATUS` is written to a status file in the MySQL data directory every fifteen seconds. The name of the file is `innodb_status.pid`, where *`pid`* is the server process ID. `InnoDB` removes the file when the server is shut down normally. If abnormal shutdowns have occurred, instances of these status files may be present and must be removed manually. Before removing the files, examine them to see if they contain useful information about the cause of abnormal shutdowns. An `innodb_status.pid` file is only created if the `innodb-status-file` configuration option is enabled. It is disabled by default.

`InnoDB` monitors should only be enabled when you actually want to see monitor information because output generation causes some performance decrement. Also, if monitor output is directed to the error log, the log may become quite large if you forget to disable the monitor later by dropping the monitor table.

Note

To assist with troubleshooting, `InnoDB` temporarily enables standard `InnoDB` Monitor output under certain conditions. For more information, see Section 14.23, “InnoDB Troubleshooting”.

Each monitor begins with a header containing a timestamp and the monitor name. For example:

```
=====================================
141016 15:41:44 INNODB MONITOR OUTPUT
=====================================
```

The header for the standard InnoDB Monitor (INNODB MONITOR OUTPUT) is also used for the Lock Monitor because the latter produces the same output with the addition of extra lock information.

Enabling an InnoDB monitor for periodic output involves using a CREATE TABLE statement to create a specially named InnoDB table that is associated with the monitor. For example, to enable the standard InnoDB Monitor, you would create an InnoDB table named innodb_monitor.

Using CREATE TABLE syntax is just a way to pass a command to the InnoDB engine through MySQL's SQL parser. The only things that matter are the table name and that it be an InnoDB table. The structure of the table and the database where the table is created are not relevant. If you shut down the server, the monitor does not restart automatically when you restart the server. Drop the monitor table and issue a new CREATE TABLE statement to start the monitor.

The PROCESS privilege is required to enable or disable InnoDB Monitors.

Enabling the Standard InnoDB Monitor

To enable the standard InnoDB Monitor for periodic output, create the innodb_monitor table:

```
CREATE TABLE innodb_monitor (a INT) ENGINE=INNODB;
```

To disable the standard InnoDB Monitor, drop the table:

```
DROP TABLE innodb_monitor;
```

Obtaining Standard InnoDB Monitor Output On Demand

As an alternative to enabling the standard InnoDB Monitor for periodic output, you can obtain standard InnoDB Monitor output on demand using the SHOW ENGINE INNODB STATUS SQL statement, which fetches the output to your client program. If you are using the mysql interactive client, the output is more readable if you replace the usual semicolon statement terminator with \G:

```
mysql> SHOW ENGINE INNODB STATUS\G
```

SHOW ENGINE INNODB STATUS output also includes InnoDB Lock Monitor data if the InnoDB Lock Monitor is enabled.

Enabling the InnoDB Lock Monitor

To enable the InnoDB Lock Monitor for periodic output, create the innodb_lock_monitor table:

```
CREATE TABLE innodb_lock_monitor (a INT) ENGINE=INNODB;
```

To disable the InnoDB Lock Monitor, drop the table:

```
DROP TABLE innodb_lock_monitor;
```

Enabling the InnoDB Tablespace Monitor

To enable the InnoDB Tablespace Monitor for periodic output, create the innodb_tablespace_monitor table:

```
CREATE TABLE innodb_tablespace_monitor (a INT) ENGINE=INNODB;
```

To disable the standard InnoDB Tablespace Monitor, drop the table:

```
DROP TABLE innodb_tablespace_monitor;
```

Enabling the InnoDB Table Monitor

To enable the InnoDB Table Monitor for periodic output, create the innodb_table_monitor table:

```
CREATE TABLE innodb_table_monitor (a INT) ENGINE=INNODB;
```

To disable the InnoDB Table Monitor, drop the table:

```
DROP TABLE innodb_table_monitor;
```

14.20.3 InnoDB Standard Monitor and Lock Monitor Output

The Lock Monitor is the same as the Standard Monitor except that it includes additional lock information. Enabling either monitor for periodic output turns on the same output stream, but the stream includes extra information if the Lock Monitor is enabled. For example, if you enable the Standard Monitor and Lock Monitor, that turns on a single output stream. The stream includes extra lock information until you disable the Lock Monitor.

Standard Monitor output is limited to 1MB when produced using the SHOW ENGINE INNODB STATUS statement. This limit does not apply to output written to server standard error output (stderr).

Example Standard Monitor output:

```
mysql> SHOW ENGINE INNODB STATUS\G
*************************** 1. row ***************************
  Type: InnoDB
  Name:
Status:
=====================================
141016 15:41:44 INNODB MONITOR OUTPUT
=====================================
Per second averages calculated from the last 6 seconds
-----------------
BACKGROUND THREAD
-----------------
srv_master_thread loops: 49 1_second, 48 sleeps, 3 10_second, 18 background,
18 flush
srv_master_thread log flush and writes: 48
----------
SEMAPHORES
----------
OS WAIT ARRAY INFO: reservation count 46, signal count 45
Mutex spin waits 30, rounds 900, OS waits 27
RW-shared spins 14, rounds 420, OS waits 14
RW-excl spins 0, rounds 150, OS waits 5
Spin rounds per wait: 30.00 mutex, 30.00 RW-shared, 150.00 RW-excl
------------------------
LATEST FOREIGN KEY ERROR
------------------------
141016 15:37:30 Transaction:
TRANSACTION 3D005, ACTIVE 0 sec inserting
mysql tables in use 1, locked 1
4 lock struct(s), heap size 1248, 3 row lock(s), undo log entries 3
MySQL thread id 1, OS thread handle 0x7f0ee440e700, query id 70 localhost root
update
INSERT INTO child VALUES
    (NULL, 1)
    , (NULL, 2)
    , (NULL, 3)
    , (NULL, 4)
    , (NULL, 5)
    , (NULL, 6)
Foreign key constraint fails for table `mysql`.`child`:
,
  CONSTRAINT `child_ibfk_1` FOREIGN KEY (`parent_id`) REFERENCES `parent` (`id`)
  ON DELETE CASCADE ON UPDATE CASCADE
Trying to add in child table, in index `par_ind` tuple:
```

```
DATA TUPLE: 2 fields;
 0: len 4; hex 80000003; asc     ;;
 1: len 4; hex 80000003; asc     ;;

But in parent table `mysql`.`parent`, in index `PRIMARY`,
the closest match we can find is record:
PHYSICAL RECORD: n_fields 3; compact format; info bits 0
 0: len 4; hex 80000004; asc     ;;
 1: len 6; hex 00000003d002; asc       ;;
 2: len 7; hex 8300001d480137; asc     H 7;;

------------------------
LATEST DETECTED DEADLOCK
------------------------
141016 15:39:58
*** (1) TRANSACTION:
TRANSACTION 3D009, ACTIVE 19 sec starting index read
mysql tables in use 1, locked 1
LOCK WAIT 2 lock struct(s), heap size 376, 1 row lock(s)
MySQL thread id 2, OS thread handle 0x7f0ee43cd700, query id 78 localhost root
updating
DELETE FROM t WHERE i = 1
*** (1) WAITING FOR THIS LOCK TO BE GRANTED:
RECORD LOCKS space id 0 page no 2428 n bits 72 index `GEN_CLUST_INDEX` of table
`mysql`.`t` trx id 3D009 lock_mode X waiting
Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 0
 0: len 6; hex 000000000700; asc       ;;
 1: len 6; hex 00000003d007; asc       ;;
 2: len 7; hex 87000009560110; asc     V  ;;
 3: len 4; hex 80000001; asc     ;;

*** (2) TRANSACTION:
TRANSACTION 3D008, ACTIVE 69 sec starting index read
mysql tables in use 1, locked 1
4 lock struct(s), heap size 1248, 3 row lock(s)
MySQL thread id 1, OS thread handle 0x7f0ee440e700, query id 79 localhost root
updating
DELETE FROM t WHERE i = 1
*** (2) HOLDS THE LOCK(S):
RECORD LOCKS space id 0 page no 2428 n bits 72 index `GEN_CLUST_INDEX` of table
`mysql`.`t` trx id 3D008 lock mode S
Record lock, heap no 1 PHYSICAL RECORD: n_fields 1; compact format; info bits 0
 0: len 8; hex 73757072656d756d; asc supremum;;

Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 0
 0: len 6; hex 000000000700; asc       ;;
 1: len 6; hex 00000003d007; asc       ;;
 2: len 7; hex 87000009560110; asc     V  ;;
 3: len 4; hex 80000001; asc     ;;

*** (2) WAITING FOR THIS LOCK TO BE GRANTED:
RECORD LOCKS space id 0 page no 2428 n bits 72 index `GEN_CLUST_INDEX` of table
`mysql`.`t` trx id 3D008 lock_mode X waiting
Record lock, heap no 2 PHYSICAL RECORD: n_fields 4; compact format; info bits 0
 0: len 6; hex 000000000700; asc       ;;
 1: len 6; hex 00000003d007; asc       ;;
 2: len 7; hex 87000009560110; asc     V  ;;
 3: len 4; hex 80000001; asc     ;;

*** WE ROLL BACK TRANSACTION (1)
------------
TRANSACTIONS
------------
Trx id counter 3D038
Purge done for trx's n:o < 3D02A undo n:o < 0
History list length 1047
Total number of lock structs in row lock hash table 0
LIST OF TRANSACTIONS FOR EACH SESSION:
---TRANSACTION 3D009, not started
MySQL thread id 2, OS thread handle 0x7f0ee43cd700, query id 78 localhost root
---TRANSACTION 3D008, not started
MySQL thread id 1, OS thread handle 0x7f0ee440e700, query id 113 localhost root
```

```
SHOW ENGINE INNODB STATUS
---TRANSACTION 3D037, ACTIVE 1 sec inserting
mysql tables in use 1, locked 1
1 lock struct(s), heap size 376, 0 row lock(s), undo log entries 11940
MySQL thread id 3, OS thread handle 0x7f0ee438c700, query id 112 localhost root
update
INSERT INTO `employees` VALUES (413215,'1962-07-08','Ronghao','Molberg','F',
'1985-06-20'),(413216,'1954-05-25','Masaru','Lieberherr','M','1992-04-08'),
(413217,'1953-03-17','Phule','Waschkowski','F','1988-07-28'),(413218,'1964-10-07',
'Vitaly','Negoita','M','1986-01-13'),(413219,'1957-03-31','Danil','Kalafatis','F',
'1985-04-12'),(413220,'1958-07-25','Jianwen','Radwan','M','1986-09-03'),(413221,
'1964-04-08','Paloma','Bach','M','1986-05-03'),(413222,'1955-06-10','Stafford',
'Muhlberg','M','1989-03-22'),(413223,'1963-10-27','Aiichiro','Benzmuller','M',
'1987-12-02'),(413224,'1955-10-02','Giordano','N
TABLE LOCK table `employees`.`employees` trx id 3D037 lock mode IX
--------
FILE I/O
--------
I/O thread 0 state: waiting for completed aio requests (insert buffer thread)
I/O thread 1 state: waiting for completed aio requests (log thread)
I/O thread 2 state: waiting for completed aio requests (read thread)
I/O thread 3 state: waiting for completed aio requests (read thread)
I/O thread 4 state: waiting for completed aio requests (read thread)
I/O thread 5 state: waiting for completed aio requests (read thread)
I/O thread 6 state: waiting for completed aio requests (write thread)
I/O thread 7 state: waiting for completed aio requests (write thread)
I/O thread 8 state: waiting for completed aio requests (write thread)
I/O thread 9 state: waiting for completed aio requests (write thread)
Pending normal aio reads: 0 [0, 0, 0, 0] , aio writes: 0 [0, 0, 0, 0] ,
 ibuf aio reads: 0, log i/o's: 0, sync i/o's: 0
Pending flushes (fsync) log: 0; buffer pool: 0
439 OS file reads, 917 OS file writes, 199 OS fsyncs
0.00 reads/s, 0 avg bytes/read, 56.32 writes/s, 7.67 fsyncs/s
-------------------------------------
INSERT BUFFER AND ADAPTIVE HASH INDEX
-------------------------------------
Ibuf: size 1, free list len 0, seg size 2, 0 merges
merged operations:
 insert 0, delete mark 0, delete 0
discarded operations:
 insert 0, delete mark 0, delete 0
Hash table size 4425293, used cells 32, node heap has 1 buffer(s)
13577.57 hash searches/s, 202.47 non-hash searches/s
---
LOG
---
Log sequence number 794838329
Log flushed up to   793815740
Last checkpoint at  788417971
0 pending log writes, 0 pending chkp writes
96 log i/o's done, 3.50 log i/o's/second
----------------------
BUFFER POOL AND MEMORY
----------------------
Total memory allocated 2217738240; in additional pool allocated 0
Dictionary memory allocated 121719
Buffer pool size   131072
Free buffers       129937
Database pages     1134
Old database pages 211
Modified db pages  187
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 0, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 426, created 708, written 768
0.00 reads/s, 40.99 creates/s, 50.49 writes/s
Buffer pool hit rate 1000 / 1000, young-making rate 0 / 1000 not 0 / 1000
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead
0.00/s
LRU len: 1134, unzip_LRU len: 0
I/O sum[0]:cur[0], unzip sum[0]:cur[0]
```

```
----------------------
INDIVIDUAL BUFFER POOL INFO
----------------------
---BUFFER POOL 0
Buffer pool size   65536
Free buffers       65029
Database pages     506
Old database pages 0
Modified db pages  95
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 0, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 137, created 369, written 412
0.00 reads/s, 20.16 creates/s, 18.00 writes/s
Buffer pool hit rate 1000 / 1000, young-making rate 0 / 1000 not 0 / 1000
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead
0.00/s
LRU len: 506, unzip_LRU len: 0
I/O sum[0]:cur[0], unzip sum[0]:cur[0]
---BUFFER POOL 1
Buffer pool size   65536
Free buffers       64908
Database pages     628
Old database pages 211
Modified db pages  92
Pending reads 0
Pending writes: LRU 0, flush list 0, single page 0
Pages made young 0, not young 0
0.00 youngs/s, 0.00 non-youngs/s
Pages read 289, created 339, written 356
0.00 reads/s, 20.83 creates/s, 32.49 writes/s
Buffer pool hit rate 1000 / 1000, young-making rate 0 / 1000 not 0 / 1000
Pages read ahead 0.00/s, evicted without access 0.00/s, Random read ahead
0.00/s
LRU len: 628, unzip_LRU len: 0
I/O sum[0]:cur[0], unzip sum[0]:cur[0]
--------------
ROW OPERATIONS
--------------
0 queries inside InnoDB, 0 queries in queue
1 read views open inside InnoDB
Main thread process no. 30091, id 139699544078080, state: sleeping
Number of rows inserted 225354, updated 0, deleted 3, read 4
13690.55 inserts/s, 0.00 updates/s, 0.00 deletes/s, 0.00 reads/s
----------------------------
END OF INNODB MONITOR OUTPUT
============================
```

Standard Monitor Output Sections

For a description of each metric reported by the Standard Monitor, refer to the Metrics chapter in the Oracle Enterprise Manager for MySQL Database User's Guide.

- `Status`

  This section shows the timestamp, the monitor name, and the number of seconds that per-second averages are based on. The number of seconds is the elapsed time between the current time and the last time `InnoDB` Monitor output was printed.

- `BACKGROUND THREAD`

  The `srv_master_thread` lines shows work done by the main background thread.

- `SEMAPHORES`

  This section reports threads waiting for a semaphore and statistics on how many times threads have needed a spin or a wait on a mutex or a rw-lock semaphore. A large number of threads waiting for semaphores may be a result of disk I/O, or contention problems inside `InnoDB`. Contention can be

due to heavy parallelism of queries or problems in operating system thread scheduling. Setting the `innodb_thread_concurrency` system variable smaller than the default value might help in such situations. The `Spin rounds per wait` line shows the number of spinlock rounds per OS wait for a mutex.

- `LATEST FOREIGN KEY ERROR`

  This section provides information about the most recent foreign key constraint error. It is not present if no such error has occurred. The contents include the statement that failed as well as information about the constraint that failed and the referenced and referencing tables.

- `LATEST DETECTED DEADLOCK`

  This section provides information about the most recent deadlock. It is not present if no deadlock has occurred. The contents show which transactions are involved, the statement each was attempting to execute, the locks they have and need, and which transaction `InnoDB` decided to roll back to break the deadlock. The lock modes reported in this section are explained in Section 14.8.1, “InnoDB Locking”.

- `TRANSACTIONS`

  If this section reports lock waits, your applications might have lock contention. The output can also help to trace the reasons for transaction deadlocks.

- `FILE I/O`

  This section provides information about threads that `InnoDB` uses to perform various types of I/O. The first few of these are dedicated to general `InnoDB` processing. The contents also display information for pending I/O operations and statistics for I/O performance.

  The number of these threads are controlled by the `innodb_read_io_threads` and `innodb_write_io_threads` parameters. See Section 14.17, “InnoDB Startup Options and System Variables”.

- `INSERT BUFFER AND ADAPTIVE HASH INDEX`

  This section shows the status of the `InnoDB` insert buffer (also referred to as the change buffer) and the adaptive hash index.

  For related information, see Section 14.7.2, “Change Buffer”, and Section 14.7.3, “Adaptive Hash Index”.

- `LOG`

  This section displays information about the `InnoDB` log. The contents include the current log sequence number, how far the log has been flushed to disk, and the position at which `InnoDB` last took a checkpoint. (See Section 14.15.3, “InnoDB Checkpoints”.) The section also displays information about pending writes and write performance statistics.

- `BUFFER POOL AND MEMORY`

  This section gives you statistics on pages read and written. You can calculate from these numbers how many data file I/O operations your queries currently are doing.

  For buffer pool statistics descriptions, see Section 14.9.2.6, “Monitoring the Buffer Pool Using the InnoDB Standard Monitor”. For additional information about the operation of the buffer pool, see Section 14.9.2.1, “The InnoDB Buffer Pool”.

- `ROW OPERATIONS`

  This section shows what the main thread is doing, including the number and performance rate for each type of row operation.

In MySQL 5.5, output from the standard `InnoDB` Monitor includes additional sections compared to the output for previous versions. For details, see Diagnostic and Monitoring Capabilities.

14.20.4 InnoDB Tablespace Monitor Output

The `InnoDB` Tablespace Monitor prints information about the file segments in the shared tablespace and validates the tablespace allocation data structures. The Tablespace Monitor does not describe file-per-table tablespaces created with the `innodb_file_per_table` option.

Example `InnoDB` Tablespace Monitor output:

```
=====================================================
090408 21:28:09 INNODB TABLESPACE MONITOR OUTPUT
=====================================================
FILE SPACE INFO: id 0
size 13440, free limit 3136, free extents 28
not full frag extents 2: used pages 78, full frag extents 3
first seg id not used 0 23845
SEGMENT id 0 1 space 0; page 2; res 96 used 46; full ext 0
fragm pages 32; free extents 0; not full extents 1: pages 14
SEGMENT id 0 2 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
SEGMENT id 0 3 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
...
SEGMENT id 0 15 space 0; page 2; res 160 used 160; full ext 2
fragm pages 32; free extents 0; not full extents 0: pages 0
SEGMENT id 0 488 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
SEGMENT id 0 17 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
...
SEGMENT id 0 171 space 0; page 2; res 592 used 481; full ext 7
fragm pages 16; free extents 0; not full extents 2: pages 17
SEGMENT id 0 172 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
SEGMENT id 0 173 space 0; page 2; res 96 used 44; full ext 0
fragm pages 32; free extents 0; not full extents 1: pages 12
...
SEGMENT id 0 601 space 0; page 2; res 1 used 1; full ext 0
fragm pages 1; free extents 0; not full extents 0: pages 0
NUMBER of file segments: 73
Validating tablespace
Validation ok
---------------------------------------
END OF INNODB TABLESPACE MONITOR OUTPUT
=======================================
```

The Tablespace Monitor output includes information about the shared tablespace as a whole, followed by a list containing a breakdown for each segment within the tablespace.

In this example using the default page size, the tablespace consists of database pages that are 16KB each. The pages are grouped into extents of size 1MB (64 consecutive pages).

The initial part of the output that displays overall tablespace information has this format:

```
FILE SPACE INFO: id 0
size 13440, free limit 3136, free extents 28
not full frag extents 2: used pages 78, full frag extents 3
first seg id not used 0 23845
```

Overall tablespace information includes these values:

- `id`

  The tablespace ID. A value of 0 refers to the shared tablespace.

- `size`

  The current tablespace size in pages.

- `free limit`

  The minimum page number for which the free list has not been initialized. Pages at or above this limit are free.

- `free extents`

  The number of free extents.

- `not full frag extents`, `used pages`

  The number of fragment extents that are not completely filled, and the number of pages in those extents that have been allocated.

- `full frag extents`

  The number of completely full fragment extents.

- `first seg id not used`

  The first unused segment ID.

Individual segment information has this format:

```
SEGMENT id 0 15 space 0; page 2; res 160 used 160; full ext 2
fragm pages 32; free extents 0; not full extents 0: pages 0
```

Segment information includes these values:

- `id`

  The segment ID.

- `space`, `page`

  The tablespace number and page within the tablespace where the segment “inode” is located. A tablespace number of 0 indicates the shared tablespace. `InnoDB` uses inodes to keep track of segments in the tablespace. The other fields displayed for a segment (`id`, `res`, and so forth) are derived from information in the inode.

- `res`

  The number of pages allocated (reserved) for the segment.

- `used`

  The number of allocated pages in use by the segment.

- `full ext`

  The number of extents allocated for the segment that are completely used.

- `fragm pages`

  The number of initial pages that have been allocated to the segment.

- `free extents`

  The number of extents allocated for the segment that are completely unused.

- `not full extents`

The number of extents allocated for the segment that are partially used.

- `pages`

  The number of pages used within the not-full extents.

When a segment grows, it starts as a single page, and `InnoDB` allocates the first pages for it one at a time, up to 32 pages (this is the `fragm pages` value). After that, `InnoDB` allocates complete extents. `InnoDB` can add up to 4 extents at a time to a large segment to ensure good sequentiality of data.

For the example segment shown earlier, it has 32 fragment pages, plus 2 full extents (64 pages each), for a total of 160 pages used out of 160 pages allocated. The following segment has 32 fragment pages and one partially full extent using 14 pages for a total of 46 pages used out of 96 pages allocated:

```
SEGMENT id 0 1 space 0; page 2; res 96 used 46; full ext 0
fragm pages 32; free extents 0; not full extents 1: pages 14
```

It is possible for a segment that has extents allocated to it to have a `fragm pages` value less than 32 if some of the individual pages have been deallocated subsequent to extent allocation.

14.20.5 InnoDB Table Monitor Output

The `InnoDB` Table Monitor prints the contents of the `InnoDB` internal data dictionary.

The output contains one section per table. The `SYS_FOREIGN` and `SYS_FOREIGN_COLS` sections are for internal data dictionary tables that maintain information about foreign keys. There are also sections for the Table Monitor table and each user-created `InnoDB` table. Suppose that the following two tables have been created in the `test` database:

```
CREATE TABLE parent
(
  par_id    INT NOT NULL,
  fname      CHAR(20),
  lname      CHAR(20),
  PRIMARY KEY (par_id),
  UNIQUE INDEX (lname, fname)
) ENGINE = INNODB;

CREATE TABLE child
(
  par_id      INT NOT NULL,
  child_id    INT NOT NULL,
  name        VARCHAR(40),
  birth       DATE,
  weight      DECIMAL(10,2),
  misc_info   VARCHAR(255),
  last_update TIMESTAMP,
  PRIMARY KEY (par_id, child_id),
  INDEX (name),
  FOREIGN KEY (par_id) REFERENCES parent (par_id)
    ON DELETE CASCADE
    ON UPDATE CASCADE
) ENGINE = INNODB;
```

Then the Table Monitor output will look something like this (reformatted slightly):

```
===========================================
090420 12:09:32 INNODB TABLE MONITOR OUTPUT
===========================================
-------------------------------------
TABLE: name SYS_FOREIGN, id 0 11, columns 7, indexes 3, appr.rows 1
  COLUMNS: ID: DATA_VARCHAR DATA_ENGLISH len 0;
           FOR_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
```

```
           REF_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
           N_COLS: DATA_INT len 4;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name ID_IND, id 0 11, fields 1/6, uniq 1, type 3
   root page 46, appr.key vals 1, leaf pages 1, size pages 1
   FIELDS:  ID DB_TRX_ID DB_ROLL_PTR FOR_NAME REF_NAME N_COLS
  INDEX: name FOR_IND, id 0 12, fields 1/2, uniq 2, type 0
   root page 47, appr.key vals 1, leaf pages 1, size pages 1
   FIELDS:  FOR_NAME ID
  INDEX: name REF_IND, id 0 13, fields 1/2, uniq 2, type 0
   root page 48, appr.key vals 1, leaf pages 1, size pages 1
   FIELDS:  REF_NAME ID
-------------------------------------
TABLE: name SYS_FOREIGN_COLS, id 0 12, columns 7, indexes 1, appr.rows 1
  COLUMNS: ID: DATA_VARCHAR DATA_ENGLISH len 0;
           POS: DATA_INT len 4;
           FOR_COL_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
           REF_COL_NAME: DATA_VARCHAR DATA_ENGLISH len 0;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name ID_IND, id 0 14, fields 2/6, uniq 2, type 3
   root page 49, appr.key vals 1, leaf pages 1, size pages 1
   FIELDS:  ID POS DB_TRX_ID DB_ROLL_PTR FOR_COL_NAME REF_COL_NAME
-------------------------------------
TABLE: name test/child, id 0 14, columns 10, indexes 2, appr.rows 201
  COLUMNS: par_id: DATA_INT DATA_BINARY_TYPE DATA_NOT_NULL len 4;
           child_id: DATA_INT DATA_BINARY_TYPE DATA_NOT_NULL len 4;
           name: DATA_VARCHAR prtype 524303 len 40;
           birth: DATA_INT DATA_BINARY_TYPE len 3;
           weight: DATA_FIXBINARY DATA_BINARY_TYPE len 5;
           misc_info: DATA_VARCHAR prtype 524303 len 255;
           last_update: DATA_INT DATA_UNSIGNED DATA_BINARY_TYPE DATA_NOT_NULL len 4;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name PRIMARY, id 0 17, fields 2/9, uniq 2, type 3
   root page 52, appr.key vals 201, leaf pages 5, size pages 6
   FIELDS:  par_id child_id DB_TRX_ID DB_ROLL_PTR name birth weight misc_info last_update
  INDEX: name name, id 0 18, fields 1/3, uniq 3, type 0
   root page 53, appr.key vals 210, leaf pages 1, size pages 1
   FIELDS:  name par_id child_id
  FOREIGN KEY CONSTRAINT test/child_ibfk_1: test/child ( par_id )
             REFERENCES test/parent ( par_id )
-------------------------------------
TABLE: name test/innodb_table_monitor, id 0 15, columns 4, indexes 1, appr.rows 0
  COLUMNS: i: DATA_INT DATA_BINARY_TYPE len 4;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name GEN_CLUST_INDEX, id 0 19, fields 0/4, uniq 1, type 1
   root page 193, appr.key vals 0, leaf pages 1, size pages 1
   FIELDS:  DB_ROW_ID DB_TRX_ID DB_ROLL_PTR i
-------------------------------------
TABLE: name test/parent, id 0 13, columns 6, indexes 2, appr.rows 299
  COLUMNS: par_id: DATA_INT DATA_BINARY_TYPE DATA_NOT_NULL len 4;
           fname: DATA_CHAR prtype 524542 len 20;
           lname: DATA_CHAR prtype 524542 len 20;
           DB_ROW_ID: DATA_SYS prtype 256 len 6;
           DB_TRX_ID: DATA_SYS prtype 257 len 6;
  INDEX: name PRIMARY, id 0 15, fields 1/5, uniq 1, type 3
   root page 50, appr.key vals 299, leaf pages 2, size pages 3
   FIELDS:  par_id DB_TRX_ID DB_ROLL_PTR fname lname
  INDEX: name lname, id 0 16, fields 2/3, uniq 2, type 2
   root page 51, appr.key vals 300, leaf pages 1, size pages 1
   FIELDS:  lname fname par_id
  FOREIGN KEY CONSTRAINT test/child_ibfk_1: test/child ( par_id )
             REFERENCES test/parent ( par_id )
-----------------------------------
END OF INNODB TABLE MONITOR OUTPUT
===================================
```

For each table, Table Monitor output contains a section that displays general information about the table and specific information about its columns, indexes, and foreign keys.

The general information for each table includes the table name (in *db_name/tbl_name* format except for internal tables), its ID, the number of columns and indexes, and an approximate row count.

The COLUMNS part of a table section lists each column in the table. Information for each column indicates its name and data type characteristics. Some internal columns are added by InnoDB, such as DB_ROW_ID (row ID), DB_TRX_ID (transaction ID), and DB_ROLL_PTR (a pointer to the rollback/undo data).

- DATA_*xxx*

  These symbols indicate the data type. There may be multiple DATA_*xxx* symbols for a given column.

- prtype

  The column's “precise” type. This field includes information such as the column data type, character set code, nullability, signedness, and whether it is a binary string. This field is described in the innobase/include/data0type.h source file.

- len

  The column length in bytes.

Each INDEX part of the table section provides the name and characteristics of one table index:

- name

  The index name. If the name is PRIMARY, the index is a primary key. If the name is GEN_CLUST_INDEX, the index is the clustered index that is created automatically if the table definition doesn't include a primary key or non-NULL unique index. See Section 14.11.2.1, “Clustered and Secondary Indexes”.

- id

  The index ID.

- fields

  The number of fields in the index, as a value in *m/n* format:

  - *m* is the number of user-defined columns; that is, the number of columns you would see in the index definition in a CREATE TABLE statement.
  - *n* is the total number of index columns, including those added internally. For the clustered index, the total includes the other columns in the table definition, plus any columns added internally. For a secondary index, the total includes the columns from the primary key that are not part of the secondary index.

- uniq

  The number of leading fields that are enough to determine index values uniquely.

- type

  The index type. This is a bit field. For example, 1 indicates a clustered index and 2 indicates a unique index, so a clustered index (which always contains unique values), will have a type value of 3. An index with a type value of 0 is neither clustered nor unique. The flag values are defined in the innobase/include/dict0mem.h source file.

- root page

  The index root page number.

- appr. key vals

The approximate index cardinality.

- `leaf pages`

  The approximate number of leaf pages in the index.

- `size pages`

  The approximate total number of pages in the index.

- `FIELDS`

  The names of the fields in the index. For a clustered index that was generated automatically, the field list begins with the internal `DB_ROW_ID` (row ID) field. `DB_TRX_ID` and `DB_ROLL_PTR` are always added internally to the clustered index, following the fields that comprise the primary key. For a secondary index, the final fields are those from the primary key that are not part of the secondary index.

The end of the table section lists the `FOREIGN KEY` definitions that apply to the table. This information appears whether the table is a referencing or referenced table.

14.21 InnoDB Backup and Recovery

This section covers topics related to `InnoDB` backup and recovery.

- For information about backup techniques applicable to `InnoDB`, see Section 14.21.1, “InnoDB Backup”.
- For information about point-in-time recovery, recovery from disk failure or corruption, and how `InnoDB` performs crash recovery, see Section 14.21.2, “InnoDB Recovery”.

14.21.1 InnoDB Backup

The key to safe database management is making regular backups. Depending on your data volume, number of MySQL servers, and database workload, you can use these backup techniques, alone or in combination: hot backup with MySQL Enterprise Backup; cold backup by copying files while the MySQL server is shut down; logical backup with `mysqldump` for smaller data volumes or to record the structure of schema objects. Hot and cold backups are physical backups that copy actual data files, which can be used directly by the `mysqld` server for faster restore.

Note

`InnoDB` does not support databases that are restored using third-party backup tools.

Hot Backups

The `mysqlbackup` command, part of the MySQL Enterprise Backup component, lets you back up a running MySQL instance, including `InnoDB` tables, with minimal disruption to operations while producing a consistent snapshot of the database. When `mysqlbackup` is copying `InnoDB` tables, reads and writes to `InnoDB` can continue. MySQL Enterprise Backup can also create compressed backup files, and back up subsets of tables and databases. In conjunction with the MySQL binary log, users can perform point-in-time recovery. MySQL Enterprise Backup is part of the MySQL Enterprise subscription. For more details, see Section 25.2, “MySQL Enterprise Backup Overview”.

Cold Backups

If you can shut down the MySQL server, you can make a physical backup that consists of all files used by `InnoDB` to manage its tables. Use the following procedure:

1. Perform a slow shutdown of the MySQL server and make sure that it stops without errors.
2. Copy all `InnoDB` data files (`ibdata` files and `.ibd` files) into a safe place.
3. Copy all the `.frm` files for `InnoDB` tables to a safe place.
4. Copy all `InnoDB` log files (`ib_logfile` files) to a safe place.
5. Copy your `my.cnf` configuration file or files to a safe place.

Logical Backups Using mysqldump

In addition to physical backups, it is recommended that you regularly create logical backups by dumping your tables using `mysqldump`. A binary file might be corrupted without you noticing it. Dumped tables are stored into text files that are human-readable, so spotting table corruption becomes easier. Also, because the format is simpler, the chance for serious data corruption is smaller. `mysqldump` also has a `--single-transaction` option for making a consistent snapshot without locking out other clients. See Section 7.3.1, “Establishing a Backup Policy”.

Replication works with `InnoDB` tables, so you can use MySQL replication capabilities to keep a copy of your database at database sites requiring high availability. See Section 14.22, “InnoDB and MySQL Replication”.

14.21.2 InnoDB Recovery

This section describes `InnoDB` recovery. Topics include:

- Point-in-Time Recovery
- Recovery from Data Corruption or Disk Failure
- InnoDB Crash Recovery

Point-in-Time Recovery

To recover an `InnoDB` database to the present from the time at which the physical backup was made, you must run MySQL server with binary logging enabled, even before taking the backup. To achieve point-in-time recovery after restoring a backup, you can apply changes from the binary log that occurred after the backup was made. See Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”.

Recovery from Data Corruption or Disk Failure

If your database becomes corrupted or disk failure occurs, you must perform the recovery using a backup. In the case of corruption, first find a backup that is not corrupted. After restoring the base backup, do a point-in-time recovery from the binary log files using `mysqlbinlog` and `mysql` to restore the changes that occurred after the backup was made.

In some cases of database corruption, it is enough to dump, drop, and re-create one or a few corrupt tables. You can use the `CHECK TABLE` statement to check whether a table is corrupt, although `CHECK TABLE` naturally cannot detect every possible kind of corruption. You can use the Tablespace Monitor to check the integrity of the file space management inside the tablespace files.

In some cases, apparent database page corruption is actually due to the operating system corrupting its own file cache, and the data on disk may be okay. It is best to try restarting the computer first. Doing so may eliminate errors that appeared to be database page corruption. If MySQL still has trouble starting because of `InnoDB` consistency problems, see Section 14.23.2, “Forcing InnoDB Recovery” for steps to start the instance in recovery mode, which permits you to dump the data.

InnoDB Crash Recovery

To recover from a MySQL server crash, the only requirement is to restart the MySQL server. `InnoDB` automatically checks the logs and performs a roll-forward of the database to the present. `InnoDB` automatically rolls back uncommitted transactions that were present at the time of the crash. During recovery, `mysqld` displays output similar to this:

```
InnoDB: Log scan progressed past the checkpoint lsn 452854464
InnoDB: Database was not shut down normally!
InnoDB: Starting crash recovery.
InnoDB: Reading tablespace information from the .ibd files...
InnoDB: Restoring possible half-written data pages from the doublewrite
InnoDB: buffer...
InnoDB: Doing recovery: scanned up to log sequence number 457028695
InnoDB: 1 transaction(s) which must be rolled back or cleaned up
InnoDB: in total 990682 row operations to undo
InnoDB: Trx id counter is 500
InnoDB: Starting an apply batch of log records to the database...
InnoDB: Progress in percents: 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69
70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93
94 95 96 97 98 99
InnoDB: Apply batch completed
InnoDB: Waiting for the background threads to start
InnoDB: Starting in background the rollback of uncommitted transactions
InnoDB: Rolling back trx with id 3B1, 990682 rows to undo
...
InnoDB: 5.5.55 started; log sequence number 457028695
...
./mysqld: ready for connections.
```

The `InnoDB` crash recovery process consists of several steps:

- Redo log application

  Redo log application is the first step and is performed during initialization, before accepting any connections. If all changes are flushed from the buffer pool to the tablespaces (`ibdata*` and `*.ibd` files) at the time of the shutdown or crash, redo log application is skipped. `InnoDB` also skips redo log application if redo log files are missing at startup.

  Removing redo logs to speed up recovery is not recommended, even if some data loss is acceptable. Removing redo logs should only be considered after a clean shutdown, with `innodb_fast_shutdown` set to `0` or `1`.

- Roll back of incomplete transactions

  Incomplete transactions are any transactions that were active at the time of crash or fast shutdown. The time it takes to roll back an incomplete transaction can be three or four times the amount of time a transaction is active before it is interrupted, depending on server load.

  You cannot cancel transactions that are being rolled back. In extreme cases, when rolling back transactions is expected to take an exceptionally long time, it may be faster to start `InnoDB` with an `innodb_force_recovery` setting of `3` or greater. See Section 14.23.2, “Forcing InnoDB Recovery”.

- Change buffer merge

  Applying changes from the change buffer (part of the system tablespace) to leaf pages of secondary indexes, as the index pages are read to the buffer pool.

- Purge

  Deleting delete-marked records that are no longer visible to active transactions.

The steps that follow redo log application do not depend on the redo log (other than for logging the writes) and are performed in parallel with normal processing. Of these, only rollback of incomplete transactions is special to crash recovery. The insert buffer merge and the purge are performed during normal processing.

After redo log application, `InnoDB` attempts to accept connections as early as possible, to reduce downtime. As part of crash recovery, `InnoDB` rolls back transactions that were not committed or in `XA PREPARE` state when the server crashed. The rollback is performed by a background thread, executed in parallel with transactions from new connections. Until the rollback operation is completed, new connections may encounter locking conflicts with recovered transactions.

In most situations, even if the MySQL server was killed unexpectedly in the middle of heavy activity, the recovery process happens automatically and no action is required of the DBA. If a hardware failure or severe system error corrupted `InnoDB` data, MySQL might refuse to start. In this case, see Section 14.23.2, “Forcing InnoDB Recovery”.

For information about the binary log and `InnoDB` crash recovery, see Section 5.4.4, “The Binary Log”.

14.22 InnoDB and MySQL Replication

MySQL replication works for `InnoDB` tables as it does for `MyISAM` tables. It is also possible to use replication in a way where the storage engine on the slave is not the same as the original storage engine on the master. For example, you can replicate modifications to an `InnoDB` table on the master to a `MyISAM` table on the slave. For more information see, Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”.

For information about setting up a new slave for a master, see Section 17.1.1.8, “Setting Up Replication with Existing Data”. To make a new slave without taking down the master or an existing slave, use the MySQL Enterprise Backup product.

Transactions that fail on the master do not affect replication at all. MySQL replication is based on the binary log where MySQL writes SQL statements that modify data. A transaction that fails (for example, because of a foreign key violation, or because it is rolled back) is not written to the binary log, so it is not sent to slaves. See Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”.

Replication and CASCADE. Cascading actions for `InnoDB` tables on the master are replicated on the slave *only* if the tables sharing the foreign key relation use `InnoDB` on both the master and slave. This is true whether you are using statement-based or row-based replication. Suppose that you have started replication, and then create two tables on the master using the following `CREATE TABLE` statements:

```
CREATE TABLE fc1 (
    i INT PRIMARY KEY,
    j INT
) ENGINE = InnoDB;

CREATE TABLE fc2 (
    m INT PRIMARY KEY,
    n INT,
    FOREIGN KEY ni (n) REFERENCES fc1 (i)
        ON DELETE CASCADE
) ENGINE = InnoDB;
```

Suppose that the slave does not have `InnoDB` support enabled. If this is the case, then the tables on the slave are created, but they use the `MyISAM` storage engine, and the `FOREIGN KEY` option is ignored. Now we insert some rows into the tables on the master:

```
master> INSERT INTO fc1 VALUES (1, 1), (2, 2);
Query OK, 2 rows affected (0.09 sec)
Records: 2  Duplicates: 0  Warnings: 0
```

```
master> INSERT INTO fc2 VALUES (1, 1), (2, 2), (3, 1);
Query OK, 3 rows affected (0.19 sec)
Records: 3  Duplicates: 0  Warnings: 0
```

At this point, on both the master and the slave, table `fc1` contains 2 rows, and table `fc2` contains 3 rows, as shown here:

```
master> SELECT * FROM fc1;
+---+------+
| i | j    |
+---+------+
| 1 |    1 |
| 2 |    2 |
+---+------+
2 rows in set (0.00 sec)

master> SELECT * FROM fc2;
+---+------+
| m | n    |
+---+------+
| 1 |    1 |
| 2 |    2 |
| 3 |    1 |
+---+------+
3 rows in set (0.00 sec)

slave> SELECT * FROM fc1;
+---+------+
| i | j    |
+---+------+
| 1 |    1 |
| 2 |    2 |
+---+------+
2 rows in set (0.00 sec)

slave> SELECT * FROM fc2;
+---+------+
| m | n    |
+---+------+
| 1 |    1 |
| 2 |    2 |
| 3 |    1 |
+---+------+
3 rows in set (0.00 sec)
```

Now suppose that you perform the following `DELETE` statement on the master:

```
master> DELETE FROM fc1 WHERE i=1;
Query OK, 1 row affected (0.09 sec)
```

Due to the cascade, table `fc2` on the master now contains only 1 row:

```
master> SELECT * FROM fc2;
+---+---+
| m | n |
+---+---+
| 2 | 2 |
+---+---+
1 row in set (0.00 sec)
```

However, the cascade does not propagate on the slave because on the slave the `DELETE` for `fc1` deletes no rows from `fc2`. The slave's copy of `fc2` still contains all of the rows that were originally inserted:

```
slave> SELECT * FROM fc2;
+---+---+
| m | n |
```

```
+---+---+
| 1 | 1 |
| 3 | 1 |
| 2 | 2 |
+---+---+
3 rows in set (0.00 sec)
```

This difference is due to the fact that the cascading deletes are handled internally by the `InnoDB` storage engine, which means that none of the changes are logged.

14.23 InnoDB Troubleshooting

The following general guidelines apply to troubleshooting `InnoDB` problems:

- When an operation fails or you suspect a bug, look at the MySQL server error log (see Section 5.4.2, “The Error Log”). Section B.3, “Server Error Codes and Messages” provides troubleshooting information for some of the common `InnoDB`-specific errors that you may encounter.
- If the failure is related to a deadlock, run with the `innodb_print_all_deadlocks` option enabled so that details about each deadlock are printed to the MySQL server error log. For information about deadlocks, see Section 14.8.5, “Deadlocks in InnoDB”.
- Issues relating to the `InnoDB` data dictionary include failed `CREATE TABLE` statements (orphan table files), inability to open `InnoDB` files, and `system cannot find the path specified` errors. For information about these sorts of problems and errors, see Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”.
- When troubleshooting, it is usually best to run the MySQL server from the command prompt, rather than through `mysqld_safe` or as a Windows service. You can then see what `mysqld` prints to the console, and so have a better grasp of what is going on. On Windows, start `mysqld` with the `--console` option to direct the output to the console window.
- Enable the `InnoDB` Monitors to obtain information about a problem (see Section 14.20, “InnoDB Monitors”). If the problem is performance-related, or your server appears to be hung, you should enable the standard Monitor to print information about the internal state of `InnoDB`. If the problem is with locks, enable the Lock Monitor. If the problem is in creation of tables or other data dictionary operations, enable the Table Monitor to print the contents of the `InnoDB` internal data dictionary. To see tablespace information enable the Tablespace Monitor.

  `InnoDB` temporarily enables standard `InnoDB` Monitor output under the following conditions:

  - A long semaphore wait
  - `InnoDB` cannot find free blocks in the buffer pool
  - Over 67% of the buffer pool is occupied by lock heaps or the adaptive hash index
- If you suspect that a table is corrupt, run `CHECK TABLE` on that table.

14.23.1 Troubleshooting InnoDB I/O Problems

The troubleshooting steps for `InnoDB` I/O problems depend on when the problem occurs: during startup of the MySQL server, or during normal operations when a DML or DDL statement fails due to problems at the file system level.

Initialization Problems

If something goes wrong when `InnoDB` attempts to initialize its tablespace or its log files, delete all files created by `InnoDB`: all `ibdata` files and all `ib_logfile` files. If you already created some `InnoDB` tables, also delete the corresponding `.frm` files for these tables, and any `.ibd` files if you are using multiple tablespaces, from the MySQL database directories. Then try the `InnoDB` database creation

again. For easiest troubleshooting, start the MySQL server from a command prompt so that you see what is happening.

Runtime Problems

If `InnoDB` prints an operating system error during a file operation, usually the problem has one of the following solutions:

- Make sure the `InnoDB` data file directory and the `InnoDB` log directory exist.
- Make sure `mysqld` has access rights to create files in those directories.
- Make sure `mysqld` can read the proper `my.cnf` or `my.ini` option file, so that it starts with the options that you specified.
- Make sure the disk is not full and you are not exceeding any disk quota.
- Make sure that the names you specify for subdirectories and data files do not clash.
- Doublecheck the syntax of the `innodb_data_home_dir` and `innodb_data_file_path` values. In particular, any `MAX` value in the `innodb_data_file_path` option is a hard limit, and exceeding that limit causes a fatal error.

14.23.2 Forcing InnoDB Recovery

To investigate database page corruption, you might dump your tables from the database with `SELECT ... INTO OUTFILE`. Usually, most of the data obtained in this way is intact. Serious corruption might cause `SELECT * FROM tbl_name` statements or `InnoDB` background operations to crash or assert, or even cause `InnoDB` roll-forward recovery to crash. In such cases, you can use the `innodb_force_recovery` option to force the `InnoDB` storage engine to start up while preventing background operations from running, so that you can dump your tables. For example, you can add the following line to the `[mysqld]` section of your option file before restarting the server:

```
[mysqld]
innodb_force_recovery = 1
```

Warning

Only set `innodb_force_recovery` to a value greater than 0 in an emergency situation, so that you can start `InnoDB` and dump your tables. Before doing so, ensure that you have a backup copy of your database in case you need to recreate it. Values of 4 or greater can permanently corrupt data files. Only use an `innodb_force_recovery` setting of 4 or greater on a production server instance after you have successfully tested the setting on a separate physical copy of your database. When forcing `InnoDB` recovery, you should always start with `innodb_force_recovery=1` and only increase the value incrementally, as necessary.

`innodb_force_recovery` is 0 by default (normal startup without forced recovery). The permissible nonzero values for `innodb_force_recovery` are 1 to 6. A larger value includes the functionality of lesser values. For example, a value of 3 includes all of the functionality of values 1 and 2.

If you are able to dump your tables with an `innodb_force_recovery` value of 3 or less, then you are relatively safe that only some data on corrupt individual pages is lost. A value of 4 or greater is considered dangerous because data files can be permanently corrupted. A value of 6 is considered drastic because database pages are left in an obsolete state, which in turn may introduce more corruption into B-trees and other database structures.

As a safety measure, `InnoDB` prevents `INSERT`, `UPDATE`, or `DELETE` operations when `innodb_force_recovery` is greater than 0.

- 1 (SRV_FORCE_IGNORE_CORRUPT)

  Lets the server run even if it detects a corrupt page. Tries to make SELECT * FROM *tbl_name* jump over corrupt index records and pages, which helps in dumping tables.

- 2 (SRV_FORCE_NO_BACKGROUND)

  Prevents the master thread and any purge threads from running. If a crash would occur during the purge operation, this recovery value prevents it.

- 3 (SRV_FORCE_NO_TRX_UNDO)

  Does not run transaction rollbacks after crash recovery.

- 4 (SRV_FORCE_NO_IBUF_MERGE)

  Prevents insert buffer merge operations. If they would cause a crash, does not do them. Does not calculate table statistics. This value can permanently corrupt data files. After using this value, be prepared to drop and recreate all secondary indexes.

- 5 (SRV_FORCE_NO_UNDO_LOG_SCAN)

  Does not look at undo logs when starting the database: InnoDB treats even incomplete transactions as committed. This value can permanently corrupt data files.

- 6 (SRV_FORCE_NO_LOG_REDO)

  Does not do the redo log roll-forward in connection with recovery. This value can permanently corrupt data files. Leaves database pages in an obsolete state, which in turn may introduce more corruption into B-trees and other database structures.

You can SELECT from tables to dump them, or DROP or CREATE tables even if forced recovery is used. If you know that a given table is causing a crash on rollback, you can drop it. You can also use this to stop a runaway rollback caused by a failing mass import or ALTER TABLE: kill the mysqld process and set innodb_force_recovery to 3 to bring the database up without the rollback, then DROP the table that is causing the runaway rollback.

If corruption within the table data prevents you from dumping the entire table contents, a query with an ORDER BY *primary_key* DESC clause might be able to dump the portion of the table after the corrupted part.

If a high innodb_force_recovery value is required to start InnoDB, there may be corrupted data structures that could cause complex queries (queries containing WHERE, ORDER BY, or other clauses) to fail. In this case, you may only be able to run basic SELECT * FROM t queries.

14.23.3 Troubleshooting InnoDB Data Dictionary Operations

Information about table definitions is stored both in the .frm files, and in the InnoDB data dictionary. If you move .frm files around, or if the server crashes in the middle of a data dictionary operation, these sources of information can become inconsistent.

If a data dictionary corruption or consistency issue prevents you from starting InnoDB, see Section 14.23.2, “Forcing InnoDB Recovery” for information about manual recovery.

CREATE TABLE Failure Due to Orphan Table

A symptom of an out-of-sync data dictionary is that a CREATE TABLE statement fails. If this occurs, look in the server's error log. If the log says that the table already exists inside the InnoDB internal data dictionary, you have an orphan table inside the InnoDB tablespace files that has no corresponding .frm file. The error message looks like this:

```
InnoDB: Error: table test/parent already exists in InnoDB internal
InnoDB: data dictionary. Have you deleted the .frm file
InnoDB: and not used DROP TABLE? Have you used DROP DATABASE
InnoDB: for InnoDB tables in MySQL version <= 3.23.43?
InnoDB: See the Restrictions section of the InnoDB manual.
InnoDB: You can drop the orphaned table inside InnoDB by
InnoDB: creating an InnoDB table with the same name in another
InnoDB: database and moving the .frm file to the current database.
InnoDB: Then MySQL thinks the table exists, and DROP TABLE will
InnoDB: succeed.
```

You can drop the orphan table by following the instructions given in the error message. If you are still unable to use `DROP TABLE` successfully, the problem may be due to name completion in the `mysql` client. To work around this problem, start the `mysql` client with the `--skip-auto-rehash` option and try `DROP TABLE` again. (With name completion on, `mysql` tries to construct a list of table names, which fails when a problem such as just described exists.)

Cannot Open File Error

Another symptom of an out-of-sync data dictionary is that MySQL prints an error that it cannot open an `InnoDB` file:

```
ERROR 1016: Can't open file: 'child2.ibd'. (errno: 1)
```

In the error log you can find a message like this:

```
InnoDB: Cannot find table test/child2 from the internal data dictionary
InnoDB: of InnoDB though the .frm file for the table exists. Maybe you
InnoDB: have deleted and recreated InnoDB data files but have forgotten
InnoDB: to delete the corresponding .frm files of InnoDB tables?
```

This means that there is an orphan `.frm` file without a corresponding table inside `InnoDB`. You can drop the orphan `.frm` file by deleting it manually.

Orphan Temporary Tables

If MySQL exits in the middle of an `ALTER TABLE` operation, you may be left with an orphan temporary table that takes up space on your system. This section describes how to identify and remove orphan temporary tables.

Orphan temporary table names begin with an `#sql-` prefix (e.g., `#sql-540_3`). The accompanying `.frm` file has the same base name as the orphan temporary table.

Note

If there is no `.frm` file, you can recreate it. The `.frm` file must have the same table schema as the orphan temporary table (it must have the same columns and indexes) and must be placed in the database directory of the orphan temporary table.

To identify orphan temporary tables on your system, you can view Table Monitor output. Look for table names that begin with `#sql`. If the original table resides in a file-per-table tablespace, the tablespace file (the `#sql-*.ibd` file) for the orphan temporary table should be visible in the database directory.

To remove an orphan temporary table, drop the table by issuing a `DROP TABLE` statement, prefixing the name of the table with `#mysql50#` and enclosing the table name in backticks. For example:

```
mysql> DROP TABLE `#mysql50##sql-540_3`;
```

The `#mysql50#` prefix tells MySQL to ignore `file name safe encoding` introduced in MySQL 5.1. Enclosing the table name in backticks is required to perform SQL statements on table names with special characters such as “#”.

Tablespace Does Not Exist

With `innodb_file_per_table` enabled, the following message might occur if the `.frm` or `.ibd` files (or both) are missing:

```
InnoDB: in InnoDB data dictionary has tablespace id N,
InnoDB: but tablespace with that id or name does not exist. Have
InnoDB: you deleted or moved .ibd files?
InnoDB: This may also be a table created with CREATE TEMPORARY TABLE
InnoDB: whose .ibd and .frm files MySQL automatically removed, but the
InnoDB: table still exists in the InnoDB internal data dictionary.
```

If this occurs, try the following procedure to resolve the problem:

1. Create a matching `.frm` file in some other database directory and copy it to the database directory where the orphan table is located.

2. Issue `DROP TABLE` for the original table. That should successfully drop the table and `InnoDB` should print a warning to the error log that the `.ibd` file was missing.

14.23.4 InnoDB Error Handling

The following items describe how `InnoDB` performs error handling. `InnoDB` sometimes rolls back only the statement that failed, other times it rolls back the entire transaction.

- If you run out of file space in a tablespace, a MySQL `Table is full` error occurs and `InnoDB` rolls back the SQL statement.

- A transaction deadlock causes `InnoDB` to roll back the entire transaction. Retry the whole transaction when this happens.

  A lock wait timeout causes `InnoDB` to roll back only the single statement that was waiting for the lock and encountered the timeout. (To have the entire transaction roll back, start the server with the `--innodb_rollback_on_timeout` option.) Retry the statement if using the current behavior, or the entire transaction if using `--innodb_rollback_on_timeout`.

  Both deadlocks and lock wait timeouts are normal on busy servers and it is necessary for applications to be aware that they may happen and handle them by retrying. You can make them less likely by doing as little work as possible between the first change to data during a transaction and the commit, so the locks are held for the shortest possible time and for the smallest possible number of rows. Sometimes splitting work between different transactions may be practical and helpful.

  When a transaction rollback occurs due to a deadlock or lock wait timeout, it cancels the effect of the statements within the transaction. But if the start-transaction statement was `START TRANSACTION` or `BEGIN` statement, rollback does not cancel that statement. Further SQL statements become part of the transaction until the occurrence of `COMMIT`, `ROLLBACK`, or some SQL statement that causes an implicit commit.

- A duplicate-key error rolls back the SQL statement, if you have not specified the `IGNORE` option in your statement.

- A `row too long error` rolls back the SQL statement.

- Other errors are mostly detected by the MySQL layer of code (above the `InnoDB` storage engine level), and they roll back the corresponding SQL statement. Locks are not released in a rollback of a single SQL statement.

During implicit rollbacks, as well as during the execution of an explicit `ROLLBACK` SQL statement, `SHOW PROCESSLIST` displays `Rolling back` in the `State` column for the relevant connection.

Chapter 15 Alternative Storage Engines

Table of Contents

15.1 Setting the Storage Engine 1784
15.2 Overview of MySQL Storage Engine Architecture 1785
15.2.1 Pluggable Storage Engine Architecture 1786
15.2.2 The Common Database Server Layer 1786
15.3 The MyISAM Storage Engine 1787
15.3.1 MyISAM Startup Options 1789
15.3.2 Space Needed for Keys 1791
15.3.3 MyISAM Table Storage Formats 1791
15.3.4 MyISAM Table Problems 1794
15.4 The MEMORY Storage Engine 1795
15.5 The CSV Storage Engine 1799
15.5.1 Repairing and Checking CSV Tables 1800
15.5.2 CSV Limitations 1801
15.6 The ARCHIVE Storage Engine 1801
15.7 The BLACKHOLE Storage Engine 1802
15.8 The MERGE Storage Engine 1805
15.8.1 MERGE Table Advantages and Disadvantages 1807
15.8.2 MERGE Table Problems 1808
15.9 The FEDERATED Storage Engine 1810
15.9.1 FEDERATED Storage Engine Overview 1810
15.9.2 How to Create FEDERATED Tables 1811
15.9.3 FEDERATED Storage Engine Notes and Tips 1813
15.9.4 FEDERATED Storage Engine Resources 1815
15.10 The EXAMPLE Storage Engine 1815
15.11 Other Storage Engines 1815

Storage engines are MySQL components that handle the SQL operations for different table types. MySQL storage engines include both those that handle transaction-safe tables and those that handle nontransaction-safe tables. `InnoDB` is the default storage engine as of MySQL 5.5.5 (The `CREATE TABLE` statement in MySQL 5.5 creates `InnoDB` tables by default.)

MySQL uses a pluggable storage engine architecture that enables storage engines to be loaded into and unloaded from a running MySQL server.

To determine which storage engines your server supports, use the `SHOW ENGINES` statement. The value in the `Support` column indicates whether an engine can be used. A value of `YES`, `NO`, or `DEFAULT` indicates that an engine is available, not available, or available and currently set as the default storage engine.

```
mysql> SHOW ENGINES\G
*************************** 1. row ***************************
      Engine: PERFORMANCE_SCHEMA
     Support: YES
     Comment: Performance Schema
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 2. row ***************************
      Engine: InnoDB
     Support: DEFAULT
     Comment: Supports transactions, row-level locking, and foreign keys
Transactions: YES
          XA: YES
  Savepoints: YES
```

```
*************************** 3. row ***************************
      Engine: MRG_MYISAM
     Support: YES
     Comment: Collection of identical MyISAM tables
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 4. row ***************************
      Engine: BLACKHOLE
     Support: YES
     Comment: /dev/null storage engine (anything you write to it disappears)
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 5. row ***************************
      Engine: MyISAM
     Support: YES
     Comment: MyISAM storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
...
```

This chapter covers use cases for special-purpose MySQL storage engines. It does not cover the default `InnoDB` storage engine or the `NDB` storage engine which are covered in Chapter 14, *The InnoDB Storage Engine* and Chapter 18, *MySQL NDB Cluster 7.2*. For advanced users, this chapter also contains a description of the pluggable storage engine architecture (see Section 15.2, “Overview of MySQL Storage Engine Architecture”).

For information about storage engine support offered in commercial MySQL Server binaries, see *MySQL Enterprise Server 5.5*, on the MySQL Web site. The storage engines available might depend on which edition of Enterprise Server you are using.

For answers to some commonly asked questions about MySQL storage engines, see Section A.2, “MySQL 5.5 FAQ: Storage Engines”.

MySQL 5.5 Supported Storage Engines

- `InnoDB`: The default storage engine as of MySQL 5.5.5. `InnoDB` is a transaction-safe (ACID compliant) storage engine for MySQL that has commit, rollback, and crash-recovery capabilities to protect user data. `InnoDB` row-level locking (without escalation to coarser granularity locks) and Oracle-style consistent nonlocking reads increase multi-user concurrency and performance. `InnoDB` stores user data in clustered indexes to reduce I/O for common queries based on primary keys. To maintain data integrity, `InnoDB` also supports `FOREIGN KEY` referential-integrity constraints. For more information about `InnoDB`, see Chapter 14, *The InnoDB Storage Engine*.

- `MyISAM`: The MySQL storage engine that is used the most in Web, data warehousing, and other application environments. `MyISAM` is supported in all MySQL configurations, and is the default storage engine prior to MySQL 5.5.5.

- `Memory`: Stores all data in RAM for extremely fast access in environments that require quick lookups of reference and other like data. This engine was formerly known as the `HEAP` engine.

- `Merge`: Enables a MySQL DBA or developer to logically group a series of identical `MyISAM` tables and reference them as one object. Good for VLDB environments such as data warehousing.

- `Archive`: Provides the perfect solution for storing and retrieving large amounts of seldom-referenced historical, archived, or security audit information.

- `Federated`: Offers the ability to link separate MySQL servers to create one logical database from many physical servers. Very good for distributed or data mart environments.

- `NDB` (also known as `NDBCLUSTER`)—This clustered database engine is particularly suited for applications that require the highest possible degree of uptime and availability.

Note

The NDB storage engine is not supported in standard MySQL 5.5 releases. Currently supported NDB Cluster releases include MySQL NDB Cluster 7.0 and MySQL NDB Cluster 7.1, which are based on MySQL 5.1, and MySQL NDB Cluster 7.2, which is based on MySQL 5.5. While based on MySQL Server, these releases also contain support for NDB.

- CSV: The CSV storage engine stores data in text files using comma-separated values format. You can use the CSV engine to easily exchange data between other software and applications that can import and export in CSV format.
- Blackhole: The Blackhole storage engine accepts but does not store data and retrievals always return an empty set. The functionality can be used in distributed database design where data is automatically replicated, but not stored locally.
- Example: The Example storage engine is “stub” engine that does nothing. You can create tables with this engine, but no data can be stored in them or retrieved from them. The purpose of this engine is to serve as an example in the MySQL source code that illustrates how to begin writing new storage engines. As such, it is primarily of interest to developers.

It is important to remember that you are not restricted to using the same storage engine for an entire server or schema: you can use a different storage engine for each table in your schema.

Choosing a Storage Engine

The various storage engines provided with MySQL are designed with different use cases in mind. To use the pluggable storage architecture effectively, it is good to have an idea of the advantages and disadvantages of the various storage engines. The following table provides an overview of some storage engines provided with MySQL:

Table 15.1 Storage Engines Feature Summary

Feature	MyISAM	Memory	InnoDB	Archive	NDB
Storage limits	256TB	RAM	64TB	None	384EB
Transactions	No	No	Yes	No	Yes
Locking granularity	Table	Table	Row	Row	Row
MVCC	No	No	Yes	No	No
Geospatial data type support	Yes	No	Yes	Yes	Yes
Geospatial indexing support	Yes	No	Yes[a]	No	No
B-tree indexes	Yes	Yes	Yes	No	No
T-tree indexes	No	No	No	No	Yes
Hash indexes	No	Yes	No[b]	No	Yes
Full-text search indexes	Yes	No	Yes[c]	No	No

Feature	MyISAM	Memory	InnoDB	Archive	NDB
Clustered indexes	No	No	Yes	No	No
Data caches	No	N/A	Yes	No	Yes
Index caches	Yes	N/A	Yes	No	Yes
Compressed data	Yes[d]	No	Yes[e]	Yes	No
Encrypted data[f]	Yes	Yes	Yes	Yes	Yes
Cluster database support	No	No	No	No	Yes
Replication support[g]	Yes	Limited[h]	Yes	Yes	Yes
Foreign key support	No	No	Yes	No	Yes[i]
Backup / point-in-time recovery[j]	Yes	Yes	Yes	Yes	Yes
Query cache support	Yes	Yes	Yes	Yes	Yes
Update statistics for data dictionary	Yes	Yes	Yes	Yes	Yes

[a] InnoDB support for geospatial indexing is available in MySQL 5.7.5 and later.

[b] InnoDB utilizes hash indexes internally for its Adaptive Hash Index feature.

[c] InnoDB support for FULLTEXT indexes is available in MySQL 5.6.4 and later.

[d] Compressed MyISAM tables are supported only when using the compressed row format. Tables using the compressed row format with MyISAM are read only.

[e] Compressed InnoDB tables require the InnoDB Barracuda file format.

[f] Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and later.

[g] Implemented in the server, rather than in the storage engine.

[h] See the discussion later in this section.

[i] Support for foreign keys is available in MySQL Cluster NDB 7.3 and later.

[j] Implemented in the server, rather than in the storage engine.

15.1 Setting the Storage Engine

When you create a new table, you can specify which storage engine to use by adding an `ENGINE` table option to the `CREATE TABLE` statement:

```
-- ENGINE=INNODB not needed as of 5.5.5 unless you have set a
-- different default storage engine.
CREATE TABLE t1 (i INT) ENGINE = INNODB;
-- Simple table definitions can be switched from one to another.
CREATE TABLE t2 (i INT) ENGINE = CSV;
CREATE TABLE t3 (i INT) ENGINE = MEMORY;
```

If you omit the `ENGINE` option, the default storage engine is used. The default engine is `InnoDB` as of MySQL 5.5.5 (`MyISAM` before 5.5.5). You can specify the default engine by using the `--default-storage-engine` server startup option, or by setting the `default-storage-engine` option in the `my.cnf` configuration file.

You can set the default storage engine to be used during the current session by setting the `default_storage_engine` variable:

```
SET default_storage_engine=MYISAM;
```

When MySQL is installed on Windows using the MySQL Configuration Wizard, the `InnoDB` or `MyISAM` storage engine can be selected as the default. See Section 2.3.6.5, “The Database Usage Dialog”.

To convert a table from one storage engine to another, use an `ALTER TABLE` statement that indicates the new engine:

```
ALTER TABLE t ENGINE = MYISAM;
```

See Section 13.1.17, “CREATE TABLE Syntax”, and Section 13.1.7, “ALTER TABLE Syntax”.

If you try to use a storage engine that is not compiled in or that is compiled in but deactivated, MySQL instead creates a table using the default storage engine. This behavior is convenient when you want to copy tables between MySQL servers that support different storage engines. (For example, in a replication setup, perhaps your master server supports transactional storage engines for increased safety, but the slave servers use only nontransactional storage engines for greater speed.)

This automatic substitution of the default storage engine for unavailable engines can be confusing for new MySQL users. A warning is generated whenever a storage engine is automatically changed. To prevent this from happening if the desired engine is unavailable, enable the `NO_ENGINE_SUBSTITUTION` SQL mode. In this case, an error occurs instead of a warning and the table is not created or altered if the desired engine is unavailable. See Section 5.1.8, “Server SQL Modes”.

For new tables, MySQL always creates an `.frm` file to hold the table and column definitions. The table's index and data may be stored in one or more other files, depending on the storage engine. The server creates the `.frm` file above the storage engine level. Individual storage engines create any additional files required for the tables that they manage. If a table name contains special characters, the names for the table files contain encoded versions of those characters as described in Section 9.2.3, “Mapping of Identifiers to File Names”.

A database may contain tables of different types. That is, tables need not all be created with the same storage engine.

15.2 Overview of MySQL Storage Engine Architecture

The MySQL pluggable storage engine architecture enables a database professional to select a specialized storage engine for a particular application need while being completely shielded from the need to manage any specific application coding requirements. The MySQL server architecture isolates the application programmer and DBA from all of the low-level implementation details at the storage level, providing a consistent and easy application model and API. Thus, although there are different capabilities across different storage engines, the application is shielded from these differences.

The pluggable storage engine architecture provides a standard set of management and support services that are common among all underlying storage engines. The storage engines themselves are the components of the database server that actually perform actions on the underlying data that is maintained at the physical server level.

This efficient and modular architecture provides huge benefits for those wishing to specifically target a particular application need—such as data warehousing, transaction processing, or high

availability situations—while enjoying the advantage of utilizing a set of interfaces and services that are independent of any one storage engine.

The application programmer and DBA interact with the MySQL database through Connector APIs and service layers that are above the storage engines. If application changes bring about requirements that demand the underlying storage engine change, or that one or more storage engines be added to support new needs, no significant coding or process changes are required to make things work. The MySQL server architecture shields the application from the underlying complexity of the storage engine by presenting a consistent and easy-to-use API that applies across storage engines.

15.2.1 Pluggable Storage Engine Architecture

MySQL Server uses a pluggable storage engine architecture that enables storage engines to be loaded into and unloaded from a running MySQL server.

Plugging in a Storage Engine

Before a storage engine can be used, the storage engine plugin shared library must be loaded into MySQL using the `INSTALL PLUGIN` statement. For example, if the `EXAMPLE` engine plugin is named `example` and the shared library is named `ha_example.so`, you load it with the following statement:

```
mysql> INSTALL PLUGIN example SONAME 'ha_example.so';
```

To install a pluggable storage engine, the plugin file must be located in the MySQL plugin directory, and the user issuing the `INSTALL PLUGIN` statement must have `INSERT` privilege for the `mysql.plugin` table.

The shared library must be located in the MySQL server plugin directory, the location of which is given by the `plugin_dir` system variable.

Unplugging a Storage Engine

To unplug a storage engine, use the `UNINSTALL PLUGIN` statement:

```
mysql> UNINSTALL PLUGIN example;
```

If you unplug a storage engine that is needed by existing tables, those tables become inaccessible, but will still be present on disk (where applicable). Ensure that there are no tables using a storage engine before you unplug the storage engine.

15.2.2 The Common Database Server Layer

A MySQL pluggable storage engine is the component in the MySQL database server that is responsible for performing the actual data I/O operations for a database as well as enabling and enforcing certain feature sets that target a specific application need. A major benefit of using specific storage engines is that you are only delivered the features needed for a particular application, and therefore you have less system overhead in the database, with the end result being more efficient and higher database performance. This is one of the reasons that MySQL has always been known to have such high performance, matching or beating proprietary monolithic databases in industry standard benchmarks.

From a technical perspective, what are some of the unique supporting infrastructure components that are in a storage engine? Some of the key feature differentiations include:

- *Concurrency*: Some applications have more granular lock requirements (such as row-level locks) than others. Choosing the right locking strategy can reduce overhead and therefore improve overall performance. This area also includes support for capabilities such as multi-version concurrency control or “snapshot” read.

- *Transaction Support*: Not every application needs transactions, but for those that do, there are very well defined requirements such as ACID compliance and more.
- *Referential Integrity*: The need to have the server enforce relational database referential integrity through DDL defined foreign keys.
- *Physical Storage*: This involves everything from the overall page size for tables and indexes as well as the format used for storing data to physical disk.
- *Index Support*: Different application scenarios tend to benefit from different index strategies. Each storage engine generally has its own indexing methods, although some (such as B-tree indexes) are common to nearly all engines.
- *Memory Caches*: Different applications respond better to some memory caching strategies than others, so although some memory caches are common to all storage engines (such as those used for user connections or MySQL's high-speed Query Cache), others are uniquely defined only when a particular storage engine is put in play.
- *Performance Aids*: This includes multiple I/O threads for parallel operations, thread concurrency, database checkpointing, bulk insert handling, and more.
- *Miscellaneous Target Features*: This may include support for geospatial operations, security restrictions for certain data manipulation operations, and other similar features.

Each set of the pluggable storage engine infrastructure components are designed to offer a selective set of benefits for a particular application. Conversely, avoiding a set of component features helps reduce unnecessary overhead. It stands to reason that understanding a particular application's set of requirements and selecting the proper MySQL storage engine can have a dramatic impact on overall system efficiency and performance.

15.3 The MyISAM Storage Engine

Before MySQL 5.5.5, `MyISAM` is the default storage engine. (The default was changed to `InnoDB` in MySQL 5.5.5.) `MyISAM` is based on the older (and no longer available) `ISAM` storage engine but has many useful extensions.

Table 15.2 `MyISAM` Storage Engine Features

Storage limits	256TB	**Transactions**	No	**Locking granularity**	Table
MVCC	No	**Geospatial data type support**	Yes	**Geospatial indexing support**	Yes
B-tree indexes	Yes	**T-tree indexes**	No	**Hash indexes**	No
Full-text search indexes	Yes	**Clustered indexes**	No	**Data caches**	No
Index caches	Yes	**Compressed data**	Yes[a]	**Encrypted data**[b]	Yes
Cluster database support	No	**Replication support**[c]	Yes	**Foreign key support**	No
Backup / point-in-time recovery[d]	Yes	**Query cache support**	Yes	**Update statistics for data dictionary**	Yes

[a] Compressed MyISAM tables are supported only when using the compressed row format. Tables using the compressed row format with MyISAM are read only.

[b] Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and later.

[c] Implemented in the server, rather than in the storage engine.

[d] Implemented in the server, rather than in the storage engine.

Each `MyISAM` table is stored on disk in three files. The files have names that begin with the table name and have an extension to indicate the file type. An `.frm` file stores the table format. The data file has an `.MYD` (`MYData`) extension. The index file has an `.MYI` (`MYIndex`) extension.

To specify explicitly that you want a MyISAM table, indicate that with an ENGINE table option:

```
CREATE TABLE t (i INT) ENGINE = MYISAM;
```

As of MySQL 5.5.5, it is normally necessary to use ENGINE to specify the MyISAM storage engine because InnoDB is the default engine. Before 5.5.5, this is unnecessary because MyISAM is the default engine unless the default has been changed. To ensure that MyISAM is used in situations where the default might have been changed, include the ENGINE option explicitly.

You can check or repair MyISAM tables with the mysqlcheck client or myisamchk utility. You can also compress MyISAM tables with myisampack to take up much less space. See Section 4.5.3, "mysqlcheck — A Table Maintenance Program", Section 4.6.3, "myisamchk — MyISAM Table-Maintenance Utility", and Section 4.6.5, "myisampack — Generate Compressed, Read-Only MyISAM Tables".

MyISAM tables have the following characteristics:

- All data values are stored with the low byte first. This makes the data machine and operating system independent. The only requirements for binary portability are that the machine uses two's-complement signed integers and IEEE floating-point format. These requirements are widely used among mainstream machines. Binary compatibility might not be applicable to embedded systems, which sometimes have peculiar processors.

  There is no significant speed penalty for storing data low byte first; the bytes in a table row normally are unaligned and it takes little more processing to read an unaligned byte in order than in reverse order. Also, the code in the server that fetches column values is not time critical compared to other code.

- All numeric key values are stored with the high byte first to permit better index compression.

- Large files (up to 63-bit file length) are supported on file systems and operating systems that support large files.

- There is a limit of $(2^{32})^2$ (1.844E+19) rows in a MyISAM table.

- The maximum number of indexes per MyISAM table is 64.

  The maximum number of columns per index is 16.

- The maximum key length is 1000 bytes. This can also be changed by changing the source and recompiling. For the case of a key longer than 250 bytes, a larger key block size than the default of 1024 bytes is used.

- When rows are inserted in sorted order (as when you are using an AUTO_INCREMENT column), the index tree is split so that the high node only contains one key. This improves space utilization in the index tree.

- Internal handling of one AUTO_INCREMENT column per table is supported. MyISAM automatically updates this column for INSERT and UPDATE operations. This makes AUTO_INCREMENT columns faster (at least 10%). Values at the top of the sequence are not reused after being deleted. (When an AUTO_INCREMENT column is defined as the last column of a multiple-column index, reuse of values deleted from the top of a sequence does occur.) The AUTO_INCREMENT value can be reset with ALTER TABLE or myisamchk.

- Dynamic-sized rows are much less fragmented when mixing deletes with updates and inserts. This is done by automatically combining adjacent deleted blocks and by extending blocks if the next block is deleted.

- MyISAM supports concurrent inserts: If a table has no free blocks in the middle of the data file, you can INSERT new rows into it at the same time that other threads are reading from the table. A

free block can occur as a result of deleting rows or an update of a dynamic length row with more data than its current contents. When all free blocks are used up (filled in), future inserts become concurrent again. See Section 8.11.3, “Concurrent Inserts”.

- You can put the data file and index file in different directories on different physical devices to get more speed with the `DATA DIRECTORY` and `INDEX DIRECTORY` table options to `CREATE TABLE`. See Section 13.1.17, “CREATE TABLE Syntax”.
- `BLOB` and `TEXT` columns can be indexed.
- `NULL` values are permitted in indexed columns. This takes 0 to 1 bytes per key.
- Each character column can have a different character set. See Section 10.1, “Character Set Support”.
- There is a flag in the `MyISAM` index file that indicates whether the table was closed correctly. If `mysqld` is started with the `--myisam-recover-options` option, `MyISAM` tables are automatically checked when opened, and are repaired if the table wasn't closed properly.
- `myisamchk` marks tables as checked if you run it with the `--update-state` option. `myisamchk --fast` checks only those tables that don't have this mark.
- `myisamchk --analyze` stores statistics for portions of keys, as well as for entire keys.
- `myisampack` can pack `BLOB` and `VARCHAR` columns.

`MyISAM` also supports the following features:

- Support for a true `VARCHAR` type; a `VARCHAR` column starts with a length stored in one or two bytes.
- Tables with `VARCHAR` columns may have fixed or dynamic row length.
- The sum of the lengths of the `VARCHAR` and `CHAR` columns in a table may be up to 64KB.
- Arbitrary length `UNIQUE` constraints.

Additional Resources

- A forum dedicated to the `MyISAM` storage engine is available at http://forums.mysql.com/list.php?21.

15.3.1 MyISAM Startup Options

The following options to `mysqld` can be used to change the behavior of `MyISAM` tables. For additional information, see Section 5.1.4, “Server Command Options”.

Table 15.3 `MyISAM` Option and Variable Reference

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
bulk_insert_buffer_size	Yes	Yes	Yes		Both	Yes
concurrent_insert	Yes	Yes	Yes		Global	Yes
delay-key-write	Yes	Yes			Global	Yes
- *Variable*: delay_key_write			Yes		Global	Yes
have_rtree_keys			Yes		Global	No
key_buffer_size	Yes	Yes	Yes		Global	Yes
log-isam	Yes	Yes				
myisam-block-size	Yes	Yes				

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
myisam_data_pointer_size	Yes	Yes	Yes		Global	Yes
myisam_max_sort_file_size	Yes	Yes	Yes		Global	Yes
myisam_mmap_size	Yes	Yes	Yes		Global	No
myisam-recover	Yes	Yes				
- *Variable*: myisam_recover_options						
myisam-recover-options	Yes	Yes				
- *Variable*: myisam_recover_options						
myisam_recover_options			Yes		Global	No
myisam_repair_threads	Yes	Yes	Yes		Both	Yes
myisam_sort_buffer_size	Yes	Yes	Yes		Both	Yes
myisam_stats_method	Yes	Yes	Yes		Both	Yes
myisam_use_mmap	Yes	Yes	Yes		Global	Yes
skip-concurrent-insert	Yes	Yes				
- *Variable*: concurrent_insert						
tmp_table_size	Yes	Yes	Yes		Both	Yes

- `--myisam-recover-options=`*mode*

  Set the mode for automatic recovery of crashed `MyISAM` tables.

- `--delay-key-write=ALL`

  Don't flush key buffers between writes for any `MyISAM` table.

Note

If you do this, you should not access `MyISAM` tables from another program (such as from another MySQL server or with `myisamchk`) when the tables are in use. Doing so risks index corruption. Using `--external-locking` does not eliminate this risk.

The following system variables affect the behavior of `MyISAM` tables. For additional information, see Section 5.1.5, “Server System Variables”.

- `bulk_insert_buffer_size`

  The size of the tree cache used in bulk insert optimization.

Note

This is a limit *per thread*!

- `myisam_max_sort_file_size`

  The maximum size of the temporary file that MySQL is permitted to use while re-creating a `MyISAM` index (during `REPAIR TABLE`, `ALTER TABLE`, or `LOAD DATA INFILE`). If the file size would be larger than this value, the index is created using the key cache instead, which is slower. The value is given in bytes.

- `myisam_sort_buffer_size`

  Set the size of the buffer used when recovering tables.

Automatic recovery is activated if you start `mysqld` with the `--myisam-recover-options` option. In this case, when the server opens a `MyISAM` table, it checks whether the table is marked as crashed or whether the open count variable for the table is not 0 and you are running the server with external locking disabled. If either of these conditions is true, the following happens:

- The server checks the table for errors.
- If the server finds an error, it tries to do a fast table repair (with sorting and without re-creating the data file).
- If the repair fails because of an error in the data file (for example, a duplicate-key error), the server tries again, this time re-creating the data file.
- If the repair still fails, the server tries once more with the old repair option method (write row by row without sorting). This method should be able to repair any type of error and has low disk space requirements.

If the recovery wouldn't be able to recover all rows from previously completed statements and you didn't specify `FORCE` in the value of the `--myisam-recover-options` option, automatic repair aborts with an error message in the error log:

```
Error: Couldn't repair table: test.g00pages
```

If you specify `FORCE`, a warning like this is written instead:

```
Warning: Found 344 of 354 rows when repairing ./test/g00pages
```

If the automatic recovery value includes `BACKUP`, the recovery process creates files with names of the form *`tbl_name-datetime`*`.BAK`. You should have a `cron` script that automatically moves these files from the database directories to backup media.

15.3.2 Space Needed for Keys

`MyISAM` tables use B-tree indexes. You can roughly calculate the size for the index file as `(key_length+4)/0.67`, summed over all keys. This is for the worst case when all keys are inserted in sorted order and the table doesn't have any compressed keys.

String indexes are space compressed. If the first index part is a string, it is also prefix compressed. Space compression makes the index file smaller than the worst-case figure if a string column has a lot of trailing space or is a `VARCHAR` column that is not always used to the full length. Prefix compression is used on keys that start with a string. Prefix compression helps if there are many strings with an identical prefix.

In `MyISAM` tables, you can also prefix compress numbers by specifying the `PACK_KEYS=1` table option when you create the table. Numbers are stored with the high byte first, so this helps when you have many integer keys that have an identical prefix.

15.3.3 MyISAM Table Storage Formats

`MyISAM` supports three different storage formats. Two of them, fixed and dynamic format, are chosen automatically depending on the type of columns you are using. The third, compressed format, can be created only with the `myisampack` utility (see Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”).

When you use `CREATE TABLE` or `ALTER TABLE` for a table that has no `BLOB` or `TEXT` columns, you can force the table format to `FIXED` or `DYNAMIC` with the `ROW_FORMAT` table option.

See Section 13.1.17, “CREATE TABLE Syntax”, for information about ROW_FORMAT.

You can decompress (unpack) compressed MyISAM tables using myisamchk --unpack; see Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”, for more information.

15.3.3.1 Static (Fixed-Length) Table Characteristics

Static format is the default for MyISAM tables. It is used when the table contains no variable-length columns (VARCHAR, VARBINARY, BLOB, or TEXT). Each row is stored using a fixed number of bytes.

Of the three MyISAM storage formats, static format is the simplest and most secure (least subject to corruption). It is also the fastest of the on-disk formats due to the ease with which rows in the data file can be found on disk: To look up a row based on a row number in the index, multiply the row number by the row length to calculate the row position. Also, when scanning a table, it is very easy to read a constant number of rows with each disk read operation.

The security is evidenced if your computer crashes while the MySQL server is writing to a fixed-format MyISAM file. In this case, myisamchk can easily determine where each row starts and ends, so it can usually reclaim all rows except the partially written one. MyISAM table indexes can always be reconstructed based on the data rows.

Note

Fixed-length row format is only available for tables without BLOB or TEXT columns. Creating a table with these columns with an explicit ROW_FORMAT clause will not raise an error or warning; the format specification will be ignored.

Static-format tables have these characteristics:

- CHAR and VARCHAR columns are space-padded to the specified column width, although the column type is not altered. BINARY and VARBINARY columns are padded with 0x00 bytes to the column width.
- NULL columns require additional space in the row to record whether their values are NULL. Each NULL column takes one bit extra, rounded up to the nearest byte.
- Very quick.
- Easy to cache.
- Easy to reconstruct after a crash, because rows are located in fixed positions.
- Reorganization is unnecessary unless you delete a huge number of rows and want to return free disk space to the operating system. To do this, use OPTIMIZE TABLE or myisamchk -r.
- Usually require more disk space than dynamic-format tables.
- The expected row length in bytes for static-sized rows is calculated using the following expression:

```
row length = 1
             + (sum of column lengths)
             + (number of NULL columns + delete_flag + 7)/8
             + (number of variable-length columns)
```

delete_flag is 1 for tables with static row format. Static tables use a bit in the row record for a flag that indicates whether the row has been deleted. *delete_flag* is 0 for dynamic tables because the flag is stored in the dynamic row header.

15.3.3.2 Dynamic Table Characteristics

Dynamic storage format is used if a MyISAM table contains any variable-length columns (VARCHAR, VARBINARY, BLOB, or TEXT), or if the table was created with the ROW_FORMAT=DYNAMIC table option.

Dynamic format is a little more complex than static format because each row has a header that indicates how long it is. A row can become fragmented (stored in noncontiguous pieces) when it is made longer as a result of an update.

You can use `OPTIMIZE TABLE` or `myisamchk -r` to defragment a table. If you have fixed-length columns that you access or change frequently in a table that also contains some variable-length columns, it might be a good idea to move the variable-length columns to other tables just to avoid fragmentation.

Dynamic-format tables have these characteristics:

- All string columns are dynamic except those with a length less than four.
- Each row is preceded by a bitmap that indicates which columns contain the empty string (for string columns) or zero (for numeric columns). This does not include columns that contain `NULL` values. If a string column has a length of zero after trailing space removal, or a numeric column has a value of zero, it is marked in the bitmap and not saved to disk. Nonempty strings are saved as a length byte plus the string contents.
- `NULL` columns require additional space in the row to record whether their values are `NULL`. Each `NULL` column takes one bit extra, rounded up to the nearest byte.
- Much less disk space usually is required than for fixed-length tables.
- Each row uses only as much space as is required. However, if a row becomes larger, it is split into as many pieces as are required, resulting in row fragmentation. For example, if you update a row with information that extends the row length, the row becomes fragmented. In this case, you may have to run `OPTIMIZE TABLE` or `myisamchk -r` from time to time to improve performance. Use `myisamchk -ei` to obtain table statistics.
- More difficult than static-format tables to reconstruct after a crash, because rows may be fragmented into many pieces and links (fragments) may be missing.
- The expected row length for dynamic-sized rows is calculated using the following expression:

```
3
+ (number of columns + 7) / 8
+ (number of char columns)
+ (packed size of numeric columns)
+ (length of strings)
+ (number of NULL columns + 7) / 8
```

  There is a penalty of 6 bytes for each link. A dynamic row is linked whenever an update causes an enlargement of the row. Each new link is at least 20 bytes, so the next enlargement probably goes in the same link. If not, another link is created. You can find the number of links using `myisamchk -ed`. All links may be removed with `OPTIMIZE TABLE` or `myisamchk -r`.

15.3.3.3 Compressed Table Characteristics

Compressed storage format is a read-only format that is generated with the `myisampack` tool. Compressed tables can be uncompressed with `myisamchk`.

Compressed tables have the following characteristics:

- Compressed tables take very little disk space. This minimizes disk usage, which is helpful when using slow disks (such as CD-ROMs).
- Each row is compressed separately, so there is very little access overhead. The header for a row takes up one to three bytes depending on the biggest row in the table. Each column is compressed differently. There is usually a different Huffman tree for each column. Some of the compression types are:
  - Suffix space compression.

- Prefix space compression.
- Numbers with a value of zero are stored using one bit.
- If values in an integer column have a small range, the column is stored using the smallest possible type. For example, a `BIGINT` column (eight bytes) can be stored as a `TINYINT` column (one byte) if all its values are in the range from `-128` to `127`.
- If a column has only a small set of possible values, the data type is converted to `ENUM`.
- A column may use any combination of the preceding compression types.

- Can be used for fixed-length or dynamic-length rows.

Note

While a compressed table is read only, and you cannot therefore update or add rows in the table, DDL (Data Definition Language) operations are still valid. For example, you may still use `DROP` to drop the table, and `TRUNCATE TABLE` to empty the table.

15.3.4 MyISAM Table Problems

The file format that MySQL uses to store data has been extensively tested, but there are always circumstances that may cause database tables to become corrupted. The following discussion describes how this can happen and how to handle it.

15.3.4.1 Corrupted MyISAM Tables

Even though the `MyISAM` table format is very reliable (all changes to a table made by an SQL statement are written before the statement returns), you can still get corrupted tables if any of the following events occur:

- The `mysqld` process is killed in the middle of a write.
- An unexpected computer shutdown occurs (for example, the computer is turned off).
- Hardware failures.
- You are using an external program (such as `myisamchk`) to modify a table that is being modified by the server at the same time.
- A software bug in the MySQL or `MyISAM` code.

Typical symptoms of a corrupt table are:

- You get the following error while selecting data from the table:

```
Incorrect key file for table: '...'. Try to repair it
```

- Queries don't find rows in the table or return incomplete results.

You can check the health of a `MyISAM` table using the `CHECK TABLE` statement, and repair a corrupted `MyISAM` table with `REPAIR TABLE`. When `mysqld` is not running, you can also check or repair a table with the `myisamchk` command. See Section 13.7.2.2, “CHECK TABLE Syntax”, Section 13.7.2.5, “REPAIR TABLE Syntax”, and Section 4.6.3, “`myisamchk` — MyISAM Table-Maintenance Utility”.

If your tables become corrupted frequently, you should try to determine why this is happening. The most important thing to know is whether the table became corrupted as a result of a server crash. You can verify this easily by looking for a recent `restarted mysqld` message in the error log. If there is

such a message, it is likely that table corruption is a result of the server dying. Otherwise, corruption may have occurred during normal operation. This is a bug. You should try to create a reproducible test case that demonstrates the problem. See Section B.5.3.3, “What to Do If MySQL Keeps Crashing”, and Section 24.5, “Debugging and Porting MySQL”.

15.3.4.2 Problems from Tables Not Being Closed Properly

Each `MyISAM` index file (`.MYI` file) has a counter in the header that can be used to check whether a table has been closed properly. If you get the following warning from `CHECK TABLE` or `myisamchk`, it means that this counter has gone out of sync:

```
clients are using or haven't closed the table properly
```

This warning doesn't necessarily mean that the table is corrupted, but you should at least check the table.

The counter works as follows:

- The first time a table is updated in MySQL, a counter in the header of the index files is incremented.
- The counter is not changed during further updates.
- When the last instance of a table is closed (because a `FLUSH TABLES` operation was performed or because there is no room in the table cache), the counter is decremented if the table has been updated at any point.
- When you repair the table or check the table and it is found to be okay, the counter is reset to zero.
- To avoid problems with interaction with other processes that might check the table, the counter is not decremented on close if it was zero.

In other words, the counter can become incorrect only under these conditions:

- A `MyISAM` table is copied without first issuing `LOCK TABLES` and `FLUSH TABLES`.
- MySQL has crashed between an update and the final close. (The table may still be okay because MySQL always issues writes for everything between each statement.)
- A table was modified by `myisamchk --recover` or `myisamchk --update-state` at the same time that it was in use by `mysqld`.
- Multiple `mysqld` servers are using the table and one server performed a `REPAIR TABLE` or `CHECK TABLE` on the table while it was in use by another server. In this setup, it is safe to use `CHECK TABLE`, although you might get the warning from other servers. However, `REPAIR TABLE` should be avoided because when one server replaces the data file with a new one, this is not known to the other servers.

  In general, it is a bad idea to share a data directory among multiple servers. See Section 5.6, “Running Multiple MySQL Instances on One Machine”, for additional discussion.

15.4 The MEMORY Storage Engine

The `MEMORY` storage engine (formerly known as `HEAP`) creates special-purpose tables with contents that are stored in memory. Because the data is vulnerable to crashes, hardware issues, or power outages, only use these tables as temporary work areas or read-only caches for data pulled from other tables.

Table 15.4 `MEMORY` Storage Engine Features

Storage limits	RAM	**Transactions**	No	**Locking granularity**	Table
MVCC	No	**Geospatial data type support**	No	**Geospatial indexing support**	No

B-tree indexes	Yes	**T-tree indexes**	No	**Hash indexes**	Yes
Full-text search indexes	No	**Clustered indexes**	No	**Data caches**	N/A
Index caches	N/A	**Compressed data**	No	**Encrypted data**[a]	Yes
Cluster database support	No	**Replication support**[b]	Limited[c]	**Foreign key support**	No
Backup / point-in-time recovery[d]	Yes	**Query cache support**	Yes	**Update statistics for data dictionary**	Yes

[a] Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and later.
[b] Implemented in the server, rather than in the storage engine.
[c] See the discussion later in this section.
[d] Implemented in the server, rather than in the storage engine.

- When to Use MEMORY or NDB Cluster
- Performance Characteristics
- Characteristics of MEMORY Tables
- DDL Operations for MEMORY Tables
- Indexes
- User-Created and Temporary Tables
- Loading Data
- MEMORY Tables and Replication
- Managing Memory Use
- Additional Resources

When to Use MEMORY or NDB Cluster

Developers looking to deploy applications that use the `MEMORY` storage engine for important, highly available, or frequently updated data should consider whether NDB Cluster is a better choice. A typical use case for the `MEMORY` engine involves these characteristics:

- Operations involving transient, non-critical data such as session management or caching. When the MySQL server halts or restarts, the data in `MEMORY` tables is lost.
- In-memory storage for fast access and low latency. Data volume can fit entirely in memory without causing the operating system to swap out virtual memory pages.
- A read-only or read-mostly data access pattern (limited updates).

NDB Cluster offers the same features as the `MEMORY` engine with higher performance levels, and provides additional features not available with `MEMORY`:

- Row-level locking and multiple-thread operation for low contention between clients.
- Scalability even with statement mixes that include writes.
- Optional disk-backed operation for data durability.
- Shared-nothing architecture and multiple-host operation with no single point of failure, enabling 99.999% availability.
- Automatic data distribution across nodes; application developers need not craft custom sharding or partitioning solutions.

- Support for variable-length data types (including `BLOB` and `TEXT`) not supported by `MEMORY`.

Performance Characteristics

`MEMORY` performance is constrained by contention resulting from single-thread execution and table lock overhead when processing updates. This limits scalability when load increases, particularly for statement mixes that include writes.

Despite the in-memory processing for `MEMORY` tables, they are not necessarily faster than `InnoDB` tables on a busy server, for general-purpose queries, or under a read/write workload. In particular, the table locking involved with performing updates can slow down concurrent usage of `MEMORY` tables from multiple sessions.

Depending on the kinds of queries performed on a `MEMORY` table, you might create indexes as either the default hash data structure (for looking up single values based on a unique key), or a general-purpose B-tree data structure (for all kinds of queries involving equality, inequality, or range operators such as less than or greater than). The following sections illustrate the syntax for creating both kinds of indexes. A common performance issue is using the default hash indexes in workloads where B-tree indexes are more efficient.

Characteristics of MEMORY Tables

The `MEMORY` storage engine associates each table with one disk file, which stores the table definition (not the data). The file name begins with the table name and has an extension of `.frm`.

`MEMORY` tables have the following characteristics:

- Space for `MEMORY` tables is allocated in small blocks. Tables use 100% dynamic hashing for inserts. No overflow area or extra key space is needed. No extra space is needed for free lists. Deleted rows are put in a linked list and are reused when you insert new data into the table. `MEMORY` tables also have none of the problems commonly associated with deletes plus inserts in hashed tables.
- `MEMORY` tables use a fixed-length row-storage format. Variable-length types such as `VARCHAR` are stored using a fixed length.
- `MEMORY` tables cannot contain `BLOB` or `TEXT` columns.
- `MEMORY` includes support for `AUTO_INCREMENT` columns.
- Non-`TEMPORARY` `MEMORY` tables are shared among all clients, just like any other non-`TEMPORARY` table.

DDL Operations for MEMORY Tables

To create a `MEMORY` table, specify the clause `ENGINE=MEMORY` on the `CREATE TABLE` statement.

```
CREATE TABLE t (i INT) ENGINE = MEMORY;
```

As indicated by the engine name, `MEMORY` tables are stored in memory. They use hash indexes by default, which makes them very fast for single-value lookups, and very useful for creating temporary tables. However, when the server shuts down, all rows stored in `MEMORY` tables are lost. The tables themselves continue to exist because their definitions are stored in `.frm` files on disk, but they are empty when the server restarts.

This example shows how you might create, use, and remove a `MEMORY` table:

```
mysql> CREATE TABLE test ENGINE=MEMORY
    ->     SELECT ip,SUM(downloads) AS down
    ->     FROM log_table GROUP BY ip;
mysql> SELECT COUNT(ip),AVG(down) FROM test;
mysql> DROP TABLE test;
```

The maximum size of MEMORY tables is limited by the max_heap_table_size system variable, which has a default value of 16MB. To enforce different size limits for MEMORY tables, change the value of this variable. The value in effect for CREATE TABLE, or a subsequent ALTER TABLE or TRUNCATE TABLE, is the value used for the life of the table. A server restart also sets the maximum size of existing MEMORY tables to the global max_heap_table_size value. You can set the size for individual tables as described later in this section.

Indexes

The MEMORY storage engine supports both HASH and BTREE indexes. You can specify one or the other for a given index by adding a USING clause as shown here:

```
CREATE TABLE lookup
    (id INT, INDEX USING HASH (id))
    ENGINE = MEMORY;
CREATE TABLE lookup
    (id INT, INDEX USING BTREE (id))
    ENGINE = MEMORY;
```

For general characteristics of B-tree and hash indexes, see Section 8.3.1, “How MySQL Uses Indexes”.

MEMORY tables can have up to 64 indexes per table, 16 columns per index and a maximum key length of 3072 bytes.

If a MEMORY table hash index has a high degree of key duplication (many index entries containing the same value), updates to the table that affect key values and all deletes are significantly slower. The degree of this slowdown is proportional to the degree of duplication (or, inversely proportional to the index cardinality). You can use a BTREE index to avoid this problem.

MEMORY tables can have nonunique keys. (This is an uncommon feature for implementations of hash indexes.)

Columns that are indexed can contain NULL values.

User-Created and Temporary Tables

MEMORY table contents are stored in memory, which is a property that MEMORY tables share with internal temporary tables that the server creates on the fly while processing queries. However, the two types of tables differ in that MEMORY tables are not subject to storage conversion, whereas internal temporary tables are:

- If an internal temporary table becomes too large, the server automatically converts it to on-disk storage, as described in Section 8.4.4, “Internal Temporary Table Use in MySQL”.
- User-created MEMORY tables are never converted to disk tables.

Loading Data

To populate a MEMORY table when the MySQL server starts, you can use the --init-file option. For example, you can put statements such as INSERT INTO ... SELECT or LOAD DATA INFILE into this file to load the table from a persistent data source. See Section 5.1.4, “Server Command Options”, and Section 13.2.6, “LOAD DATA INFILE Syntax”.

For loading data into MEMORY tables accessed by other sessions concurrently, MEMORY supports INSERT DELAYED. See Section 13.2.5.3, “INSERT DELAYED Syntax”.

MEMORY Tables and Replication

A server's MEMORY tables become empty when it is shut down and restarted. If the server is a replication master, its slaves are not aware that these tables have become empty, so you see out-of-

date content if you select data from the tables on the slaves. To synchronize master and slave MEMORY tables, when a MEMORY table is used on a master for the first time since it was started, a DELETE statement is written to the master's binary log, to empty the table on the slaves also. The slave still has outdated data in the table during the interval between the master's restart and its first use of the table. To avoid this interval when a direct query to the slave could return stale data, use the --init-file option to populate the MEMORY table on the master at startup.

Managing Memory Use

The server needs sufficient memory to maintain all MEMORY tables that are in use at the same time.

Memory is not reclaimed if you delete individual rows from a MEMORY table. Memory is reclaimed only when the entire table is deleted. Memory that was previously used for deleted rows is re-used for new rows within the same table. To free all the memory used by a MEMORY table when you no longer require its contents, execute DELETE or TRUNCATE TABLE to remove all rows, or remove the table altogether using DROP TABLE. To free up the memory used by deleted rows, use ALTER TABLE ENGINE=MEMORY to force a table rebuild.

The memory needed for one row in a MEMORY table is calculated using the following expression:

```
SUM_OVER_ALL_BTREE_KEYS(max_length_of_key + sizeof(char*) * 4)
+ SUM_OVER_ALL_HASH_KEYS(sizeof(char*) * 2)
+ ALIGN(length_of_row+1, sizeof(char*))
```

ALIGN() represents a round-up factor to cause the row length to be an exact multiple of the char pointer size. sizeof(char*) is 4 on 32-bit machines and 8 on 64-bit machines.

As mentioned earlier, the max_heap_table_size system variable sets the limit on the maximum size of MEMORY tables. To control the maximum size for individual tables, set the session value of this variable before creating each table. (Do not change the global max_heap_table_size value unless you intend the value to be used for MEMORY tables created by all clients.) The following example creates two MEMORY tables, with a maximum size of 1MB and 2MB, respectively:

```
mysql> SET max_heap_table_size = 1024*1024;
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t1 (id INT, UNIQUE(id)) ENGINE = MEMORY;
Query OK, 0 rows affected (0.01 sec)

mysql> SET max_heap_table_size = 1024*1024*2;
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE TABLE t2 (id INT, UNIQUE(id)) ENGINE = MEMORY;
Query OK, 0 rows affected (0.00 sec)
```

Both tables revert to the server's global max_heap_table_size value if the server restarts.

You can also specify a MAX_ROWS table option in CREATE TABLE statements for MEMORY tables to provide a hint about the number of rows you plan to store in them. This does not enable the table to grow beyond the max_heap_table_size value, which still acts as a constraint on maximum table size. For maximum flexibility in being able to use MAX_ROWS, set max_heap_table_size at least as high as the value to which you want each MEMORY table to be able to grow.

Additional Resources

A forum dedicated to the MEMORY storage engine is available at http://forums.mysql.com/list.php?92.

15.5 The CSV Storage Engine

The CSV storage engine stores data in text files using comma-separated values format.

The CSV storage engine is always compiled into the MySQL server.

To examine the source for the CSV engine, look in the storage/csv directory of a MySQL source distribution.

When you create a CSV table, the server creates a table format file in the database directory. The file begins with the table name and has an .frm extension. The storage engine also creates a data file. Its name begins with the table name and has a .CSV extension. The data file is a plain text file. When you store data into the table, the storage engine saves it into the data file in comma-separated values format.

```
mysql> CREATE TABLE test (i INT NOT NULL, c CHAR(10) NOT NULL)
    -> ENGINE = CSV;
Query OK, 0 rows affected (0.12 sec)

mysql> INSERT INTO test VALUES(1,'record one'),(2,'record two');
Query OK, 2 rows affected (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM test;
+------+------------+
| i    | c          |
+------+------------+
|    1 | record one |
|    2 | record two |
+------+------------+
2 rows in set (0.00 sec)
```

Creating a CSV table also creates a corresponding Metafile that stores the state of the table and the number of rows that exist in the table. The name of this file is the same as the name of the table with the extension CSM.

If you examine the test.CSV file in the database directory created by executing the preceding statements, its contents should look like this:

```
"1","record one"
"2","record two"
```

This format can be read, and even written, by spreadsheet applications such as Microsoft Excel or StarOffice Calc.

15.5.1 Repairing and Checking CSV Tables

The CSV storage engines supports the CHECK and REPAIR statements to verify and if possible repair a damaged CSV table.

When running the CHECK statement, the CSV file will be checked for validity by looking for the correct field separators, escaped fields (matching or missing quotation marks), the correct number of fields compared to the table definition and the existence of a corresponding CSV metafile. The first invalid row discovered will report an error. Checking a valid table produces output like that shown below:

```
mysql> check table csvtest;
+--------------+-------+----------+----------+
| Table        | Op    | Msg_type | Msg_text |
+--------------+-------+----------+----------+
| test.csvtest | check | status   | OK       |
+--------------+-------+----------+----------+
1 row in set (0.00 sec)
```

A check on a corrupted table returns a fault:

```
mysql> check table csvtest;
+--------------+-------+----------+----------+
| Table        | Op    | Msg_type | Msg_text |
+--------------+-------+----------+----------+
| test.csvtest | check | error    | Corrupt  |
+--------------+-------+----------+----------+
1 row in set (0.01 sec)
```

If the check fails, the table is marked as crashed (corrupt). Once a table has been marked as corrupt, it is automatically repaired when you next run `CHECK` or execute a `SELECT` statement. The corresponding corrupt status and new status will be displayed when running `CHECK`:

```
mysql> check table csvtest;
+--------------+-------+----------+----------------------------+
| Table        | Op    | Msg_type | Msg_text                   |
+--------------+-------+----------+----------------------------+
| test.csvtest | check | warning  | Table is marked as crashed |
| test.csvtest | check | status   | OK                         |
+--------------+-------+----------+----------------------------+
2 rows in set (0.08 sec)
```

To repair a table you can use `REPAIR`, this copies as many valid rows from the existing CSV data as possible, and then replaces the existing CSV file with the recovered rows. Any rows beyond the corrupted data are lost.

```
mysql> repair table csvtest;
+--------------+--------+----------+----------+
| Table        | Op     | Msg_type | Msg_text |
+--------------+--------+----------+----------+
| test.csvtest | repair | status   | OK       |
+--------------+--------+----------+----------+
1 row in set (0.02 sec)
```

Warning

During repair, only the rows from the CSV file up to the first damaged row are copied to the new table. All other rows from the first damaged row to the end of the table are removed, even valid rows.

15.5.2 CSV Limitations

The `CSV` storage engine does not support indexing.

Partitioning is not supported for tables using the `CSV` storage engine.

All tables that you create using the `CSV` storage engine must have the `NOT NULL` attribute on all columns. However, for backward compatibility, you can continue to use tables with nullable columns that were created in previous MySQL releases. (Bug #32050)

15.6 The ARCHIVE Storage Engine

The `ARCHIVE` storage engine is used for storing large amounts of data without indexes in a very small footprint.

Table 15.5 `ARCHIVE` Storage Engine Features

Storage limits	None	**Transactions**	No	**Locking granularity**	Row
MVCC	No	**Geospatial data type support**	Yes	**Geospatial indexing support**	No
B-tree indexes	No	**T-tree indexes**	No	**Hash indexes**	No
Full-text search indexes	No	**Clustered indexes**	No	**Data caches**	No
Index caches	No	**Compressed data**	Yes	**Encrypted data**[a]	Yes
Cluster database support	No	**Replication support**[b]	Yes	**Foreign key support**	No
Backup / point-in-time recovery[c]	Yes	**Query cache support**	Yes	**Update statistics for data dictionary**	Yes

[a] Implemented in the server (via encryption functions). Data-at-rest tablespace encryption is available in MySQL 5.7 and later.

[b] Implemented in the server, rather than in the storage engine.

[c] Implemented in the server, rather than in the storage engine.

The ARCHIVE storage engine is included in MySQL binary distributions. To enable this storage engine if you build MySQL from source, invoke CMake with the -DWITH_ARCHIVE_STORAGE_ENGINE option.

To examine the source for the ARCHIVE engine, look in the storage/archive directory of a MySQL source distribution.

You can check whether the ARCHIVE storage engine is available with the SHOW ENGINES statement.

When you create an ARCHIVE table, the server creates a table format file in the database directory. The file begins with the table name and has an .frm extension. The storage engine creates other files, all having names beginning with the table name. The data file has an extension of .ARZ. An .ARN file may appear during optimization operations.

The ARCHIVE engine supports INSERT, REPLACE, and SELECT, but not DELETE or UPDATE. It does support ORDER BY operations, BLOB columns, and basically all but spatial data types (see Section 11.5.1, “Spatial Data Types”). The ARCHIVE engine uses row-level locking.

The ARCHIVE engine supports the AUTO_INCREMENT column attribute. The AUTO_INCREMENT column can have either a unique or nonunique index. Attempting to create an index on any other column results in an error. The ARCHIVE engine also supports the AUTO_INCREMENT table option in CREATE TABLE statements to specify the initial sequence value for a new table or reset the sequence value for an existing table, respectively.

ARCHIVE does not support inserting a value into an AUTO_INCREMENT column less than the current maximum column value. Attempts to do so result in an ER_DUP_KEY error.

The ARCHIVE engine ignores BLOB columns if they are not requested and scans past them while reading.

Storage: Rows are compressed as they are inserted. The ARCHIVE engine uses zlib lossless data compression (see http://www.zlib.net/). You can use OPTIMIZE TABLE to analyze the table and pack it into a smaller format (for a reason to use OPTIMIZE TABLE, see later in this section). The engine also supports CHECK TABLE. There are several types of insertions that are used:

- An INSERT statement just pushes rows into a compression buffer, and that buffer flushes as necessary. The insertion into the buffer is protected by a lock. A SELECT forces a flush to occur, unless the only insertions that have come in were INSERT DELAYED (those flush as necessary). See Section 13.2.5.3, “INSERT DELAYED Syntax”.
- A bulk insert is visible only after it completes, unless other inserts occur at the same time, in which case it can be seen partially. A SELECT never causes a flush of a bulk insert unless a normal insert occurs while it is loading.

Retrieval: On retrieval, rows are uncompressed on demand; there is no row cache. A SELECT operation performs a complete table scan: When a SELECT occurs, it finds out how many rows are currently available and reads that number of rows. SELECT is performed as a consistent read. Note that lots of SELECT statements during insertion can deteriorate the compression, unless only bulk or delayed inserts are used. To achieve better compression, you can use OPTIMIZE TABLE or REPAIR TABLE. The number of rows in ARCHIVE tables reported by SHOW TABLE STATUS is always accurate. See Section 13.7.2.4, “OPTIMIZE TABLE Syntax”, Section 13.7.2.5, “REPAIR TABLE Syntax”, and Section 13.7.5.37, “SHOW TABLE STATUS Syntax”.

Additional Resources

- A forum dedicated to the ARCHIVE storage engine is available at http://forums.mysql.com/list.php?112.

15.7 The BLACKHOLE Storage Engine

The BLACKHOLE storage engine acts as a “black hole” that accepts data but throws it away and does not store it. Retrievals always return an empty result:

```
mysql> CREATE TABLE test(i INT, c CHAR(10)) ENGINE = BLACKHOLE;
Query OK, 0 rows affected (0.03 sec)

mysql> INSERT INTO test VALUES(1,'record one'),(2,'record two');
Query OK, 2 rows affected (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM test;
Empty set (0.00 sec)
```

To enable the `BLACKHOLE` storage engine if you build MySQL from source, invoke `CMake` with the `-DWITH_BLACKHOLE_STORAGE_ENGINE` option.

To examine the source for the `BLACKHOLE` engine, look in the `sql` directory of a MySQL source distribution.

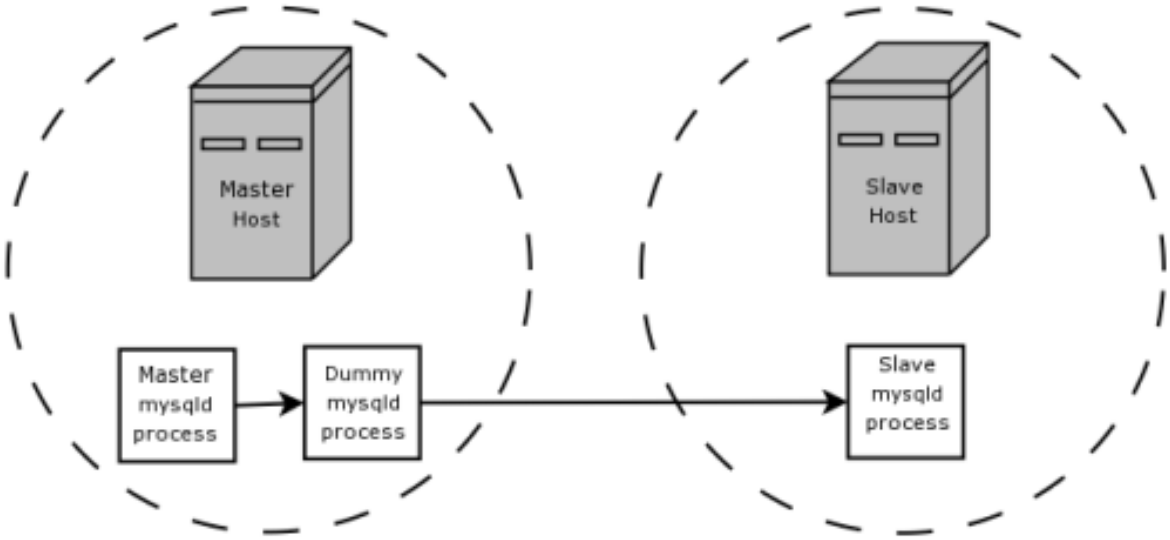
When you create a `BLACKHOLE` table, the server creates a table format file in the database directory. The file begins with the table name and has an `.frm` extension. There are no other files associated with the table.

The `BLACKHOLE` storage engine supports all kinds of indexes. That is, you can include index declarations in the table definition.

You can check whether the `BLACKHOLE` storage engine is available with the `SHOW ENGINES` statement.

Inserts into a `BLACKHOLE` table do not store any data, but if statement based binary logging is enabled, the SQL statements are logged and replicated to slave servers. This can be useful as a repeater or filter mechanism.

Suppose that your application requires slave-side filtering rules, but transferring all binary log data to the slave first results in too much traffic. In such a case, it is possible to set up on the master host a "dummy" slave process whose default storage engine is `BLACKHOLE`, depicted as follows:



The master writes to its binary log. The "dummy" `mysqld` process acts as a slave, applying the desired combination of `replicate-do-*` and `replicate-ignore-*` rules, and writes a new, filtered binary log of its own. (See Section 17.1.3, "Replication and Binary Logging Options and Variables".) This filtered log is provided to the slave.

The dummy process does not actually store any data, so there is little processing overhead incurred by running the additional `mysqld` process on the replication master host. This type of setup can be repeated with additional replication slaves.

`INSERT` triggers for `BLACKHOLE` tables work as expected. However, because the `BLACKHOLE` table does not actually store any data, `UPDATE` and `DELETE` triggers are not activated: The `FOR EACH ROW` clause in the trigger definition does not apply because there are no rows.

Other possible uses for the `BLACKHOLE` storage engine include:

- Verification of dump file syntax.
- Measurement of the overhead from binary logging, by comparing performance using `BLACKHOLE` with and without binary logging enabled.
- `BLACKHOLE` is essentially a “no-op” storage engine, so it could be used for finding performance bottlenecks not related to the storage engine itself.

The `BLACKHOLE` engine is transaction-aware, in the sense that committed transactions are written to the binary log and rolled-back transactions are not.

Blackhole Engine and Auto Increment Columns

The Blackhole engine is a no-op engine. Any operations performed on a table using Blackhole will have no effect. This should be born in mind when considering the behavior of primary key columns that auto increment. The engine will not automatically increment field values, and does not retain auto increment field state. This has important implications in replication.

Consider the following replication scenario where all three of the following conditions apply:

1. On a master server there is a blackhole table with an auto increment field that is a primary key.
2. On a slave the same table exists but using the MyISAM engine.
3. Inserts are performed into the master's table without explicitly setting the auto increment value in the `INSERT` statement itself or through using a `SET INSERT_ID` statement.

In this scenario replication will fail with a duplicate entry error on the primary key column.

In statement based replication, the value of `INSERT_ID` in the context event will always be the same. Replication will therefore fail due to trying insert a row with a duplicate value for a primary key column.

In row based replication, the value that the engine returns for the row always be the same for each insert. This will result in the slave attempting to replay two insert log entries using the same value for the primary key column, and so replication will fail.

Column Filtering

When using row-based replication, (`binlog_format=ROW`), a slave where the last columns are missing from a table is supported, as described in the section Section 17.4.1.9, “Replication with Differing Table Definitions on Master and Slave”.

This filtering works on the slave side, that is, the columns are copied to the slave before they are filtered out. There are at least two cases where it is not desirable to copy the columns to the slave:

1. If the data is confidential, so the slave server should not have access to it.
2. If the master has many slaves, filtering before sending to the slaves may reduce network traffic.

Master column filtering can be achieved using the `BLACKHOLE` engine. This is carried out in a way similar to how master table filtering is achieved - by using the `BLACKHOLE` engine and the `--replicate-do-table` or `--replicate-ignore-table` option.

The setup for the master is:

```
CREATE TABLE t1 (public_col_1, ..., public_col_N,
                 secret_col_1, ..., secret_col_M) ENGINE=MyISAM;
```

The setup for the trusted slave is:

```
CREATE TABLE t1 (public_col_1, ..., public_col_N) ENGINE=BLACKHOLE;
```

The setup for the untrusted slave is:

```
CREATE TABLE t1 (public_col_1, ..., public_col_N) ENGINE=MyISAM;
```

15.8 The MERGE Storage Engine

The MERGE storage engine, also known as the MRG_MyISAM engine, is a collection of identical MyISAM tables that can be used as one. “Identical” means that all tables have identical column data types and index information. You cannot merge MyISAM tables in which the columns are listed in a different order, do not have exactly the same data types in corresponding columns, or have the indexes in different order. However, any or all of the MyISAM tables can be compressed with myisampack. See Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”. Differences between tables such as these do not matter:

- Names of corresponding columns and indexes can differ.
- Comments for tables, columns, and indexes can differ.
- Table options such as AVG_ROW_LENGTH, MAX_ROWS, or PACK_KEYS can differ.

An alternative to a MERGE table is a partitioned table, which stores partitions of a single table in separate files. Partitioning enables some operations to be performed more efficiently and is not limited to the MyISAM storage engine. For more information, see Chapter 19, *Partitioning*.

When you create a MERGE table, MySQL creates two files on disk. The files have names that begin with the table name and have an extension to indicate the file type. An .frm file stores the table format, and an .MRG file contains the names of the underlying MyISAM tables that should be used as one. The tables do not have to be in the same database as the MERGE table.

You can use SELECT, DELETE, UPDATE, and INSERT on MERGE tables. You must have SELECT, DELETE, and UPDATE privileges on the MyISAM tables that you map to a MERGE table.

Note

The use of MERGE tables entails the following security issue: If a user has access to MyISAM table *t*, that user can create a MERGE table *m* that accesses *t*. However, if the user's privileges on *t* are subsequently revoked, the user can continue to access *t* by doing so through *m*.

Use of DROP TABLE with a MERGE table drops only the MERGE specification. The underlying tables are not affected.

To create a MERGE table, you must specify a UNION=(*list-of-tables*) option that indicates which MyISAM tables to use. You can optionally specify an INSERT_METHOD option to control how inserts into the MERGE table take place. Use a value of FIRST or LAST to cause inserts to be made in the first or last underlying table, respectively. If you specify no INSERT_METHOD option or if you specify it with a value of NO, inserts into the MERGE table are not permitted and attempts to do so result in an error.

The following example shows how to create a MERGE table:

```
mysql> CREATE TABLE t1 (
    ->    a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    ->    message CHAR(20)) ENGINE=MyISAM;
mysql> CREATE TABLE t2 (
    ->    a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    ->    message CHAR(20)) ENGINE=MyISAM;
mysql> INSERT INTO t1 (message) VALUES ('Testing'),('table'),('t1');
mysql> INSERT INTO t2 (message) VALUES ('Testing'),('table'),('t2');
```

```
mysql> CREATE TABLE total (
    ->    a INT NOT NULL AUTO_INCREMENT,
    ->    message CHAR(20), INDEX(a))
    ->    ENGINE=MERGE UNION=(t1,t2) INSERT_METHOD=LAST;
```

Column `a` is indexed as a `PRIMARY KEY` in the underlying `MyISAM` tables, but not in the `MERGE` table. There it is indexed but not as a `PRIMARY KEY` because a `MERGE` table cannot enforce uniqueness over the set of underlying tables. (Similarly, a column with a `UNIQUE` index in the underlying tables should be indexed in the `MERGE` table but not as a `UNIQUE` index.)

After creating the `MERGE` table, you can use it to issue queries that operate on the group of tables as a whole:

```
mysql> SELECT * FROM total;
+---+---------+
| a | message |
+---+---------+
| 1 | Testing |
| 2 | table   |
| 3 | t1      |
| 1 | Testing |
| 2 | table   |
| 3 | t2      |
+---+---------+
```

To remap a `MERGE` table to a different collection of `MyISAM` tables, you can use one of the following methods:

- `DROP` the `MERGE` table and re-create it.
- Use `ALTER TABLE tbl_name UNION=(...)` to change the list of underlying tables.

  It is also possible to use `ALTER TABLE ... UNION=()` (that is, with an empty `UNION` clause) to remove all of the underlying tables. However, in this case, the table is effectively empty and inserts fail because there is no underlying table to take new rows. Such a table might be useful as a template for creating new `MERGE` tables with `CREATE TABLE ... LIKE`.

The underlying table definitions and indexes must conform closely to the definition of the `MERGE` table. Conformance is checked when a table that is part of a `MERGE` table is opened, not when the `MERGE` table is created. If any table fails the conformance checks, the operation that triggered the opening of the table fails. This means that changes to the definitions of tables within a `MERGE` may cause a failure when the `MERGE` table is accessed. The conformance checks applied to each table are:

- The underlying table and the `MERGE` table must have the same number of columns.
- The column order in the underlying table and the `MERGE` table must match.
- Additionally, the specification for each corresponding column in the parent `MERGE` table and the underlying tables are compared and must satisfy these checks:
  - The column type in the underlying table and the `MERGE` table must be equal.
  - The column length in the underlying table and the `MERGE` table must be equal.
  - The column of the underlying table and the `MERGE` table can be `NULL`.
- The underlying table must have at least as many indexes as the `MERGE` table. The underlying table may have more indexes than the `MERGE` table, but cannot have fewer.

Note

A known issue exists where indexes on the same columns must be in identical order, in both the `MERGE` table and the underlying `MyISAM` table. See Bug #33653.

Each index must satisfy these checks:

- The index type of the underlying table and the `MERGE` table must be the same.
- The number of index parts (that is, multiple columns within a compound index) in the index definition for the underlying table and the `MERGE` table must be the same.
- For each index part:
  - Index part lengths must be equal.
  - Index part types must be equal.
  - Index part languages must be equal.
  - Check whether index parts can be `NULL`.

If a `MERGE` table cannot be opened or used because of a problem with an underlying table, `CHECK TABLE` displays information about which table caused the problem.

Additional Resources

- A forum dedicated to the `MERGE` storage engine is available at http://forums.mysql.com/list.php?93.

15.8.1 MERGE Table Advantages and Disadvantages

`MERGE` tables can help you solve the following problems:

- Easily manage a set of log tables. For example, you can put data from different months into separate tables, compress some of them with `myisampack`, and then create a `MERGE` table to use them as one.
- Obtain more speed. You can split a large read-only table based on some criteria, and then put individual tables on different disks. A `MERGE` table structured this way could be much faster than using a single large table.
- Perform more efficient searches. If you know exactly what you are looking for, you can search in just one of the underlying tables for some queries and use a `MERGE` table for others. You can even have many different `MERGE` tables that use overlapping sets of tables.
- Perform more efficient repairs. It is easier to repair individual smaller tables that are mapped to a `MERGE` table than to repair a single large table.
- Instantly map many tables as one. A `MERGE` table need not maintain an index of its own because it uses the indexes of the individual tables. As a result, `MERGE` table collections are *very* fast to create or remap. (You must still specify the index definitions when you create a `MERGE` table, even though no indexes are created.)
- If you have a set of tables from which you create a large table on demand, you can instead create a `MERGE` table from them on demand. This is much faster and saves a lot of disk space.
- Exceed the file size limit for the operating system. Each `MyISAM` table is bound by this limit, but a collection of `MyISAM` tables is not.
- You can create an alias or synonym for a `MyISAM` table by defining a `MERGE` table that maps to that single table. There should be no really notable performance impact from doing this (only a couple of indirect calls and `memcpy()` calls for each read).

The disadvantages of `MERGE` tables are:

- You can use only identical `MyISAM` tables for a `MERGE` table.

- Some MyISAM features are unavailable in MERGE tables. For example, you cannot create FULLTEXT indexes on MERGE tables. (You can create FULLTEXT indexes on the underlying MyISAM tables, but you cannot search the MERGE table with a full-text search.)
- If the MERGE table is nontemporary, all underlying MyISAM tables must be nontemporary. If the MERGE table is temporary, the MyISAM tables can be any mix of temporary and nontemporary.
- MERGE tables use more file descriptors than MyISAM tables. If 10 clients are using a MERGE table that maps to 10 tables, the server uses (10 × 10) + 10 file descriptors. (10 data file descriptors for each of the 10 clients, and 10 index file descriptors shared among the clients.)
- Index reads are slower. When you read an index, the MERGE storage engine needs to issue a read on all underlying tables to check which one most closely matches a given index value. To read the next index value, the MERGE storage engine needs to search the read buffers to find the next value. Only when one index buffer is used up does the storage engine need to read the next index block. This makes MERGE indexes much slower on eq_ref searches, but not much slower on ref searches. For more information about eq_ref and ref, see Section 13.8.2, “EXPLAIN Syntax”.

15.8.2 MERGE Table Problems

The following are known problems with MERGE tables:

- In versions of MySQL Server prior to 5.1.23, it was possible to create temporary merge tables with nontemporary child MyISAM tables.

  From versions 5.1.23, MERGE children were locked through the parent table. If the parent was temporary, it was not locked and so the children were not locked either. Parallel use of the MyISAM tables corrupted them.

- If you use ALTER TABLE to change a MERGE table to another storage engine, the mapping to the underlying tables is lost. Instead, the rows from the underlying MyISAM tables are copied into the altered table, which then uses the specified storage engine.
- The INSERT_METHOD table option for a MERGE table indicates which underlying MyISAM table to use for inserts into the MERGE table. However, use of the AUTO_INCREMENT table option for that MyISAM table has no effect for inserts into the MERGE table until at least one row has been inserted directly into the MyISAM table.
- A MERGE table cannot maintain uniqueness constraints over the entire table. When you perform an INSERT, the data goes into the first or last MyISAM table (as determined by the INSERT_METHOD option). MySQL ensures that unique key values remain unique within that MyISAM table, but not over all the underlying tables in the collection.
- Because the MERGE engine cannot enforce uniqueness over the set of underlying tables, REPLACE does not work as expected. The two key facts are:
  - REPLACE can detect unique key violations only in the underlying table to which it is going to write (which is determined by the INSERT_METHOD option). This differs from violations in the MERGE table itself.
  - If REPLACE detects a unique key violation, it will change only the corresponding row in the underlying table it is writing to; that is, the first or last table, as determined by the INSERT_METHOD option.

  Similar considerations apply for INSERT ... ON DUPLICATE KEY UPDATE.
- MERGE tables do not support partitioning. That is, you cannot partition a MERGE table, nor can any of a MERGE table's underlying MyISAM tables be partitioned.
- You should not use ANALYZE TABLE, REPAIR TABLE, OPTIMIZE TABLE, ALTER TABLE, DROP TABLE, DELETE without a WHERE clause, or TRUNCATE TABLE on any of the tables that are mapped into an open MERGE table. If you do so, the MERGE table may still refer to the original table and yield

unexpected results. To work around this problem, ensure that no MERGE tables remain open by issuing a FLUSH TABLES statement prior to performing any of the named operations.

The unexpected results include the possibility that the operation on the MERGE table will report table corruption. If this occurs after one of the named operations on the underlying MyISAM tables, the corruption message is spurious. To deal with this, issue a FLUSH TABLES statement after modifying the MyISAM tables.

- DROP TABLE on a table that is in use by a MERGE table does not work on Windows because the MERGE storage engine's table mapping is hidden from the upper layer of MySQL. Windows does not permit open files to be deleted, so you first must flush all MERGE tables (with FLUSH TABLES) or drop the MERGE table before dropping the table.

- The definition of the MyISAM tables and the MERGE table are checked when the tables are accessed (for example, as part of a SELECT or INSERT statement). The checks ensure that the definitions of the tables and the parent MERGE table definition match by comparing column order, types, sizes and associated indexes. If there is a difference between the tables, an error is returned and the statement fails. Because these checks take place when the tables are opened, any changes to the definition of a single table, including column changes, column ordering, and engine alterations will cause the statement to fail.

- The order of indexes in the MERGE table and its underlying tables should be the same. If you use ALTER TABLE to add a UNIQUE index to a table used in a MERGE table, and then use ALTER TABLE to add a nonunique index on the MERGE table, the index ordering is different for the tables if there was already a nonunique index in the underlying table. (This happens because ALTER TABLE puts UNIQUE indexes before nonunique indexes to facilitate rapid detection of duplicate keys.) Consequently, queries on tables with such indexes may return unexpected results.

- If you encounter an error message similar to ERROR 1017 (HY000): Can't find file: '*tbl_name*.MRG' (errno: 2), it generally indicates that some of the underlying tables do not use the MyISAM storage engine. Confirm that all of these tables are MyISAM.

- The maximum number of rows in a MERGE table is 2^{64} (~1.844E+19; the same as for a MyISAM table). It is not possible to merge multiple MyISAM tables into a single MERGE table that would have more than this number of rows.

- The MERGE storage engine does not support INSERT DELAYED statements.

- Use of underlying MyISAM tables of differing row formats with a parent MERGE table is currently known to fail. See Bug #32364.

- You cannot change the union list of a nontemporary MERGE table when LOCK TABLES is in effect. The following does *not* work:

```
CREATE TABLE m1 ... ENGINE=MRG_MYISAM ...;
LOCK TABLES t1 WRITE, t2 WRITE, m1 WRITE;
ALTER TABLE m1 ... UNION=(t1,t2) ...;
```

  However, you can do this with a temporary MERGE table.

- You cannot create a MERGE table with CREATE ... SELECT, neither as a temporary MERGE table, nor as a nontemporary MERGE table. For example:

```
CREATE TABLE m1 ... ENGINE=MRG_MYISAM ... SELECT ...;
```

  Attempts to do this result in an error: *tbl_name* is not BASE TABLE.

- In some cases, differing PACK_KEYS table option values among the MERGE and underlying tables cause unexpected results if the underlying tables contain CHAR or BINARY columns. As a workaround, use ALTER TABLE to ensure that all involved tables have the same PACK_KEYS value. (Bug #50646)

15.9 The FEDERATED Storage Engine

The `FEDERATED` storage engine lets you access data from a remote MySQL database without using replication or cluster technology. Querying a local `FEDERATED` table automatically pulls the data from the remote (federated) tables. No data is stored on the local tables.

To include the `FEDERATED` storage engine if you build MySQL from source, invoke `CMake` with the `-DWITH_FEDERATED_STORAGE_ENGINE` option.

The `FEDERATED` storage engine is not enabled by default in the running server; to enable `FEDERATED`, you must start the MySQL server binary using the `--federated` option.

To examine the source for the `FEDERATED` engine, look in the `storage/federated` directory of a MySQL source distribution.

15.9.1 FEDERATED Storage Engine Overview

When you create a table using one of the standard storage engines (such as `MyISAM`, `CSV` or `InnoDB`), the table consists of the table definition and the associated data. When you create a `FEDERATED` table, the table definition is the same, but the physical storage of the data is handled on a remote server.

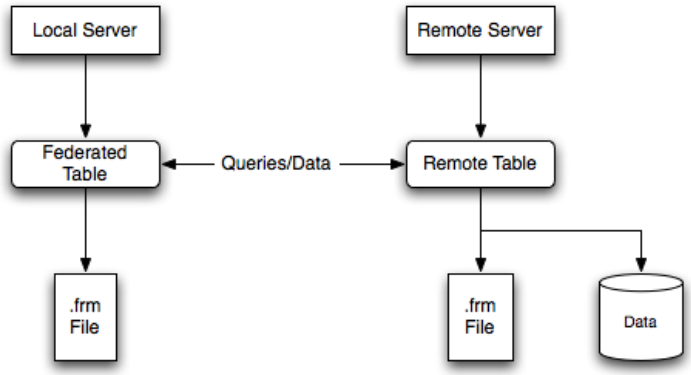
A `FEDERATED` table consists of two elements:

- A *remote server* with a database table, which in turn consists of the table definition (stored in the `.frm` file) and the associated table. The table type of the remote table may be any type supported by the remote `mysqld` server, including `MyISAM` or `InnoDB`.
- A *local server* with a database table, where the table definition matches that of the corresponding table on the remote server. The table definition is stored within the `.frm` file. However, there is no data file on the local server. Instead, the table definition includes a connection string that points to the remote table.

When executing queries and statements on a `FEDERATED` table on the local server, the operations that would normally insert, update or delete information from a local data file are instead sent to the remote server for execution, where they update the data file on the remote server or return matching rows from the remote server.

The basic structure of a `FEDERATED` table setup is shown in Figure 15.1, “FEDERATED Table Structure”.

Figure 15.1 FEDERATED Table Structure



When a client issues an SQL statement that refers to a `FEDERATED` table, the flow of information between the local server (where the SQL statement is executed) and the remote server (where the data is physically stored) is as follows:

1. The storage engine looks through each column that the `FEDERATED` table has and constructs an appropriate SQL statement that refers to the remote table.
2. The statement is sent to the remote server using the MySQL client API.
3. The remote server processes the statement and the local server retrieves any result that the statement produces (an affected-rows count or a result set).
4. If the statement produces a result set, each column is converted to internal storage engine format that the `FEDERATED` engine expects and can use to display the result to the client that issued the original statement.

The local server communicates with the remote server using MySQL client C API functions. It invokes `mysql_real_query()` to send the statement. To read a result set, it uses `mysql_store_result()` and fetches rows one at a time using `mysql_fetch_row()`.

15.9.2 How to Create FEDERATED Tables

To create a `FEDERATED` table you should follow these steps:

1. Create the table on the remote server. Alternatively, make a note of the table definition of an existing table, perhaps using the `SHOW CREATE TABLE` statement.
2. Create the table on the local server with an identical table definition, but adding the connection information that links the local table to the remote table.

For example, you could create the following table on the remote server:

```
CREATE TABLE test_table (
    id     INT(20) NOT NULL AUTO_INCREMENT,
    name   VARCHAR(32) NOT NULL DEFAULT '',
    other  INT(20) NOT NULL DEFAULT '0',
    PRIMARY KEY  (id),
    INDEX name (name),
    INDEX other_key (other)
)
ENGINE=MyISAM
DEFAULT CHARSET=latin1;
```

To create the local table that will be federated to the remote table, there are two options available. You can either create the local table and specify the connection string (containing the server name, login, password) to be used to connect to the remote table using the `CONNECTION`, or you can use an existing connection that you have previously created using the `CREATE SERVER` statement.

Important

When you create the local table it *must* have an identical field definition to the remote table.

Note

You can improve the performance of a `FEDERATED` table by adding indexes to the table on the host. The optimization will occur because the query sent to the remote server will include the contents of the `WHERE` clause and will be sent to the remote server and subsequently executed locally. This reduces the network traffic that would otherwise request the entire table from the server for local processing.

15.9.2.1 Creating a FEDERATED Table Using CONNECTION

To use the first method, you must specify the `CONNECTION` string after the engine type in a `CREATE TABLE` statement. For example:

```
CREATE TABLE federated_table (
    id     INT(20) NOT NULL AUTO_INCREMENT,
    name   VARCHAR(32) NOT NULL DEFAULT '',
    other  INT(20) NOT NULL DEFAULT '0',
    PRIMARY KEY  (id),
    INDEX name (name),
    INDEX other_key (other)
)
ENGINE=FEDERATED
DEFAULT CHARSET=latin1
CONNECTION='mysql://fed_user@remote_host:9306/federated/test_table';
```

Note

`CONNECTION` replaces the `COMMENT` used in some previous versions of MySQL.

The `CONNECTION` string contains the information required to connect to the remote server containing the table that will be used to physically store the data. The connection string specifies the server name, login credentials, port number and database/table information. In the example, the remote table is on the server `remote_host`, using port 9306. The name and port number should match the host name (or IP address) and port number of the remote MySQL server instance you want to use as your remote table.

The format of the connection string is as follows:

```
scheme://user_name[:password]@host_name[:port_num]/db_name/tbl_name
```

Where:

- *`scheme`*: A recognized connection protocol. Only `mysql` is supported as the *`scheme`* value at this point.
- *`user_name`*: The user name for the connection. This user must have been created on the remote server, and must have suitable privileges to perform the required actions (`SELECT`, `INSERT`, `UPDATE`, and so forth) on the remote table.
- *`password`*: (Optional) The corresponding password for *`user_name`*.
- *`host_name`*: The host name or IP address of the remote server.
- *`port_num`*: (Optional) The port number for the remote server. The default is 3306.
- *`db_name`*: The name of the database holding the remote table.
- *`tbl_name`*: The name of the remote table. The name of the local and the remote table do not have to match.

Sample connection strings:

```
CONNECTION='mysql://username:password@hostname:port/database/tablename'
CONNECTION='mysql://username@hostname/database/tablename'
CONNECTION='mysql://username:password@hostname/database/tablename'
```

15.9.2.2 Creating a FEDERATED Table Using CREATE SERVER

If you are creating a number of `FEDERATED` tables on the same server, or if you want to simplify the process of creating `FEDERATED` tables, you can use the `CREATE SERVER` statement to define the server connection parameters, just as you would with the `CONNECTION` string.

The format of the `CREATE SERVER` statement is:

```
CREATE SERVER
server_name
```

```
FOREIGN DATA WRAPPER wrapper_name
OPTIONS (option [, option] ...)
```

The *server_name* is used in the connection string when creating a new FEDERATED table.

For example, to create a server connection identical to the CONNECTION string:

```
CONNECTION='mysql://fed_user@remote_host:9306/federated/test_table';
```

You would use the following statement:

```
CREATE SERVER fedlink
FOREIGN DATA WRAPPER mysql
OPTIONS (USER 'fed_user', HOST 'remote_host', PORT 9306, DATABASE 'federated');
```

To create a FEDERATED table that uses this connection, you still use the CONNECTION keyword, but specify the name you used in the CREATE SERVER statement.

```
CREATE TABLE test_table (
    id     INT(20) NOT NULL AUTO_INCREMENT,
    name   VARCHAR(32) NOT NULL DEFAULT '',
    other  INT(20) NOT NULL DEFAULT '0',
    PRIMARY KEY  (id),
    INDEX name (name),
    INDEX other_key (other)
)
ENGINE=FEDERATED
DEFAULT CHARSET=latin1
CONNECTION='fedlink/test_table';
```

The connection name in this example contains the name of the connection (fedlink) and the name of the table (test_table) to link to, separated by a slash. If you specify only the connection name without a table name, the table name of the local table is used instead.

For more information on CREATE SERVER, see Section 13.1.16, “CREATE SERVER Syntax”.

The CREATE SERVER statement accepts the same arguments as the CONNECTION string. The CREATE SERVER statement updates the rows in the mysql.servers table. See the following table for information on the correspondence between parameters in a connection string, options in the CREATE SERVER statement, and the columns in the mysql.servers table. For reference, the format of the CONNECTION string is as follows:

```
scheme://user_name[:password]@host_name[:port_num]/db_name/tbl_name
```

Description	CONNECTION string	CREATE SERVER option	mysql.servers column
Connection scheme	*scheme*	wrapper_name	Wrapper
Remote user	*user_name*	USER	Username
Remote password	*password*	PASSWORD	Password
Remote host	*host_name*	HOST	Host
Remote port	*port_num*	PORT	Port
Remote database	*db_name*	DATABASE	Db

15.9.3 FEDERATED Storage Engine Notes and Tips

You should be aware of the following points when using the FEDERATED storage engine:

- FEDERATED tables may be replicated to other slaves, but you must ensure that the slave servers are able to use the user/password combination that is defined in the CONNECTION string (or the row in the mysql.servers table) to connect to the remote server.

The following items indicate features that the FEDERATED storage engine does and does not support:

- The remote server must be a MySQL server.
- The remote table that a `FEDERATED` table points to *must* exist before you try to access the table through the `FEDERATED` table.
- It is possible for one `FEDERATED` table to point to another, but you must be careful not to create a loop.
- A `FEDERATED` table does not support indexes in the usual sense; because access to the table data is handled remotely, it is actually the remote table that makes use of indexes. This means that, for a query that cannot use any indexes and so requires a full table scan, the server fetches all rows from the remote table and filters them locally. This occurs regardless of any `WHERE` or `LIMIT` used with this `SELECT` statement; these clauses are applied locally to the returned rows.

  Queries that fail to use indexes can thus cause poor performance and network overload. In addition, since returned rows must be stored in memory, such a query can also lead to the local server swapping, or even hanging.
- Care should be taken when creating a `FEDERATED` table since the index definition from an equivalent `MyISAM` or other table may not be supported. For example, creating a `FEDERATED` table with an index prefix on `VARCHAR`, `TEXT` or `BLOB` columns will fail. The following definition in `MyISAM` is valid:

  ```
  CREATE TABLE `T1`(`A` VARCHAR(100),UNIQUE KEY(`A`(30))) ENGINE=MYISAM;
  ```

  The key prefix in this example is incompatible with the `FEDERATED` engine, and the equivalent statement will fail:

  ```
  CREATE TABLE `T1`(`A` VARCHAR(100),UNIQUE KEY(`A`(30))) ENGINE=FEDERATED
    CONNECTION='MYSQL://127.0.0.1:3306/TEST/T1';
  ```

  If possible, you should try to separate the column and index definition when creating tables on both the remote server and the local server to avoid these index issues.
- Internally, the implementation uses `SELECT`, `INSERT`, `UPDATE`, and `DELETE`, but not `HANDLER`.
- The `FEDERATED` storage engine supports `SELECT`, `INSERT`, `UPDATE`, `DELETE`, `TRUNCATE TABLE`, and indexes. It does not support `ALTER TABLE`, or any Data Definition Language statements that directly affect the structure of the table, other than `DROP TABLE`. The current implementation does not use prepared statements.
- `FEDERATED` accepts `INSERT ... ON DUPLICATE KEY UPDATE` statements, but if a duplicate-key violation occurs, the statement fails with an error.
- Transactions are not supported.
- `FEDERATED` performs bulk-insert handling such that multiple rows are sent to the remote table in a batch, which improves performance. Also, if the remote table is transactional, it enables the remote storage engine to perform statement rollback properly should an error occur. This capability has the following limitations:
  - The size of the insert cannot exceed the maximum packet size between servers. If the insert exceeds this size, it is broken into multiple packets and the rollback problem can occur.
  - Bulk-insert handling does not occur for `INSERT ... ON DUPLICATE KEY UPDATE`.
- There is no way for the `FEDERATED` engine to know if the remote table has changed. The reason for this is that this table must work like a data file that would never be written to by anything other than the database system. The integrity of the data in the local table could be breached if there was any change to the remote database.
- When using a `CONNECTION` string, you cannot use an '@' character in the password. You can get round this limitation by using the `CREATE SERVER` statement to create a server connection.

- The `insert_id` and `timestamp` options are not propagated to the data provider.
- Any `DROP TABLE` statement issued against a `FEDERATED` table drops only the local table, not the remote table.
- `FEDERATED` tables do not work with the query cache.
- User-defined partitioning is not supported for `FEDERATED` tables.

15.9.4 FEDERATED Storage Engine Resources

The following additional resources are available for the `FEDERATED` storage engine:

- A forum dedicated to the `FEDERATED` storage engine is available at http://forums.mysql.com/list.php?105.

15.10 The EXAMPLE Storage Engine

The `EXAMPLE` storage engine is a stub engine that does nothing. Its purpose is to serve as an example in the MySQL source code that illustrates how to begin writing new storage engines. As such, it is primarily of interest to developers.

To enable the `EXAMPLE` storage engine if you build MySQL from source, invoke `CMake` with the `-DWITH_EXAMPLE_STORAGE_ENGINE` option.

To examine the source for the `EXAMPLE` engine, look in the `storage/example` directory of a MySQL source distribution.

When you create an `EXAMPLE` table, the server creates a table format file in the database directory. The file begins with the table name and has an `.frm` extension. No other files are created. No data can be stored into the table. Retrievals return an empty result.

```
mysql> CREATE TABLE test (i INT) ENGINE = EXAMPLE;
Query OK, 0 rows affected (0.78 sec)

mysql> INSERT INTO test VALUES(1),(2),(3);
ERROR 1031 (HY000): Table storage engine for 'test' doesn't »
                    have this option

mysql> SELECT * FROM test;
Empty set (0.31 sec)
```

The `EXAMPLE` storage engine does not support indexing.

15.11 Other Storage Engines

Other storage engines may be available from third parties and community members that have used the Custom Storage Engine interface.

Third party engines are not supported by MySQL. For further information, documentation, installation guides, bug reporting or for any help or assistance with these engines, please contact the developer of the engine directly.

For more information on developing a customer storage engine that can be used with the Pluggable Storage Engine Architecture, see MySQL Internals: Writing a Custom Storage Engine.

Chapter 16 High Availability and Scalability

Table of Contents

16.1 Using ZFS Replication 1819
16.1.1 Using ZFS for File System Replication 1820
16.1.2 Configuring MySQL for ZFS Replication 1821
16.1.3 Handling MySQL Recovery with ZFS 1822
16.2 Using MySQL with `memcached` 1822
16.2.1 Installing `memcached` 1823
16.2.2 Using `memcached` 1825
16.2.3 Developing a `memcached` Application 1843
16.2.4 Getting `memcached` Statistics 1868
16.2.5 `memcached` FAQ 1876

Data is the currency of today's web, mobile, social, enterprise and cloud applications. Ensuring data is always available is a top priority for any organization. Minutes of downtime can result in significant loss of revenue and reputation.

There is no “one size fits all” approach to delivering High Availability (HA). Unique application attributes, business requirements, operational capabilities and legacy infrastructure can all influence HA technology selection. And technology is only one element in delivering HA: people and processes are just as critical as the technology itself.

MySQL is deployed into many applications demanding availability and scalability. **Availability** refers to the ability to cope with, and if necessary recover from, failures on the host, including failures of MySQL, the operating system, or the hardware and maintenance activity that may otherwise cause downtime. Scalability refers to the ability to spread both the database and the load of your application queries across multiple MySQL servers.

Because each application has different operational and availability requirements, MySQL offers a range of certified and supported solutions, delivering the appropriate levels of High Availability (HA) and scalability to meet service level requirements. Such solutions extend from replication, through virtualization and geographically redundant, multi-data center solutions delivering 99.999% uptime.

Selecting the right high availability solution for an application largely depends on:

- The level of availability required.
- The type of application being deployed.
- Accepted best practices within your own environment.

The primary solutions supported by MySQL include:

- MySQL Replication. Learn more: Chapter 17, *Replication*.
- MySQL Cluster. Learn more: Chapter 18, *MySQL NDB Cluster 7.2*.
- Oracle MySQL Cloud Service. Learn more about MySQL Cloud Service.
- Oracle Clusterware Agent for MySQL. Learn more about Oracle Clusterware.
- MySQL with Solaris Cluster. Learn more about Solaris Cluster.

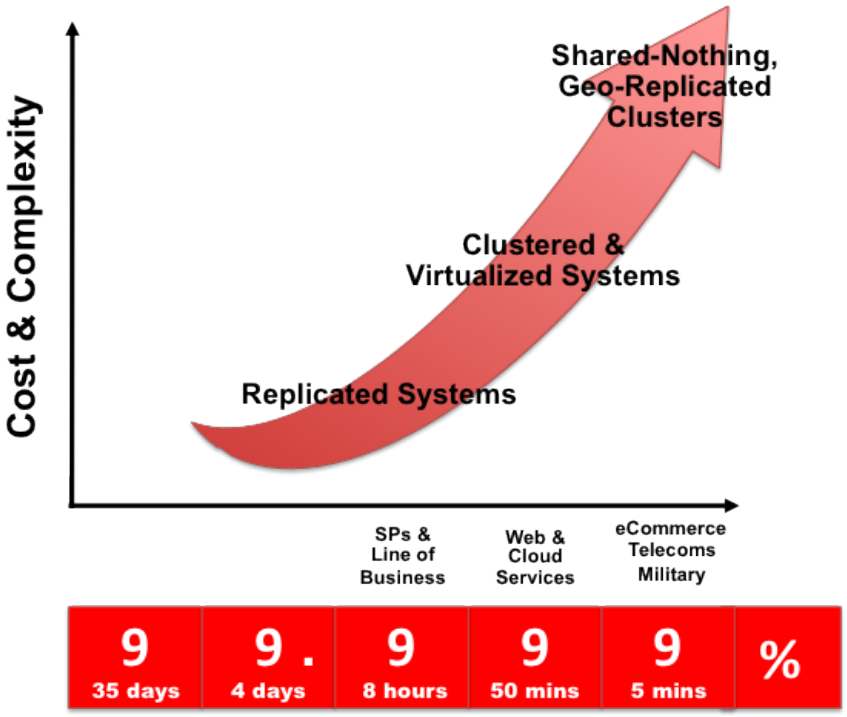
Further options are available using third-party solutions.

Each architecture used to achieve highly available database services is differentiated by the levels of uptime it offers. These architectures can be grouped into three main categories:

- Data Replication.
- Clustered & Virtualized Systems.
- Shared-Nothing, Geographically-Replicated Clusters.

As illustrated in the following figure, each of these architectures offers progressively higher levels of uptime, which must be balanced against potentially greater levels of cost and complexity that each can incur. Simply deploying a high availability architecture is not a guarantee of actually delivering HA. In fact, a poorly implemented and maintained shared-nothing cluster could easily deliver lower levels of availability than a simple data replication solution.

Figure 16.1 Tradeoffs: Cost and Complexity versus Availability



The following table compares the HA and Scalability capabilities of the various MySQL solutions:

Table 16.1 Feature Comparison of MySQL HA Solutions

Requirement	MySQL Replication	MySQL Cluster
Availability		
Platform Support	All Supported by MySQL Server (http://www.mysql.com/support/supportedplatforms/database.html)	All Supported by MySQL Cluster (http://www.mysql.com/support/supportedplatforms/cluster.html)
Automated IP Failover	No	Depends on Connector and Configuration
Automated Database Failover	No	Yes
Automatic Data Resynchronization	No	Yes
Typical Failover Time	User / Script Dependent	1 Second and Less
Synchronous Replication	No, Asynchronous and Semisynchronous	Yes
Shared Storage	No, Distributed	No, Distributed

Requirement	MySQL Replication	MySQL Cluster
Geographic redundancy support	Yes	Yes, via MySQL Replication
Update Schema On-Line	No	Yes
Scalability		
Number of Nodes	One Master, Multiple Slaves	255
Built-in Load Balancing	Reads, via MySQL Replication	Yes, Reads and Writes
Supports Read-Intensive Workloads	Yes	Yes
Supports Write-Intensive Workloads	Yes, via Application-Level Sharding	Yes, via Auto-Sharding
Scale On-Line (add nodes, repartition, etc.)	No	Yes

16.1 Using ZFS Replication

To support high availability environments, providing an instant copy of the information on both the currently active machine and the hot backup is a critical part of the HA solution. There are many solutions to this problem, such as Chapter 17, *Replication*.

The ZFS file system provides functionality to create a snapshot of the file system contents, transfer the snapshot to another machine, and extract the snapshot to recreate the file system. You can create a snapshot at any time, and you can create as many snapshots as you like. By continually creating, transferring, and restoring snapshots, you can provide synchronization between one or more machines in a fashion similar to DRBD.

The following example shows a simple Solaris system running with a single ZFS pool, mounted at `/scratchpool`:

```
Filesystem             size   used  avail capacity  Mounted on
/dev/dsk/c0d0s0        4.6G   3.7G   886M    82%    /
/devices                 0K     0K     0K     0%    /devices
ctfs                     0K     0K     0K     0%    /system/contract
proc                     0K     0K     0K     0%    /proc
mnttab                   0K     0K     0K     0%    /etc/mnttab
swap                   1.4G   892K   1.4G     1%    /etc/svc/volatile
objfs                    0K     0K     0K     0%    /system/object
/usr/lib/libc/libc_hwcap1.so.1
                       4.6G   3.7G   886M    82%    /lib/libc.so.1
fd                       0K     0K     0K     0%    /dev/fd
swap                   1.4G    40K   1.4G     1%    /tmp
swap                   1.4G    28K   1.4G     1%    /var/run
/dev/dsk/c0d0s7         26G   913M    25G     4%    /export/home
scratchpool             16G    24K    16G     1%    /scratchpool
```

The MySQL data is stored in a directory on `/scratchpool`. To help demonstrate some of the basic replication functionality, there are also other items stored in `/scratchpool` as well:

```
total 17
drwxr-xr-x  31 root     bin           50 Jul 21 07:32 DTT/
drwxr-xr-x   4 root     bin            5 Jul 21 07:32 SUNWmlib/
drwxr-xr-x  14 root     sys           16 Nov  5 09:56 SUNWspro/
drwxrwxrwx  19 1000     1000          40 Nov  6 19:16 emacs-22.1/
```

To create a snapshot of the file system, you use `zfs snapshot`, specifying the pool and the snapshot name:

```
root-shell> zfs snapshot scratchpool@snap1
```

To list the snapshots already taken:

```
root-shell> zfs list -t snapshot
NAME                USED  AVAIL  REFER  MOUNTPOINT
scratchpool@snap1      0      -  24.5K  -
scratchpool@snap2      0      -  24.5K  -
```

The snapshots themselves are stored within the file system metadata, and the space required to keep them varies as time goes on because of the way the snapshots are created. The initial creation of a snapshot is very quick, because instead of taking an entire copy of the data and metadata required to hold the entire snapshot, ZFS records only the point in time and metadata of when the snapshot was created.

As more changes to the original file system are made, the size of the snapshot increases because more space is required to keep the record of the old blocks. If you create lots of snapshots, say one per day, and then delete the snapshots from earlier in the week, the size of the newer snapshots might also increase, as the changes that make up the newer state have to be included in the more recent snapshots, rather than being spread over the seven snapshots that make up the week.

You cannot directly back up the snapshots because they exist within the file system metadata rather than as regular files. To get the snapshot into a format that you can copy to another file system, tape, and so on, you use the `zfs send` command to create a stream version of the snapshot.

For example, to write the snapshot out to a file:

```
root-shell> zfs send scratchpool@snap1 >/backup/scratchpool-snap1
```

Or tape:

```
root-shell> zfs send scratchpool@snap1 >/dev/rmt/0
```

You can also write out the incremental changes between two snapshots using `zfs send`:

```
root-shell> zfs send scratchpool@snap1 scratchpool@snap2 >/backup/scratchpool-changes
```

To recover a snapshot, you use `zfs recv`, which applies the snapshot information either to a new file system, or to an existing one.

16.1.1 Using ZFS for File System Replication

Because `zfs send` and `zfs recv` use streams to exchange data, you can use them to replicate information from one system to another by combining `zfs send`, `ssh`, and `zfs recv`.

For example, to copy a snapshot of the `scratchpool` file system to a new file system called `slavepool` on a new server, you would use the following command. This sequence combines the snapshot of `scratchpool`, the transmission to the slave machine (using `ssh` with login credentials), and the recovery of the snapshot on the slave using `zfs recv`:

```
root-shell> zfs send scratchpool@snap1 |ssh id@host pfexec zfs recv -F slavepool
```

The first part of the pipeline, `zfs send scratchpool@snap1`, streams the snapshot. The `ssh` command, and the command that it executes on the other server, `pfexec zfs recv -F slavepool`, receives the streamed snapshot data and writes it to slavepool. In this instance, I've specified the `-F` option which forces the snapshot data to be applied, and is therefore destructive. This is fine, as I'm creating the first version of my replicated file system.

On the slave machine, the replicated file system contains the exact same content:

```
root-shell> ls -al /slavepool/
total 23
drwxr-xr-x   6 root     root           7 Nov  8 09:13 ./
drwxr-xr-x  29 root     root          34 Nov  9 07:06 ../
drwxr-xr-x  31 root     bin           50 Jul 21 07:32 DTT/
drwxr-xr-x   4 root     bin            5 Jul 21 07:32 SUNWmlib/
drwxr-xr-x  14 root     sys           16 Nov  5 09:56 SUNWspro/
drwxrwxrwx  19 1000     1000          40 Nov  6 19:16 emacs-22.1/
```

Once a snapshot has been created, to synchronize the file system again, you create a new snapshot and then use the incremental snapshot feature of `zfs send` to send the changes between the two snapshots to the slave machine again:

```
root-shell> zfs send -i scratchpool@snapshot1 scratchpool@snapshot2 |ssh id@host pfexec zfs recv slavep
```

This operation only succeeds if the file system on the slave machine has not been modified at all. You cannot apply the incremental changes to a destination file system that has changed. In the example above, the `ls` command would cause problems by changing the metadata, such as the last access time for files or directories.

To prevent changes on the slave file system, set the file system on the slave to be read-only:

```
root-shell> zfs set readonly=on slavepool
```

Setting `readonly` means that you cannot change the file system on the slave by normal means, including the file system metadata. Operations that would normally update metadata (like our `ls`) silently perform their function without attempting to update the file system state.

In essence, the slave file system is nothing but a static copy of the original file system. However, even when configured to be read-only, a file system can have snapshots applied to it. With the file system set to read only, re-run the initial copy:

```
root-shell> zfs send scratchpool@snap1 |ssh id@host pfexec zfs recv -F slavepool
```

Now you can make changes to the original file system and replicate them to the slave.

16.1.2 Configuring MySQL for ZFS Replication

Configuring MySQL on the source file system is a case of creating the data on the file system that you intend to replicate. The configuration file in the example below has been updated to use `/scratchpool/mysql-data` as the data directory, and now you can initialize the tables:

```
root-shell> mysql_install_db --defaults-file=/etc/mysql/5.5/my.cnf --user=mysql
```

To synchronize the initial information, perform a new snapshot and then send an incremental snapshot to the slave using `zfs send`:

```
root-shell> zfs snapshot scratchpool@snap2
root-shell> zfs send -i scratchpool@snap1 scratchpool@snap2|ssh id@host pfexec zfs recv slavepool
```

Doublecheck that the slave has the data by looking at the MySQL data directory on the `slavepool`:

```
root-shell> ls -al /slavepool/mysql-data/
```

Now you can start up MySQL, create some data, and then replicate the changes using `zfs send`/`zfs recv` to the slave to synchronize the changes.

The rate at which you perform the synchronization depends on your application and environment. The limitation is the speed required to perform the snapshot and then to send the changes over the network.

To automate the process, create a script that performs the snapshot, send, and receive operation, and use `cron` to synchronize the changes at set times or intervals.

16.1.3 Handling MySQL Recovery with ZFS

When using ZFS replication to provide a constant copy of your data, ensure that you can recover your tables, either manually or automatically, in the event of a failure of the original system.

In the event of a failure, follow this sequence:

1. Stop the script on the master, if it is still up and running.
2. Set the slave file system to be read/write:

```
root-shell> zfs set readonly=off slavepool
```

3. Start up `mysqld` on the slave. If you are using `InnoDB`, you get auto-recovery, if it is needed, to make sure the table data is correct, as shown here when I started up from our mid-INSERT snapshot:

```
InnoDB: The log sequence number in ibdata files does not match
InnoDB: the log sequence number in the ib_logfiles!
081109 15:59:59  InnoDB: Database was not shut down normally!
InnoDB: Starting crash recovery.
InnoDB: Reading tablespace information from the .ibd files...
InnoDB: Restoring possible half-written data pages from the doublewrite
InnoDB: buffer...
081109 16:00:03  InnoDB: Started; log sequence number 0 1142807951
081109 16:00:03 [Note] /slavepool/mysql-5.0.67-solaris10-i386/bin/mysqld: ready for connections.
Version: '5.0.67'  socket: '/tmp/mysql.sock'  port: 3306  MySQL Community Server (GPL)
```

Use `InnoDB` tables and a regular synchronization schedule to reduce the risk for significant data loss. On MyISAM tables, you might need to run `REPAIR TABLE`, and you might even have lost some information.

16.2 Using MySQL with `memcached`

`memcached` is a simple, highly scalable key-based cache that stores data and objects wherever dedicated or spare RAM is available for quick access by applications, without going through layers of parsing or disk I/O. To use, you run the `memcached` command on one or more hosts and then use the shared cache to store objects. For more usage instructions, see Section 16.2.2, “Using `memcached`”

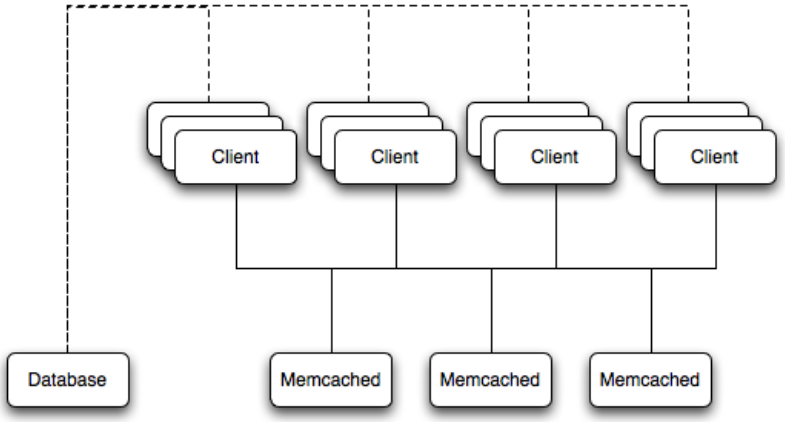
Benefits of using `memcached` include:

- Because all information is stored in RAM, the access speed is faster than loading the information each time from disk.
- Because the “value” portion of the key-value pair does not have any data type restrictions, you can cache data such as complex structures, documents, images, or a mixture of such things.
- If you use the in-memory cache to hold transient information, or as a read-only cache for information also stored in a database, the failure of any `memcached` server is not critical. For persistent data, you can fall back to an alternative lookup method using database queries, and reload the data into RAM on a different server.

The typical usage environment is to modify your application so that information is read from the cache provided by `memcached`. If the information is not in `memcached`, then the data is loaded from the MySQL database and written into the cache so that future requests for the same object benefit from the cached data.

For a typical deployment layout, see Figure 16.2, “`memcached` Architecture Overview”.

Figure 16.2 memcached Architecture Overview



In the example structure, any of the clients can contact one of the memcached servers to request a given key. Each client is configured to talk to all of the servers shown in the illustration. Within the client, when the request is made to store the information, the key used to reference the data is hashed and this hash is then used to select one of the memcached servers. The selection of the memcached server takes place on the client before the server is contacted, keeping the process lightweight.

The same algorithm is used again when a client requests the same key. The same key generates the same hash, and the same memcached server is selected as the source for the data. Using this method, the cached data is spread among all of the memcached servers, and the cached information is accessible from any client. The result is a distributed, memory-based, cache that can return information, particularly complex data and structures, much faster than natively reading the information from the database.

The data held within a traditional memcached server is never stored on disk (only in RAM, which means there is no persistence of data), and the RAM cache is always populated from the backing store (a MySQL database). If a memcached server fails, the data can always be recovered from the MySQL database.

16.2.1 Installing memcached

You can build and install memcached from the source code directly, or you can use an existing operating system package or installation.

Installing memcached from a Binary Distribution

To install memcached on a Red Hat, or Fedora host, use yum:

```
root-shell> yum install memcached
```

Note

On CentOS, you may be able to obtain a suitable RPM from another source, or use the source tarball.

To install memcached on a Debian or Ubuntu host, use apt-get:

```
root-shell> apt-get install memcached
```

To install memcached on a Gentoo host, use emerge:

```
root-shell> emerge install memcached
```

Building memcached from Source

On other Unix-based platforms, including Solaris, AIX, HP-UX and OS X, and Linux distributions not mentioned already, you must install from source. For Linux, make sure you have a 2.6-based kernel, which includes the improved epoll interface. For all platforms, ensure that you have libevent 1.1 or higher installed. You can obtain libevent from libevent web page.

You can obtain the source for memcached from memcached Web site.

To build memcached, follow these steps:

1. Extract the memcached source package:

```
shell> gunzip -c memcached-1.2.5.tar.gz | tar xf -
```

2. Change to the memcached-1.2.5 directory:

```
shell> cd memcached-1.2.5
```

3. Run configure

```
shell> ./configure
```

   Some additional options you might specify to the configure:

   - --prefix

     To specify a different installation directory, use the --prefix option:

     ```
     shell> ./configure --prefix=/opt
     ```

     The default is to use the /usr/local directory.

   - --with-libevent

     If you have installed libevent and configure cannot find the library, use the --with-libevent option to specify the location of the installed library.

   - --enable-64bit

     To build a 64-bit version of memcached (which enables you to use a single instance with a large RAM allocation), use --enable-64bit.

   - --enable-threads

     To enable multi-threading support in memcached, which improves the response times on servers with a heavy load, use --enable-threads. You must have support for the POSIX threads within your operating system to enable thread support. For more information on the threading support, see Section 16.2.2.8, “memcached Thread Support”.

   - --enable-dtrace

     memcached includes a range of DTrace threads that can be used to monitor and benchmark a memcached instance. For more information, see Section 16.2.2.6, “Using memcached and DTrace”.

4. Run make to build memcached:

```
shell> make
```

5. Run make install to install memcached:

```
shell> make install
```

16.2.2 Using memcached

To start using memcached, start the memcached service on one or more servers. Running memcached sets up the server, allocates the memory and starts listening for connections from clients.

Note

You do not need to be a privileged user (root) to run memcached except to listen on one of the privileged TCP/IP ports (below 1024). You must, however, use a user that has not had their memory limits restricted using setrlimit or similar.

To start the server, run memcached as a nonprivileged (that is, non-root) user:

```
shell> memcached
```

By default, memcached uses the following settings:

- Memory allocation of 64MB
- Listens for connections on all network interfaces, using port 11211
- Supports a maximum of 1024 simultaneous connections

Typically, you would specify the full combination of options that you want when starting memcached, and normally provide a startup script to handle the initialization of memcached. For example, the following line starts memcached with a maximum of 1024MB RAM for the cache, listening on port 11211 on the IP address 198.51.100.110, running as a background daemon:

```
shell> memcached -d -m 1024 -p 11211 -l 198.51.100.110
```

To ensure that memcached is started up on boot, check the init script and configuration parameters.

16.2.2.1 memcached Command-Line Options

memcached supports the following options:

- -u user

  If you start memcached as root, use the -u option to specify the user for executing memcached:

  ```
  shell> memcached -u memcache
  ```

- -m memory

  Set the amount of memory allocated to memcached for object storage. Default is 64MB.

  To increase the amount of memory allocated for the cache, use the -m option to specify the amount of RAM to be allocated (in megabytes). The more RAM you allocate, the more data you can store and therefore the more effective your cache is.

Warning

Do not specify a memory allocation larger than your available RAM. If you specify too large a value, then some RAM allocated for memcached uses swap space, and not physical RAM. This may lead to delays when storing

and retrieving values, because data is swapped to disk, instead of storing the data directly in RAM.

You can use the output of the vmstat command to get the free memory, as shown in free column:

```
shell> vmstat
kthr      memory            page            disk          faults      cpu
r b w   swap  free  re  mf pi po fr de sr s1 s2 -- --   in   sy   cs us sy id
0 0 0 5170504 3450392 2  7  2  0  0  0  4  0  0  0  0  296   54  199  0  0 100
```

For example, to allocate 3GB of RAM:

```
shell> memcached -m 3072
```

On 32-bit x86 systems where you are using PAE to access memory above the 4GB limit, you cannot allocate RAM beyond the maximum process size. You can get around this by running multiple instances of memcached, each listening on a different port:

```
shell> memcached -m 1024 -p11211
shell> memcached -m 1024 -p11212
shell> memcached -m 1024 -p11213
```

Note

On all systems, particularly 32-bit, ensure that you leave enough room for both memcached application in addition to the memory setting. For example, if you have a dedicated memcached host with 4GB of RAM, do not set the memory size above 3500MB. Failure to do this may cause either a crash or severe performance issues.

- `-l interface`

  Specify a network interface/address to listen for connections. The default is to listen on all available address (INADDR_ANY).

  ```
  shell> memcached -l 198.51.100.110
  ```

  Support for IPv6 address support was added in memcached 1.2.5.

- `-p port`

  Specify the TCP port to use for connections. Default is 18080.

  ```
  shell> memcached -p 18080
  ```

- `-U port`

  Specify the UDP port to use for connections. Default is 11211, 0 switches UDP off.

  ```
  shell> memcached -U 18080
  ```

- `-s socket`

  Specify a Unix socket to listen on.

  If you are running memcached on the same server as the clients, you can disable the network interface and use a local Unix socket using the -s option:

  ```
  ```

```
shell> memcached -s /tmp/memcached
```

Using a Unix socket automatically disables network support, and saves network ports (allowing more ports to be used by your web server or other process).

- `-a mask`

  Specify the access mask to be used for the Unix socket, in octal. Default is 0700.

- `-c connections`

  Specify the maximum number of simultaneous connections to the `memcached` service. The default is 1024.

  ```
  shell> memcached -c 2048
  ```

  Use this option, either to reduce the number of connections (to prevent overloading `memcached` service) or to increase the number to make more effective use of the server running `memcached` server.

- `-t threads`

  Specify the number of threads to use when processing incoming requests.

  By default, `memcached` is configured to use 4 concurrent threads. The threading improves the performance of storing and retrieving data in the cache, using a locking system to prevent different threads overwriting or updating the same values. To increase or decrease the number of threads, use the `-t` option:

  ```
  shell> memcached -t 8
  ```

- `-d`

  Run `memcached` as a daemon (background) process:

  ```
  shell> memcached -d
  ```

- `-r`

  Maximize the size of the core file limit. In the event of a failure, this attempts to dump the entire memory space to disk as a core file, up to any limits imposed by `setrlimit`.

- `-M`

  Return an error to the client when the memory has been exhausted. This replaces the normal behavior of removing older items from the cache to make way for new items.

- `-k`

  Lock down all paged memory. This reserves the memory before use, instead of allocating new slabs of memory as new items are stored in the cache.

  Note

  There is a user-level limit on how much memory you can lock. Trying to allocate more than the available memory fails. You can set the limit for the user you started the daemon with (not for the `-u user` user) within the shell by using `ulimit -S -l NUM_KB`

- `-v`

Verbose mode. Prints errors and warnings while executing the main event loop.

- `-vv`

  Very verbose mode. In addition to information printed by `-v`, also prints each client command and the response.

- `-vvv`

  Extremely verbose mode. In addition to information printed by `-vv`, also show the internal state transitions.

- `-h`

  Print the help message and exit.

- `-i`

  Print the `memcached` and `libevent` license.

- `-I mem`

  Specify the maximum size permitted for storing an object within the `memcached` instance. The size supports a unit postfix (`k` for kilobytes, `m` for megabytes). For example, to increase the maximum supported object size to 32MB:

  ```
  shell> memcached -I 32m
  ```

  The maximum object size you can specify is 128MB, the default remains at 1MB.

  This option was added in 1.4.2.

- `-b`

  Set the backlog queue limit. The backlog queue configures how many network connections can be waiting to be processed by `memcached`. Increasing this limit may reduce errors received by the client that it is not able to connect to the `memcached` instance, but does not improve the performance of the server. The default is 1024.

- `-P pidfile`

  Save the process ID of the `memcached` instance into `file`.

- `-f`

  Set the chunk size growth factor. When allocating new memory chunks, the allocated size of new chunks is determined by multiplying the default slab size by this factor.

  To see the effects of this option without extensive testing, use the `-vv` command-line option to show the calculated slab sizes. For more information, see Section 16.2.2.9, “`memcached` Logs”.

- `-n bytes`

  The minimum space allocated for the key+value+flags information. The default is 48 bytes.

- `-L`

  On systems that support large memory pages, enables large memory page use. Using large memory pages enables `memcached` to allocate the item cache in one large chunk, which can improve the performance by reducing the number misses when accessing memory.

- `-C`

Disable the use of compare and swap (CAS) operations.

This option was added in memcached 1.3.x.

- -D char

  Set the default character to be used as a delimiter between the key prefixes and IDs. This is used for the per-prefix statistics reporting (see Section 16.2.4, “Getting memcached Statistics”). The default is the colon (:). If this option is used, statistics collection is turned on automatically. If not used, you can enable stats collection by sending the stats detail on command to the server.

  This option was added in memcached 1.3.x.

- -R num

  Sets the maximum number of requests per event process. The default is 20.

- -B protocol

  Set the binding protocol, that is, the default memcached protocol support for client connections. Options are ascii, binary or auto. Automatic (auto) is the default.

  This option was added in memcached 1.4.0.

16.2.2.2 memcached Deployment

When using memcached you can use a number of different potential deployment strategies and topologies. The exact strategy to use depends on your application and environment. When developing a system for deploying memcached within your system, keep in mind the following points:

- memcached is only a caching mechanism. It shouldn't be used to store information that you cannot otherwise afford to lose and then load from a different location.
- There is no security built into the memcached protocol. At a minimum, make sure that the servers running memcached are only accessible from inside your network, and that the network ports being used are blocked (using a firewall or similar). If the information on the memcached servers that is being stored is any sensitive, then encrypt the information before storing it in memcached.
- memcached does not provide any sort of failover. Because there is no communication between different memcached instances. If an instance fails, your application must capable of removing it from the list, reloading the data and then writing data to another memcached instance.
- Latency between the clients and the memcached can be a problem if you are using different physical machines for these tasks. If you find that the latency is a problem, move the memcached instances to be on the clients.
- Key length is determined by the memcached server. The default maximum key size is 250 bytes.
- Try to use at least two memcached instances, especially for multiple clients, to avoid having a single point of failure. Ideally, create as many memcached nodes as possible. When adding and removing memcached instances from a pool, the hashing and distribution of key/value pairs may be affected. For information on how to avoid problems, see Section 16.2.2.5, “memcached Hashing/Distribution Types”.

16.2.2.3 Using Namespaces

The memcached cache is a very simple massive key/value storage system, and as such there is no way of compartmentalizing data automatically into different sections. For example, if you are storing information by the unique ID returned from a MySQL database, then storing the data from two different tables could run into issues because the same ID might be valid in both tables.

Some interfaces provide an automated mechanism for creating *namespaces* when storing information into the cache. In practice, these namespaces are merely a prefix before a given ID that is applied every time a value is stored or retrieve from the cache.

You can implement the same basic principle by using keys that describe the object and the unique identifier within the key that you supply when the object is stored. For example, when storing user data, prefix the ID of the user with `user:` or `user-`.

Note

Using namespaces or prefixes only controls the keys stored/retrieved. There is no security within `memcached`, and therefore no way to enforce that a particular client only accesses keys with a particular namespace. Namespaces are only useful as a method of identifying data and preventing corruption of key/value pairs.

16.2.2.4 Data Expiry

There are two types of data expiry within a `memcached` instance. The first type is applied at the point when you store a new key/value pair into the `memcached` instance. If there is not enough space within a suitable slab to store the value, then an existing least recently used (LRU) object is removed (evicted) from the cache to make room for the new item.

The LRU algorithm ensures that the object that is removed is one that is either no longer in active use or that was used so long ago that its data is potentially out of date or of little value. However, in a system where the memory allocated to `memcached` is smaller than the number of regularly used objects required in the cache, a lot of expired items could be removed from the cache even though they are in active use. You use the statistics mechanism to get a better idea of the level of evictions (expired objects). For more information, see Section 16.2.4, “Getting `memcached` Statistics”.

You can change this eviction behavior by setting the `-M` command-line option when starting `memcached`. This option forces an error to be returned when the memory has been exhausted, instead of automatically evicting older data.

The second type of expiry system is an explicit mechanism that you can set when a key/value pair is inserted into the cache, or when deleting an item from the cache. Using an expiration time can be a useful way of ensuring that the data in the cache is up to date and in line with your application needs and requirements.

A typical scenario for explicitly setting the expiry time might include caching session data for a user when accessing a Web site. `memcached` uses a lazy expiry mechanism where the explicit expiry time that has been set is compared with the current time when the object is requested. Only objects that have not expired are returned.

You can also set the expiry time when explicitly deleting an object from the cache. In this case, the expiry time is really a timeout and indicates the period when any attempts to set the value for a given key are rejected.

16.2.2.5 `memcached` Hashing/Distribution Types

The `memcached` client interface supports a number of different distribution algorithms that are used in multi-server configurations to determine which host should be used when setting or getting data from a given `memcached` instance. When you get or set a value, a hash is constructed from the supplied key and then used to select a host from the list of configured servers. Because the hashing mechanism uses the supplied key as the basis for the hash, the same server is selected during both set and get operations.

You can think of this process as follows. Given an array of servers (a, b, and c), the client uses a hashing algorithm that returns an integer based on the key being stored or retrieved. The resulting value is then used to select a server from the list of servers configured in the client. Most standard

client hashing within memcache clients uses a simple modulus calculation on the value against the number of configured memcached servers. You can summarize the process in pseudocode as:

```
@memcservers = ['a.memc','b.memc','c.memc'];
$value = hash($key);
$chosen = $value % length(@memcservers);
```

Replacing the above with values:

```
@memcservers = ['a.memc','b.memc','c.memc'];
$value = hash('myid');
$chosen = 7009 % 3;
```

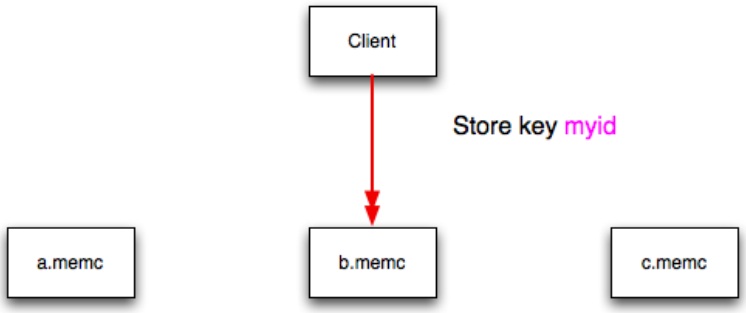
In the above example, the client hashing algorithm chooses the server at index 1 (`7009 % 3 = 1`), and store or retrieve the key and value with that server.

Note

This selection and hashing process is handled automatically by the memcached client you are using; you need only provide the list of memcached servers to use.

You can see a graphical representation of this below in Figure 16.3, "memcached Hash Selection".

Figure 16.3 memcached Hash Selection



The same hashing and selection process takes place during any operation on the specified key within the memcached client.

Using this method provides a number of advantages:

- The hashing and selection of the server to contact is handled entirely within the client. This eliminates the need to perform network communication to determine the right machine to contact.
- Because the determination of the memcached server occurs entirely within the client, the server can be selected automatically regardless of the operation being executed (set, get, increment, etc.).
- Because the determination is handled within the client, the hashing algorithm returns the same value for a given key; values are not affected or reset by differences in the server environment.
- Selection is very fast. The hashing algorithm on the key value is quick and the resulting selection of the server is from a simple array of available machines.
- Using client-side hashing simplifies the distribution of data over each memcached server. Natural distribution of the values returned by the hashing algorithm means that keys are automatically spread over the available servers.

Providing that the list of servers configured within the client remains the same, the same stored key returns the same value, and therefore selects the same server.

However, if you do not use the same hashing mechanism then the same data may be recorded on different servers by different interfaces, both wasting space on your memcached and leading to potential differences in the information.

Note

One way to use a multi-interface compatible hashing mechanism is to use the libmemcached library and the associated interfaces. Because the interfaces for the different languages (including C, Ruby, Perl and Python) use the same client library interface, they always generate the same hash code from the ID.

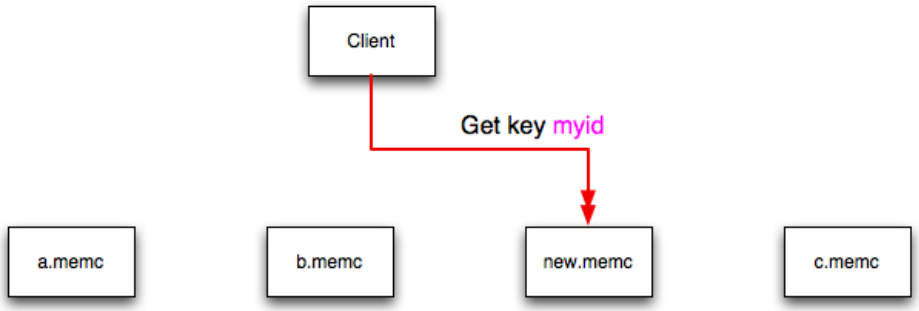
The problem with client-side selection of the server is that the list of the servers (including their sequential order) *must* remain consistent on each client using the memcached servers, and the servers must be available. If you try to perform an operation on a key when:

- A new memcached instance has been added to the list of available instances
- A memcached instance has been removed from the list of available instances
- The order of the memcached instances has changed

When the hashing algorithm is used on the given key, but with a different list of servers, the hash calculation may choose a different server from the list.

If a new memcached instance is added into the list of servers, as new.memc is in the example below, then a GET operation using the same key, myid, can result in a cache-miss. This is because the same value is computed from the key, which selects the same index from the array of servers, but index 2 now points to the new server, not the server c.memc where the data was originally stored. This would result in a cache miss, even though the key exists within the cache on another memcached instance.

Figure 16.4 memcached Hash Selection with New memcached instance



This means that servers c.memc and new.memc both contain the information for key myid, but the information stored against the key in eachs server may be different in each instance. A more significant problem is a much higher number of cache-misses when retrieving data, as the addition of a new server changes the distribution of keys, and this in turn requires rebuilding the cached data on the memcached instances, causing an increase in database reads.

The same effect can occur if you actively manage the list of servers configured in your clients, adding and removing the configured memcached instances as each instance is identified as being available. For example, removing a memcached instance when the client notices that the instance can no longer be contacted can cause the server selection to fail as described here.

To prevent this causing significant problems and invalidating your cache, you can select the hashing algorithm used to select the server. There are two common types of hashing algorithm, *consistent* and *modula*.

With *consistent* hashing algorithms, the same key when applied to a list of servers always uses the same server to store or retrieve the keys, even if the list of configured servers changes. This means

that you can add and remove servers from the configure list and always use the same server for a given key. There are two types of consistent hashing algorithms available, Ketama and Wheel. Both types are supported by libmemcached, and implementations are available for PHP and Java.

Any consistent hashing algorithm has some limitations. When you add servers to an existing list of configured servers, keys are distributed to the new servers as part of the normal distribution. When you remove servers from the list, the keys are re-allocated to another server within the list, meaning that the cache needs to be re-populated with the information. Also, a consistent hashing algorithm does not resolve the issue where you want consistent selection of a server across multiple clients, but where each client contains a different list of servers. The consistency is enforced only within a single client.

With a *modula* hashing algorithm, the client selects a server by first computing the hash and then choosing a server from the list of configured servers. As the list of servers changes, so the server selected when using a modula hashing algorithm also changes. The result is the behavior described above; changes to the list of servers mean that different servers are selected when retrieving data, leading to cache misses and increase in database load as the cache is re-seeded with information.

If you use only a single memcached instance for each client, or your list of memcached servers configured for a client never changes, then the selection of a hashing algorithm is irrelevant, as it has no noticeable effect.

If you change your servers regularly, or you use a common set of servers that are shared among a large number of clients, then using a consistent hashing algorithm should help to ensure that your cache data is not duplicated and the data is evenly distributed.

16.2.2.6 Using memcached and DTrace

memcached includes a number of different DTrace probes that can be used to monitor the operation of the server. The probes included can monitor individual connections, slab allocations, and modifications to the hash table when a key/value pair is added, updated, or removed.

For more information on DTrace and writing DTrace scripts, read the DTrace User Guide.

Support for DTrace probes was added to memcached 1.2.6 includes a number of DTrace probes that can be used to help monitor your application. DTrace is supported on Solaris 10, OpenSolaris, OS X 10.5 and FreeBSD. To enable the DTrace probes in memcached, build from source and use the --enable-dtrace option. For more information, see Section 16.2.1, “Installing memcached”.

The probes supported by memcached are:

- conn-allocate(connid)

  Fired when a connection object is allocated from the connection pool.

  - connid: The connection ID.

- conn-release(connid)

  Fired when a connection object is released back to the connection pool.

  Arguments:

  - connid: The connection ID.

- conn-create(ptr)

  Fired when a new connection object is being created (that is, there are no free connection objects in the connection pool).

  Arguments:

  - ptr: A pointer to the connection. object

- conn-destroy(ptr)

  Fired when a connection object is being destroyed.

  Arguments:

  - ptr: A pointer to the connection object.

- conn-dispatch(connid, threadid)

  Fired when a connection is dispatched from the main or connection-management thread to a worker thread.

  Arguments:

  - connid: The connection ID.
  - threadid: The thread ID.

- slabs-allocate(size, slabclass, slabsize, ptr)

  Allocate memory from the slab allocator.

  Arguments:

  - size: The requested size.
  - slabclass: The allocation is fulfilled in this class.
  - slabsize: The size of each item in this class.
  - ptr: A pointer to allocated memory.

- slabs-allocate-failed(size, slabclass)

  Failed to allocate memory (out of memory).

  Arguments:

  - size: The requested size.
  - slabclass: The class that failed to fulfill the request.

- slabs-slabclass-allocate(slabclass)

  Fired when a slab class needs more space.

  Arguments:

  - slabclass: The class that needs more memory.

- slabs-slabclass-allocate-failed(slabclass)

  Failed to allocate memory (out of memory).

  Arguments:

  - slabclass: The class that failed to grab more memory.

- slabs-free(size, slabclass, ptr)

  Release memory.

  Arguments:

- size: The amount of memory to release, in bytes.
- slabclass: The class the memory belongs to.
- ptr: A pointer to the memory to release.

- assoc-find(key, depth)

  Fired when we have searched the hash table for a named key. These two elements provide an insight into how well the hash function operates. Traversals are a sign of a less optimal function, wasting CPU capacity.

  Arguments:

  - key: The key searched for.
  - depth: The depth in the list of hash table.

- assoc-insert(key, nokeys)

  Fired when a new item has been inserted.

  Arguments:

  - key: The key just inserted.
  - nokeys: The total number of keys currently being stored, including the key for which insert was called.

- assoc-delete(key, nokeys)

  Fired when a new item has been removed.

  Arguments:

  - key: The key just deleted.
  - nokeys: The total number of keys currently being stored, excluding the key for which delete was called.

- item-link(key, size)

  Fired when an item is being linked in the cache.

  Arguments:

  - key: The items key.
  - size: The size of the data.

- item-unlink(key, size)

  Fired when an item is being deleted.

  Arguments:

  - key: The items key.
  - size: The size of the data.

- item-remove(key, size)

  Fired when the refcount for an item is reduced.

Arguments:

- key: The item's key.
- size: The size of the data.

- item-update(key, size)

  Fired when the "last referenced" time is updated.

  Arguments:

  - key: The item's key.
  - size: The size of the data.

- item-replace(oldkey, oldsize, newkey, newsize)

  Fired when an item is being replaced with another item.

  Arguments:

  - oldkey: The key of the item to replace.
  - oldsize: The size of the old item.
  - newkey: The key of the new item.
  - newsize: The size of the new item.

- process-command-start(connid, request, size)

  Fired when the processing of a command starts.

  Arguments:

  - connid: The connection ID.
  - request: The incoming request.
  - size: The size of the request.

- process-command-end(connid, response, size)

  Fired when the processing of a command is done.

  Arguments:

  - connid: The connection ID.
  - response: The response to send back to the client.
  - size: The size of the response.

- command-get(connid, key, size)

  Fired for a get command.

  Arguments:

  - connid: The connection ID.
  - key: The requested key.

    - size: The size of the key's data (or -1 if not found).
- command-gets(connid, key, size, casid)

  Fired for a gets command.

  Arguments:

  - connid: The connection ID.
  - key: The requested key.
  - size: The size of the key's data (or -1 if not found).
  - casid: The casid for the item.
- command-add(connid, key, size)

  Fired for a add command.

  Arguments:

  - connid: The connection ID.
  - key: The requested key.
  - size: The new size of the key's data (or -1 if not found).
- command-set(connid, key, size)

  Fired for a set command.

  Arguments:

  - connid: The connection ID.
  - key: The requested key.
  - size: The new size of the key's data (or -1 if not found).
- command-replace(connid, key, size)

  Fired for a replace command.

  Arguments:

  - connid: The connection ID.
  - key: The requested key.
  - size: The new size of the key's data (or -1 if not found).
- command-prepend(connid, key, size)

  Fired for a prepend command.

  Arguments:

  - connid: The connection ID.
  - key: The requested key.
  - size: The new size of the key's data (or -1 if not found).

- `command-append(connid, key, size)`

  Fired for a `append` command.

  Arguments:

  - `connid`: The connection ID.
  - `key`: The requested key.
  - `size`: The new size of the key's data (or -1 if not found).

- `command-cas(connid, key, size, casid)`

  Fired for a `cas` command.

  Arguments:

  - `connid`: The connection ID.
  - `key`: The requested key.
  - `size`: The size of the key's data (or -1 if not found).
  - `casid`: The cas ID requested.

- `command-incr(connid, key, val)`

  Fired for `incr` command.

  Arguments:

  - `connid`: The connection ID.
  - `key`: The requested key.
  - `val`: The new value.

- `command-decr(connid, key, val)`

  Fired for `decr` command.

  Arguments:

  - `connid`: The connection ID.
  - `key`: The requested key.
  - `val`: The new value.

- `command-delete(connid, key, exptime)`

  Fired for a `delete` command.

  Arguments:

  - `connid`: The connection ID.
  - `key`: The requested key.
  - `exptime`: The expiry time.

16.2.2.7 Memory Allocation within memcached

When you first start memcached, the memory that you have configured is not automatically allocated. Instead, memcached only starts allocating and reserving physical memory once you start saving information into the cache.

When you start to store data into the cache, memcached does not allocate the memory for the data on an item by item basis. Instead, a slab allocation is used to optimize memory usage and prevent memory fragmentation when information expires from the cache.

With slab allocation, memory is reserved in blocks of 1MB. The slab is divided up into a number of blocks of equal size. When you try to store a value into the cache, memcached checks the size of the value that you are adding to the cache and determines which slab contains the right size allocation for the item. If a slab with the item size already exists, the item is written to the block within the slab.

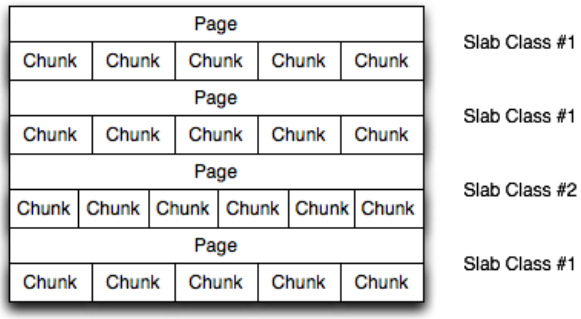
If the new item is bigger than the size of any existing blocks, then a new slab is created, divided up into blocks of a suitable size. If an existing slab with the right block size already exists, but there are no free blocks, a new slab is created. If you update an existing item with data that is larger than the existing block allocation for that key, then the key is re-allocated into a suitable slab.

For example, the default size for the smallest block is 88 bytes (40 bytes of value, and the default 48 bytes for the key and flag data). If the size of the first item you store into the cache is less than 40 bytes, then a slab with a block size of 88 bytes is created and the value stored.

If the size of the data that you intend to store is larger than this value, then the block size is increased by the chunk size factor until a block size large enough to hold the value is determined. The block size is always a function of the scale factor, rounded up to a block size which is exactly divisible into the chunk size.

For a sample of the structure, see Figure 16.5, “Memory Allocation in memcached”.

Figure 16.5 Memory Allocation in memcached



The result is that you have multiple pages allocated within the range of memory allocated to memcached. Each page is 1MB in size (by default), and is split into a different number of chunks, according to the chunk size required to store the key/value pairs. Each instance has multiple pages allocated, and a page is always created when a new item needs to be created requiring a chunk of a particular size. A slab may consist of multiple pages, and each page within a slab contains an equal number of chunks.

The chunk size of a new slab is determined by the base chunk size combined with the chunk size growth factor. For example, if the initial chunks are 104 bytes in size, and the default chunk size growth factor is used (1.25), then the next chunk size allocated would be the best power of 2 fit for 104*1.25, or 136 bytes.

Allocating the pages in this way ensures that memory does not get fragmented. However, depending on the distribution of the objects that you store, it may lead to an inefficient distribution of the slabs and chunks if you have significantly different sized items. For example, having a relatively small number of items within each chunk size may waste a lot of memory with just few chunks in each allocated page.

You can tune the growth factor to reduce this effect by using the `-f` command line option, which adapts the growth factor applied to make more effective use of the chunks and slabs allocated. For information on how to determine the current slab allocation statistics, see Section 16.2.4.2, "`memcached` Slabs Statistics".

If your operating system supports it, you can also start `memcached` with the `-L` command line option. This option preallocates all the memory during startup using large memory pages. This can improve performance by reducing the number of misses in the CPU memory cache.

16.2.2.8 `memcached` Thread Support

If you enable the thread implementation within when building `memcached` from source, then `memcached` uses multiple threads in addition to the `libevent` system to handle requests.

When enabled, the threading implementation operates as follows:

- Threading is handled by wrapping functions within the code to provide basic protection from updating the same global structures at the same time.
- Each thread uses its own instance of the `libevent` to help improve performance.
- TCP/IP connections are handled with a single thread listening on the TCP/IP socket. Each connection is then distributed to one of the active threads on a simple round-robin basis. Each connection then operates solely within this thread while the connection remains open.
- For UDP connections, all the threads listen to a single UDP socket for incoming requests. Threads that are not currently dealing with another request ignore the incoming packet. One of the remaining, nonbusy, threads reads the request and sends the response. This implementation can lead to increased CPU load as threads wake from sleep to potentially process the request.

Using threads can increase the performance on servers that have multiple CPU cores available, as the requests to update the hash table can be spread between the individual threads. To minimize overhead from the locking mechanism employed, experiment with different thread values to achieve the best performance based on the number and type of requests within your given workload.

16.2.2.9 `memcached` Logs

If you enable verbose mode, using the `-v`, `-vv`, or `-vvv` options, then the information output by `memcached` includes details of the operations being performed.

Without the verbose options, `memcached` normally produces no output during normal operating.

- **Output when using `-v`**

  The lowest verbosity level shows you:

  - Errors and warnings
  - Transient errors
  - Protocol and socket errors, including exhausting available connections
  - Each registered client connection, including the socket descriptor number and the protocol used.

    For example:

    ```
    32: Client using the ascii protocol
    33: Client using the ascii protocol
    ```

    The socket descriptor is only valid while the client remains connected. Non-persistent connections may not be effectively represented.

  Examples of the error messages output at this level include:

```
<%d send buffer was %d, now %d
Can't listen for events on fd %d
Can't read from libevent pipe
Catastrophic: event fd doesn't match conn fd!
Couldn't build response
Couldn't realloc input buffer
Couldn't update event
Failed to build UDP headers
Failed to read, and not due to blocking
Too many open connections
Unexpected state %d
```

- **Output when using `-vv`**

  When using the second level of verbosity, you get more detailed information about protocol operations, keys updated, chunk and network operatings and details.

  During the initial start-up of `memcached` with this level of verbosity, you are shown the sizes of the individual slab classes, the chunk sizes, and the number of entries per slab. These do not show the allocation of the slabs, just the slabs that would be created when data is added. You are also given information about the listen queues and buffers used to send information. A sample of the output generated for a TCP/IP based system with the default memory and growth factors is given below:

```
shell> memcached -vv
slab class   1: chunk size     80 perslab 13107
slab class   2: chunk size    104 perslab 10082
slab class   3: chunk size    136 perslab  7710
slab class   4: chunk size    176 perslab  5957
slab class   5: chunk size    224 perslab  4681
slab class   6: chunk size    280 perslab  3744
slab class   7: chunk size    352 perslab  2978
slab class   8: chunk size    440 perslab  2383
slab class   9: chunk size    552 perslab  1899
slab class  10: chunk size    696 perslab  1506
slab class  11: chunk size    872 perslab  1202
slab class  12: chunk size   1096 perslab   956
slab class  13: chunk size   1376 perslab   762
slab class  14: chunk size   1720 perslab   609
slab class  15: chunk size   2152 perslab   487
slab class  16: chunk size   2696 perslab   388
slab class  17: chunk size   3376 perslab   310
slab class  18: chunk size   4224 perslab   248
slab class  19: chunk size   5280 perslab   198
slab class  20: chunk size   6600 perslab   158
slab class  21: chunk size   8256 perslab   127
slab class  22: chunk size  10320 perslab   101
slab class  23: chunk size  12904 perslab    81
slab class  24: chunk size  16136 perslab    64
slab class  25: chunk size  20176 perslab    51
slab class  26: chunk size  25224 perslab    41
slab class  27: chunk size  31536 perslab    33
slab class  28: chunk size  39424 perslab    26
slab class  29: chunk size  49280 perslab    21
slab class  30: chunk size  61600 perslab    17
slab class  31: chunk size  77000 perslab    13
slab class  32: chunk size  96256 perslab    10
slab class  33: chunk size 120320 perslab     8
slab class  34: chunk size 150400 perslab     6
slab class  35: chunk size 188000 perslab     5
slab class  36: chunk size 235000 perslab     4
slab class  37: chunk size 293752 perslab     3
slab class  38: chunk size 367192 perslab     2
slab class  39: chunk size 458992 perslab     2
<26 server listening (auto-negotiate)
<29 server listening (auto-negotiate)
<30 send buffer was 57344, now 2097152
<31 send buffer was 57344, now 2097152
```

```
<30 server listening (udp)
<30 server listening (udp)
<31 server listening (udp)
<30 server listening (udp)
<30 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
<31 server listening (udp)
```

Using this verbosity level can be a useful way to check the effects of the growth factor used on slabs with different memory allocations, which in turn can be used to better tune the growth factor to suit the data you are storing in the cache. For example, if you set the growth factor to 4 (quadrupling the size of each slab):

```
shell> memcached -f 4 -m 1g -vv
slab class   1: chunk size     80 perslab 13107
slab class   2: chunk size    320 perslab  3276
slab class   3: chunk size   1280 perslab   819
slab class   4: chunk size   5120 perslab   204
slab class   5: chunk size  20480 perslab    51
slab class   6: chunk size  81920 perslab    12
slab class   7: chunk size 327680 perslab     3
...
```

During use of the cache, this verbosity level also prints out detailed information on the storage and recovery of keys and other information. An example of the output during a typical set/get and increment/decrement operation is shown below.

```
32: Client using the ascii protocol
<32 set my_key 0 0 10
>32 STORED
<32 set object_key 1 0 36
>32 STORED
<32 get my_key
>32 sending key my_key
>32 END
<32 get object_key
>32 sending key object_key
>32 END
<32 set key 0 0 6
>32 STORED
<32 incr key 1
>32 789544
<32 decr key 1
>32 789543
<32 incr key 2
>32 789545
<32 set my_key 0 0 10
>32 STORED
<32 set object_key 1 0 36
>32 STORED
<32 get my_key
>32 sending key my_key
>32 END
<32 get object_key
>32 sending key object_key1 1 36

>32 END
<32 set key 0 0 6
>32 STORED
<32 incr key 1
>32 789544
<32 decr key 1
>32 789543
<32 incr key 2
>32 789545
```

During client communication, for each line, the initial character shows the direction of flow of the information. The < for communication from the client to the memcached server and > for communication back to the client. The number is the numeric socket descriptor for the connection.

- **Output when using -vvv**

  This level of verbosity includes the transitions of connections between different states in the event library while reading and writing content to/from the clients. It should be used to diagnose and identify issues in client communication. For example, you can use this information to determine if memcached is taking a long time to return information to the client, during the read of the client operation or before returning and completing the operation. An example of the typical sequence for a set operation is provided below:

```
<32 new auto-negotiating client connection
32: going from conn_new_cmd to conn_waiting
32: going from conn_waiting to conn_read
32: going from conn_read to conn_parse_cmd
32: Client using the ascii protocol
<32 set my_key 0 0 10
32: going from conn_parse_cmd to conn_nread
> NOT FOUND my_key
>32 STORED
32: going from conn_nread to conn_write
32: going from conn_write to conn_new_cmd
32: going from conn_new_cmd to conn_waiting
32: going from conn_waiting to conn_read
32: going from conn_read to conn_closing
<32 connection closed.
```

All of the verbosity levels in memcached are designed to be used during debugging or examination of issues. The quantity of information generated, particularly when using -vvv, is significant, particularly on a busy server. Also be aware that writing the error information out, especially to disk, may negate some of the performance gains you achieve by using memcached. Therefore, use in production or deployment environments is not recommended.

16.2.3 Developing a memcached Application

A number of language interfaces let applications store and retrieve information with memcached servers. You can write memcached applications in popular languages such as Perl, PHP, Python, Ruby, C, and Java.

Data stored into a memcached server is referred to by a single string (the key), with storage into the cache and retrieval from the cache using the key as the reference. The cache therefore operates like a large associative array or hash table. It is not possible to structure or otherwise organize the information stored in the cache. To emulate database notions such as multiple tables or composite key values, you must encode the extra information into the strings used as keys. For example, to store or look up the address corresponding to a specific latitude and longitude, you might turn those two numeric values into a single comma-separated string to use as a key.

16.2.3.1 Basic memcached Operations

The interface to memcached supports the following methods for storing and retrieving information in the cache, and these are consistent across all the different APIs, although the language specific mechanics might be different:

- get(*key*): Retrieves information from the cache. Returns the value associated with the key if the specified key exists. Returns NULL, nil, undefined, or the closest equivalent in the corresponding language, if the specified key does not exist.
- set(*key, value [, expiry]*): Sets the item associated with a key in the cache to the specified value. This either updates an existing item if the key already exists, or adds a new key/value pair if

the key doesn't exist. If the expiry time is specified, then the item expires (and is deleted) when the expiry time is reached. The time is specified in seconds, and is taken as a relative time if the value is less than 30 days (30*24*60*60), or an absolute time (epoch) if larger than this value.

- `add(key, value [, expiry])`: Adds the key and associated value to the cache, if the specified key does not already exist.
- `replace(key, value [, expiry])`: Replaces the item associated with the specified `key`, only if the key already exists. The new value is given by the `value` parameter.
- `delete(key [, time])`: Deletes the `key` and its associated item from the cache. If you supply a `time`, then adding another item with the specified `key` is blocked for the specified period.
- `incr(key , value)`: Increments the item associated with the `key` by the specified `value`.
- `decr(key , value)`: Decrements the item associated with the `key` by the specified `value`.
- `flush_all`: Invalidates (or expires) all the current items in the cache. Technically they still exist (they are not deleted), but they are silently destroyed the next time you try to access them.

In all implementations, most or all of these functions are duplicated through the corresponding native language interface.

When practical, use `memcached` to store full items, rather than caching a single column value from the database. For example, when displaying a record about an object (invoice, user history, or blog post), load all the data for the associated entry from the database, and compile it into the internal structure that would normally be required by the application. Save the complete object in the cache.

Complex data structures cannot be stored directly. Most interfaces serialize the data for you, that is, put it in a textual form that can reconstruct the original pointers and nesting. Perl uses `Storable`, PHP uses `serialize`, Python uses `cPickle` (or `Pickle`) and Java uses the `Serializable` interface. In most cases, the serialization interface used is customizable. To share data stored in `memcached` instances between different language interfaces, consider using a common serialization solution such as JSON (Javascript Object Notation).

16.2.3.2 Using `memcached` as a MySQL Caching Layer

When using `memcached` to cache MySQL data, your application must retrieve data from the database and load the appropriate key-value pairs into the cache. Then, subsequent lookups can be done directly from the cache.

Because MySQL has its own in-memory caching mechanisms for queried data, such as the `InnoDB` buffer pool and the MySQL query cache, look for opportunities beyond loading individual column values or rows into the cache. Prefer to cache composite values, such as those retrieved from multiple tables through a join query, or result sets assembled from multiple rows.

Caution

Limit the information in the cache to non-sensitive data, because there is no security required to access or update the information within a `memcached` instance. Anybody with access to the machine has the ability to read, view and potentially update the information. To keep the data secure, encrypt the information before caching it. To restrict the users capable of connecting to the server, either disable network access, or use IPTables or similar techniques to restrict access to the `memcached` ports to a select set of hosts.

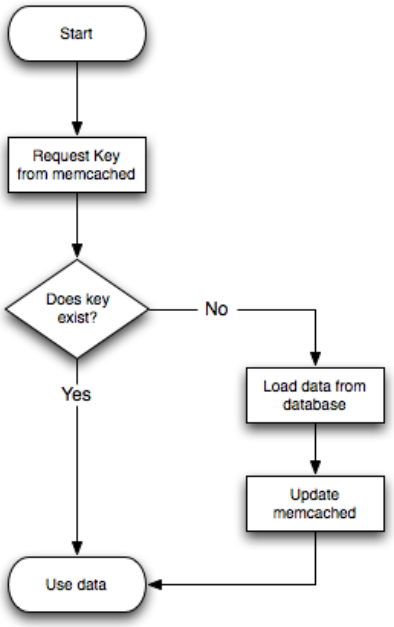
You can introduce `memcached` to an existing application, even if caching was not part of the original design. In many languages and environments the changes to the application will be just a few lines, first to attempt to read from the cache when loading data, fall back to the old method if the information is not cached, and to update the cache with information once the data has been read.

The general sequence for using memcached in any language as a caching solution for MySQL is as follows:

1. Request the item from the cache.
2. If the item exists, use the item data.
3. If the item does not exist, load the data from MySQL, and store the value into the cache. This means the value is available to the next client that requests it from the cache.

For a flow diagram of this sequence, see Figure 16.6, “Typical memcached Application Flowchart”.

Figure 16.6 Typical memcached Application Flowchart



Adapting Database Best Practices to memcached Applications

The most direct way to cache MySQL data is to use a 2-column table, where the first column is a primary key. Because of the uniqueness requirements for memcached keys, make sure your database schema makes appropriate use of primary keys and unique constraints.

If you combine multiple column values into a single memcached item value, choose data types to make it easy to parse the value back into its components, for example by using a separator character between numeric values.

The queries that map most easily to memcached lookups are those with a single WHERE clause, using an = or IN operator. For complicated WHERE clauses, or those using operators such as <, >, BETWEEN, or LIKE, memcached does not provide a simple or efficient way to scan through or filter the keys or associated values, so typically you perform those operations as SQL queries on the underlying database.

16.2.3.3 Using libmemcached with C and C++

The libmemcached library provides both C and C++ interfaces to memcached and is also the basis for a number of different additional API implementations, including Perl, Python and Ruby. Understanding the core libmemcached functions can help when using these other interfaces.

The C library is the most comprehensive interface library for memcached and provides functions and operational systems not always exposed in interfaces not based on the libmemcached library.

The different functions can be divided up according to their basic operation. In addition to functions that interface to the core API, a number of utility functions provide extended functionality, such as appending and prepending data.

To build and install libmemcached, download the libmemcached package, run configure, and then build and install:

```
shell> tar xjf libmemcached-0.21.tar.gz
shell> cd libmemcached-0.21
shell> ./configure
shell> make
shell> make install
```

On many Linux operating systems, you can install the corresponding libmemcached package through the usual yum, apt-get, or similar commands.

To build an application that uses the library, first set the list of servers. Either directly manipulate the servers configured within the main memcached_st structure, or separately populate a list of servers, and then add this list to the memcached_st structure. The latter method is used in the following example. Once the server list has been set, you can call the functions to store or retrieve data. A simple application for setting a preset value to localhost is provided here:

```
#include <stdio.h>
#include <string.h>
#include <unistd.h>
#include <libmemcached/memcached.h>

int main(int argc, char *argv[])
{
  memcached_server_st *servers = NULL;
  memcached_st *memc;
  memcached_return rc;
  char *key= "keystring";
  char *value= "keyvalue";

  memcached_server_st *memcached_servers_parse (char *server_strings);
  memc= memcached_create(NULL);

  servers= memcached_server_list_append(servers, "localhost", 11211, &rc);
  rc= memcached_server_push(memc, servers);

  if (rc == MEMCACHED_SUCCESS)
    fprintf(stderr,"Added server successfully\n");
  else
    fprintf(stderr,"Couldn't add server: %s\n",memcached_strerror(memc, rc));

  rc= memcached_set(memc, key, strlen(key), value, strlen(value), (time_t)0, (uint32_t)0);

  if (rc == MEMCACHED_SUCCESS)
    fprintf(stderr,"Key stored successfully\n");
  else
    fprintf(stderr,"Couldn't store key: %s\n",memcached_strerror(memc, rc));

  return 0;
}
```

To test the success of an operation, use the return value, or populated result code, for a given function. The value is always set to MEMCACHED_SUCCESS if the operation succeeded. In the event of a failure, use the memcached_strerror() function to translate the result code into a printable string.

To build the application, specify the memcached library:

```
shell> gcc -o memc_basic memc_basic.c -lmemcached
```

Running the above sample application, after starting a memcached server, should return a success message:

```
shell> memc_basic
Added server successfully
Key stored successfully
```

libmemcached Base Functions

The base libmemcached functions let you create, destroy and clone the main memcached_st structure that is used to interface with the memcached servers. The main functions are defined below:

```
memcached_st *memcached_create (memcached_st *ptr);
```

Creates a new memcached_st structure for use with the other libmemcached API functions. You can supply an existing, static, memcached_st structure, or NULL to have a new structured allocated. Returns a pointer to the created structure, or NULL on failure.

```
void memcached_free (memcached_st *ptr);
```

Frees the structure and memory allocated to a previously created memcached_st structure.

```
memcached_st *memcached_clone(memcached_st *clone, memcached_st *source);
```

Clones an existing memcached structure from the specified source, copying the defaults and list of servers defined in the structure.

libmemcached Server Functions

The libmemcached API uses a list of servers, stored within the memcached_server_st structure, to act as the list of servers used by the rest of the functions. To use memcached, you first create the server list, and then apply the list of servers to a valid libmemcached object.

Because the list of servers, and the list of servers within an active libmemcached object can be manipulated separately, you can update and manage server lists while an active libmemcached interface is running.

The functions for manipulating the list of servers within a memcached_st structure are:

```
memcached_return
   memcached_server_add (memcached_st *ptr,
                         char *hostname,
                         unsigned int port);
```

Adds a server, using the given hostname and port into the memcached_st structure given in ptr.

```
memcached_return
   memcached_server_add_unix_socket (memcached_st *ptr,
                                     char *socket);
```

Adds a Unix socket to the list of servers configured in the memcached_st structure.

```
unsigned int memcached_server_count (memcached_st *ptr);
```

Returns a count of the number of configured servers within the memcached_st structure.

```
memcached_server_st *
   memcached_server_list (memcached_st *ptr);
```

Returns an array of all the defined hosts within a memcached_st structure.

```
memcached_return
   memcached_server_push (memcached_st *ptr,
                          memcached_server_st *list);
```

Pushes an existing list of servers onto list of servers configured for a current memcached_st structure. This adds servers to the end of the existing list, and duplicates are not checked.

The memcached_server_st structure can be used to create a list of memcached servers which can then be applied individually to memcached_st structures.

```
memcached_server_st *
   memcached_server_list_append (memcached_server_st *ptr,
                                 char *hostname,
                                 unsigned int port,
                                 memcached_return *error);
```

Adds a server, with hostname and port, to the server list in ptr. The result code is handled by the error argument, which should point to an existing memcached_return variable. The function returns a pointer to the returned list.

```
unsigned int memcached_server_list_count (memcached_server_st *ptr);
```

Returns the number of the servers in the server list.

```
void memcached_server_list_free (memcached_server_st *ptr);
```

Frees the memory associated with a server list.

```
memcached_server_st *memcached_servers_parse (char *server_strings);
```

Parses a string containing a list of servers, where individual servers are separated by a comma, space, or both, and where individual servers are of the form *server*[:*port*]. The return value is a server list structure.

libmemcached Set Functions

The set-related functions within libmemcached provide the same functionality as the core functions supported by the memcached protocol. The full definition for the different functions is the same for all the base functions (add, replace, prepend, append). For example, the function definition for memcached_set() is:

```
memcached_return
   memcached_set (memcached_st *ptr,
                  const char *key,
                  size_t key_length,
                  const char *value,
                  size_t value_length,
                  time_t expiration,
                  uint32_t flags);
```

The ptr is the memcached_st structure. The key and key_length define the key name and length, and value and value_length the corresponding value and length. You can also set the expiration and optional flags. For more information, see Controlling libmemcached Behaviors.

This table outlines the remainder of the set-related libmemcached functions and the equivalent core functions supported by the memcached protocol.

libmemcached Function	Equivalent Core Function
memcached_set(memc, key, key_length, value, value_length, expiration, flags)	Generic set() operation.
memcached_add(memc, key, key_length, value, value_length, expiration, flags)	Generic add() function.
memcached_replace(memc, key, key_length, value, value_length, expiration, flags)	Generic replace().
memcached_prepend(memc, key, key_length, value, value_length, expiration, flags)	Prepends the specified value before the current value of the specified key.
memcached_append(memc, key, key_length, value, value_length, expiration, flags)	Appends the specified value after the current value of the specified key.
memcached_cas(memc, key, key_length, value, value_length, expiration, flags, cas)	Overwrites the data for a given key as long as the corresponding cas value is still the same within the server.
memcached_set_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)	Similar to the generic set(), but has the option of an additional master key that can be used to identify an individual server.
memcached_add_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)	Similar to the generic add(), but has the option of an additional master key that can be used to identify an individual server.
memcached_replace_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)	Similar to the generic replace(), but has the option of an additional master key that can be used to identify an individual server.
memcached_prepend_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)	Similar to the memcached_prepend(), but has the option of an additional master key that can be used to identify an individual server.
memcached_append_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)	Similar to the memcached_append(), but has the option of an additional master key that can be used to identify an individual server.
memcached_cas_by_key(memc, master_key, master_key_length, key, key_length, value, value_length, expiration, flags)	Similar to the memcached_cas(), but has the option of an additional master key that can be used to identify an individual server.

The by_key methods add two further arguments that define the master key, to be used and applied during the hashing stage for selecting the servers. You can see this in the following definition:

```
memcached_return
   memcached_set_by_key(memcached_st *ptr,
                        const char *master_key,
                        size_t master_key_length,
                        const char *key,
                        size_t key_length,
                        const char *value,
```

```
                        size_t value_length,
                        time_t expiration,
                        uint32_t flags);
```

All the functions return a value of type memcached_return, which you can compare against the MEMCACHED_SUCCESS constant.

libmemcached Get Functions

The libmemcached functions provide both direct access to a single item, and a multiple-key request mechanism that provides much faster responses when fetching a large number of keys simultaneously.

The main get-style function, which is equivalent to the generic get() is memcached_get(). This function returns a string pointer, pointing to the value associated with the specified key.

```
char *memcached_get (memcached_st *ptr,
                     const char *key, size_t key_length,
                     size_t *value_length,
                     uint32_t *flags,
                     memcached_return *error);
```

A multi-key get, memcached_mget(), is also available. Using a multiple key get operation is much quicker to do in one block than retrieving the key values with individual calls to memcached_get(). To start the multi-key get, call memcached_mget():

```
memcached_return
    memcached_mget (memcached_st *ptr,
                    char **keys, size_t *key_length,
                    unsigned int number_of_keys);
```

The return value is the success of the operation. The keys parameter should be an array of strings containing the keys, and key_length an array containing the length of each corresponding key. number_of_keys is the number of keys supplied in the array.

To fetch the individual values, use memcached_fetch() to get each corresponding value.

```
char *memcached_fetch (memcached_st *ptr,
                       const char *key, size_t *key_length,
                       size_t *value_length,
                       uint32_t *flags,
                       memcached_return *error);
```

The function returns the key value, with the key, key_length and value_length parameters being populated with the corresponding key and length information. The function returns NULL when there are no more values to be returned. A full example, including the populating of the key data and the return of the information is provided here.

```
#include <stdio.h>
#include <sstring.h>
#include <unistd.h>
#include <libmemcached/memcached.h>

int main(int argc, char *argv[])
{
  memcached_server_st *servers = NULL;
  memcached_st *memc;
  memcached_return rc;
  char *keys[]= {"huey", "dewey", "louie"};
  size_t key_length[3];
  char *values[]= {"red", "blue", "green"};
  size_t value_length[3];
  unsigned int x;
  uint32_t flags;
```

```
  char return_key[MEMCACHED_MAX_KEY];
  size_t return_key_length;
  char *return_value;
  size_t return_value_length;

  memc= memcached_create(NULL);

  servers= memcached_server_list_append(servers, "localhost", 11211, &rc);
  rc= memcached_server_push(memc, servers);

  if (rc == MEMCACHED_SUCCESS)
    fprintf(stderr,"Added server successfully\n");
  else
    fprintf(stderr,"Couldn't add server: %s\n",memcached_strerror(memc, rc));

  for(x= 0; x < 3; x++)
    {
      key_length[x] = strlen(keys[x]);
      value_length[x] = strlen(values[x]);

      rc= memcached_set(memc, keys[x], key_length[x], values[x],
                        value_length[x], (time_t)0, (uint32_t)0);
      if (rc == MEMCACHED_SUCCESS)
        fprintf(stderr,"Key %s stored successfully\n",keys[x]);
      else
        fprintf(stderr,"Couldn't store key: %s\n",memcached_strerror(memc, rc));
    }

  rc= memcached_mget(memc, keys, key_length, 3);

  if (rc == MEMCACHED_SUCCESS)
    {
      while ((return_value= memcached_fetch(memc, return_key, &return_key_length,
                                            &return_value_length, &flags, &rc)) != NULL)
        {
          if (rc == MEMCACHED_SUCCESS)
            {
              fprintf(stderr,"Key %s returned %s\n",return_key, return_value);
            }
        }
    }

  return 0;
}
```

Running the above application produces the following output:

```
shell> memc_multi_fetch
Added server successfully
Key huey stored successfully
Key dewey stored successfully
Key louie stored successfully
Key huey returned red
Key dewey returned blue
Key louie returned green
```

Controlling libmemcached Behaviors

The behavior of libmemcached can be modified by setting one or more behavior flags. These can either be set globally, or they can be applied during the call to individual functions. Some behaviors also accept an additional setting, such as the hashing mechanism used when selecting servers.

To set global behaviors:

```
memcached_return
   memcached_behavior_set (memcached_st *ptr,
                           memcached_behavior flag,
                           uint64_t data);
```

To get the current behavior setting:

```
uint64_t
   memcached_behavior_get (memcached_st *ptr,
                           memcached_behavior flag);
```

The following table describes libmemcached behavior flags.

Behavior	Description
MEMCACHED_BEHAVIOR_NO_BLOCK	Caused libmemcached to use asynchronous I/O.
MEMCACHED_BEHAVIOR_TCP_NODELAY	Turns on no-delay for network sockets.
MEMCACHED_BEHAVIOR_HASH	Without a value, sets the default hashing algorithm for keys to use MD5. Other valid values include MEMCACHED_HASH_DEFAULT, MEMCACHED_HASH_MD5, MEMCACHED_HASH_CRC, MEMCACHED_HASH_FNV1_64, MEMCACHED_HASH_FNV1A_64, MEMCACHED_HASH_FNV1_32, and MEMCACHED_HASH_FNV1A_32.
MEMCACHED_BEHAVIOR_DISTRIBUTION	Changes the method of selecting the server used to store a given value. The default method is MEMCACHED_DISTRIBUTION_MODULA. You can enable consistent hashing by setting MEMCACHED_DISTRIBUTION_CONSISTENT. MEMCACHED_DISTRIBUTION_CONSISTENT is an alias for the value MEMCACHED_DISTRIBUTION_CONSISTENT_KETAMA.
MEMCACHED_BEHAVIOR_CACHE_LOOKUPS	Cache the lookups made to the DNS service. This can improve the performance if you are using names instead of IP addresses for individual hosts.
MEMCACHED_BEHAVIOR_SUPPORT_CAS	Support CAS operations. By default, this is disabled because it imposes a performance penalty.
MEMCACHED_BEHAVIOR_KETAMA	Sets the default distribution to MEMCACHED_DISTRIBUTION_CONSISTENT_KETAMA and the hash to MEMCACHED_HASH_MD5.
MEMCACHED_BEHAVIOR_POLL_TIMEOUT	Modify the timeout value used by poll(). Supply a signed int pointer for the timeout value.
MEMCACHED_BEHAVIOR_BUFFER_REQUEST	Buffers IO requests instead of them being sent. A get operation, or closing the connection causes the data to be flushed.
MEMCACHED_BEHAVIOR_VERIFY_KEY	Forces libmemcached to verify that a specified key is valid.
MEMCACHED_BEHAVIOR_SORT_HOSTS	If set, hosts added to the list of configured hosts for a memcached_st structure are placed into the host list in sorted order. This breaks consistent hashing if that behavior has been enabled.
MEMCACHED_BEHAVIOR_CONNECT_TIMEOUT	In nonblocking mode this changes the value of the timeout during socket connection.

libmemcached Command-Line Utilities

In addition to the main C library interface, libmemcached also includes a number of command-line utilities that can be useful when working with and debugging memcached applications.

All of the command-line tools accept a number of arguments, the most critical of which is servers, which specifies the list of servers to connect to when returning information.

The main tools are:

- memcat: Display the value for each ID given on the command line:

```
shell> memcat --servers=localhost hwkey
Hello world
```

- memcp: Copy the contents of a file into the cache, using the file name as the key:

```
shell> echo "Hello World" > hwkey
shell> memcp --servers=localhost hwkey
shell> memcat --servers=localhost hwkey
Hello world
```

- memrm: Remove an item from the cache:

```
shell> memcat --servers=localhost hwkey
Hello world
shell> memrm --servers=localhost hwkey
shell> memcat --servers=localhost hwkey
```

- memslap: Test the load on one or more memcached servers, simulating get/set and multiple client operations. For example, you can simulate the load of 100 clients performing get operations:

```
shell> memslap --servers=localhost --concurrency=100 --flush --test=get
memslap --servers=localhost --concurrency=100 --flush --test=get Threads connecting to servers 100
 Took 13.571 seconds to read data
```

- memflush: Flush (empty) the contents of the memcached cache.

```
shell> memflush --servers=localhost
```

16.2.3.4 Using MySQL and memcached with Perl

The Cache::Memcached module provides a native interface to the Memcache protocol, and provides support for the core functions offered by memcached. Install the module using your operating system's package management system, or using CPAN:

```
root-shell> perl -MCPAN -e 'install Cache::Memcached'
```

To use memcached from Perl through the Cache::Memcached module, first create a new Cache::Memcached object that defines the list of servers and other parameters for the connection. The only argument is a hash containing the options for the cache interface. For example, to create a new instance that uses three memcached servers:

```
use Cache::Memcached;

my $cache = new Cache::Memcached {
    'servers' => [
        '198.51.100.100:11211',
        '198.51.100.101:11211',
        '198.51.100.102:11211',
 ],
};
```

Note

When using the Cache::Memcached interface with multiple servers, the API automatically performs certain operations across all the servers in the group. For example, getting statistical information through Cache::Memcached

> returns a hash that contains data on a host-by-host basis, as well as generalized statistics for all the servers in the group.

You can set additional properties on the cache object instance when it is created by specifying the option as part of the option hash. Alternatively, you can use a corresponding method on the instance:

- `servers` or method `set_servers()`: Specifies the list of the servers to be used. The servers list should be a reference to an array of servers, with each element as the address and port number combination (separated by a colon). You can also specify a local connection through a Unix socket (for example `/tmp/sock/memcached`). To specify the server with a weight (indicating how much more frequently the server should be used during hashing), specify an array reference with the `memcached` server instance and a weight number. Higher numbers give higher priority.
- `compress_threshold` or method `set_compress_threshold()`: Specifies the threshold when values are compressed. Values larger than the specified number are automatically compressed (using `zlib`) during storage and retrieval.
- `no_rehash` or method `set_norehash()`: Disables finding a new server if the original choice is unavailable.
- `readonly` or method `set_readonly()`: Disables writes to the `memcached` servers.

Once the `Cache::Memcached` object instance has been configured, you can use the `set()` and `get()` methods to store and retrieve information from the `memcached` servers. Objects stored in the cache are automatically serialized and deserialized using the `Storable` module.

The `Cache::Memcached` interface supports the following methods for storing/retrieving data, and relate to the generic methods as shown in the table.

`Cache::Memcached` Function	**Equivalent Generic Method**
`get()`	Generic `get()`.
`get_multi(keys)`	Gets multiple `keys` from memcache using just one query. Returns a hash reference of key/value pairs.
`set()`	Generic `set()`.
`add()`	Generic `add()`.
`replace()`	Generic `replace()`.
`delete()`	Generic `delete()`.
`incr()`	Generic `incr()`.
`decr()`	Generic `decr()`.

Below is a complete example for using `memcached` with Perl and the `Cache::Memcached` module:

```
#!/usr/bin/perl

use Cache::Memcached;
use DBI;
use Data::Dumper;

# Configure the memcached server

my $cache = new Cache::Memcached {
    'servers' => [
                  'localhost:11211',
                  ],
    };
```

```
# Get the film name from the command line
# memcached keys must not contain spaces, so create
# a key name by replacing spaces with underscores

my $filmname = shift or die "Must specify the film name\n";
my $filmkey = $filmname;
$filmkey =~ s/ /_/;

# Load the data from the cache

my $filmdata = $cache->get($filmkey);

# If the data wasn't in the cache, then we load it from the database

if (!defined($filmdata))
{
    $filmdata = load_filmdata($filmname);

    if (defined($filmdata))
    {

# Set the data into the cache, using the key

 if ($cache->set($filmkey,$filmdata))
        {
            print STDERR "Film data loaded from database and cached\n";
        }
        else
        {
            print STDERR "Couldn't store to cache\n";
 }
    }
    else
    {
      die "Couldn't find $filmname\n";
    }
}
else
{
    print STDERR "Film data loaded from Memcached\n";
}

sub load_filmdata
{
    my ($filmname) = @_;

    my $dsn = "DBI:mysql:database=sakila;host=localhost;port=3306";

    $dbh = DBI->connect($dsn, 'sakila','password');

    my ($filmbase) = $dbh->selectrow_hashref(sprintf('select * from film where title = %s',
                                                     $dbh->quote($filmname)));

    if (!defined($filmname))
    {
      return (undef);
    }

    $filmbase->{stars} =
 $dbh->selectall_arrayref(sprintf('select concat(first_name," ",last_name) ' .
                                        'from film_actor left join (actor) ' .
                                        'on (film_actor.actor_id = actor.actor_id) ' .
                                        ' where film_id=%s',
                                        $dbh->quote($filmbase->{film_id})));

    return($filmbase);
}
```

The example uses the Sakila database, obtaining film data from the database and writing a composite record of the film and actors to memcached. When calling it for a film does not exist, you get this result:

```
```

```
shell> memcached-sakila.pl "ROCK INSTINCT"
Film data loaded from database and cached
```

When accessing a film that has already been added to the cache:

```
shell> memcached-sakila.pl "ROCK INSTINCT"
Film data loaded from Memcached
```

16.2.3.5 Using MySQL and memcached with Python

The Python memcache module interfaces to memcached servers, and is written in pure Python (that is, without using one of the C APIs). You can download and install a copy from Python Memcached.

To install, download the package and then run the Python installer:

```
python setup.py install
running install
running bdist_egg
running egg_info
creating python_memcached.egg-info
...
removing 'build/bdist.linux-x86_64/egg' (and everything under it)
Processing python_memcached-1.43-py2.4.egg
creating /usr/lib64/python2.4/site-packages/python_memcached-1.43-py2.4.egg
Extracting python_memcached-1.43-py2.4.egg to /usr/lib64/python2.4/site-packages
Adding python-memcached 1.43 to easy-install.pth file

Installed /usr/lib64/python2.4/site-packages/python_memcached-1.43-py2.4.egg
Processing dependencies for python-memcached==1.43
Finished processing dependencies for python-memcached==1.43
```

Once installed, the memcache module provides a class-based interface to your memcached servers. When you store Python data structures as memcached items, they are automatically serialized (turned into string values) using the Python cPickle or pickle modules.

To create a new memcache interface, import the memcache module and create a new instance of the memcache.Client class. For example, if the memcached daemon is running on localhost using the default port:

```
import memcache
memc = memcache.Client(['127.0.0.1:11211'])
```

The first argument is an array of strings containing the server and port number for each memcached instance to use. To enable debugging, set the optional debug parameter to 1.

By default, the hashing mechanism used to divide the items among multiple servers is crc32. To change the function used, set the value of memcache.serverHashFunction to the alternate function to use. For example:

```
from zlib import adler32
memcache.serverHashFunction = adler32
```

Once you have defined the servers to use within the memcache instance, the core functions provide the same functionality as in the generic interface specification. The following table provides a summary of the supported functions:

Python memcache Function	Equivalent Generic Function
get()	Generic get().

Python memcache Function	Equivalent Generic Function
get_multi(keys)	Gets multiple values from the supplied array of keys. Returns a hash reference of key/value pairs.
set()	Generic set().
set_multi(dict [, expiry [, key_prefix]])	Sets multiple key/value pairs from the supplied dict.
add()	Generic add().
replace()	Generic replace().
prepend(key, value [, expiry])	Prepends the supplied value to the value of the existing key.
append(key, value [, expiry[)	Appends the supplied value to the value of the existing key.
delete()	Generic delete().
delete_multi(keys [, expiry [, key_prefix]])	Deletes all the keys from the hash matching each string in the array keys.
incr()	Generic incr().
decr()	Generic decr().

Note

Within the Python memcache module, all the *_multi()functions support an optional key_prefix parameter. If supplied, then the string is used as a prefix to all key lookups. For example, if you call:

```
memc.get_multi(['a','b'], key_prefix='users:')
```

The function retrieves the keys users:a and users:b from the servers.

Here is an example showing the storage and retrieval of information to a memcache instance, loading the raw data from MySQL:

```
import sys
import MySQLdb
import memcache

memc = memcache.Client(['127.0.0.1:11211'], debug=1);

try:
    conn = MySQLdb.connect (host = "localhost",
                            user = "sakila",
                            passwd = "password",
                            db = "sakila")
except MySQLdb.Error, e:
     print "Error %d: %s" % (e.args[0], e.args[1])
     sys.exit (1)

popularfilms = memc.get('top5films')

if not popularfilms:
    cursor = conn.cursor()
    cursor.execute('select film_id,title from film order by rental_rate desc limit 5')
    rows = cursor.fetchall()
    memc.set('top5films',rows,60)
    print "Updated memcached with MySQL data"
else:
    print "Loaded data from memcached"
    for row in popularfilms:
        print "%s, %s" % (row[0], row[1])
```

When executed for the first time, the data is loaded from the MySQL database and stored to the memcached server.

```
shell> python memc_python.py
Updated memcached with MySQL data
```

Because the data is automatically serialized using cPickle/pickle, when you load the data back from memcached, you can use the object directly. In the example above, the information stored to memcached is in the form of rows from a Python DB cursor. When accessing the information (within the 60 second expiry time), the data is loaded from memcached and dumped:

```
shell> python memc_python.py
Loaded data from memcached
2, ACE GOLDFINGER
7, AIRPLANE SIERRA
8, AIRPORT POLLOCK
10, ALADDIN CALENDAR
13, ALI FOREVER
```

The serialization and deserialization happens automatically. Because serialization of Python data may be incompatible with other interfaces and languages, you can change the serialization module used during initialization. For example, you might use JSON format when you store complex data structures using a script written in one language, and access them in a script written in a different language.

16.2.3.6 Using MySQL and memcached with PHP

PHP provides support for the Memcache functions through a PECL extension. To enable the PHP memcache extensions, build PHP using the --enable-memcache option to configure when building from source.

If you are installing on a Red Hat-based server, you can install the php-pecl-memcache RPM:

```
root-shell> yum --install php-pecl-memcache
```

On Debian-based distributions, use the php-memcache package.

To set global runtime configuration options, specify the configuration option values within your php.ini file. The following table provides the name, default value, and a description for each global runtime configuration option.

Configuration option	Default	Description
memcache.allow_failover	1	Specifies whether another server in the list should be queried if the first server selected fails.
memcache.max_failover_attempts	20	Specifies the number of servers to try before returning a failure.
memcache.chunk_size	8192	Defines the size of network chunks used to exchange data with the memcached server.
memcache.default_port	11211	Defines the default port to use when communicating with the memcached servers.
memcache.hash_strategy	standard	Specifies which hash strategy to use. Set to consistent to enable servers to be added or removed from the pool without causing the keys to be remapped to other servers. When set to standard, an older (modula) strategy

Configuration option	Default	Description
		is used that potentially uses different servers for storage.
memcache.hash_function	crc32	Specifies which function to use when mapping keys to servers. crc32 uses the standard CRC32 hash. fnv uses the FNV-1a hashing algorithm.

To create a connection to a memcached server, create a new Memcache object and then specify the connection options. For example:

```
<?php

$cache = new Memcache;
$cache->connect('localhost',11211);
?>
```

This opens an immediate connection to the specified server.

To use multiple memcached servers, you need to add servers to the memcache object using addServer():

```
bool Memcache::addServer ( string $host [, int $port [, bool $persistent
                [, int $weight [, int $timeout [, int $retry_interval
                [, bool $status [, callback $failure_callback
                ]]]]]] )
```

The server management mechanism within the php-memcache module is a critical part of the interface as it controls the main interface to the memcached instances and how the different instances are selected through the hashing mechanism.

To create a simple connection to two memcached instances:

```
<?php

$cache = new Memcache;
$cache->addServer('198.51.100.100',11211);
$cache->addServer('198.51.100.101',11211);
?>
```

In this scenario, the instance connection is not explicitly opened, but only opened when you try to store or retrieve a value. To enable persistent connections to memcached instances, set the $persistent argument to true. This is the default setting, and causes the connections to remain open.

To help control the distribution of keys to different instances, use the global memcache.hash_strategy setting. This sets the hashing mechanism used to select. You can also add another weight to each server, which effectively increases the number of times the instance entry appears in the instance list, therefore increasing the likelihood of the instance being chosen over other instances. To set the weight, set the value of the $weight argument to more than one.

The functions for setting and retrieving information are identical to the generic functional interface offered by memcached, as shown in this table:

PECL memcache Function	Generic Function
get()	Generic get().
set()	Generic set().
add()	Generic add().

PECL memcache Function	Generic Function
replace()	Generic replace().
delete()	Generic delete().
increment()	Generic incr().
decrement()	Generic decr().

A full example of the PECL memcache interface is provided below. The code loads film data from the Sakila database when the user provides a film name. The data stored into the memcached instance is recorded as a mysqli result row, and the API automatically serializes the information for you.

```
<?php

$memc = new Memcache;
$memc->addServer('localhost','11211');

if(empty($_POST['film'])) {
?>
  <html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en" lang="en">
    <head>
      <meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
      <title>Simple Memcache Lookup</title>
    </head>
    <body>
      <form method="post">
        <p><b>Film</b>: <input type="text" size="20" name="film"></p>
        <input type="submit">
      </form>
      <hr/>
<?php

} else {

    echo "Loading data...\n";

    $film   = htmlspecialchars($_POST['film'], ENT_QUOTES, 'UTF-8');
    $mfilms = $memc->get($film);

    if ($mfilms) {

        printf("<p>Film data for %s loaded from memcache</p>", $mfilms['title']);

        foreach (array_keys($mfilms) as $key) {
            printf("<p><b>%s</b>: %s</p>", $key, $mfilms[$key]);
        }

    } else {

        $mysqli = mysqli('localhost','sakila','password','sakila');

        if (mysqli_connect_error()) {
            sprintf("Database error: (%d) %s", mysqli_connect_errno(), mysqli_connect_error());
            exit;
        }

        $sql = sprintf('SELECT * FROM film WHERE title="%s"', $mysqli->real_escape_string($film));

        $result = $mysqli->query($sql);

        if (!$result) {
            sprintf("Database error: (%d) %s", $mysqli->errno, $mysqli->error);
            exit;
        }

        $row = $result->fetch_assoc();

        $memc->set($row['title'], $row);
```

```
        printf("<p>Loaded (%s) from MySQL</p>", htmlspecialchars($row['title'], ENT_QUOTES, 'UTF-8');
    }
}
?>
  </body>
</html>
```

With PHP, the connections to the memcached instances are kept open as long as the PHP and associated Apache instance remain running. When adding or removing servers from the list in a running instance (for example, when starting another script that mentions additional servers), the connections are shared, but the script only selects among the instances explicitly configured within the script.

To ensure that changes to the server list within a script do not cause problems, make sure to use the consistent hashing mechanism.

16.2.3.7 Using MySQL and memcached with Ruby

There are a number of different modules for interfacing to memcached within Ruby. The Ruby-MemCache client library provides a native interface to memcached that does not require any external libraries, such as libmemcached. You can obtain the installer package from http://www.deveiate.org/projects/RMemCache.

To install, extract the package and then run install.rb:

```
shell> install.rb
```

If you have RubyGems, you can install the Ruby-MemCache gem:

```
shell> gem install Ruby-MemCache
Bulk updating Gem source index for: http://gems.rubyforge.org
Install required dependency io-reactor? [Yn]  y
Successfully installed Ruby-MemCache-0.0.1
Successfully installed io-reactor-0.05
Installing ri documentation for io-reactor-0.05...
Installing RDoc documentation for io-reactor-0.05...
```

To use a memcached instance from within Ruby, create a new instance of the MemCache object.

```
require 'memcache'
memc = MemCache::new '198.51.100.100:11211'
```

You can add a weight to each server to increase the likelihood of the server being selected during hashing by appending the weight count to the server host name/port string:

```
require 'memcache'
memc = MemCache::new '198.51.100.100:11211:3'
```

To add servers to an existing list, you can append them directly to the MemCache object:

```
memc += ["198.51.100.101:11211"]
```

To set data into the cache, you can just assign a value to a key within the new cache object, which works just like a standard Ruby hash object:

```
memc["key"] = "value"
```

Or to retrieve the value:

```
print memc["key"]
```

For more explicit actions, you can use the method interface, which mimics the main memcached API functions, as summarized in the following table:

Ruby MemCache Method	Equivalent memcached API Functions
get()	Generic get().
get_hash(keys)	Get the values of multiple keys, returning the information as a hash of the keys and their values.
set()	Generic set().
set_many(pairs)	Set the values of the keys and values in the hash pairs.
add()	Generic add().
replace()	Generic replace().
delete()	Generic delete().
incr()	Generic incr().
decr()	Generic decr().

16.2.3.8 Using MySQL and memcached with Java

The com.danga.MemCached class within Java provides a native interface to memcached instances. You can obtain the client from https://github.com/gwhalin/Memcached-Java-Client/downloads. The Java class uses hashes that are compatible with libmemcached, so you can mix and match Java and libmemcached applications accessing the same memcached instances. The serialization between Java and other interfaces are not compatible. If this is a problem, use JSON or a similar nonbinary serialization format.

On most systems, you can download the package and use the jar directly.

To use the com.danga.MemCached interface, you create a MemCachedClient instance and then configure the list of servers by configuring the SockIOPool. Through the pool specification you set up the server list, weighting, and the connection parameters to optimized the connections between your client and the memcached instances that you configure.

Generally, you can configure the memcached interface once within a single class, then use this interface throughout the rest of your application.

For example, to create a basic interface, first configure the MemCachedClient and base SockIOPool settings:

```
public class MyClass {

    protected static MemCachedClient mcc = new MemCachedClient();

    static {

        String[] servers =
            {
                "localhost:11211",
            };

        Integer[] weights = { 1 };

        SockIOPool pool = SockIOPool.getInstance();
```

```
        pool.setServers( servers );
        pool.setWeights( weights );
```

In the above sample, the list of servers is configured by creating an array of the memcached instances to use. You can then configure individual weights for each server.

The remainder of the properties for the connection are optional, but you can set the connection numbers (initial connections, minimum connections, maximum connections, and the idle timeout) by setting the pool parameters:

```
pool.setInitConn( 5 );
pool.setMinConn( 5 );
pool.setMaxConn( 250 );
pool.setMaxIdle( 1000 * 60 * 60 * 6
```

Once the parameters have been configured, initialize the connection pool:

```
pool.initialize();
```

The pool, and the connection to your memcached instances should now be ready to use.

To set the hashing algorithm used to select the server used when storing a given key, use pool.setHashingAlg():

```
pool.setHashingAlg( SockIOPool.NEW_COMPAT_HASH );
```

Valid values are NEW_COMPAT_HASH, OLD_COMPAT_HASH and NATIVE_HASH are also basic modula hashing algorithms. For a consistent hashing algorithm, use CONSISTENT_HASH. These constants are equivalent to the corresponding hash settings within libmemcached.

The following table outlines the Java com.danga.MemCached methods and the equivalent generic methods in the memcached interface specification.

Java com.danga.MemCached Method	Equivalent Generic Method
get()	Generic get().
getMulti(keys)	Get the values of multiple keys, returning the information as Hash map using java.lang.String for the keys and java.lang.Object for the corresponding values.
set()	Generic set().
add()	Generic add().
replace()	Generic replace().
delete()	Generic delete().
incr()	Generic incr().
decr()	Generic decr().

16.2.3.9 Using the memcached TCP Text Protocol

Communicating with a memcached server can be achieved through either the TCP or UDP protocols. When using the TCP protocol, you can use a simple text based interface for the exchange of information.

When communicating with memcached, you can connect to the server using the port configured for the server. You can open a connection with the server without requiring authorization or login. As soon as you have connected, you can start to send commands to the server. When you have finished, you can terminate the connection without sending any specific disconnection command. Clients are encouraged to keep their connections open to decrease latency and improve performance.

Data is sent to the memcached server in two forms:

- Text lines, which are used to send commands to the server, and receive responses from the server.
- Unstructured data, which is used to receive or send the value information for a given key. Data is returned to the client in exactly the format it was provided.

Both text lines (commands and responses) and unstructured data are always terminated with the string \r\n. Because the data being stored may contain this sequence, the length of the data (returned by the client before the unstructured data is transmitted should be used to determine the end of the data.

Commands to the server are structured according to their operation:

- **Storage commands**: set, add, replace, append, prepend, cas

  Storage commands to the server take the form:

  ```
  command key [flags] [exptime] length [noreply]
  ```

  Or when using compare and swap (cas):

  ```
  cas key [flags] [exptime] length [casunique] [noreply]
  ```

  Where:

  - command: The command name.
    - set: Store value against key
    - add: Store this value against key if the key does not already exist
    - replace: Store this value against key if the key already exists
    - append: Append the supplied value to the end of the value for the specified key. The flags and exptime arguments should not be used.
    - prepend: Append value currently in the cache to the end of the supplied value for the specified key. The flags and exptime arguments should not be used.
    - cas: Set the specified key to the supplied value, only if the supplied casunique matches. This is effectively the equivalent of change the information if nobody has updated it since I last fetched it.
  - key: The key. All data is stored using a the specific key. The key cannot contain control characters or whitespace, and can be up to 250 characters in size.
  - flags: The flags for the operation (as an integer). Flags in memcached are transparent. The memcached server ignores the contents of the flags. They can be used by the client to indicate any type of information. In memcached 1.2.0 and lower the value is a 16-bit integer value. In memcached 1.2.1 and higher the value is a 32-bit integer.
  - exptime: The expiry time, or zero for no expiry.
  - length: The length of the supplied value block in bytes, excluding the terminating \r\n characters.

- casunique: A unique 64-bit value of an existing entry. This is used to compare against the existing value. Use the value returned by the gets command when issuing cas updates.
- noreply: Tells the server not to reply to the command.

For example, to store the value abcdef into the key xyzkey, you would use:

```
set xyzkey 0 0 6\r\nabcdef\r\n
```

The return value from the server is one line, specifying the status or error information. For more information, see Table 16.3, "memcached Protocol Responses".

- **Retrieval commands**: get, gets

Retrieval commands take the form:

```
get key1 [key2 .... keyn]
gets key1 [key2 ... keyn]
```

You can supply multiple keys to the commands, with each requested key separated by whitespace.

The server responds with an information line of the form:

```
VALUE key flags bytes [casunique]
```

Where:

- key: The key name.
- flags: The value of the flag integer supplied to the memcached server when the value was stored.
- bytes: The size (excluding the terminating \r\n character sequence) of the stored value.
- casunique: The unique 64-bit integer that identifies the item.

The information line is immediately followed by the value data block. For example:

```
get xyzkey\r\n
VALUE xyzkey 0 6\r\n
abcdef\r\n
```

If you have requested multiple keys, an information line and data block is returned for each key found. If a requested key does not exist in the cache, no information is returned.

- **Delete commands**: delete

Deletion commands take the form:

```
delete key [time] [noreply]
```

Where:

- key: The key name.
- time: The time in seconds (or a specific Unix time) for which the client wishes the server to refuse add or replace commands on this key. All add, replace, get, and gets commands fail during this period. set operations succeed. After this period, the key is deleted permanently and all commands are accepted.

If not supplied, the value is assumed to be zero (delete immediately).

- noreply: Tells the server not to reply to the command.

Responses to the command are either DELETED to indicate that the key was successfully removed, or NOT_FOUND to indicate that the specified key could not be found.

- **Increment/Decrement**: incr, decr

The increment and decrement commands change the value of a key within the server without performing a separate get/set sequence. The operations assume that the currently stored value is a 64-bit integer. If the stored value is not a 64-bit integer, then the value is assumed to be zero before the increment or decrement operation is applied.

Increment and decrement commands take the form:

```
incr key value [noreply]
decr key value [noreply]
```

Where:

- key: The key name.
- value: An integer to be used as the increment or decrement value.
- noreply: Tells the server not to reply to the command.

The response is:

- NOT_FOUND: The specified key could not be located.
- value: The new value associated with the specified key.

Values are assumed to be unsigned. For decr operations, the value is never decremented below 0. For incr operations, the value wraps around the 64-bit maximum.

- **Statistics commands**: stats

The stats command provides detailed statistical information about the current status of the memcached instance and the data it is storing.

Statistics commands take the form:

```
STAT [name] [value]
```

Where:

- name: The optional name of the statistics to return. If not specified, the general statistics are returned.
- value: A specific value to be used when performing certain statistics operations.

The return value is a list of statistics data, formatted as follows:

```
STAT name value
```

The statistics are terminated with a single line, END.

For more information, see Section 16.2.4, “Getting memcached Statistics”.

For reference, a list of the different commands supported and their formats is provided below.

Table 16.2 memcached Command Reference

Command	Command Formats
set	set key flags exptime length, set key flags exptime length noreply
add	add key flags exptime length, add key flags exptime length noreply
replace	replace key flags exptime length, replace key flags exptime length noreply
append	append key length, append key length noreply
prepend	prepend key length, prepend key length noreply
cas	cas key flags exptime length casunique, cas key flags exptime length casunique noreply
get	get key1 [key2 ... keyn]
gets	
delete	delete key, delete key noreply, delete key expiry, delete key expiry noreply
incr	incr key, incr key noreply, incr key value, incr key value noreply
decr	decr key, decr key noreply, decr key value, decr key value noreply
stat	stat, stat name, stat name value

When sending a command to the server, the response from the server is one of the settings in the following table. All response values from the server are terminated by \r\n:

Table 16.3 memcached Protocol Responses

String	Description
STORED	Value has successfully been stored.
NOT_STORED	The value was not stored, but not because of an error. For commands where you are adding a or updating a value if it exists (such as add and replace), or where the item has already been set to be deleted.
EXISTS	When using a cas command, the item you are trying to store already exists and has been modified since you last checked it.
NOT_FOUND	The item you are trying to store, update or delete does not exist or has already been deleted.
ERROR	You submitted a nonexistent command name.
CLIENT_ERROR errorstring	There was an error in the input line, the detail is contained in errorstring.
SERVER_ERROR errorstring	There was an error in the server that prevents it from returning the information. In extreme conditions, the server may disconnect the client after this error occurs.
VALUE keys flags length	The requested key has been found, and the stored key, flags and data block are returned, of the specified length.
DELETED	The requested key was deleted from the server.
STAT name value	A line of statistics data.

String	Description
END	The end of the statistics data.

16.2.4 Getting memcached Statistics

The memcached system has a built-in statistics system that collects information about the data being stored into the cache, cache hit ratios, and detailed information on the memory usage and distribution of information through the slab allocation used to store individual items. Statistics are provided at both a basic level that provide the core statistics, and more specific statistics for specific areas of the memcached server.

This information can be useful to ensure that you are getting the correct level of cache and memory usage, and that your slab allocation and configuration properties are set at an optimal level.

The stats interface is available through the standard memcached protocol, so the reports can be accessed by using telnet to connect to the memcached. The supplied memcached-tool includes support for obtaining the Section 16.2.4.2, “memcached Slabs Statistics” and Section 16.2.4.1, “memcached General Statistics” information. For more information, see Section 16.2.4.6, “Using memcached-tool”.

Alternatively, most of the language API interfaces provide a function for obtaining the statistics from the server.

For example, to get the basic stats using telnet:

```
shell> telnet localhost 11211
Trying ::1...
Connected to localhost.
Escape character is '^]'.
stats
STAT pid 23599
STAT uptime 675
STAT time 1211439587
STAT version 1.2.5
STAT pointer_size 32
STAT rusage_user 1.404992
STAT rusage_system 4.694685
STAT curr_items 32
STAT total_items 56361
STAT bytes 2642
STAT curr_connections 53
STAT total_connections 438
STAT connection_structures 55
STAT cmd_get 113482
STAT cmd_set 80519
STAT get_hits 78926
STAT get_misses 34556
STAT evictions 0
STAT bytes_read 6379783
STAT bytes_written 4860179
STAT limit_maxbytes 67108864
STAT threads 1
END
```

When using Perl and the Cache::Memcached module, the stats() function returns information about all the servers currently configured in the connection object, and total statistics for all the memcached servers as a whole.

For example, the following Perl script obtains the stats and dumps the hash reference that is returned:

```
use Cache::Memcached;
use Data::Dumper;

my $memc = new Cache::Memcached;
```

```
$memc->set_servers(\@ARGV);

print Dumper($memc->stats());
```

When executed on the same memcached as used in the Telnet example above we get a hash reference with the host by host and total statistics:

```
$VAR1 = {
    'hosts' => {
           'localhost:11211' => {
                      'misc' => {
                            'bytes' => '2421',
                            'curr_connections' => '3',
                            'connection_structures' => '56',
                            'pointer_size' => '32',
                            'time' => '1211440166',
                            'total_items' => '410956',
                            'cmd_set' => '588167',
                            'bytes_written' => '35715151',
                            'evictions' => '0',
                            'curr_items' => '31',
                            'pid' => '23599',
                            'limit_maxbytes' => '67108864',
                            'uptime' => '1254',
                            'rusage_user' => '9.857805',
                            'cmd_get' => '838451',
                            'rusage_system' => '34.096988',
                            'version' => '1.2.5',
                            'get_hits' => '581511',
                            'bytes_read' => '46665716',
                            'threads' => '1',
                            'total_connections' => '3104',
                            'get_misses' => '256940'
                          },
                      'sizes' => {
                             '128' => '16',
                             '64' => '15'
                           }
                    }
         },
    'self' => {},
    'total' => {
           'cmd_get' => 838451,
           'bytes' => 2421,
           'get_hits' => 581511,
           'connection_structures' => 56,
           'bytes_read' => 46665716,
           'total_items' => 410956,
           'total_connections' => 3104,
           'cmd_set' => 588167,
           'bytes_written' => 35715151,
           'curr_items' => 31,
           'get_misses' => 256940
         }
       };
```

The statistics are divided up into a number of distinct sections, and then can be requested by adding the type to the stats command. Each statistics output is covered in more detail in the following sections.

- General statistics, see Section 16.2.4.1, “memcached General Statistics”.
- Slab statistics (slabs), see Section 16.2.4.2, “memcached Slabs Statistics”.
- Item statistics (items), see Section 16.2.4.3, “memcached Item Statistics”.
- Size statistics (sizes), see Section 16.2.4.4, “memcached Size Statistics”.
- Detailed status (detail), see Section 16.2.4.5, “memcached Detail Statistics”.

16.2.4.1 memcached General Statistics

The output of the general statistics provides an overview of the performance and use of the memcached instance. The statistics returned by the command and their meaning is shown in the following table.

The following terms are used to define the value type for each statistics value:

- 32u: 32-bit unsigned integer
- 64u: 64-bit unsigned integer
- 32u:32u: Two 32-bit unsigned integers separated by a colon
- String: Character string

Statistic	Data type	Description	Version
pid	32u	Process ID of the memcached instance.	
uptime	32u	Uptime (in seconds) for this memcached instance.	
time	32u	Current time (as epoch).	
version	string	Version string of this instance.	
pointer_size	string	Size of pointers for this host specified in bits (32 or 64).	
rusage_user	32u:32u	Total user time for this instance (seconds:microseconds).	
rusage_system	32u:32u	Total system time for this instance (seconds:microseconds).	
curr_items	32u	Current number of items stored by this instance.	
total_items	32u	Total number of items stored during the life of this instance.	
bytes	64u	Current number of bytes used by this server to store items.	
curr_connections	32u	Current number of open connections.	
total_connections	32u	Total number of connections opened since the server started running.	
connection_structures	32u	Number of connection structures allocated by the server.	
cmd_get	64u	Total number of retrieval requests (get operations).	
cmd_set	64u	Total number of storage requests (set operations).	
get_hits	64u	Number of keys that have been requested and found present.	
get_misses	64u	Number of items that have been requested and not found.	
delete_hits	64u	Number of keys that have been deleted and found present.	1.3.x
delete_misses	64u	Number of items that have been delete and not found.	1.3.x
incr_hits	64u	Number of keys that have been incremented and found present.	1.3.x
incr_misses	64u	Number of items that have been incremented and not found.	1.3.x
decr_hits	64u	Number of keys that have been decremented and found present.	1.3.x

Statistic	Data type	Description	Version
decr_misses	64u	Number of items that have been decremented and not found.	1.3.x
cas_hits	64u	Number of keys that have been compared and swapped and found present.	1.3.x
cas_misses	64u	Number of items that have been compared and swapped and not found.	1.3.x
cas_badvalue	64u	Number of keys that have been compared and swapped, but the comparison (original) value did not match the supplied value.	1.3.x
evictions	64u	Number of valid items removed from cache to free memory for new items.	
bytes_read	64u	Total number of bytes read by this server from network.	
bytes_written	64u	Total number of bytes sent by this server to network.	
limit_maxbytes	32u	Number of bytes this server is permitted to use for storage.	
threads	32u	Number of worker threads requested.	
conn_yields	64u	Number of yields for connections (related to the -R option).	1.4.0

The most useful statistics from those given here are the number of cache hits, misses, and evictions.

A large number of get_misses may just be an indication that the cache is still being populated with information. The number should, over time, decrease in comparison to the number of cache get_hits. If, however, you have a large number of cache misses compared to cache hits after an extended period of execution, it may be an indication that the size of the cache is too small and you either need to increase the total memory size, or increase the number of the memcached instances to improve the hit ratio.

A large number of evictions from the cache, particularly in comparison to the number of items stored is a sign that your cache is too small to hold the amount of information that you regularly want to keep cached. Instead of items being retained in the cache, items are being evicted to make way for new items keeping the turnover of items in the cache high, reducing the efficiency of the cache.

16.2.4.2 memcached Slabs Statistics

To get the slabs statistics, use the stats slabs command, or the API equivalent.

The slab statistics provide you with information about the slabs that have created and allocated for storing information within the cache. You get information both on each individual slab-class and total statistics for the whole slab.

```
STAT 1:chunk_size 104
STAT 1:chunks_per_page 10082
STAT 1:total_pages 1
STAT 1:total_chunks 10082
STAT 1:used_chunks 10081
STAT 1:free_chunks 1
STAT 1:free_chunks_end 10079
STAT 9:chunk_size 696
STAT 9:chunks_per_page 1506
STAT 9:total_pages 63
STAT 9:total_chunks 94878
STAT 9:used_chunks 94878
STAT 9:free_chunks 0
STAT 9:free_chunks_end 0
STAT active_slabs 2
```

```
STAT total_malloced 67083616
END
```

Individual stats for each slab class are prefixed with the slab ID. A unique ID is given to each allocated slab from the smallest size up to the largest. The prefix number indicates the slab class number in relation to the calculated chunk from the specified growth factor. Hence in the example, 1 is the first chunk size and 9 is the 9th chunk allocated size.

The parameters returned for each chunk size and a description of each parameter are provided in the following table.

Statistic	Description	Version
chunk_size	Space allocated to each chunk within this slab class.	
chunks_per_page	Number of chunks within a single page for this slab class.	
total_pages	Number of pages allocated to this slab class.	
total_chunks	Number of chunks allocated to the slab class.	
used_chunks	Number of chunks allocated to an item..	
free_chunks	Number of chunks not yet allocated to items.	
free_chunks_end	Number of free chunks at the end of the last allocated page.	
get_hits	Number of get hits to this chunk	1.3.x
cmd_set	Number of set commands on this chunk	1.3.x
delete_hits	Number of delete hits to this chunk	1.3.x
incr_hits	Number of increment hits to this chunk	1.3.x
decr_hits	Number of decrement hits to this chunk	1.3.x
cas_hits	Number of CAS hits to this chunk	1.3.x
cas_badval	Number of CAS hits on this chunk where the existing value did not match	1.3.x
mem_requested	The true amount of memory of memory requested within this chunk	1.4.1

The following additional statistics cover the information for the entire server, rather than on a chunk by chunk basis:

Statistic	Description	Version
active_slabs	Total number of slab classes allocated.	
total_malloced	Total amount of memory allocated to slab pages.	

The key values in the slab statistics are the chunk_size, and the corresponding total_chunks and used_chunks parameters. These given an indication of the size usage of the chunks within the system. Remember that one key/value pair is placed into a chunk of a suitable size.

From these stats, you can get an idea of your size and chunk allocation and distribution. If you store many items with a number of largely different sizes, consider adjusting the chunk size growth factor to increase in larger steps to prevent chunk and memory wastage. A good indication of a bad growth factor is a high number of different slab classes, but with relatively few chunks actually in use within each slab. Increasing the growth factor creates fewer slab classes and therefore makes better use of the allocated pages.

16.2.4.3 memcached Item Statistics

To get the items statistics, use the stats items command, or the API equivalent.

The items statistics give information about the individual items allocated within a given slab class.

```
STAT items:2:number 1
STAT items:2:age 452
STAT items:2:evicted 0
STAT items:2:evicted_nonzero 0
STAT items:2:evicted_time 2
STAT items:2:outofmemory 0
STAT items:2:tailrepairs 0
...
STAT items:27:number 1
STAT items:27:age 452
STAT items:27:evicted 0
STAT items:27:evicted_nonzero 0
STAT items:27:evicted_time 2
STAT items:27:outofmemory 0
STAT items:27:tailrepairs 0
```

The prefix number against each statistics relates to the corresponding chunk size, as returned by the stats slabs statistics. The result is a display of the number of items stored within each chunk within each slab size, and specific statistics about their age, eviction counts, and out of memory counts. A summary of the statistics is given in the following table.

Statistic	Description	
number	The number of items currently stored in this slab class.	
age	The age of the oldest item within the slab class, in seconds.	
evicted	The number of items evicted to make way for new entries.	
evicted_time	The time of the last evicted entry	
evicted_nonzero	The time of the last evicted non-zero entry	1.4.0
outofmemory	The number of items for this slab class that have triggered an out of memory error (only value when the -M command line option is in effect).	
tailrepairs	Number of times the entries for a particular ID need repairing	

Item level statistics can be used to determine how many items are stored within a given slab and their freshness and recycle rate. You can use this to help identify whether there are certain slab classes that are triggering a much larger number of evictions that others.

16.2.4.4 memcached Size Statistics

To get size statistics, use the stats sizes command, or the API equivalent.

The size statistics provide information about the sizes and number of items of each size within the cache. The information is returned as two columns, the first column is the size of the item (rounded up to the nearest 32 byte boundary), and the second column is the count of the number of items of that size within the cache:

```
96 35
128 38
160 807
192 804
224 410
256 222
288 83
320 39
352 53
384 33
416 64
448 51
```

```
480 30
512 54
544 39
576 10065
```

Caution

Running this statistic locks up your cache as each item is read from the cache and its size calculated. On a large cache, this may take some time and prevent any set or get operations until the process completes.

The item size statistics are useful only to determine the sizes of the objects you are storing. Since the actual memory allocation is relevant only in terms of the chunk size and page size, the information is only useful during a careful debugging or diagnostic session.

16.2.4.5 memcached Detail Statistics

For memcached 1.3.x and higher, you can enable and obtain detailed statistics about the get, set, and del operations on theindividual keys stored in the cache, and determine whether the attempts hit (found) a particular key. These operations are only recorded while the detailed stats analysis is turned on.

To enable detailed statistics, you must send the stats detail on command to the memcached server:

```
$ telnet localhost 11211
Trying 127.0.0.1...
Connected to tiger.
Escape character is '^]'.
stats detail on
OK
```

Individual statistics are recorded for every get, set and del operation on a key, including keys that are not currently stored in the server. For example, if an attempt is made to obtain the value of key abckey and it does not exist, the get operating on the specified key are recorded while detailed statistics are in effect, even if the key is not currently stored. The hits, that is, the number of get or del operations for a key that exists in the server are also counted.

To turn detailed statistics off, send the stats detail off command to the memcached server:

```
$ telnet localhost 11211
Trying 127.0.0.1...
Connected to tiger.
Escape character is '^]'.
stats detail off
OK
```

To obtain the detailed statistics recorded during the process, send the stats detail dump command to the memcached server:

```
stats detail dump
PREFIX hykkey get 0 hit 0 set 1 del 0
PREFIX xyzkey get 0 hit 0 set 1 del 0
PREFIX yukkey get 1 hit 0 set 0 del 0
PREFIX abckey get 3 hit 3 set 1 del 0
END
```

You can use the detailed statistics information to determine whether your memcached clients are using a large number of keys that do not exist in the server by comparing the hit and get or del counts. Because the information is recorded by key, you can also determine whether the failures or operations are clustered around specific keys.

16.2.4.6 Using memcached-tool

The memcached-tool, located within the scripts directory within the memcached source directory. The tool provides convenient access to some reports and statistics from any memcached instance.

The basic format of the command is:

```
shell> ./memcached-tool hostname:port [command]
```

The default output produces a list of the slab allocations and usage. For example:

```
shell> memcached-tool localhost:11211 display
  #  Item_Size  Max_age   Pages   Count   Full?  Evicted Evict_Time OOM
  1      80B        93s       1      20      no        0        0    0
  2     104B        93s       1      16      no        0        0    0
  3     136B      1335s       1      28      no        0        0    0
  4     176B      1335s       1      24      no        0        0    0
  5     224B      1335s       1      32      no        0        0    0
  6     280B      1335s       1      34      no        0        0    0
  7     352B      1335s       1      36      no        0        0    0
  8     440B      1335s       1      46      no        0        0    0
  9     552B      1335s       1      58      no        0        0    0
 10     696B      1335s       1      66      no        0        0    0
 11     872B      1335s       1      89      no        0        0    0
 12     1.1K      1335s       1     112      no        0        0    0
 13     1.3K      1335s       1     145      no        0        0    0
 14     1.7K      1335s       1     123      no        0        0    0
 15     2.1K      1335s       1     198      no        0        0    0
 16     2.6K      1335s       1     199      no        0        0    0
 17     3.3K      1335s       1     229      no        0        0    0
 18     4.1K      1335s       1     248     yes       36        2    0
 19     5.2K      1335s       2     328      no        0        0    0
 20     6.4K      1335s       2     316     yes      387        1    0
 21     8.1K      1335s       3     381     yes      492        1    0
 22    10.1K      1335s       3     303     yes      598        2    0
 23    12.6K      1335s       5     405     yes      605        1    0
 24    15.8K      1335s       6     384     yes      766        2    0
 25    19.7K      1335s       7     357     yes      908      170    0
 26    24.6K      1336s       7     287     yes     1012        1    0
 27    30.8K      1336s       7     231     yes     1193      169    0
 28    38.5K      1336s       4     104     yes     1323      169    0
 29    48.1K      1336s       1      21     yes     1287        1    0
 30    60.2K      1336s       1      17     yes     1093      169    0
 31    75.2K      1337s       1      13     yes      713      168    0
 32    94.0K      1337s       1      10     yes      278      168    0
 33   117.5K      1336s       1       3      no        0        0    0
```

This output is the same if you specify the command as display:

```
shell> memcached-tool localhost:11211 display
  #  Item_Size  Max_age   Pages   Count   Full?  Evicted Evict_Time OOM
  1      80B        93s       1      20      no        0        0    0
  2     104B        93s       1      16      no        0        0    0
...
```

The output shows a summarized version of the output from the slabs statistics. The columns provided in the output are shown below:

- #: The slab number
- Item_Size: The size of the slab
- Max_age: The age of the oldest item in the slab
- Pages: The number of pages allocated to the slab

- Count: The number of items in this slab
- Full?: Whether the slab is fully populated
- Evicted: The number of objects evicted from this slab
- Evict_Time: The time (in seconds) since the last eviction
- OOM: The number of items that have triggered an out of memory error

You can also obtain a dump of the general statistics for the server using the stats command:

```
shell> memcached-tool localhost:11211 stats
#localhost:11211   Field       Value
         accepting_conns           1
                   bytes         162
              bytes_read         485
           bytes_written        6820
              cas_badval           0
                cas_hits           0
              cas_misses           0
               cmd_flush           0
                 cmd_get           4
                 cmd_set           2
             conn_yields           0
   connection_structures          11
        curr_connections          10
              curr_items           2
               decr_hits           0
             decr_misses           1
             delete_hits           0
           delete_misses           0
               evictions           0
                get_hits           4
              get_misses           0
               incr_hits           0
             incr_misses           2
          limit_maxbytes    67108864
     listen_disabled_num           0
                     pid       12981
           pointer_size          32
          rusage_system    0.013911
            rusage_user    0.011876
                threads           4
                   time  1255518565
       total_connections          20
             total_items           2
                  uptime         880
                 version       1.4.2
```

16.2.5 memcached FAQ

16.2.5.1 Can memcached be run on a Windows environment? 1877
16.2.5.2 What is the maximum size of an object you can store in memcached? Is that configurable? 1877
16.2.5.3 Is it true memcached will be much more effective with db-read-intensive applications than with db-write-intensive applications? 1877
16.2.5.4 Is there any overhead in not using persistent connections? If persistent is always recommended, what are the downsides (for example, locking up)? 1877
16.2.5.5 How is an event such as a crash of one of the memcached servers handled by the memcached client? 1877
16.2.5.6 What is a recommended hardware configuration for a memcached server? 1878
16.2.5.7 Is memcached more effective for video and audio as opposed to textual read/writes? 1878
16.2.5.8 Can memcached work with ASPX? 1878
16.2.5.9 How expensive is it to establish a memcache connection? Should those connections be pooled? 1878

16.2.5.10 How is the data handled when the memcached server is down? 1878
16.2.5.11 How are auto-increment columns in the MySQL database coordinated across multiple instances of memcached? 1878
16.2.5.12 Is compression available? 1878
16.2.5.13 Can we implement different types of memcached as different nodes in the same server, so can there be deterministic and non-deterministic in the same server? 1878
16.2.5.14 What are best practices for testing an implementation, to ensure that it improves performance, and to measure the impact of memcached configuration changes? And would you recommend keeping the configuration very simple to start? 1879

16.2.5.1 Can memcached be run on a Windows environment?

No. Currently memcached is available only on the Unix/Linux platform. There is an unofficial port available, see http://www.codeplex.com/memcachedproviders.

16.2.5.2 What is the maximum size of an object you can store in memcached? Is that configurable?

The default maximum object size is 1MB. In memcached 1.4.2 and later, you can change the maximum size of an object using the `-I` command line option.

For versions before this, to increase this size, you have to re-compile memcached. You can modify the value of the `POWER_BLOCK` within the `slabs.c` file within the source.

In memcached 1.4.2 and higher, you can configure the maximum supported object size by using the `-I` command-line option. For example, to increase the maximum object size to 5MB:

```
$ memcached -I 5m
```

If an object is larger than the maximum object size, you must manually split it. memcached is very simple: you give it a key and some data, it tries to cache it in RAM. If you try to store more than the default maximum size, the value is just truncated for speed reasons.

16.2.5.3 Is it true memcached will be much more effective with db-read-intensive applications than with db-write-intensive applications?

Yes. memcached plays no role in database writes, it is a method of caching data already read from the database in RAM.

16.2.5.4 Is there any overhead in not using persistent connections? If persistent is always recommended, what are the downsides (for example, locking up)?

If you don't use persistent connections when communicating with memcached, there will be a small increase in the latency of opening the connection each time. The effect is comparable to use nonpersistent connections with MySQL.

In general, the chance of locking or other issues with persistent connections is minimal, because there is very little locking within memcached. If there is a problem, eventually your request will time out and return no result, so your application will need to load from MySQL again.

16.2.5.5 How is an event such as a crash of one of the memcached servers handled by the memcached client?

There is no automatic handling of this. If your client fails to get a response from a server, code a fallback mechanism to load the data from the MySQL database.

The client APIs all provide the ability to add and remove memcached instances on the fly. If within your application you notice that memcached server is no longer responding, you can remove the server from the list of servers, and keys will automatically be redistributed to another memcached server in the list. If retaining the cache content on all your servers is important, make sure you use an API that supports a consistent hashing algorithm. For more information, see Section 16.2.2.5, “memcached Hashing/Distribution Types”.

16.2.5.6. What is a recommended hardware configuration for a memcached server?

memcached has a very low processing overhead. All that is required is spare physical RAM capacity. A memcached server does not require a dedicated machine. If you have web, application, or database servers that have spare RAM capacity, then use them with memcached.

To build and deploy a dedicated memcached server, use a relatively low-power CPU, lots of RAM, and one or more Gigabit Ethernet interfaces.

16.2.5.7. Is memcached more effective for video and audio as opposed to textual read/writes?

memcached works equally well for all kinds of data. To memcached, any value you store is just a stream of data. Remember, though, that the maximum size of an object you can store in memcached is 1MB, but can be configured to be larger by using the -I option in memcached 1.4.2 and later, or by modifying the source in versions before 1.4.2. If you plan on using memcached with audio and video content, you will probably want to increase the maximum object size. Also remember that memcached is a solution for caching information for reading. It shouldn't be used for writes, except when updating the information in the cache.

16.2.5.8. Can memcached work with ASPX?

There are ports and interfaces for many languages and environments. ASPX relies on an underlying language such as C# or VisualBasic, and if you are using ASP.NET then there is a C# memcached library. For more information, see https://sourceforge.net/projects/memcacheddotnet/.

16.2.5.9. How expensive is it to establish a memcache connection? Should those connections be pooled?

Opening the connection is relatively inexpensive, because there is no security, authentication or other handshake taking place before you can start sending requests and getting results. Most APIs support a persistent connection to a memcached instance to reduce the latency. Connection pooling would depend on the API you are using, but if you are communicating directly over TCP/IP, then connection pooling would provide some small performance benefit.

16.2.5.10. How is the data handled when the memcached server is down?

The behavior is entirely application dependent. Most applications fall back to loading the data from the database (just as if they were updating the memcached information). If you are using multiple memcached servers, you might also remove a downed server from the list to prevent it from affecting performance. Otherwise, the client will still attempt to communicate with the memcached server that corresponds to the key you are trying to load.

16.2.5.11. How are auto-increment columns in the MySQL database coordinated across multiple instances of memcached?

They aren't. There is no relationship between MySQL and memcached unless your application (or, if you are using the MySQL UDFs for memcached, your database definition) creates one.

If you are storing information based on an auto-increment key into multiple instances of memcached, the information is only stored on one of the memcached instances anyway. The client uses the key value to determine which memcached instance to store the information. It doesn't store the same information across all the instances, as that would be a waste of cache memory.

16.2.5.12. Is compression available?

Yes. Most of the client APIs support some sort of compression, and some even allow you to specify the threshold at which a value is deemed appropriate for compression during storage.

16.2.5.13. Can we implement different types of memcached as different nodes in the same server, so can there be deterministic and non-deterministic in the same server?

Yes. You can run multiple instances of memcached on a single server, and in your client configuration you choose the list of servers you want to use.

16.2.5.14: What are best practices for testing an implementation, to ensure that it improves performance, and to measure the impact of memcached configuration changes? And would you recommend keeping the configuration very simple to start?

The best way to test the performance is to start up a memcached instance. First, modify your application so that it stores the data just before the data is about to be used or displayed into memcached. Since the APIs handle the serialization of the data, it should just be a one-line modification to your code. Then, modify the start of the process that would normally load that information from MySQL with the code that requests the data from memcached. If the data cannot be loaded from memcached, default to the MySQL process.

All of the changes required will probably amount to just a few lines of code. To get the best benefit, make sure you cache entire objects (for example, all the components of a web page, blog post, discussion thread, and so on), rather than using memcached as a simple cache of individual rows of MySQL tables.

Keeping the configuration simple at the start, or even over the long term, is easy with memcached. Once you have the basic structure up and running, often the only ongoing change is to add more servers into the list of servers used by your applications. You don't need to manage the memcached servers, and there is no complex configuration; just add more servers to the list and let the client API and the memcached servers make the decisions.

Chapter 17 Replication

Table of Contents

17.1 Replication Configuration 1882
17.1.1 How to Set Up Replication 1883
17.1.2 Replication Formats 1892
17.1.3 Replication and Binary Logging Options and Variables 1899
17.1.4 Common Replication Administration Tasks 1948
17.2 Replication Implementation 1951
17.2.1 Replication Implementation Details 1951
17.2.2 Replication Relay and Status Logs 1953
17.2.3 How Servers Evaluate Replication Filtering Rules 1955
17.3 Replication Solutions 1962
17.3.1 Using Replication for Backups 1963
17.3.2 Using Replication with Different Master and Slave Storage Engines 1966
17.3.3 Using Replication for Scale-Out 1967
17.3.4 Replicating Different Databases to Different Slaves 1968
17.3.5 Improving Replication Performance 1970
17.3.6 Switching Masters During Failover 1971
17.3.7 Setting Up Replication to Use Encrypted Connections 1973
17.3.8 Semisynchronous Replication 1974
17.4 Replication Notes and Tips 1979
17.4.1 Replication Features and Issues 1979
17.4.2 Replication Compatibility Between MySQL Versions 2004
17.4.3 Upgrading a Replication Setup 2005
17.4.4 Troubleshooting Replication 2006
17.4.5 How to Report Replication Bugs or Problems 2007

Replication enables data from one MySQL database server (the master) to be replicated to one or more MySQL database servers (the slaves). Replication is asynchronous by default, therefore slaves do not need to be connected permanently to receive updates from the master. This means that updates can occur over long-distance connections and even over temporary or intermittent connections such as a dial-up service. Depending on the configuration, you can replicate all databases, selected databases, or even selected tables within a database.

For answers to some questions often asked by those who are new to MySQL Replication, see Section A.13, “MySQL 5.5 FAQ: Replication”.

Advantages of replication in MySQL include:

- Scale-out solutions - spreading the load among multiple slaves to improve performance. In this environment, all writes and updates must take place on the master server. Reads, however, may take place on one or more slaves. This model can improve the performance of writes (since the master is dedicated to updates), while dramatically increasing read speed across an increasing number of slaves.
- Data security - because data is replicated to the slave, and the slave can pause the replication process, it is possible to run backup services on the slave without corrupting the corresponding master data.
- Analytics - live data can be created on the master, while the analysis of the information can take place on the slave without affecting the performance of the master.
- Long-distance data distribution - if a branch office would like to work with a copy of your main data, you can use replication to create a local copy of the data for their use without requiring permanent access to the master.

Replication in MySQL features support for one-way, asynchronous replication, in which one server acts as the master, while one or more other servers act as slaves. This is in contrast to the *synchronous* replication which is a characteristic of NDB Cluster (see Chapter 18, *MySQL NDB Cluster 7.2*).
In MySQL 5.5, an interface to semisynchronous replication is supported in addition to the built-in asynchronous replication. With semisynchronous replication, a commit performed on the master side blocks before returning to the session that performed the transaction until at least one slave acknowledges that it has received and logged the events for the transaction. See Section 17.3.8, “Semisynchronous Replication”

There are a number of solutions available for setting up replication between two servers, but the best method to use depends on the presence of data and the engine types you are using. For more information on the available options, see Section 17.1.1, “How to Set Up Replication”.

There are two core types of replication format, Statement Based Replication (SBR), which replicates entire SQL statements, and Row Based Replication (RBR), which replicates only the changed rows. You may also use a third variety, Mixed Based Replication (MBR). For more information on the different replication formats, see Section 17.1.2, “Replication Formats”. In MySQL 5.5, statement-based format is the default.

Replication is controlled through a number of different options and variables. These control the core operation of the replication, timeouts, and the databases and filters that can be applied on databases and tables. For more information on the available options, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

You can use replication to solve a number of different problems, including problems with performance, supporting the backup of different databases, and as part of a larger solution to alleviate system failures. For information on how to address these issues, see Section 17.3, “Replication Solutions”.

For notes and tips on how different data types and statements are treated during replication, including details of replication features, version compatibility, upgrades, and problems and their resolution, including an FAQ, see Section 17.4, “Replication Notes and Tips”.

For detailed information on the implementation of replication, how replication works, the process and contents of the binary log, background threads and the rules used to decide how statements are recorded and replication, see Section 17.2, “Replication Implementation”.

17.1 Replication Configuration

Replication between servers in MySQL is based on the binary logging mechanism. The MySQL instance operating as the master (the source of the database changes) writes updates and changes as “events” to the binary log. The information in the binary log is stored in different logging formats according to the database changes being recorded. Slaves are configured to read the binary log from the master and to execute the events in the binary log on the slave's local database.

The master is “dumb” in this scenario. Once binary logging has been enabled, all statements are recorded in the binary log. Each slave receives a copy of the entire contents of the binary log. It is the responsibility of the slave to decide which statements in the binary log should be executed; you cannot configure the master to log only certain events. If you do not specify otherwise, all events in the master binary log are executed on the slave. If required, you can configure the slave to process only events that apply to particular databases or tables.

Each slave keeps a record of the binary log coordinates: The file name and position within the file that it has read and processed from the master. This means that multiple slaves can be connected to the master and executing different parts of the same binary log. Because the slaves control this process, individual slaves can be connected and disconnected from the server without affecting the master's operation. Also, because each slave remembers the position within the binary log, it is possible for slaves to be disconnected, reconnect and then “catch up” by continuing from the recorded position.

Both the master and each slave must be configured with a unique ID (using the `server-id` option). In addition, each slave must be configured with information about the master host name, log file name, and position within that file. These details can be controlled from within a MySQL session using the

`CHANGE MASTER TO` statement on the slave. The details are stored within the slave's `master.info` file.

This section describes the setup and configuration required for a replication environment, including step-by-step instructions for creating a new replication environment. The major components of this section are:

- For a guide to setting up two or more servers for replication, Section 17.1.1, “How to Set Up Replication”, deals with the configuration of the systems and provides methods for copying data between the master and slaves.
- Events in the binary log are recorded using a number of formats. These are referred to as statement-based replication (SBR) or row-based replication (RBR). A third type, mixed-format replication (MIXED), uses SBR or RBR replication automatically to take advantage of the benefits of both SBR and RBR formats when appropriate. The different formats are discussed in Section 17.1.2, “Replication Formats”.
- Detailed information on the different configuration options and variables that apply to replication is provided in Section 17.1.3, “Replication and Binary Logging Options and Variables”.
- Once started, the replication process should require little administration or monitoring. However, for advice on common tasks that you may want to execute, see Section 17.1.4, “Common Replication Administration Tasks”.

17.1.1 How to Set Up Replication

This section describes how to set up complete replication of a MySQL server. There are a number of different methods for setting up replication, and the exact method to use depends on how you are setting up replication, and whether you already have data within your master database.

There are some generic tasks that are common to all replication setups:

- On the master, you must enable binary logging and configure a unique server ID. This might require a server restart. See Section 17.1.1.1, “Setting the Replication Master Configuration”.
- On each slave that you want to connect to the master, you must configure a unique server ID. This might require a server restart. See Section 17.1.1.2, “Setting the Replication Slave Configuration”.
- You may want to create a separate user that will be used by your slaves to authenticate with the master to read the binary log for replication. The step is optional. See Section 17.1.1.3, “Creating a User for Replication”.
- Before creating a data snapshot or starting the replication process, you should record the position of the binary log on the master. You will need this information when configuring the slave so that the slave knows where within the binary log to start executing events. See Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”.
- If you already have data on your master and you want to use it to synchronize your slave, you will need to create a data snapshot. You can create a snapshot using `mysqldump` (see Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”) or by copying the data files directly (see Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”).
- You will need to configure the slave with settings for connecting to the master, such as the host name, login credentials, and binary log file name and position. See Section 17.1.1.10, “Setting the Master Configuration on the Slave”.

Once you have configured the basic options, you will need to follow the instructions for your replication setup. A number of alternatives are provided:

- If you are establishing a new MySQL master and one or more slaves, you need only set up the configuration, as you have no data to exchange. For guidance on setting up replication in this situation, see Section 17.1.1.7, “Setting Up Replication with New Master and Slaves”.

- If you are already running a MySQL server, and therefore already have data that must be transferred to your slaves before replication starts, have not previously configured the binary log and are able to shut down your MySQL server for a short period during the process, see Section 17.1.1.8, “Setting Up Replication with Existing Data”.
- If you are adding slaves to an existing replication environment, you can set up the slaves without affecting the master. See Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”.

If you will be administering MySQL replication servers, we suggest that you read this entire chapter through and try all statements mentioned in Section 13.4.1, “SQL Statements for Controlling Master Servers”, and Section 13.4.2, “SQL Statements for Controlling Slave Servers”. You should also familiarize yourself with the replication startup options described in Section 17.1.3, “Replication and Binary Logging Options and Variables”.

Note

Note that certain steps within the setup process require the `SUPER` privilege. If you do not have this privilege, it might not be possible to enable replication.

17.1.1.1 Setting the Replication Master Configuration

On a replication master, you must enable binary logging and establish a unique server ID. If this has not already been done, this part of master setup requires a server restart.

Binary logging *must* be enabled on the master because the binary log is the basis for sending data changes from the master to its slaves. If binary logging is not enabled, replication will not be possible.

Each server within a replication group must be configured with a unique server ID. This ID is used to identify individual servers within the group, and must be a positive integer between 1 and (2^{32})−1. How you organize and select the numbers is entirely up to you.

To configure the binary log and server ID options, you will need to shut down your MySQL server and edit the `my.cnf` or `my.ini` file. Add the following options to the configuration file within the `[mysqld]` section. If these options already exist, but are commented out, uncomment the options and alter them according to your needs. For example, to enable binary logging using a log file name prefix of `mysql-bin`, and configure a server ID of 1, use these lines:

```
[mysqld]
log-bin=mysql-bin
server-id=1
```

After making the changes, restart the server.

Note

If you omit `server-id` (or set it explicitly to its default value of 0), a master refuses connections from all slaves.

Note

For the greatest possible durability and consistency in a replication setup using `InnoDB` with transactions, you should use `innodb_flush_log_at_trx_commit=1` and `sync_binlog=1` in the master `my.cnf` file.

Note

Ensure that the `skip-networking` option is not enabled on your replication master. If networking has been disabled, your slave will not able to communicate with the master and replication will fail.

17.1.1.2 Setting the Replication Slave Configuration

On a replication slave, you must establish a unique server ID. If this has not already been done, this part of slave setup requires a server restart.

If the slave server ID is not already set, or the current value conflicts with the value that you have chosen for the master server, you should shut down your slave server and edit the configuration to specify a unique server ID. For example:

```
[mysqld]
server-id=2
```

After making the changes, restart the server.

If you are setting up multiple slaves, each one must have a unique `server-id` value that differs from that of the master and from each of the other slaves. Think of `server-id` values as something similar to IP addresses: These IDs uniquely identify each server instance in the community of replication partners.

Note

If you omit `server-id` (or set it explicitly to its default value of 0), a slave refuses to connect to a master.

You do not have to enable binary logging on the slave for replication to be enabled. However, if you enable binary logging on the slave, you can use the binary log for data backups and crash recovery on the slave, and also use the slave as part of a more complex replication topology (for example, where the slave acts as a master to other slaves).

17.1.1.3 Creating a User for Replication

Each slave must connect to the master using a MySQL user name and password, so there must be a user account on the master that the slave can use to connect. Any account can be used for this operation, providing it has been granted the `REPLICATION SLAVE` privilege. You may wish to create a different account for each slave, or connect to the master using the same account for each slave.

You need not create an account specifically for replication. However, you should be aware that the user name and password will be stored in plain text within the `master.info` file (see Section 17.2.2.2, “Slave Status Logs”). Therefore, you may want to create a separate account that has privileges only for the replication process, to minimize the possibility of compromise to other accounts.

To create a new account, use `CREATE USER`. To grant this account the privileges required for replication, use the `GRANT` statement. If you create an account solely for the purposes of replication, that account needs only the `REPLICATION SLAVE` privilege. For example, to set up a new user, `repl`, that can connect for replication from any host within the `mydomain.com` domain, issue these statements on the master:

```
mysql> CREATE USER 'repl'@'%.mydomain.com' IDENTIFIED BY 'slavepass';
mysql> GRANT REPLICATION SLAVE ON *.* TO 'repl'@'%.mydomain.com';
```

See Section 13.7.1, “Account Management Statements”, for more information on statements for manipulation of user accounts.

17.1.1.4 Obtaining the Replication Master Binary Log Coordinates

To configure replication on the slave you must determine the master's current coordinates within its binary log. You will need this information so that when the slave starts the replication process, it is able to start processing events from the binary log at the correct point.

If you have existing data on your master that you want to synchronize on your slaves before starting the replication process, you must stop processing statements on the master, and then obtain its current binary log coordinates and dump its data, before permitting the master to continue executing

statements. If you do not stop the execution of statements, the data dump and the master status information that you use will not match and you will end up with inconsistent or corrupted databases on the slaves.

To obtain the master binary log coordinates, follow these steps:

1. Start a session on the master by connecting to it with the command-line client, and flush all tables and block write statements by executing the `FLUSH TABLES WITH READ LOCK` statement:

   ```
   mysql> FLUSH TABLES WITH READ LOCK;
   ```

   For `InnoDB` tables, note that `FLUSH TABLES WITH READ LOCK` also blocks `COMMIT` operations.

   Warning

   Leave the client from which you issued the `FLUSH TABLES` statement running so that the read lock remains in effect. If you exit the client, the lock is released.

2. In a different session on the master, use the `SHOW MASTER STATUS` statement to determine the current binary log file name and position:

   ```
   mysql > SHOW MASTER STATUS;
   +------------------+----------+--------------+------------------+
   | File             | Position | Binlog_Do_DB | Binlog_Ignore_DB |
   +------------------+----------+--------------+------------------+
   | mysql-bin.000003 | 73       | test         | manual,mysql     |
   +------------------+----------+--------------+------------------+
   ```

   The `File` column shows the name of the log file and `Position` shows the position within the file. In this example, the binary log file is `mysql-bin.000003` and the position is 73. Record these values. You need them later when you are setting up the slave. They represent the replication coordinates at which the slave should begin processing new updates from the master.

   If the master has been running previously without binary logging enabled, the log file name and position values displayed by `SHOW MASTER STATUS` or `mysqldump --master-data` will be empty. In that case, the values that you need to use later when specifying the slave's log file and position are the empty string (`''`) and `4`.

You now have the information you need to enable the slave to start reading from the binary log in the correct place to start replication.

If you have existing data that needs be to synchronized with the slave before you start replication, leave the client running so that the lock remains in place and then proceed to Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”, or Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”. The idea here is to prevent any further changes so that the data copied to the slaves is in synchrony with the master.

If you are setting up a brand new master and slave replication group, you can exit the first session to release the read lock.

17.1.1.5 Creating a Data Snapshot Using mysqldump

One way to create a snapshot of the data in an existing master database is to use the `mysqldump` tool to create a dump of all the databases you want to replicate. Once the data dump has been completed, you then import this data into the slave before starting the replication process.

The example shown here dumps all databases to a file named `dbdump.db`, and includes the `--master-data` option which automatically appends the `CHANGE MASTER TO` statement required on the slave to start the replication process:

```
```

```
shell> mysqldump --all-databases --master-data > dbdump.db
```

If you do not use `--master-data`, then it is necessary to lock all tables in a separate session manually (using `FLUSH TABLES WITH READ LOCK`) prior to running `mysqldump`, then exiting or running UNLOCK TABLES from the second session to release the locks. You must also obtain binary log position information matching the snapshot, using `SHOW MASTER STATUS`, and use this to issue the appropriate `CHANGE MASTER TO` statement when starting the slave.

When choosing databases to include in the dump, remember that you need to filter out databases on each slave that you do not want to include in the replication process.

To import the data, either copy the dump file to the slave, or access the file from the master when connecting remotely to the slave.

17.1.1.6 Creating a Data Snapshot Using Raw Data Files

If your database is large, copying the raw data files can be more efficient than using `mysqldump` and importing the file on each slave. This technique skips the overhead of updating indexes as the `INSERT` statements are replayed.

Using this method with tables in storage engines with complex caching or logging algorithms requires extra steps to produce a perfect “point in time” snapshot: the initial copy command might leave out cache information and logging updates, even if you have acquired a global read lock. How the storage engine responds to this depends on its crash recovery abilities.

This method also does not work reliably if the master and slave have different values for `ft_stopword_file`, `ft_min_word_len`, or `ft_max_word_len` and you are copying tables having full-text indexes.

If you use `InnoDB` tables, you can use the `mysqlbackup` command from the MySQL Enterprise Backup component to produce a consistent snapshot. This command records the log name and offset corresponding to the snapshot to be later used on the slave. MySQL Enterprise Backup is a commercial product that is included as part of a MySQL Enterprise subscription. See Section 25.2, “MySQL Enterprise Backup Overview” for detailed information.

Otherwise, use the cold backup technique to obtain a reliable binary snapshot of `InnoDB` tables: copy all data files after doing a slow shutdown of the MySQL Server.

To create a raw data snapshot of `MyISAM` tables, you can use standard copy tools such as `cp` or `copy`, a remote copy tool such as `scp` or `rsync`, an archiving tool such as `zip` or `tar`, or a file system snapshot tool such as `dump`, providing that your MySQL data files exist on a single file system. If you are replicating only certain databases, copy only those files that relate to those tables. (For `InnoDB`, all tables in all databases are stored in the system tablespace files, unless you have the `innodb_file_per_table` option enabled.)

You might want to specifically exclude the following files from your archive:

- Files relating to the `mysql` database.
- The `master.info` file.
- The master's binary log files.
- Any relay log files.

To get the most consistent results with a raw data snapshot, shut down the master server during the process, as follows:

1. Acquire a read lock and get the master's status. See Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”.
2. In a separate session, shut down the master server:

```
shell> mysqladmin shutdown
```

3. Make a copy of the MySQL data files. The following examples show common ways to do this. You need to choose only one of them:

```
shell> tar cf /tmp/db.tar ./data
shell> zip -r /tmp/db.zip ./data
shell> rsync --recursive ./data /tmp/dbdata
```

4. Restart the master server.

If you are not using `InnoDB` tables, you can get a snapshot of the system from a master without shutting down the server as described in the following steps:

1. Acquire a read lock and get the master's status. See Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”.
2. Make a copy of the MySQL data files. The following examples show common ways to do this. You need to choose only one of them:

```
shell> tar cf /tmp/db.tar ./data
shell> zip -r /tmp/db.zip ./data
shell> rsync --recursive ./data /tmp/dbdata
```

3. In the client where you acquired the read lock, release the lock:

```
mysql> UNLOCK TABLES;
```

Once you have created the archive or copy of the database, copy the files to each slave before starting the slave replication process.

17.1.1.7 Setting Up Replication with New Master and Slaves

The easiest and most straightforward method for setting up replication is to use new master and slave servers.

You can also use this method if you are setting up new servers but have an existing dump of the databases from a different server that you want to load into your replication configuration. By loading the data into a new master, the data will be automatically replicated to the slaves.

To set up replication between a new master and slave:

1. Configure the MySQL master with the necessary configuration properties. See Section 17.1.1.1, “Setting the Replication Master Configuration”.
2. Start up the MySQL master.
3. Set up a user. See Section 17.1.1.3, “Creating a User for Replication”.
4. Obtain the master status information. See Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”.
5. On the master, release the read lock:

```
mysql> UNLOCK TABLES;
```

6. On the slave, edit the MySQL configuration. See Section 17.1.1.2, “Setting the Replication Slave Configuration”.
7. Start up the MySQL slave.
8. Execute a `CHANGE MASTER TO` statement to set the master replication server configuration. See Section 17.1.1.10, “Setting the Master Configuration on the Slave”.

Perform the slave setup steps on each slave.

Because there is no data to load or exchange on a new server configuration you do not need to copy or import any information.

If you are setting up a new replication environment using the data from a different existing database server, you will now need to run the dump file generated from that server on the new master. The database updates will automatically be propagated to the slaves:

```
shell> mysql -h master < fulldb.dump
```

17.1.1.8 Setting Up Replication with Existing Data

When setting up replication with existing data, you will need to decide how best to get the data from the master to the slave before starting the replication service.

The basic process for setting up replication with existing data is as follows:

1. With the MySQL master running, create a user to be used by the slave when connecting to the master during replication. See Section 17.1.1.3, “Creating a User for Replication”.

2. If you have not already configured the `server-id` and enabled binary logging on the master server, you will need to shut it down to configure these options. See Section 17.1.1.1, “Setting the Replication Master Configuration”.

   If you have to shut down your master server, this is a good opportunity to take a snapshot of its databases. You should obtain the master status (see Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”) before taking down the master, updating the configuration and taking a snapshot. For information on how to create a snapshot using raw data files, see Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”.

3. If your master server is already correctly configured, obtain its status (see Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”) and then use `mysqldump` to take a snapshot (see Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”) or take a raw snapshot of the live server using the guide in Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”.

4. Update the configuration of the slave. See Section 17.1.1.2, “Setting the Replication Slave Configuration”.

5. The next step depends on how you created the snapshot of data on the master.

   If you used `mysqldump`:

   a. Start the slave, using the `--skip-slave-start` option so that replication does not start.

   b. Import the dump file:

      ```
      shell> mysql < fulldb.dump
      ```

   If you created a snapshot using the raw data files:

   a. Extract the data files into your slave data directory. For example:

      ```
      shell> tar xvf dbdump.tar
      ```

      You may need to set permissions and ownership on the files so that the slave server can access and modify them.

   b. Start the slave, using the `--skip-slave-start` option so that replication does not start.

6. Configure the slave with the replication coordinates from the master. This tells the slave the binary log file and position within the file where replication needs to start. Also, configure the slave with the login credentials and host name of the master. For more information on the `CHANGE MASTER TO` statement required, see Section 17.1.1.10, “Setting the Master Configuration on the Slave”.

7. Start the slave threads:

```
mysql> START SLAVE;
```

After you have performed this procedure, the slave should connect to the master and catch up on any updates that have occurred since the snapshot was taken.

If you have forgotten to set the `server-id` option for the master, slaves cannot connect to it.

If you have forgotten to set the `server-id` option for the slave, you get the following error in the slave's error log:

```
Warning: You should set server-id to a non-0 value if master_host
is set; we will force server id to 2, but this MySQL server will
not act as a slave.
```

You also find error messages in the slave's error log if it is not able to replicate for any other reason.

Once a slave is replicating, you can find in its data directory one file named `master.info` and another named `relay-log.info`. The slave uses these two files to keep track of how much of the master's binary log it has processed. Do *not* remove or edit these files unless you know exactly what you are doing and fully understand the implications. Even in that case, it is preferred that you use the `CHANGE MASTER TO` statement to change replication parameters. The slave will use the values specified in the statement to update the status files automatically.

Note

The content of `master.info` overrides some of the server options specified on the command line or in `my.cnf`. See Section 17.1.3, “Replication and Binary Logging Options and Variables”, for more details.

A single snapshot of the master suffices for multiple slaves. To set up additional slaves, use the same master snapshot and follow the slave portion of the procedure just described.

17.1.1.9 Introducing Additional Slaves to an Existing Replication Environment

To add another slave to an existing replication configuration, you can do so without stopping the master. Instead, set up the new slave by making a copy of an existing slave, except that you configure the new slave with a different `server-id` value.

To duplicate an existing slave:

1. Shut down the existing slave:

```
shell> mysqladmin shutdown
```

2. Copy the data directory from the existing slave to the new slave. You can do this by creating an archive using `tar` or `WinZip`, or by performing a direct copy using a tool such as `cp` or `rsync`. Ensure that you also copy the log files and relay log files.

   A common problem that is encountered when adding new replication slaves is that the new slave fails with a series of warning and error messages like these:

```
071118 16:44:10 [Warning] Neither --relay-log nor --relay-log-index were used; so
replication may break when this MySQL server acts as a slave and has his hostname
changed!! Please use '--relay-log=new_slave_hostname-relay-bin' to avoid this problem.
```

```
071118 16:44:10 [ERROR] Failed to open the relay log './old_slave_hostname-relay-bin.003525'
(relay_log_pos 22940879)
071118 16:44:10 [ERROR] Could not find target log during relay log initialization
071118 16:44:10 [ERROR] Failed to initialize the master info structure
```

This is due to the fact that, if the `--relay-log` option is not specified, the relay log files contain the host name as part of their file names. (This is also true of the relay log index file if the `--relay-log-index` option is not used. See Section 17.1.3, “Replication and Binary Logging Options and Variables”, for more information about these options.)

To avoid this problem, use the same value for `--relay-log` on the new slave that was used on the existing slave. (If this option was not set explicitly on the existing slave, use *`existing_slave_hostname`*`-relay-bin`.) If this is not feasible, copy the existing slave's relay log index file to the new slave and set the `--relay-log-index` option on the new slave to match what was used on the existing slave. (If this option was not set explicitly on the existing slave, use *`existing_slave_hostname`*`-relay-bin.index`.) Alternatively—if you have already tried to start the new slave (after following the remaining steps in this section) and have encountered errors like those described previously—then perform the following steps:

a. If you have not already done so, issue a `STOP SLAVE` on the new slave.

   If you have already started the existing slave again, issue a `STOP SLAVE` on the existing slave as well.

b. Copy the contents of the existing slave's relay log index file into the new slave's relay log index file, making sure to overwrite any content already in the file.

c. Proceed with the remaining steps in this section.

3. Copy the `master.info` and `relay-log.info` files from the existing slave to the new slave if they were not located in the data directory. These files hold the current log coordinates for the master's binary log and the slave's relay log.

4. Start the existing slave.

5. On the new slave, edit the configuration and give the new slave a unique `server-id` not used by the master or any of the existing slaves.

6. Start the new slave. The slave will use the information in its `master.info` file to start the replication process.

17.1.1.10 Setting the Master Configuration on the Slave

To set up the slave to communicate with the master for replication, you must tell the slave the necessary connection information. To do this, execute the following statement on the slave, replacing the option values with the actual values relevant to your system:

```
mysql> CHANGE MASTER TO
    ->     MASTER_HOST='master_host_name',
    ->     MASTER_USER='replication_user_name',
    ->     MASTER_PASSWORD='replication_password',
    ->     MASTER_LOG_FILE='recorded_log_file_name',
    ->     MASTER_LOG_POS=recorded_log_position;
```

Note

Replication cannot use Unix socket files. You must be able to connect to the master MySQL server using TCP/IP.

The `CHANGE MASTER TO` statement has other options as well. For example, it is possible to set up secure replication using SSL. For a full list of options, and information about the maximum permissible length for the string-valued options, see Section 13.4.2.1, “CHANGE MASTER TO Syntax”.

17.1.2 Replication Formats

Replication works because events written to the binary log are read from the master and then processed on the slave. The events are recorded within the binary log in different formats according to the type of event. The different replication formats used correspond to the binary logging format used when the events were recorded in the master's binary log. The correlation between binary logging formats and the terms used during replication are:

- Replication capabilities in MySQL originally were based on propagation of SQL statements from master to slave. This is called *statement-based replication* (often abbreviated as *SBR*), which corresponds to the standard statement-based binary logging format. In older versions of MySQL (5.1.4 and earlier), binary logging and replication used this format exclusively.
- Row-based binary logging logs changes in individual table rows. When used with MySQL replication, this is known as *row-based replication* (often abbreviated as *RBR*). In row-based replication, the master writes *events* to the binary log that indicate how individual table rows are changed.
- The server can change the binary logging format in real time according to the type of event using *mixed-format logging*.

  When the mixed format is in effect, statement-based logging is used by default, but automatically switches to row-based logging in particular cases as described later. Replication using the mixed format is often referred to as *mixed-based replication* or *mixed-format replication*. For more information, see Section 5.4.4.3, “Mixed Binary Logging Format”.

In MySQL 5.5, statement-based format is the default.

NDB Cluster. The default binary logging format in all MySQL NDB Cluster 7.2 releases, beginning with MySQL NDB Cluster 7.2.1, is `STATEMENT`. (This is a change from previous versions of NDB Cluster.) You should note that NDB Cluster Replication always uses row-based replication, and that the `NDB` storage engine is incompatible with statement-based replication. This means that you must manually set the format to `ROW` prior to enabling NDB Cluster Replication. See Section 18.6.2, “General Requirements for NDB Cluster Replication”, for more information.

When using `MIXED` format, the binary logging format is determined in part by the storage engine being used and the statement being executed. For more information on mixed-format logging and the rules governing the support of different logging formats, see Section 5.4.4.3, “Mixed Binary Logging Format”.

The logging format in a running MySQL server is controlled by setting the `binlog_format` server system variable. This variable can be set with session or global scope. The rules governing when and how the new setting takes effect are the same as for other MySQL server system variables—setting the variable for the current session lasts only until the end of that session, and the change is not visible to other sessions; setting the variable globally requires a restart of the server to take effect. For more information, see Section 13.7.4.1, “SET Syntax for Variable Assignment”.

There are conditions under which you cannot change the binary logging format at runtime or doing so causes replication to fail. See Section 5.4.4.2, “Setting The Binary Log Format”.

You must have the `SUPER` privilege to set either the global or session `binlog_format` value.

The statement-based and row-based replication formats have different issues and limitations. For a comparison of their relative advantages and disadvantages, see Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

With statement-based replication, you may encounter issues with replicating stored routines or triggers. You can avoid these issues by using row-based replication instead. For more information, see Section 20.7, “Binary Logging of Stored Programs”.

17.1.2.1 Advantages and Disadvantages of Statement-Based and Row-Based Replication

Each binary logging format has advantages and disadvantages. For most users, the mixed replication format should provide the best combination of data integrity and performance. If, however, you want to

take advantage of the features specific to the statement-based or row-based replication format when performing certain tasks, you can use the information in this section, which provides a summary of their relative advantages and disadvantages, to determine which is best for your needs.

- Advantages of statement-based replication
- Disadvantages of statement-based replication
- Advantages of row-based replication
- Disadvantages of row-based replication

Advantages of statement-based replication

- Proven technology.
- Less data written to log files. When updates or deletes affect many rows, this results in *much* less storage space required for log files. This also means that taking and restoring from backups can be accomplished more quickly.
- Log files contain all statements that made any changes, so they can be used to audit the database.

Disadvantages of statement-based replication

- **Statements that are unsafe for SBR.**
  Not all statements which modify data (such as `INSERT DELETE`, `UPDATE`, and `REPLACE` statements) can be replicated using statement-based replication. Any nondeterministic behavior is difficult to replicate when using statement-based replication. Examples of such DML (Data Modification Language) statements include the following:
  - A statement that depends on a UDF or stored program that is nondeterministic, since the value returned by such a UDF or stored program or depends on factors other than the parameters supplied to it. (Row-based replication, however, simply replicates the value returned by the UDF or stored program, so its effect on table rows and data is the same on both the master and slave.) See Section 17.4.1.15, “Replication of Invoked Features”, for more information.
  - `DELETE` and `UPDATE` statements that use a `LIMIT` clause without an `ORDER BY` are nondeterministic. See Section 17.4.1.16, “Replication and LIMIT”.
  - Statements using any of the following functions cannot be replicated properly using statement-based replication:
    - `LOAD_FILE()`
    - `UUID()`, `UUID_SHORT()`
    - `USER()`
    - `FOUND_ROWS()`
    - `SYSDATE()` (unless both the master and the slave are started with the `--sysdate-is-now` option)
    - `GET_LOCK()`
    - `IS_FREE_LOCK()`
    - `IS_USED_LOCK()`
    - `MASTER_POS_WAIT()`
    - `RAND()`

- `RELEASE_LOCK()`
- `SLEEP()`
- `VERSION()`

  However, all other functions are replicated correctly using statement-based replication, including `NOW()` and so forth.

  For more information, see Section 17.4.1.14, “Replication and System Functions”.

Statements that cannot be replicated correctly using statement-based replication are logged with a warning like the one shown here:

```
[Warning] Statement is not safe to log in statement format.
```

A similar warning is also issued to the client in such cases. The client can display it using `SHOW WARNINGS`.

- `INSERT ... SELECT` requires a greater number of row-level locks than with row-based replication.
- `UPDATE` statements that require a table scan (because no index is used in the `WHERE` clause) must lock a greater number of rows than with row-based replication.
- For `InnoDB`: An `INSERT` statement that uses `AUTO_INCREMENT` blocks other nonconflicting `INSERT` statements.
- For complex statements, the statement must be evaluated and executed on the slave before the rows are updated or inserted. With row-based replication, the slave only has to modify the affected rows, not execute the full statement.
- If there is an error in evaluation on the slave, particularly when executing complex statements, statement-based replication may slowly increase the margin of error across the affected rows over time. See Section 17.4.1.29, “Slave Errors During Replication”.
- Stored functions execute with the same `NOW()` value as the calling statement. However, this is not true of stored procedures.
- Deterministic UDFs must be applied on the slaves.
- Table definitions must be (nearly) identical on master and slave. See Section 17.4.1.9, “Replication with Differing Table Definitions on Master and Slave”, for more information.

Advantages of row-based replication

- All changes can be replicated. This is the safest form of replication.

  The `mysql` database is not replicated. The `mysql` database is instead seen as a node-specific database. Row-based replication is not supported on tables in this database. Instead, statements that would normally update this information—such as `GRANT`, `REVOKE` and the manipulation of triggers, stored routines (including stored procedures), and views—are all replicated to slaves using statement-based replication.

  For statements such as `CREATE TABLE ... SELECT`, a `CREATE` statement is generated from the table definition and replicated using statement-based format, while the row insertions are replicated using row-based format.
- The technology is the same as in most other database management systems; knowledge about other systems transfers to MySQL.
- Fewer row locks are required on the master, which thus achieves higher concurrency, for the following types of statements:

- `INSERT ... SELECT`
- `INSERT` statements with `AUTO_INCREMENT`
- `UPDATE` or `DELETE` statements with `WHERE` clauses that do not use keys or do not change most of the examined rows.

- Fewer row locks are required on the slave for any `INSERT`, `UPDATE`, or `DELETE` statement.

Disadvantages of row-based replication

- RBR tends to generate more data that must be logged. To replicate a DML statement (such as an `UPDATE` or `DELETE` statement), statement-based replication writes only the statement to the binary log. By contrast, row-based replication writes each changed row to the binary log. If the statement changes many rows, row-based replication may write significantly more data to the binary log; this is true even for statements that are rolled back. This also means that taking and restoring from backup can require more time. In addition, the binary log is locked for a longer time to write the data, which may cause concurrency problems.

- Deterministic UDFs that generate large `BLOB` values take longer to replicate with row-based replication than with statement-based replication. This is because the `BLOB` column value is logged, rather than the statement generating the data.

- You cannot examine the logs to see what statements were executed, nor can you see on the slave what statements were received from the master and executed.

  However, you can see what data was changed using `mysqlbinlog` with the options `--base64-output=DECODE-ROWS` and `--verbose`.

- For tables using the `MyISAM` storage engine, a stronger lock is required on the slave for `INSERT` statements when applying them as row-based events to the binary log than when applying them as statements. This means that concurrent inserts on `MyISAM` tables are not supported when using row-based replication.

17.1.2.2 Usage of Row-Based Logging and Replication

Major changes in the replication environment and in the behavior of applications can result from using row-based logging (RBL) or row-based replication (RBR) rather than statement-based logging or replication. This section describes a number of issues known to exist when using row-based logging or replication, and discusses some best practices for taking advantage of row-based logging and replication.

For additional information, see Section 17.1.2, “Replication Formats”, and Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

For information about issues specific to NDB Cluster Replication (which depends on row-based replication), see Section 18.6.3, “Known Issues in NDB Cluster Replication”.

- **RBL, RBR, and temporary tables.** As noted in Section 17.4.1.31, “Replication and Temporary Tables”, temporary tables are not replicated when using row-based format. When mixed format is in effect, “safe” statements involving temporary tables are logged using statement-based format. For more information, see Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”.

  Temporary tables are not replicated when using row-based format because there is no need. In addition, because temporary tables can be read only from the thread which created them, there is seldom if ever any benefit obtained from replicating them, even when using statement-based format.

  Beginning with MySQL 5.5.5, you can switch from statement-based to row-based binary logging mode even when temporary tables have been created. However, while using the row-based format,

the MySQL server cannot determine the logging mode that was in effect when a given temporary table was created. For this reason, the server in such cases logs a `DROP TEMPORARY TABLE IF EXISTS` statement for each temporary table that still exists for a given client session when that session ends. (Bug #11760229, Bug #11762267) While this means that it is possible that an unnecessary `DROP TEMPORARY TABLE` statement might be logged in some cases, the statement is harmless, and does not cause an error even if the table does not exist, due to the presence of the `IF EXISTS` option.

- **RBL and synchronization of nontransactional tables.** When many rows are affected, the set of changes is split into several events; when the statement commits, all of these events are written to the binary log. When executing on the slave, a table lock is taken on all tables involved, and then the rows are applied in batch mode. (This may or may not be effective, depending on the engine used for the slave's copy of the table.)

- **Latency and binary log size.** Because RBL writes changes for each row to the binary log, its size can increase quite rapidly. In a replication environment, this can significantly increase the time required to make changes on the slave that match those on the master. You should be aware of the potential for this delay in your applications.

- **Reading the binary log.** `mysqlbinlog` displays row-based events in the binary log using the `BINLOG` statement (see Section 13.7.6.1, “BINLOG Syntax”). This statement displays an event in printable form, but as a base 64-encoded string the meaning of which is not evident. When invoked with the `--base64-output=DECODE-ROWS` and `--verbose` options, `mysqlbinlog` formats the contents of the binary log in a manner that is easily human readable. This is helpful when binary log events were written in row-based format if you want to read or recover from a replication or database failure using the contents of the binary log. For more information, see Section 4.6.7.2, “mysqlbinlog Row Event Display”.

- **Binary log execution errors and slave_exec_mode.** If `slave_exec_mode` is `IDEMPOTENT`, a failure to apply changes from RBL because the original row cannot be found does not trigger an error or cause replication to fail. This means that it is possible that updates are not applied on the slave, so that the master and slave are no longer synchronized. Latency issues and use of nontransactional tables with RBR when `slave_exec_mode` is `IDEMPOTENT` can cause the master and slave to diverge even further. For more information about `slave_exec_mode`, see Section 5.1.5, “Server System Variables”.

  Note

  `slave_exec_mode=IDEMPOTENT` is generally useful only for circular replication or multi-master replication with NDB Cluster, for which `IDEMPOTENT` is the default value (see Section 18.6, “NDB Cluster Replication”).

  For other scenarios, setting `slave_exec_mode` to `STRICT` is normally sufficient; this is the default value for storage engines other than `NDB`.

- **Lack of binary log checksums.** RBL uses no checksums. This means that network, disk, and other errors may not be identified when processing the binary log. To ensure that data is transmitted without network corruption, you may want to consider using SSL, which adds another layer of checksumming, for replication connections. The `CHANGE MASTER TO` statement has options to enable replication over SSL. See also Section 13.4.2.1, “CHANGE MASTER TO Syntax”, for general information about setting up MySQL with SSL.

  This is not an issue in MySQL 5.6 and later, which support checksums for the binary log; see Checksum options.

- **Filtering based on server ID not supported.** A common practice is to filter out changes on some slaves by using a `WHERE` clause that includes the relation `@@server_id <> id_value` clause with `UPDATE` and `DELETE` statements, a simple example of such a clause being `WHERE @@server_id <> 1`. However, this does not work correctly with row-based logging.

If you must use the `server_id` system variable for statement filtering, you must also use `--binlog_format=STATEMENT`.

In MySQL 5.5, you can do filtering based on server ID by using the `IGNORE_SERVER_IDS` option for the `CHANGE MASTER TO` statement. This option works with the statement-based and row-based logging formats.

- **Database-level replication options.** The effects of the `--replicate-do-db`, `--replicate-ignore-db`, and `--replicate-rewrite-db` options differ considerably depending on whether row-based or statement-based logging is used. Because of this, it is recommended to avoid database-level options and instead use table-level options such as `--replicate-do-table` and `--replicate-ignore-table`. For more information about these options and the impact that your choice of replication format has on how they operate, see Section 17.1.3, "Replication and Binary Logging Options and Variables".

- **RBL, nontransactional tables, and stopped slaves.** When using row-based logging, if the slave server is stopped while a slave thread is updating a nontransactional table, the slave database may reaches an inconsistent state. For this reason, it is recommended that you use a transactional storage engine such as `InnoDB` for all tables replicated using the row-based format.

  Use of `STOP SLAVE` (or `STOP SLAVE SQL_THREAD` in MySQL 5.5.9 and later) prior to shutting down the slave MySQL server helps prevent such issues from occurring, and is always recommended regardless of the logging format or storage engines employed.

17.1.2.3 Determination of Safe and Unsafe Statements in Binary Logging

When speaking of the "safeness" of a statement in MySQL Replication, we are referring to whether a statement and its effects can be replicated correctly using statement-based format. If this is true of the statement, we refer to the statement as *safe*; otherwise, we refer to it as *unsafe*.

In general, a statement is safe if it deterministic, and unsafe if it is not. However, certain nondeterministic functions are *not* considered unsafe (see Nondeterministic functions not considered unsafe, later in this section). In addition, statements using results from floating-point math functions—which are hardware-dependent—are always considered unsafe (see Section 17.4.1.12, "Replication and Floating-Point Values").

Handling of safe and unsafe statements. A statement is treated differently depending on whether the statement is considered safe, and with respect to the binary logging format (that is, the current value of `binlog_format`).

- No distinction is made in the treatment of safe and unsafe statements when the binary logging mode is `ROW`.

- If the binary logging format is `MIXED`, statements flagged as unsafe are logged using the row-based format; statements regarded as safe are logged using the statement-based format.

- If the binary logging format is `STATEMENT`, statements flagged as being unsafe generate a warning to this effect. (Safe statements are logged normally.)

Each statement flagged as unsafe generates a warning. Formerly, in cases where a great many such statements were executed on the master, this could lead to very large error log files, sometimes even filling up an entire disk unexpectedly. To guard against this, MySQL 5.5.27 introduced a warning suppression mechanism, which behaves as follows: Whenever the 50 most recent `ER_BINLOG_UNSAFE_STATEMENT` warnings have been generated more than 50 times in any 50-second period, warning suppression is enabled. When activated, this causes such warnings not to be written to the error log; instead, for each 50 warnings of this type, a note `The last warning was repeated N times in last S seconds` is written to the error log. This continues as long as the 50 most recent such warnings were issued in 50 seconds or less; once the rate has decreased below this threshold, the warnings are once again logged normally. Warning suppression has no effect on how the safety of statements for statement-based logging is determined, nor on how warnings are sent to the client (MySQL clients still receive one warning for each such statement).

For more information, see Section 17.1.2, “Replication Formats”.

Statements considered unsafe.
Statements having the following characteristics are considered unsafe:

- **Statements containing system functions that may return a different value on slave.** These functions include `FOUND_ROWS()`, `GET_LOCK()`, `IS_FREE_LOCK()`, `IS_USED_LOCK()`, `LOAD_FILE()`, `MASTER_POS_WAIT()`, `RAND()`, `RELEASE_LOCK()`, `ROW_COUNT()`, `SESSION_USER()`, `SLEEP()`, `SYSDATE()`, `SYSTEM_USER()`, `USER()`, `UUID()`, and `UUID_SHORT()`.

  Nondeterministic functions not considered unsafe. Although these functions are not deterministic, they are treated as safe for purposes of logging and replication: `CONNECTION_ID()`, `CURDATE()`, `CURRENT_DATE()`, `CURRENT_TIME()`, `CURRENT_TIMESTAMP()`, `CURTIME()`, `LOCALTIME()`, `LOCALTIMESTAMP()`, `NOW()`, `UNIX_TIMESTAMP()`, `UTC_DATE()`, `UTC_TIME()`, `UTC_TIMESTAMP()`, and `LAST_INSERT_ID()`

  For more information, see Section 17.4.1.14, “Replication and System Functions”.

- **References to system variables.** Most system variables are not replicated correctly using the statement-based format. For exceptions, see Section 5.4.4.3, “Mixed Binary Logging Format”.

  See Section 17.4.1.38, “Replication and Variables”.

- **UDFs.** Since we have no control over what a UDF does, we must assume that it is executing unsafe statements.

- **Updates a table having an AUTO_INCREMENT column.** Prior to MySQL 5.5.3, all such statements were always considered unsafe because the order in which the rows are updated could differ on the master and the slave. In MySQL 5.3.3 and later, these statements are unsafe only when they are executed by a trigger or stored program (Bug #50192, Bug #11758052).

  An `INSERT` into a table that has a composite primary key containing an `AUTO_INCREMENT` column that is not the first column of this composite key is unsafe.

  For more information, see Section 17.4.1.1, “Replication and AUTO_INCREMENT”.

- **INSERT DELAYED statement.** This statement is considered unsafe because the insertion of the rows may interleave with concurrently executing statements.

- **INSERT ... ON DUPLICATE KEY UPDATE statements on tables with multiple primary or unique keys.** When executed against a table that contains more than one primary or unique key, this statement is considered unsafe, being sensitive to the order in which the storage engine checks the keys, which is not deterministic, and on which the choice of rows updated by the MySQL Server depends.

  An `INSERT ... ON DUPLICATE KEY UPDATE` statement against a table having more than one unique or primary key is marked as unsafe for statement-based replication beginning with MySQL 5.5.24. (Bug #11765650, Bug #58637)

- **Updates using LIMIT.** The order in which rows are retrieved is not specified.

  See Section 17.4.1.16, “Replication and LIMIT”.

- **Accesses or references log tables.** The contents of the system log table may differ between master and slave.

- **Nontransactional operations after transactional operations.** Within a transaction, allowing any nontransactional reads or writes to execute after any transactional reads or writes is considered unsafe.

  For more information, see Section 17.4.1.35, “Replication and Transactions”.

- **Accesses or references self-logging tables.** All reads and writes to self-logging tables are considered unsafe. Within a transaction, any statement following a read or write to self-logging tables is also considered unsafe.
- **LOAD DATA INFILE statements.** Beginning with MySQL 5.5.6, `LOAD DATA INFILE` is treated as unsafe and when `binlog_format=mixed` the statement is logged in row-based format. When `binlog_format=statement` `LOAD DATA INFILE` does not generate a warning, unlike other unsafe statements.

For additional information, see Section 17.4.1, “Replication Features and Issues”.

17.1.3 Replication and Binary Logging Options and Variables

The next few sections contain information about `mysqld` options and server variables that are used in replication and for controlling the binary log. Options and variables for use on replication masters and replication slaves are covered separately, as are options and variables relating to binary logging. A set of quick-reference tables providing basic information about these options and variables is also included (in the next section following this one).

Of particular importance is the `--server-id` option.

Command-Line Format	`--server-id=#`	
System Variable	**Name**	`server_id`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4294967295`

This option is common to both master and slave replication servers, and is used in replication to enable master and slave servers to identify themselves uniquely. For additional information, see Section 17.1.3.2, “Replication Master Options and Variables”, and Section 17.1.3.3, “Replication Slave Options and Variables”.

On the master and each slave, you *must* use the `--server-id` option to establish a unique replication ID in the range from 1 to $2^{32} - 1$. “Unique”, means that each ID must be different from every other ID in use by any other replication master or slave. Example: `server-id=3`.

If you omit `--server-id`, the default ID is 0, in which case the master refuses connections from all slaves, and slaves refuse to connect to the master. In MySQL 5.5, whether the server ID is set to 0 explicitly or the default is allowed to be used, the server sets the `server_id` system variable to 1; this is a known issue that is fixed in MySQL 5.7.

For more information, see Section 17.1.1.2, “Setting the Replication Slave Configuration”.

17.1.3.1 Replication and Binary Logging Option and Variable Reference

The following tables list basic information about the MySQL command-line options and system variables applicable to replication and the binary log.

Table 17.1 Summary of Replication options and variables in MySQL 5.5

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`abort-slave-event-count`		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		
Com_change_master		
No	No	Yes
No	Both	No
DESCRIPTION: Count of CHANGE MASTER TO statements		
Com_show_master_status		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW MASTER STATUS statements		
Com_show_new_master		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW NEW MASTER statements		
Com_show_slave_hosts		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW SLAVE HOSTS statements		
Com_show_slave_status		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW SLAVE STATUS statements		
Com_slave_start		
No	No	Yes
No	Both	No
DESCRIPTION: Count of START SLAVE statements		
Com_slave_stop		
No	No	Yes
No	Both	No
DESCRIPTION: Count of STOP SLAVE statements		
disconnect-slave-event-count		
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		
init_slave		
Yes	Yes	No
Yes	Global	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Statements that are executed when a slave connects to a master		
log-slave-updates		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Tells the slave to log the updates performed by its SQL thread to its own binary log		
log_slave_updates		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Whether the slave should log the updates performed by its SQL thread to its own binary log. Read-only; set using the --log-slave-updates server option.		
master-connect-retry		
Yes	No	No
Yes		No
DESCRIPTION: Number of seconds the slave thread will sleep before retrying to connect to the master in case the master goes down or the connection is lost		
master-host		
Yes	No	No
Yes		No
DESCRIPTION: Master host name or IP address for replication		
master-info-file		
Yes	No	No
Yes		No
DESCRIPTION: The location and name of the file that remembers the master and where the I/O replication thread is in the master's binary logs		
master-password		
Yes	No	No
Yes		No
DESCRIPTION: The password the slave thread will authenticate with when connecting to master		
master-port		
Yes	No	No
Yes		No
DESCRIPTION: The port the master is listening on		
master-retry-count		
Yes	No	No
Yes		No
DESCRIPTION: Number of tries the slave makes to connect to the master before giving up		
master-ssl		
Yes	No	No
Yes		No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Enable the slave to connect to the master using SSL `master-ssl-ca`		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL CA file; applies only if master-ssl is enabled `master-ssl-capath`		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL CA path; applies only if master-ssl is enabled `master-ssl-cert`		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL certificate file name; applies only if master-ssl is enabled `master-ssl-cipher`		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL cipher; applies only if master-ssl is enabled `master-ssl-key`		
Yes	No	No
Yes		No
DESCRIPTION: Master SSL key file name; applies only if master-ssl is enabled `master-user`		
Yes	No	No
Yes		No
DESCRIPTION: The user name the slave thread will use for authentication when connecting to master. The user must have FILE privilege. If the master user is not set, user test is assumed. The value in master.info will take precedence if it can be read `relay-log`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The location and base name to use for relay logs `relay-log-index`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The location and name to use for the file that keeps a list of the last relay logs `relay-log-info-file`		
Yes	No	No
Yes		No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: The location and name of the file that remembers where the SQL replication thread is in the relay logs		
`relay-log-recovery`		
Yes	No	No
Yes		No
DESCRIPTION: Enables automatic recovery of relay log files from master at startup		
`relay_log_index`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The name of the relay log index file		
`relay_log_info_file`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The name of the file in which the slave records information about the relay logs		
`relay_log_purge`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Determines whether relay logs are purged		
`relay_log_recovery`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Whether automatic recovery of relay log files from master at startup is enabled; must be enabled for a crash-safe slave.		
`relay_log_space_limit`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Maximum space to use for all relay logs		
`replicate-do-db`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread to restrict replication to the specified database		
`replicate-do-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread to restrict replication to the specified table		
`replicate-ignore-db`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread not to replicate to the specified database		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`replicate-ignore-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave SQL thread not to replicate to the specified table		
`replicate-rewrite-db`		
Yes	No	No
Yes		No
DESCRIPTION: Updates to a database with a different name than the original		
`replicate-same-server-id`		
Yes	No	No
Yes		No
DESCRIPTION: In replication, if set to 1, do not skip events having our server id		
`replicate-wild-do-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave thread to restrict replication to the tables that match the specified wildcard pattern		
`replicate-wild-ignore-table`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the slave thread not to replicate to the tables that match the given wildcard pattern		
`report-host`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Host name or IP of the slave to be reported to the master during slave registration		
`report-password`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: An arbitrary password that the slave server should report to the master. Not the same as the password for the MySQL replication user account.		
`report-port`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Port for connecting to slave reported to the master during slave registration		
`report-user`		
Yes	Yes	No
Yes	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: An arbitrary user name that a slave server should report to the master. Not the same as the name used with the MySQL replication user account.		
rpl_recovery_rank		
No	Yes	No
No	Global	Yes
DESCRIPTION: Not used; removed in later versions		
Rpl_semi_sync_master_clients		
No	No	Yes
No	Global	No
DESCRIPTION: Number of semisynchronous slaves		
rpl_semi_sync_master_enabled		
No	Yes	No
No	Global	Yes
DESCRIPTION: Whether semisynchronous replication is enabled on the master		
Rpl_semi_sync_master_net_avg_wait_time		
No	No	Yes
No	Global	No
DESCRIPTION: The average time the master waited for a slave reply		
Rpl_semi_sync_master_net_wait_time		
No	No	Yes
No	Global	No
DESCRIPTION: The total time the master waited for slave replies		
Rpl_semi_sync_master_net_waits		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of times the master waited for slave replies		
Rpl_semi_sync_master_no_times		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times the master turned off semisynchronous replication		
Rpl_semi_sync_master_no_tx		
No	No	Yes
No	Global	No
DESCRIPTION: Number of commits not acknowledged successfully		
Rpl_semi_sync_master_status		
No	No	Yes
No	Global	No
DESCRIPTION: Whether semisynchronous replication is operational on the master		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Rpl_semi_sync_master_timefunc_failures		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times the master failed when calling time functions		
rpl_semi_sync_master_timeout		
No	Yes	No
No	Global	Yes
DESCRIPTION: Number of milliseconds to wait for slave acknowledgment		
rpl_semi_sync_master_trace_level		
No	Yes	No
No	Global	Yes
DESCRIPTION: The semisynchronous replication debug trace level on the master		
Rpl_semi_sync_master_tx_avg_wait_time		
No	No	Yes
No	Global	No
DESCRIPTION: The average time the master waited for each transaction		
Rpl_semi_sync_master_tx_wait_time		
No	No	Yes
No	Global	No
DESCRIPTION: The total time the master waited for transactions		
Rpl_semi_sync_master_tx_waits		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of times the master waited for transactions		
rpl_semi_sync_master_wait_no_slave		
No	Yes	No
No	Global	Yes
DESCRIPTION: Whether master waits for timeout even with no slaves		
Rpl_semi_sync_master_wait_pos_backtraverse		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of times the master waited for an event with binary coordinates lower than events waited for previously		
Rpl_semi_sync_master_wait_sessions		
No	No	Yes
No	Global	No
DESCRIPTION: Number of sessions currently waiting for slave replies		
Rpl_semi_sync_master_yes_tx		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	No	Yes
No	Global	No
DESCRIPTION: Number of commits acknowledged successfully		
`rpl_semi_sync_slave_enabled`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Whether semisynchronous replication is enabled on slave		
`Rpl_semi_sync_slave_status`		
No	No	Yes
No	Global	No
DESCRIPTION: Whether semisynchronous replication is operational on slave		
`rpl_semi_sync_slave_trace_level`		
No	Yes	No
No	Global	Yes
DESCRIPTION: The semisynchronous replication debug trace level on the slave		
`Rpl_status`		
No	No	Yes
No	Global	No
DESCRIPTION: The status of fail-safe replication (not implemented)		
`show-slave-auth-info`		
Yes	No	No
Yes		No
DESCRIPTION: Show user name and password in SHOW SLAVE HOSTS on this master		
`skip-slave-start`		
Yes	No	No
Yes		No
DESCRIPTION: If set, slave is not autostarted		
`slave-load-tmpdir`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The location where the slave should put its temporary files when replicating a LOAD DATA INFILE statement		
`slave-max-allowed-packet`		
Yes	No	No
Yes		No
DESCRIPTION: Maximum size, in bytes, of a packet that can be sent from a replication master to a slave; overrides max_allowed_packet.		
`slave_net_timeout`		
Yes	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Global	Yes
DESCRIPTION: Number of seconds to wait for more data from a master/slave connection before aborting the read		
`slave-skip-errors`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Tells the slave thread to continue replication when a query returns an error from the provided list		
`slave_compressed_protocol`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Use compression on master/slave protocol		
`slave_exec_mode`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Allows for switching the slave thread between IDEMPOTENT mode (key and some other errors suppressed) and STRICT mode; STRICT mode is the default, except for NDB Cluster, where IDEMPOTENT is always used		
`Slave_heartbeat_period`		
No	No	Yes
No	Global	No
DESCRIPTION: The slave's replication heartbeat interval, in seconds		
`slave_max_allowed_packet`		
No	Yes	No
No	Global	Yes
DESCRIPTION: Maximum size, in bytes, of a packet that can be sent from a replication master to a slave; overrides max_allowed_packet.		
`Slave_open_temp_tables`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of temporary tables that the slave SQL thread currently has open		
`Slave_retried_transactions`		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of times since startup that the replication slave SQL thread has retried transactions		
`Slave_running`		
No	No	Yes
No	Global	No
DESCRIPTION: The state of this server as a replication slave (slave I/O thread status)		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
	slave_transaction_retries	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Number of times the slave SQL thread will retry a transaction in case it failed with a deadlock or elapsed lock wait timeout, before giving up and stopping		
	slave_type_conversions	
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Controls type conversion mode on replication slave. Value is a list of zero or more elements from the list: ALL_LOSSY, ALL_NON_LOSSY. Set to an empty string to disallow type conversions between master and slave.		
	sql_slave_skip_counter	
No	Yes	No
No	Global	Yes
DESCRIPTION: Number of events from the master that a slave server should skip. Not compatible with GTID replication.		
	sync_binlog	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Synchronously flush binary log to disk after every #th event		
	sync_master_info	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Synchronize master.info to disk after every #th event.		
	sync_relay_log	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Synchronize relay log to disk after every #th event.		
	sync_relay_log_info	
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Synchronize relay.info file to disk after every #th event.		

Section 17.1.3.2, “Replication Master Options and Variables”, provides more detailed information about options and variables relating to replication master servers. For more information about options and variables relating to replication slaves, see Section 17.1.3.3, “Replication Slave Options and Variables”.

Table 17.2 Summary of Binary Logging options and variables in MySQL 5.5

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`binlog-do-db`		
Yes	No	No
Yes		No
DESCRIPTION: Limits binary logging to specific databases		
`binlog_format`		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies the format of the binary log		
`binlog-ignore-db`		
Yes	No	No
Yes		No
DESCRIPTION: Tells the master that updates to the given database should not be logged to the binary log		
`binlog-row-event-max-size`		
Yes	No	No
Yes		No
DESCRIPTION: Binary log max event size		
`Binlog_cache_disk_use`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions that used a temporary file instead of the binary log cache		
`binlog_cache_size`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Size of the cache to hold the SQL statements for the binary log during a transaction		
`Binlog_cache_use`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions that used the temporary binary log cache		
`binlog_direct_non_transactional_updates`		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Causes updates using statement format to nontransactional engines to be written directly to binary log. See documentation before using.		
`Binlog_stmt_cache_disk_use`		
No	No	Yes
No	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of nontransactional statements that used a temporary file instead of the binary log statement cache		
`binlog_stmt_cache_size`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Size of the cache to hold nontransactional statements for the binary log during a transaction		
`Binlog_stmt_cache_use`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of statements that used the temporary binary log statement cache		
`Com_show_binlog_events`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW BINLOG EVENTS statements		
`Com_show_binlogs`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW BINLOGS statements		
`log-bin-use-v1-row-events`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Use version 1 binary log row events		
`log_bin_use_v1_row_events`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Shows whether server is using version 1 binary log row events		
`max-binlog-dump-events`		
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		
`max_binlog_cache_size`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Can be used to restrict the total size used to cache a multi-statement transaction		
`max_binlog_size`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Binary log will be rotated automatically when size exceeds this value		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`max_binlog_stmt_cache_size`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Can be used to restrict the total size used to cache all nontransactional statements during a transaction		
`sporadic-binlog-dump-fail`		
Yes	No	No
Yes		No
DESCRIPTION: Option used by mysql-test for debugging and testing of replication		

Section 17.1.3.4, “Binary Log Options and Variables”, provides more detailed information about options and variables relating to binary logging. For additional general information about the binary log, see Section 5.4.4, “The Binary Log”.

For information about the `sql_log_bin` and `sql_log_off` variables, see Section 5.1.5, “Server System Variables”.

For a table showing *all* command-line options, system and status variables used with `mysqld`, see Section 5.1.3, “Server Option and Variable Reference”.

17.1.3.2 Replication Master Options and Variables

This section describes the server options and system variables that you can use on replication master servers. You can specify the options either on the command line or in an option file. You can specify system variable values using `SET`.

On the master and each slave, you must use the `server-id` option to establish a unique replication ID. For each server, you should pick a unique positive integer in the range from 1 to $2^{32} - 1$, and each ID must be different from every other ID in use by any other replication master or slave. Example: `server-id=3`.

For options used on the master for controlling binary logging, see Section 17.1.3.4, “Binary Log Options and Variables”.

Startup Options for Replication Masters

The following list describes startup options for controlling replication master servers. Replication-related system variables are discussed later in this section.

- `--show-slave-auth-info`

Command-Line Format	`--show-slave-auth-info`	
Permitted Values	**Type**	boolean
	Default	`FALSE`

Display slave user names and passwords in the output of `SHOW SLAVE HOSTS` on the master server for slaves started with the `--report-user` and `--report-password` options.

System Variables Used on Replication Masters

The following system variables are used in controlling replication masters:

- `auto_increment_increment`

System Variable	Name	auto_increment_increment
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	1
	Minimum	1
	Maximum	65535

`auto_increment_increment` and `auto_increment_offset` are intended for use with master-to-master replication, and can be used to control the operation of `AUTO_INCREMENT` columns. Both variables have global and session values, and each can assume an integer value between 1 and 65,535 inclusive. Setting the value of either of these two variables to 0 causes its value to be set to 1 instead. Attempting to set the value of either of these two variables to an integer greater than 65,535 or less than 0 causes its value to be set to 65,535 instead. Attempting to set the value of `auto_increment_increment` or `auto_increment_offset` to a noninteger value gives rise to an error, and the actual value of the variable remains unchanged.

Note

`auto_increment_increment` is also supported for use with `NDB` tables.

These two variables affect `AUTO_INCREMENT` column behavior as follows:

- `auto_increment_increment` controls the interval between successive column values. For example:

```
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 1     |
| auto_increment_offset    | 1     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc1
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
  Query OK, 0 rows affected (0.04 sec)

mysql> SET @@auto_increment_increment=10;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 1     |
+--------------------------+-------+
2 rows in set (0.01 sec)

mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
```

```
|  11 |
|  21 |
|  31 |
+-----+
4 rows in set (0.00 sec)
```

- `auto_increment_offset` determines the starting point for the `AUTO_INCREMENT` column value. Consider the following, assuming that these statements are executed during the same session as the example given in the description for `auto_increment_increment`:

```
mysql> SET @@auto_increment_offset=5;
Query OK, 0 rows affected (0.00 sec)

mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 5     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> CREATE TABLE autoinc2
    -> (col INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
Query OK, 0 rows affected (0.06 sec)

mysql> INSERT INTO autoinc2 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc2;
+-----+
| col |
+-----+
|   5 |
|  15 |
|  25 |
|  35 |
+-----+
4 rows in set (0.02 sec)
```

  If the value of `auto_increment_offset` is greater than that of `auto_increment_increment`, the value of `auto_increment_offset` is ignored.

Should one or both of these variables be changed and then new rows inserted into a table containing an `AUTO_INCREMENT` column, the results may seem counterintuitive because the series of `AUTO_INCREMENT` values is calculated without regard to any values already present in the column, and the next value inserted is the least value in the series that is greater than the maximum existing value in the `AUTO_INCREMENT` column. In other words, the series is calculated like so:

`auto_increment_offset` + *N* × `auto_increment_increment`

where *N* is a positive integer value in the series [1, 2, 3, ...]. For example:

```
mysql> SHOW VARIABLES LIKE 'auto_inc%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| auto_increment_increment | 10    |
| auto_increment_offset    | 5     |
+--------------------------+-------+
2 rows in set (0.00 sec)

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
```

```
|   1 |
|  11 |
|  21 |
|  31 |
+-----+
4 rows in set (0.00 sec)

mysql> INSERT INTO autoinc1 VALUES (NULL), (NULL), (NULL), (NULL);
Query OK, 4 rows affected (0.00 sec)
Records: 4  Duplicates: 0  Warnings: 0

mysql> SELECT col FROM autoinc1;
+-----+
| col |
+-----+
|   1 |
|  11 |
|  21 |
|  31 |
|  35 |
|  45 |
|  55 |
|  65 |
+-----+
8 rows in set (0.00 sec)
```

The values shown for `auto_increment_increment` and `auto_increment_offset` generate the series 5 + *N* × 10, that is, [5, 15, 25, 35, 45, ...]. The greatest value present in the `col` column prior to the `INSERT` is 31, and the next available value in the `AUTO_INCREMENT` series is 35, so the inserted values for `col` begin at that point and the results are as shown for the `SELECT` query.

It is not possible to confine the effects of these two variables to a single table, and thus they do not take the place of the sequences offered by some other database management systems; these variables control the behavior of all `AUTO_INCREMENT` columns in *all* tables on the MySQL server. If the global value of either variable is set, its effects persist until the global value is changed or overridden by setting the session value, or until `mysqld` is restarted. If the local value is set, the new value affects `AUTO_INCREMENT` columns for all tables into which new rows are inserted by the current user for the duration of the session, unless the values are changed during that session.

The default value of `auto_increment_increment` is 1. See Section 17.4.1.1, “Replication and AUTO_INCREMENT”.

- `auto_increment_offset`

System Variable	Name	`auto_increment_offset`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`1`
	Minimum	`1`
	Maximum	`65535`

This variable has a default value of 1. For particulars, see the description for `auto_increment_increment`.

Note

`auto_increment_offset` is also supported for use with `NDB` tables.

17.1.3.3 Replication Slave Options and Variables

Startup Options for Replication Slaves

Obsolete Replication Slave Options

System Variables Used on Replication Slaves

This section describes the server options and system variables that apply to slave replication servers. You can specify the options either on the command line or in an option file. Many of the options can be set while the server is running by using the `CHANGE MASTER TO` statement. You can specify system variable values using `SET`.

Server ID. On the master and each slave, you must use the `server-id` option to establish a unique replication ID in the range from 1 to $2^{32} - 1$. “Unique” means that each ID must be different from every other ID in use by any other replication master or slave. Example `my.cnf` file:

```
[mysqld]
server-id=3
```

Startup Options for Replication Slaves

The following list describes startup options for controlling replication slave servers. Many of these options can be set while the server is running by using the `CHANGE MASTER TO` statement. Others, such as the `--replicate-*` options, can be set only when the slave server starts. Replication-related system variables are discussed later in this section.

- `--abort-slave-event-count`

Command-Line Format	`--abort-slave-event-count=#`	
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`

When this option is set to some positive integer *`value`* other than 0 (the default) it affects replication behavior as follows: After the slave SQL thread has started, *`value`* log events are permitted to be executed; after that, the slave SQL thread does not receive any more events, just as if the network connection from the master were cut. The slave thread continues to run, and the output from `SHOW SLAVE STATUS` displays `Yes` in both the `Slave_IO_Running` and the `Slave_SQL_Running` columns, but no further events are read from the relay log.

This option is used internally by the MySQL test suite for replication testing and debugging. It is not intended for use in a production setting.

- `--disconnect-slave-event-count`

Command-Line Format	`--disconnect-slave-event-count=#`	
Permitted Values	Type	integer
	Default	`0`

This option is used internally by the MySQL test suite for replication testing and debugging.

- `--log-slave-updates`

Command-Line Format	`--log-slave-updates`	
System Variable	Name	`log_slave_updates`
	Scope	Global

	Dynamic	No
Permitted Values	**Type**	boolean
	Default	`OFF`

Normally, a slave does not log to its own binary log any updates that are received from a master server. This option tells the slave to log the updates performed by its SQL thread to its own binary log. For this option to have any effect, the slave must also be started with the `--log-bin` option to enable binary logging. Prior to MySQL 5.5, the server would not start when using the `--log-slave-updates` option without also starting the server with the `--log-bin` option, and would fail with an error; in MySQL 5.5, only a warning is generated. (Bug #44663) `--log-slave-updates` is used when you want to chain replication servers. For example, you might want to set up replication servers using this arrangement:

```
A -> B -> C
```

Here, `A` serves as the master for the slave `B`, and `B` serves as the master for the slave `C`. For this to work, `B` must be both a master *and* a slave. You must start both `A` and `B` with `--log-bin` to enable binary logging, and `B` with the `--log-slave-updates` option so that updates received from `A` are logged by `B` to its binary log.

- `--log-slow-slave-statements`

Command-Line Format	`--log-slow-slave-statements`	
Permitted Values	**Type**	boolean
	Default	`OFF`

When the slow query log is enabled, this option enables logging for queries that have taken more than `long_query_time` seconds to execute on the slave.

Note that all statements logged in row format in the master will not be logged in the slave's slow log, even if this option is enabled.

- `--log-warnings[=level]`

Command-Line Format	`--log-warnings[=#]`	
System Variable	**Name**	`log_warnings`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`1`
	Minimum	`0`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`1`
	Minimum	`0`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`1`
	Minimum	`0`
	Maximum	`18446744073709551615`

This option causes a server to print more messages to the error log about what it is doing. With respect to replication, the server generates warnings that it succeeded in reconnecting after a network/connection failure, and informs you as to how each slave thread started. This option is enabled (1) by default; to disable it, use `--log-warnings=0`. If the value is greater than 1, aborted connections are written to the error log, and access-denied errors for new connection attempts are written. See Section B.5.2.11, “Communication Errors and Aborted Connections”.

Note

The effects of this option are not limited to replication. It affects diagnostic messages across a spectrum of server activities.

- `--master-info-file=file_name`

Command-Line Format	`--master-info-file=file_name`	
Permitted Values	**Type**	file name
	Default	`master.info`

The name to use for the file in which the slave records information about the master. The default name is `master.info` in the data directory. For information about the format of this file, see Section 17.2.2.2, “Slave Status Logs”.

- `--master-retry-count=count`

Command-Line Format	`--master-retry-count=#`	
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`86400`
	Minimum	`0`
	Maximum	`4294967295`
Permitted Values (64-bit platforms)	**Type**	integer
	Default	`86400`
	Minimum	`0`
	Maximum	`18446744073709551615`

The number of times that the slave tries to connect to the master before giving up. Reconnects are attempted at intervals set by the `MASTER_CONNECT_RETRY` option of the `CHANGE MASTER TO` statement (default 60). Reconnects are triggered when data reads by the slave time out according to the `--slave-net-timeout` option. The default value is 86400. A value of 0 means “infinite”; the slave attempts to connect forever.

- `slave-max-allowed-packet=bytes`

Introduced	5.5.26	
Command-Line Format	`--slave-max-allowed-packet=#`	
Permitted Values	**Type**	integer
	Default	`1073741824`
	Minimum	`1024`
	Maximum	`1073741824`

In MySQL 5.5.26 and later, this option sets the maximum packet size in bytes for the slave SQL and I/O threads, so that large updates using row-based replication do not cause replication to fail because an update exceeded `max_allowed_packet`. (Bug #12400221, Bug #60926)

The corresponding server variable `slave_max_allowed_packet` always has a value that is a positive integer multiple of 1024; if you set it to some value that is not such a multiple, the value is automatically rounded down to the next highest multiple of 1024. (For example, if you start the server with `--slave-max-allowed-packet=10000`, the value used is 9216; setting 0 as the value causes 1024 to be used.) A truncation warning is issued in such cases.

The maximum (and default) value is 1073741824 (1 GB); the minimum is 1024.

- `--max-relay-log-size=size`

Command-Line Format	`--max-relay-log-size=#`	
System Variable	Name	`max_relay_log_size`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`1073741824`

The size at which the server rotates relay log files automatically. If this value is nonzero, the relay log is rotated automatically when its size exceeds this value. If this value is zero (the default), the size at which relay log rotation occurs is determined by the value of `max_binlog_size`. For more information, see Section 17.2.2.1, “The Slave Relay Log”.

- `--relay-log=file_name`

Command-Line Format	`--relay-log=file_name`	
System Variable	Name	`relay_log`
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The base name for the relay log. The default base name is *`host_name`*`-relay-bin`. The server writes the file in the data directory unless the base name is given with a leading absolute path name to specify a different directory. The server creates relay log files in sequence by adding a numeric suffix to the base name.

Due to the manner in which MySQL parses server options, if you specify this option, you must supply a value; *the default base name is used only if the option is not actually specified*. If you use the `--relay-log` option without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Section 4.2.3, “Specifying Program Options”.

If you specify this option, the value specified is also used as the base name for the relay log index file. You can override this behavior by specifying a different relay log index file base name using the `--relay-log-index` option.

Starting with MySQL 5.5.20, when the server reads an entry from the index file, it checks whether the entry contains a relative path. If it does, the relative part of the path in replaced with the absolute path set using the `--relay-log` option. An absolute path remains unchanged; in such a case, the index must be edited manually to enable the new path or paths to be used. Prior to MySQL 5.5.20, manual intervention was required whenever relocating the binary log or relay log files. (Bug #11745230, Bug #12133)

You may find the `--relay-log` option useful in performing the following tasks:

- Creating relay logs whose names are independent of host names.
- If you need to put the relay logs in some area other than the data directory because your relay logs tend to be very large and you do not want to decrease `max_relay_log_size`.
- To increase speed by using load-balancing between disks.

- `--relay-log-index=file_name`

Command-Line Format	--relay-log-index=file_name	
System Variable	Name	relay_log_index
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The name to use for the relay log index file. The default name is *`host_name`*`-relay-bin.index` in the data directory, where *`host_name`* is the name of the slave server.

Due to the manner in which MySQL parses server options, if you specify this option, you must supply a value; *the default base name is used only if the option is not actually specified*. If you use the `--relay-log-index` option without specifying a value, unexpected behavior is likely to result; this behavior depends on the other options used, the order in which they are specified, and whether they are specified on the command line or in an option file. For more information about how MySQL handles server options, see Section 4.2.3, “Specifying Program Options”.

- `--relay-log-info-file=file_name`

Command-Line Format	--relay-log-info-file=file_name	
Permitted Values	Type	file name
	Default	relay-log.info

The name to use for the file in which the slave records information about the relay logs. The default name is `relay-log.info` in the data directory. For information about the format of this file, see Section 17.2.2.2, “Slave Status Logs”.

- `--relay-log-purge={0|1}`

Command-Line Format	--relay-log-purge	
System Variable	Name	relay_log_purge
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	TRUE

Disable or enable automatic purging of relay logs as soon as they are no longer needed. The default value is 1 (enabled). This is a global variable that can be changed dynamically with `SET GLOBAL relay_log_purge = N`.

- `--relay-log-recovery={0|1}`

Command-Line Format	--relay-log-recovery	
Permitted Values	Type	boolean

	Default	FALSE

Enables automatic relay log recovery immediately following server startup, which means that the replication slave discards all unprocessed relay logs and retrieves them from the replication master. This should be used following a crash on the replication slave to ensure that no possibly corrupted relay logs are processed. The default value is 0 (disabled).

- `--relay-log-space-limit=size`

Command-Line Format	`--relay-log-space-limit=#`	
System Variable	**Name**	`relay_log_space_limit`
	Scope	Global
	Dynamic	No
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4294967295`
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`18446744073709547520`
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	`0`
	Minimum	`0`
	Maximum	`18446744073709551615`

This option places an upper limit on the total size in bytes of all relay logs on the slave. A value of 0 means “no limit.” This is useful for a slave server host that has limited disk space. When the limit is reached, the I/O thread stops reading binary log events from the master server until the SQL thread has caught up and deleted some unused relay logs. Note that this limit is not absolute: There are cases where the SQL thread needs more events before it can delete relay logs. In that case, the I/O thread exceeds the limit until it becomes possible for the SQL thread to delete some relay logs because not doing so would cause a deadlock. You should not set `--relay-log-space-limit` to less than twice the value of `--max-relay-log-size` (or `--max-binlog-size` if `--max-relay-log-size` is 0). In that case, there is a chance that the I/O thread waits for free space because `--relay-log-space-limit` is exceeded, but the SQL thread has no relay log to purge and is unable to satisfy the I/O thread. This forces the I/O thread to ignore `--relay-log-space-limit` temporarily.

- `--replicate-do-db=db_name`

Command-Line Format	`--replicate-do-db=name`	
Permitted Values	**Type**	string

The effects of this option depend on whether statement-based or row-based replication is in use.

Statement-based replication. Tell the slave SQL thread to restrict replication to statements where the default database (that is, the one selected by `USE`) is *`db_name`*. To specify more than one database, use this option multiple times, once for each database; however, doing so does *not* replicate cross-database statements such as `UPDATE some_db.some_table SET foo='bar'` while a different database (or no database) is selected.

Warning

To specify multiple databases you *must* use multiple instances of this option. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

An example of what does not work as you might expect when using statement-based replication: If the slave is started with `--replicate-do-db=sales` and you issue the following statements on the master, the `UPDATE` statement is *not* replicated:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The main reason for this “check just the default database” behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table `DELETE` statements or multiple-table `UPDATE` statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

Row-based replication. Tells the slave SQL thread to restrict replication to database *`db_name`*. Only tables belonging to *`db_name`* are changed; the current database has no effect on this. Suppose that the slave is started with `--replicate-do-db=sales` and row-based replication is in effect, and then the following statements are run on the master:

```
USE prices;
UPDATE sales.february SET amount=amount+100;
```

The `february` table in the `sales` database on the slave is changed in accordance with the `UPDATE` statement; this occurs whether or not the `USE` statement was issued. However, issuing the following statements on the master has no effect on the slave when using row-based replication and `--replicate-do-db=sales`:

```
USE prices;
UPDATE prices.march SET amount=amount-25;
```

Even if the statement `USE prices` were changed to `USE sales`, the `UPDATE` statement's effects would still not be replicated.

Another important difference in how `--replicate-do-db` is handled in statement-based replication as opposed to row-based replication occurs with regard to statements that refer to multiple databases. Suppose that the slave is started with `--replicate-do-db=db1`, and the following statements are executed on the master:

```
USE db1;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

If you are using statement-based replication, then both tables are updated on the slave. However, when using row-based replication, only `table1` is affected on the slave; since `table2` is in a different database, `table2` on the slave is not changed by the `UPDATE`. Now suppose that, instead of the `USE db1` statement, a `USE db4` statement had been used:

```
USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

In this case, the `UPDATE` statement would have no effect on the slave when using statement-based replication. However, if you are using row-based replication, the `UPDATE` would change `table1` on the slave, but not `table2`—in other words, only tables in the database named by `--replicate-do-db` are changed, and the choice of default database has no effect on this behavior.

If you need cross-database updates to work, use `--replicate-wild-do-table=db_name.%` instead. See Section 17.2.3, "How Servers Evaluate Replication Filtering Rules".

Note

This option affects replication in the same manner that `--binlog-do-db` affects binary logging, and the effects of the replication format on how `--replicate-do-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-do-db`.

This option has no effect on `BEGIN`, `COMMIT`, or `ROLLBACK` statements.

- `--replicate-ignore-db=db_name`

Command-Line Format	`--replicate-ignore-db=name`	
Permitted Values	Type	string

As with `--replicate-do-db`, the effects of this option depend on whether statement-based or row-based replication is in use.

Statement-based replication. Tells the slave SQL thread not to replicate any statement where the default database (that is, the one selected by `USE`) is *db_name*.

Row-based replication. Tells the slave SQL thread not to update any tables in the database *db_name*. The default database has no effect.

When using statement-based replication, the following example does not work as you might expect. Suppose that the slave is started with `--replicate-ignore-db=sales` and you issue the following statements on the master:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The `UPDATE` statement *is* replicated in such a case because `--replicate-ignore-db` applies only to the default database (determined by the `USE` statement). Because the `sales` database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based replication, the `UPDATE` statement's effects are *not* propagated to the slave, and the slave's copy of the `sales.january` table is unchanged; in this instance, `--replicate-ignore-db=sales` causes *all* changes made to tables in the master's copy of the `sales` database to be ignored by the slave.

To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, if you supply a comma separated list then the list will be treated as the name of a single database.

You should not use this option if you are using cross-database updates and you do not want these updates to be replicated. See Section 17.2.3, "How Servers Evaluate Replication Filtering Rules".

If you need cross-database updates to work, use `--replicate-wild-ignore-table=db_name.%` instead. See Section 17.2.3, "How Servers Evaluate Replication Filtering Rules".

Note

This option affects replication in the same manner that `--binlog-ignore-db` affects binary logging, and the effects of the replication format on how `--replicate-ignore-db` affects replication behavior are the same as those of the logging format on the behavior of `--binlog-ignore-db`.

This option has no effect on `BEGIN`, `COMMIT`, or `ROLLBACK` statements.

- `--replicate-do-table=db_name.tbl_name`

Command-Line Format	`--replicate-do-table=name`	
Permitted Values	Type	string

Tells the slave SQL thread to restrict replication to the specified table. To specify more than one table, use this option multiple times, once for each table. This works for both cross-database updates and default database updates, in contrast to `--replicate-do-db`. See Section 17.2.3, "How Servers Evaluate Replication Filtering Rules".

This option affects only statements that apply to tables. It does not affect statements that apply only to other database objects, such as stored routines. To filter statements operating on stored routines, use one or more of the `--replicate-*-db` options.

- `--replicate-ignore-table=db_name.tbl_name`

Command-Line Format	`--replicate-ignore-table=name`	
Permitted Values	Type	string

Tells the slave SQL thread not to replicate any statement that updates the specified table, even if any other tables might be updated by the same statement. To specify more than one table to ignore, use this option multiple times, once for each table. This works for cross-database updates, in contrast to `--replicate-ignore-db`. See Section 17.2.3, "How Servers Evaluate Replication Filtering Rules".

This option affects only statements that apply to tables. It does not affect statements that apply only to other database objects, such as stored routines. To filter statements operating on stored routines, use one or more of the `--replicate-*-db` options.

- `--replicate-rewrite-db=from_name->to_name`

Command-Line Format	`--replicate-rewrite-db=old_name->new_name`	
Permitted Values	Type	string

Tells the slave to translate the default database (that is, the one selected by `USE`) to *`to_name`* if it was *`from_name`* on the master. Only statements involving tables are affected (not statements such as `CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE`), and only if *`from_name`* is the default database on the master. To specify multiple rewrites, use this option multiple times. The server uses the first one with a *`from_name`* value that matches. The database name translation is done *before* the `--replicate-*` rules are tested.

Statements in which table names are qualified with database names when using this option do not work with table-level replication filtering options such as `--replicate-do-table`. Suppose we have a database named `a` on the master, one named `b` on the slave, each containing a table `t`, and have started the master with `--replicate-rewrite-db='a->b'`. At a later point in time, we execute `DELETE FROM a.t`. In this case, no relevant filtering rule works, for the reasons shown here:

1. `--replicate-do-table=a.t` does not work because the slave has table `t` in database `b`.
2. `--replicate-do-table=b.t` does not match the original statement and so is ignored.
3. `--replicate-do-table=*.t` is handled identically to `--replicate-do-table=a.t`, and thus does not work, either.

Similarly, the `--replication-rewrite-db` option does not work with cross-database updates.

If you use this option on the command line and the > character is special to your command interpreter, quote the option value. For example:

```
shell> mysqld --replicate-rewrite-db="olddb->newdb"
```

- `--replicate-same-server-id`

Command-Line Format	`--replicate-same-server-id`	
Permitted Values	Type	boolean
	Default	FALSE

To be used on slave servers. Usually you should use the default setting of 0, to prevent infinite loops caused by circular replication. If set to 1, the slave does not skip events having its own server ID. Normally, this is useful only in rare configurations. Cannot be set to 1 if `--log-slave-updates` is used. By default, the slave I/O thread does not write binary log events to the relay log if they have the slave's server ID (this optimization helps save disk usage). If you want to use `--replicate-same-server-id`, be sure to start the slave with this option before you make the slave read its own events that you want the slave SQL thread to execute.

- `--replicate-wild-do-table=db_name.tbl_name`

Command-Line Format	`--replicate-wild-do-table=name`	
Permitted Values	Type	string

Tells the slave thread to restrict replication to statements where any of the updated tables match the specified database and table name patterns. Patterns can contain the `%` and `_` wildcard characters, which have the same meaning as for the `LIKE` pattern-matching operator. To specify more than one table, use this option multiple times, once for each table. This works for cross-database updates. See Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”.

This option applies to tables, views, and triggers. It does not apply to stored procedures and functions, or events. To filter statements operating on the latter objects, use one or more of the `--replicate-*-db` options.

Example: `--replicate-wild-do-table=foo%.bar%` replicates only updates that use a table where the database name starts with `foo` and the table name starts with `bar`.

If the table name pattern is `%`, it matches any table name and the option also applies to database-level statements (`CREATE DATABASE`, `DROP DATABASE`, and `ALTER DATABASE`). For example, if you use `--replicate-wild-do-table=foo%.%`, database-level statements are replicated if the database name matches the pattern `foo%`.

To include literal wildcard characters in the database or table name patterns, escape them with a backslash. For example, to replicate all tables of a database that is named `my_own%db`, but not replicate tables from the `my1ownAABCdb` database, you should escape the `_` and `%` characters like this: `--replicate-wild-do-table=my\_own\%db`. If you use the option on the command line, you might need to double the backslashes or quote the option value, depending on your command interpreter. For example, with the `bash` shell, you would need to type `--replicate-wild-do-table=my\\_own\\%db`.

- `--replicate-wild-ignore-table=db_name.tbl_name`

Command-Line Format	`--replicate-wild-ignore-table=name`	
Permitted Values	Type	string

Tells the slave thread not to replicate a statement where any table matches the given wildcard pattern. To specify more than one table to ignore, use this option multiple times, once for each table. This works for cross-database updates. See Section 17.2.3, "How Servers Evaluate Replication Filtering Rules".

Example: `--replicate-wild-ignore-table=foo%.bar%` does not replicate updates that use a table where the database name starts with `foo` and the table name starts with `bar`.

For information about how matching works, see the description of the `--replicate-wild-do-table` option. The rules for including literal wildcard characters in the option value are the same as for `--replicate-wild-ignore-table` as well.

- `--report-host=host_name`

Command-Line Format	`--report-host=host_name`	
System Variable	Name	`report_host`
	Scope	Global
	Dynamic	No
Permitted Values	Type	string

The host name or IP address of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server. Leave the value unset if you do not want the slave to register itself with the master. Note that it is not sufficient for the master to simply read the IP address of the slave from the TCP/IP socket after the slave connects. Due to NAT and other routing issues, that IP may not be valid for connecting to the slave from the master or other hosts.

- `--report-password=password`

Command-Line Format	`--report-password=name`	
System Variable	Name	`report_password`
	Scope	Global
	Dynamic	No
Permitted Values	Type	string

The account password of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the master was started with `--show-slave-auth-info`.

Although the name of this option might imply otherwise, `--report-password` is not connected to the MySQL user privilege system and so is not necessarily (or even likely to be) the same as the password for the MySQL replication user account.

- `--report-port=slave_port_num`

Command-Line Format	`--report-port=#`	
System Variable	Name	`report_port`
	Scope	Global
	Dynamic	No
Permitted Values (<= 5.5.22)	Type	integer
	Default	`3306`
	Minimum	`0`

	Maximum	65535
Permitted Values (>= 5.5.23)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	65535

The TCP/IP port number for connecting to the slave, to be reported to the master during slave registration. Set this only if the slave is listening on a nondefault port or if you have a special tunnel from the master or other clients to the slave. If you are not sure, do not use this option.

Prior to MySQL 5.5.23, the default value for this option was 3306. In MySQL 5.5.23 and later, the value shown is the port number actually used by the slave (Bug #13333431). This change also affects the default value displayed by `SHOW SLAVE HOSTS`.

- `--report-user=user_name`

Command-Line Format	`--report-user=name`	
System Variable	**Name**	`report_user`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	string

The account user name of the slave to be reported to the master during slave registration. This value appears in the output of `SHOW SLAVE HOSTS` on the master server if the master was started with `--show-slave-auth-info`.

Although the name of this option might imply otherwise, `--report-user` is not connected to the MySQL user privilege system and so is not necessarily (or even likely to be) the same as the name of the MySQL replication user account.

- `--skip-slave-start`

Command-Line Format	`--skip-slave-start`	
Permitted Values	**Type**	boolean
	Default	`FALSE`

Tells the slave server not to start the slave threads when the server starts. To start the threads later, use a `START SLAVE` statement.

- `--slave_compressed_protocol={0|1}`

Command-Line Format	`--slave-compressed-protocol`	
System Variable	**Name**	`slave_compressed_protocol`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

If this option is set to 1, use compression for the slave/master protocol if both the slave and the master support it. The default is 0 (no compression).

- `--slave-load-tmpdir=dir_name`

Command-Line Format	--slave-load-tmpdir=dir_name	
System Variable	Name	slave_load_tmpdir
	Scope	Global
	Dynamic	No
Permitted Values	Type	directory name
	Default	/tmp

The name of the directory where the slave creates temporary files. This option is by default equal to the value of the `tmpdir` system variable. When the slave SQL thread replicates a `LOAD DATA INFILE` statement, it extracts the file to be loaded from the relay log into temporary files, and then loads these into the table. If the file loaded on the master is huge, the temporary files on the slave are huge, too. Therefore, it might be advisable to use this option to tell the slave to put temporary files in a directory located in some file system that has a lot of available space. In that case, the relay logs are huge as well, so you might also want to use the `--relay-log` option to place the relay logs in that file system.

The directory specified by this option should be located in a disk-based file system (not a memory-based file system) because the temporary files used to replicate `LOAD DATA INFILE` must survive machine restarts. The directory also should not be one that is cleared by the operating system during the system startup process.

- `--slave-net-timeout=`*`seconds`*

Command-Line Format	--slave-net-timeout=#	
System Variable	Name	slave_net_timeout
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	3600
	Minimum	1

The number of seconds to wait for more data from the master before the slave considers the connection broken, aborts the read, and tries to reconnect. The first retry occurs immediately after the timeout. The interval between retries is controlled by the `MASTER_CONNECT_RETRY` option for the `CHANGE MASTER TO` statement, and the number of reconnection attempts is limited by the `--master-retry-count` option. The default is 3600 seconds (one hour).

- `--slave-skip-errors=[`*`err_code1`*`,`*`err_code2`*`,...|all]`

(*MySQL NDB Cluster 7.2.6 and later:*) `--slave-skip-errors=[`*`err_code1`*`,`*`err_code2`*`,...|all|ddl_exist_errors]`

Command-Line Format	--slave-skip-errors=name	
System Variable	Name	slave_skip_errors
	Scope	Global
	Dynamic	No
Permitted Values (>= 5.5.22)	Type	string
	Default	OFF
	Valid Values	OFF
		[list of error codes]

		`all`
		`ddl_exist_errors`

Normally, replication stops when an error occurs on the slave. This gives you the opportunity to resolve the inconsistency in the data manually. This option tells the slave SQL thread to continue replication when a statement returns any of the errors listed in the option value.

Do not use this option unless you fully understand why you are getting errors. If there are no bugs in your replication setup and client programs, and no bugs in MySQL itself, an error that stops replication should never occur. Indiscriminate use of this option results in slaves becoming hopelessly out of synchrony with the master, with you having no idea why this has occurred.

For error codes, you should use the numbers provided by the error message in your slave error log and in the output of `SHOW SLAVE STATUS`. Appendix B, *Errors, Error Codes, and Common Problems*, lists server error codes.

You can also (but should not) use the very nonrecommended value of `all` to cause the slave to ignore all error messages and keeps going regardless of what happens. Needless to say, if you use `all`, there are no guarantees regarding the integrity of your data. Please do not complain (or file bug reports) in this case if the slave's data is not anywhere close to what it is on the master. *You have been warned*.

MySQL NDB Cluster 7.2.6 and later support an additional shorthand value `ddl_exist_errors` for use with the enhanced failover mechanism which is implemented beginning with that version of NDB Cluster. This value is equivalent to the error code list `1007,1008,1050,1051,1054,1060,1061,1068,1094,1146`. *This value is not supported by the `mysqld` binary included with the MySQL Server 5.5 distribution*. (Bug #11762277, Bug #54854) For more information, see Section 18.6.8, “Implementing Failover with NDB Cluster Replication”.

Examples:

```
--slave-skip-errors=1062,1053
--slave-skip-errors=all
--slave-skip-errors=ddl_exist_errors
```

Obsolete Replication Slave Options

The following options are removed in MySQL 5.5. If you attempt to start `mysqld` with any of these options in MySQL 5.5, the server aborts with an `unknown variable` error. To set the replication parameters formerly associated with these options, you must use the `CHANGE MASTER TO ...` statement (see Section 13.4.2.1, “CHANGE MASTER TO Syntax”).

The options affected are shown in this list:

- `--master-host`
- `--master-user`
- `--master-password`
- `--master-port`
- `--master-connect-retry`
- `--master-ssl`
- `--master-ssl-ca`
- `--master-ssl-capath`
- `--master-ssl-cert`

- `--master-ssl-cipher`
- `--master-ssl-key`

System Variables Used on Replication Slaves

The following list describes system variables for controlling replication slave servers. They can be set at server startup and some of them can be changed at runtime using `SET`. Server options used with replication slaves are listed earlier in this section.

- `init_slave`

Command-Line Format	`--init-slave=name`	
System Variable	Name	`init_slave`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	string

This variable is similar to `init_connect`, but is a string to be executed by a slave server each time the SQL thread starts. The format of the string is the same as for the `init_connect` variable.

Note

The SQL thread sends an acknowledgment to the client before it executes `init_slave`. Therefore, it is not guaranteed that `init_slave` has been executed when `START SLAVE` returns. See Section 13.4.2.5, “START SLAVE Syntax”, for more information.

- `relay_log`

Command-Line Format	`--relay-log=file_name`	
System Variable	Name	`relay_log`
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name

The name of the relay log file.

- `relay_log_index`

Command-Line Format	`--relay-log-index`	
System Variable	Name	`relay_log_index`
	Scope	Global
	Dynamic	No
Permitted Values	Type	file name
	Default	`*host_name*-relay-bin.index`

The name of the relay log index file. The default name is *`host_name`*`-relay-bin.index` in the data directory, where *`host_name`* is the name of the slave server.

- `relay_log_info_file`

Command-Line Format	`--relay-log-info-file=file_name`	
System Variable	Name	`relay_log_info_file`

	Scope	Global
	Dynamic	No
Permitted Values	**Type**	file name
	Default	`relay-log.info`

The name of the file in which the slave records information about the relay logs. The default name is `relay-log.info` in the data directory.

- `relay_log_recovery`

Command-Line Format	`--relay-log-recovery`	
System Variable	**Name**	`relay_log_recovery`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`FALSE`

Enables automatic relay log recovery immediately following server startup, which means that the replication slave discards all unprocessed relay logs and retrieves them from the replication master. This should be used following a crash on the replication slave to ensure that no possibly corrupted relay logs are processed. The default value is 0 (disabled). This global variable can be changed dynamically, or by starting the slave with the `--relay-log-recovery` option.

- `rpl_recovery_rank`

This variable is unused, and is removed in MySQL 5.6.

- `slave_compressed_protocol`

Command-Line Format	`--slave-compressed-protocol`	
System Variable	**Name**	`slave_compressed_protocol`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Whether to use compression of the slave/master protocol if both the slave and the master support it.

- `slave_exec_mode`

Command-Line Format	`--slave-exec-mode=mode`	
System Variable	**Name**	`slave_exec_mode`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`STRICT` (ALL)
	Default	`IDEMPOTENT` (NDB)
	Valid Values	`IDEMPOTENT`
		`STRICT`

Controls how a slave thread resolves conflicts and errors during replication. `IDEMPOTENT` mode causes suppression of duplicate-key and no-key-found errors; `STRICT` means no such suppression takes place.

`IDEMPOTENT` mode is intended for use in multi-master replication, circular replication, and some other special replication scenarios for NDB Cluster Replication. (See Section 18.6.10, "NDB Cluster Replication: Multi-Master and Circular Replication", and Section 18.6.11, "NDB Cluster Replication Conflict Resolution", for more information.) NDB Cluster ignores any value explicitly set for `slave_exec_mode`, and always treats it as `IDEMPOTENT`.

In MySQL Server 5.5, `STRICT` mode is the default value.

For storage engines other than `NDB`, *`IDEMPOTENT` mode should be used only when you are absolutely sure that duplicate-key errors and key-not-found errors can safely be ignored*. It is meant to be used in fail-over scenarios for NDB Cluster where multi-master replication or circular replication is employed, and is not recommended for use in other cases.

- `slave_load_tmpdir`

Command-Line Format	`--slave-load-tmpdir=dir_name`	
System Variable	**Name**	`slave_load_tmpdir`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	directory name
	Default	`/tmp`

The name of the directory where the slave creates temporary files for replicating `LOAD DATA INFILE` statements.

- `slave_max_allowed_packet`

Introduced	5.5.26	
System Variable	**Name**	`slave_max_allowed_packet`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer
	Default	`1073741824`
	Minimum	`1024`
	Maximum	`1073741824`

In MySQL 5.5.26 and later, this variable sets the maximum packet size for the slave SQL and I/O threads, so that large updates using row-based replication do not cause replication to fail because an update exceeded `max_allowed_packet`.

This global variable always has a value that is a positive integer multiple of 1024; if you set it to some value that is not, the value is rounded down to the next highest multiple of 1024 for it is stored or used; setting `slave_max_allowed_packet` to 0 causes 1024 to be used. (A truncation warning is issued in all such cases.) The default and maximum value is 1073741824 (1 GB); the minimum is 1024.

`slave_max_allowed_packet` can also be set at startup, using the `--slave-max-allowed-packet` option.

- `slave_net_timeout`

Command-Line Format	--slave-net-timeout=#	
System Variable	Name	slave_net_timeout
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	3600
	Minimum	1

The number of seconds to wait for more data from a master/slave connection before aborting the read.

- slave_skip_errors

Command-Line Format	--slave-skip-errors=name	
System Variable	Name	slave_skip_errors
	Scope	Global
	Dynamic	No
Permitted Values (>= 5.5.22)	Type	string
	Default	OFF
	Valid Values	OFF
		[list of error codes]
		all
		ddl_exist_errors

Normally, replication stops when an error occurs on the slave. This gives you the opportunity to resolve the inconsistency in the data manually. This variable tells the slave SQL thread to continue replication when a statement returns any of the errors listed in the variable value.

- slave_transaction_retries

Command-Line Format	--slave-transaction-retries=#	
System Variable	Name	slave_transaction_retries
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	10
	Minimum	0
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	Type	integer
	Default	10
	Minimum	0
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	Type	integer
	Default	10
	Minimum	0
	Maximum	18446744073709551615

If a replication slave SQL thread fails to execute a transaction because of an `InnoDB` deadlock or because the transaction's execution time exceeded `InnoDB`'s `innodb_lock_wait_timeout` or `NDBCLUSTER`'s `TransactionDeadlockDetectionTimeout` or `TransactionInactiveTimeout`, it automatically retries `slave_transaction_retries` times before stopping with an error. The default value is 10.

- `slave_type_conversions`

Introduced	5.5.3	
Command-Line Format	`--slave-type-conversions=set`	
System Variable	**Name**	`slave_type_conversions`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	set
	Default	
	Valid Values	`ALL_LOSSY`
		`ALL_NON_LOSSY`

Controls the type conversion mode in effect on the slave when using row-based replication, including NDB Cluster Replication. Its value is a comma-delimited set of zero or more elements from the list: `ALL_LOSSY`, `ALL_NON_LOSSY`. Set this variable to an empty string to disallow type conversions between the master and the slave. Changes require a restart of the slave to take effect.

For additional information on type conversion modes applicable to attribute promotion and demotion in row-based replication, see Row-based replication: attribute promotion and demotion.

This variable was added in MySQL 5.5.3.

- `sql_slave_skip_counter`

System Variable	**Name**	`sql_slave_skip_counter`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	integer

The number of events from the master that a slave server should skip.

Important

If skipping the number of events specified by setting this variable would cause the slave to begin in the middle of an event group, the slave continues to skip until it finds the beginning of the next event group and begins from that point. For more information, see Section 13.4.2.4, “SET GLOBAL sql_slave_skip_counter Syntax”.

- `sync_master_info`

Command-Line Format	`--sync-master-info=#`	
System Variable	**Name**	`sync_master_info`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer

	Default	0
	Minimum	0
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	18446744073709551615

If the value of this variable is greater than 0, a replication slave synchronizes its `master.info` file to disk (using `fdatasync()`) after every `sync_master_info` events. The default value is 0 (recommended in most situations), which does not force any synchronization to disk by the MySQL server; in this case, the server relies on the operating system to flush the `master.info` file's contents from time to time as for any other file.

- `sync_relay_log`

Command-Line Format	`--sync-relay-log=#`	
System Variable	**Name**	`sync_relay_log`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	0
	Minimum	0
	Maximum	18446744073709551615

If the value of this variable is greater than 0, the MySQL server synchronizes its relay log to disk (using `fdatasync()`) after every `sync_relay_log` events are written to the relay log.

The default value of `sync_relay_log` is 0, which does no synchronizing to disk; in this case, the server relies on the operating system to flush the relay log's contents from time to time as for any other file.

A value of 1 is the safest choice because in the event of a crash you lose at most one event from the relay log. However, it is also the slowest choice (unless the disk has a battery-backed cache, which makes synchronization very fast).

- `sync_relay_log_info`

Command-Line Format	--sync-relay-log-info=#	
System Variable	Name	sync_relay_log_info
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	0
	Minimum	0
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	Type	integer
	Default	0
	Minimum	0
	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	Type	integer
	Default	0
	Minimum	0
	Maximum	18446744073709551615

If the value of this variable is greater than 0, a replication slave synchronizes its `relay-log.info` file to disk (using `fdatasync()`) after every `sync_relay_log_info` transactions. A value of 1 is the generally the best choice. The default value of `sync_relay_log_info` is 0, which does not force any synchronization to disk by the MySQL server—in this case, the server relies on the operating system to flush the `relay-log.info` file's contents from time to time as for any other file.

17.1.3.4 Binary Log Options and Variables

Startup Options Used with Binary Logging

System Variables Used with Binary Logging

You can use the `mysqld` options and system variables that are described in this section to affect the operation of the binary log as well as to control which statements are written to the binary log. For additional information about the binary log, see Section 5.4.4, “The Binary Log”. For additional information about using MySQL server options and system variables, see Section 5.1.4, “Server Command Options”, and Section 5.1.5, “Server System Variables”.

Startup Options Used with Binary Logging

The following list describes startup options for enabling and configuring the binary log. System variables used with binary logging are discussed later in this section.

- `--binlog-row-event-max-size=N`

Command-Line Format	--binlog-row-event-max-size=#	
Permitted Values (32-bit platforms)	Type	integer
	Default	1024
	Minimum	256
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	Type	integer
	Default	1024
	Minimum	256

	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	1024
	Minimum	256
	Maximum	18446744073709551615

Specify the maximum size of a row-based binary log event, in bytes. Rows are grouped into events smaller than this size if possible. The value should be a multiple of 256. The default is 1024. See Section 17.1.2, “Replication Formats”.

- `--log-bin[=base_name]`

Command-Line Format	`--log-bin`	
System Variable	**Name**	`log_bin`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	file name

Enable binary logging. The server logs all statements that change data to the binary log, which is used for backup and replication. See Section 5.4.4, “The Binary Log”.

The option value, if given, is the base name for the log sequence. The server creates binary log files in sequence by adding a numeric suffix to the base name. It is recommended that you specify a base name (see Section B.5.7, “Known Issues in MySQL”, for the reason). Otherwise, MySQL uses *`host_name`*`-bin` as the base name.

In MySQL 5.5.20 and later, when the server reads an entry from the index file, it checks whether the entry contains a relative path, and if it does, the relative part of the path is replaced with the absolute path set using the `--log-bin` option. An absolute path remains unchanged; in such a case, the index must be edited manually to enable the new path or paths to be used. Previous to MySQL 5.5.20, manual intervention was required whenever relocating the binary log or relay log files. (Bug #11745230, Bug #12133)

Setting this option causes the `log_bin` system variable to be set to `ON` (or `1`), and not to the base name. This is a known issue; see Bug #19614 for more information.

- `--log-bin-index[=file_name]`

Command-Line Format	`--log-bin-index=file_name`	
Permitted Values	**Type**	file name

The index file for binary log file names. See Section 5.4.4, “The Binary Log”. If you omit the file name, and if you did not specify one with `--log-bin`, MySQL uses *`host_name`*`-bin.index` as the file name.

- `--log-bin-trust-function-creators[={0|1}]`

Command-Line Format	`--log-bin-trust-function-creators`	
System Variable	**Name**	`log_bin_trust_function_creators`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	FALSE

This option sets the corresponding `log_bin_trust_function_creators` system variable. If no argument is given, the option sets the variable to 1. `log_bin_trust_function_creators` affects how MySQL enforces restrictions on stored function and trigger creation. See Section 20.7, "Binary Logging of Stored Programs".

- `--log-bin-use-v1-row-events[={0|1}]`

Introduced	5.5.15-ndb-7.2.1	
Command-Line Format	`--log-bin-use-v1-row-events[={0|1}]`	
System Variable	**Name**	`log_bin_use_v1_row_events`
	Scope	Global
	Dynamic	No
Permitted Values (>= 5.5.15-ndb-7.2.1)	**Type**	boolean
	Default	`0`

Version 2 binary log row events are used by default beginning with MySQL NDB Cluster 7.2.1; however, Version 2 events cannot be read by previous NDB Cluster releases. Setting `--log-bin-use-v1-row-events` to 1 causes `mysqld` to write the binary log using Version 1 logging events, which is the only version of binary log events used in previous releases, and thus produce binary logs that can be read by older slaves.

The value used for this option can be obtained from the read-only `log_bin_use_v1_row_events` system variable.

`--log-bin-use-v1-row-events` is chiefly of interest when setting up replication conflict detection and resolution using `NDB$EPOCH_TRANS()` as the conflict detection function, which requires Version 2 binary log row events. Thus, this option and `--ndb-log-transaction-id` are not compatible.

Note

Version 2 binary log row events are also available in MySQL NDB Cluster 7.0.27 and MySQL NDB Cluster 7.1.6 and later MySQL NDB Cluster 7.0 and 7.1 releases. However, prior to MySQL NDB Cluster 7.2.1, Version 1 events are the default (and so the default value for this option is 1 in those versions). You should keep this mind when planning upgrades for setups using NDB Cluster Replication.

`--log-bin-use-v1-row-events` is not supported in mainline MySQL Server 5.5 releases.

For more information, see Section 18.6.11, "NDB Cluster Replication Conflict Resolution".

Statement selection options. The options in the following list affect which statements are written to the binary log, and thus sent by a replication master server to its slaves. There are also options for slave servers that control which statements received from the master should be executed or ignored. For details, see Section 17.1.3.3, "Replication Slave Options and Variables".

- `--binlog-do-db=`*`db_name`*

Command-Line Format	`--binlog-do-db=name`	
Permitted Values	**Type**	string

This option affects binary logging in a manner similar to the way that `--replicate-do-db` affects replication.

The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--replicate-do-db` depend on whether statement-based or row-based replication is in use. You should keep in mind that the format used to log a given statement may not necessarily be the same as that indicated by the value of `binlog_format`. For example, DDL statements such as `CREATE TABLE` and `ALTER TABLE` are always logged as statements, without regard to the logging format in effect, so the following statement-based rules for `--binlog-do-db` always apply in determining whether or not the statement is logged.

Statement-based logging. Only those statements are written to the binary log where the default database (that is, the one selected by `USE`) is *`db_name`*. To specify more than one database, use this option multiple times, once for each database; however, doing so does *not* cause cross-database statements such as `UPDATE some_db.some_table SET foo='bar'` to be logged while a different database (or no database) is selected.

Warning

To specify multiple databases you *must* use multiple instances of this option. Because database names can contain commas, the list will be treated as the name of a single database if you supply a comma-separated list.

An example of what does not work as you might expect when using statement-based logging: If the server is started with `--binlog-do-db=sales` and you issue the following statements, the `UPDATE` statement is *not* logged:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The main reason for this “just check the default database” behavior is that it is difficult from the statement alone to know whether it should be replicated (for example, if you are using multiple-table `DELETE` statements or multiple-table `UPDATE` statements that act across multiple databases). It is also faster to check only the default database rather than all databases if there is no need.

Another case which may not be self-evident occurs when a given database is replicated even though it was not specified when setting the option. If the server is started with `--binlog-do-db=sales`, the following `UPDATE` statement is logged even though `prices` was not included when setting `--binlog-do-db`:

```
USE sales;
UPDATE prices.discounts SET percentage = percentage + 10;
```

Because `sales` is the default database when the `UPDATE` statement is issued, the `UPDATE` is logged.

Row-based logging. Logging is restricted to database *`db_name`*. Only changes to tables belonging to *`db_name`* are logged; the default database has no effect on this. Suppose that the server is started with `--binlog-do-db=sales` and row-based logging is in effect, and then the following statements are executed:

```
USE prices;
UPDATE sales.february SET amount=amount+100;
```

The changes to the `february` table in the `sales` database are logged in accordance with the `UPDATE` statement; this occurs whether or not the `USE` statement was issued. However, when using the row-based logging format and `--binlog-do-db=sales`, changes made by the following `UPDATE` are not logged:

```
USE prices;
```

```
UPDATE prices.march SET amount=amount-25;
```

Even if the `USE prices` statement were changed to `USE sales`, the `UPDATE` statement's effects would still not be written to the binary log.

Another important difference in `--binlog-do-db` handling for statement-based logging as opposed to the row-based logging occurs with regard to statements that refer to multiple databases. Suppose that the server is started with `--binlog-do-db=db1`, and the following statements are executed:

```
USE db1;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

If you are using statement-based logging, the updates to both tables are written to the binary log. However, when using the row-based format, only the changes to `table1` are logged; `table2` is in a different database, so it is not changed by the `UPDATE`. Now suppose that, instead of the `USE db1` statement, a `USE db4` statement had been used:

```
USE db4;
UPDATE db1.table1 SET col1 = 10, db2.table2 SET col2 = 20;
```

In this case, the `UPDATE` statement is not written to the binary log when using statement-based logging. However, when using row-based logging, the change to `table1` is logged, but not that to `table2`—in other words, only changes to tables in the database named by `--binlog-do-db` are logged, and the choice of default database has no effect on this behavior.

- `--binlog-ignore-db=`*`db_name`*

Command-Line Format	`--binlog-ignore-db=name`	
Permitted Values	**Type**	string

This option affects binary logging in a manner similar to the way that `--replicate-ignore-db` affects replication.

The effects of this option depend on whether the statement-based or row-based logging format is in use, in the same way that the effects of `--replicate-ignore-db` depend on whether statement-based or row-based replication is in use. You should keep in mind that the format used to log a given statement may not necessarily be the same as that indicated by the value of `binlog_format`. For example, DDL statements such as `CREATE TABLE` and `ALTER TABLE` are always logged as statements, without regard to the logging format in effect, so the following statement-based rules for `--binlog-ignore-db` always apply in determining whether or not the statement is logged.

Statement-based logging. Tells the server to not log any statement where the default database (that is, the one selected by `USE`) is *`db_name`*.

Prior to MySQL 5.5.32, this option caused any statements containing fully qualified table names not to be logged if there was no default database specified (that is, when `SELECT DATABASE()` returned `NULL`). In MySQL 5.5.32 and later, when there is no default database, no `--binlog-ignore-db` options are applied, and such statements are always logged. (Bug #11829838, Bug #60188)

Row-based format. Tells the server not to log updates to any tables in the database *`db_name`*. The current database has no effect.

When using statement-based logging, the following example does not work as you might expect. Suppose that the server is started with `--binlog-ignore-db=sales` and you issue the following statements:

```
USE prices;
UPDATE sales.january SET amount=amount+1000;
```

The UPDATE statement *is* logged in such a case because --binlog-ignore-db applies only to the default database (determined by the USE statement). Because the sales database was specified explicitly in the statement, the statement has not been filtered. However, when using row-based logging, the UPDATE statement's effects are *not* written to the binary log, which means that no changes to the sales.january table are logged; in this instance, --binlog-ignore-db=sales causes *all* changes made to tables in the master's copy of the sales database to be ignored for purposes of binary logging.

To specify more than one database to ignore, use this option multiple times, once for each database. Because database names can contain commas, the list will be treated as the name of a single database if you supply a comma-separated list.

You should not use this option if you are using cross-database updates and you do not want these updates to be logged.

Testing and debugging options. The following binary log options are used in replication testing and debugging. They are not intended for use in normal operations.

- --max-binlog-dump-events=*N*

Command-Line Format	--max-binlog-dump-events=#	
Permitted Values	Type	integer
	Default	0

This option is used internally by the MySQL test suite for replication testing and debugging.

- --sporadic-binlog-dump-fail

Command-Line Format	--sporadic-binlog-dump-fail	
Permitted Values	Type	boolean
	Default	FALSE

This option is used internally by the MySQL test suite for replication testing and debugging.

System Variables Used with Binary Logging

The following list describes system variables for controlling binary logging. They can be set at server startup and some of them can be changed at runtime using SET. Server options used to control binary logging are listed earlier in this section. For information about the sql_log_bin and sql_log_off variables, see Section 5.1.5, “Server System Variables”.

- binlog_cache_size

Command-Line Format	--binlog-cache-size=#	
System Variable	Name	binlog_cache_size
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	Type	integer
	Default	32768
	Minimum	4096
	Maximum	4294967295
Permitted Values (64-bit platforms, <= 5.5.2)	Type	integer
	Default	32768
	Minimum	4096

	Maximum	18446744073709547520
Permitted Values (64-bit platforms, >= 5.5.3)	**Type**	integer
	Default	32768
	Minimum	4096
	Maximum	18446744073709551615

The size of the cache to hold changes to the binary log during a transaction. A binary log cache is allocated for each client if the server supports any transactional storage engines and if the server has the binary log enabled (`--log-bin` option). If you often use large transactions, you can increase this cache size to get better performance. The `Binlog_cache_use` and `Binlog_cache_disk_use` status variables can be useful for tuning the size of this variable. See Section 5.4.4, “The Binary Log”.

In MySQL 5.5.3, a separate binary log cache (the binary log statement cache) was introduced for nontransactional statements and in MySQL 5.5.3 through 5.5.8, this variable sets.the size for both caches. This means that, in these MySQL versions, the total memory used for these caches is double the value set for `binlog_cache_size`.

Beginning with MySQL 5.5.9, `binlog_cache_size` sets the size for the transaction cache only, and the size of the statement cache is governed by the `binlog_stmt_cache_size` system variable.

- `binlog_direct_non_transactional_updates`

Introduced	5.5.2	
Command-Line Format	`--binlog-direct-non-transactional-updates[=value]`	
System Variable	**Name**	`binlog_direct_non_transactional_updates`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`OFF`

Due to concurrency issues, a slave can become inconsistent when a transaction contains updates to both transactional and nontransactional tables. MySQL tries to preserve causality among these statements by writing nontransactional statements to the transaction cache, which is flushed upon commit. However, problems arise when modifications done to nontransactional tables on behalf of a transaction become immediately visible to other connections because these changes may not be written immediately into the binary log.

Beginning with MySQL 5.5.2, the `binlog_direct_non_transactional_updates` variable offers one possible workaround to this issue. By default, this variable is disabled. Enabling `binlog_direct_non_transactional_updates` causes updates to nontransactional tables to be written directly to the binary log, rather than to the transaction cache.

`binlog_direct_non_transactional_updates` works only for statements that are replicated using the statement-based binary logging format; that is, it works only when the value of `binlog_format` is `STATEMENT`, or when `binlog_format` is `MIXED` and a given statement is being replicated using the statement-based format. This variable has no effect when the binary log format is `ROW`, or when `binlog_format` is set to `MIXED` and a given statement is replicated using the row-based format.

Important

Before enabling this variable, you must make certain that there are no dependencies between transactional and nontransactional tables; an

> example of such a dependency would be the statement `INSERT INTO myisam_table SELECT * FROM innodb_table`. Otherwise, such statements are likely to cause the slave to diverge from the master.

Beginning with MySQL 5.5.5, this variable has no effect when the binary log format is `ROW` or `MIXED`. (Bug #51291)

- `binlog_format`

Command-Line Format	`--binlog-format=format`	
System Variable	**Name**	`binlog_format`
	Scope	Global, Session
	Dynamic	Yes
Permitted Values	**Type**	enumeration
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.5.15-ndb-7.2.1, <= 5.5.30-ndb-7.2.12)	**Type**	enumeration
	Default	`STATEMENT`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`
Permitted Values (>= 5.5.31-ndb-7.2.13)	**Type**	enumeration
	Default	`MIXED`
	Valid Values	`ROW`
		`STATEMENT`
		`MIXED`

This variable sets the binary logging format, and can be any one of `STATEMENT`, `ROW`, or `MIXED`. See Section 17.1.2, “Replication Formats”. `binlog_format` is set by the `--binlog-format` option at startup, or by the `binlog_format` system variable at runtime.

> **Note**
>
> While you can change the logging format at runtime, it is *not* recommended that you change it while replication is ongoing. This is due in part to the fact that slaves do not honor the master's `binlog_format` setting; a given MySQL Server can change only its own logging format.

In MySQL 5.5, the default format is `STATEMENT`.

Exception. In MySQL NDB Cluster 7.2.1 through MySQL NDB Cluster 7.2.12, the default for this variable is `STATEMENT`. In MySQL NDB Cluster 7.2.13 and later, when the `NDB` storage engine is enabled, the default is `MIXED`. (Bug #16417224) See also Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”, and Section 18.6.7, “Using Two Replication Channels for NDB Cluster Replication”.

You must have the `SUPER` privilege to set either the global or session `binlog_format` value.

The rules governing when changes to this variable take effect and how long the effect lasts are the same as for other MySQL server system variables. For more information, see Section 13.7.4.1, “SET Syntax for Variable Assignment”.

When `MIXED` is specified, statement-based replication is used, except for cases where only row-based replication is guaranteed to lead to proper results. For example, this happens when statements contain user-defined functions (UDF) or the `UUID()` function. An exception to this rule is that `MIXED` always uses statement-based replication for stored functions and triggers.

There are exceptions when you cannot switch the replication format at runtime:

- From within a stored function or a trigger.
- If the session is currently in row-based replication mode and has open temporary tables.
- Beginning with MySQL 5.5.3, within a transaction. (Bug #47863)

Trying to switch the format in those cases results in an error.

Note

Prior to MySQL NDB Cluster 7.2.1, it was also not possible to change the binary logging format at runtime when the `NDBCLUSTER` storage engine was enabled. In MySQL NDB Cluster 7.2.1 and later, this restriction is removed.

The binary log format affects the behavior of the following server options:

- `--replicate-do-db`
- `--replicate-ignore-db`
- `--binlog-do-db`
- `--binlog-ignore-db`

These effects are discussed in detail in the descriptions of the individual options.

- `binlog_stmt_cache_size`

Introduced	5.5.9	
Command-Line Format	`--binlog-stmt-cache-size=#`	
System Variable	**Name**	`binlog_stmt_cache_size`
	Scope	Global
	Dynamic	Yes
Permitted Values (32-bit platforms)	**Type**	integer
	Default	`32768`
	Minimum	`4096`
	Maximum	`4294967295`
Permitted Values (64-bit platforms)	**Type**	integer
	Default	`32768`
	Minimum	`4096`
	Maximum	`18446744073709551615`

Beginning with MySQL 5.5.9, this variable determines the size of the cache for the binary log to hold nontransactional statements issued during a transaction. In MySQL 5.5.3 and later,

separate binary log transaction and statement caches are allocated for each client if the server supports any transactional storage engines and if the server has the binary log enabled (`--log-bin` option). If you often use large nontransactional statements during transactions, you can increase this cache size to get more performance. The `Binlog_stmt_cache_use` and `Binlog_stmt_cache_disk_use` status variables can be useful for tuning the size of this variable. See Section 5.4.4, “The Binary Log”.

In MySQL 5.5.3 through 5.5.8, the size for both caches is set using `binlog_cache_size`. This means that, in these MySQL versions, the total memory used for these caches is double the value set for `binlog_cache_size`. Beginning with MySQL 5.5.9, `binlog_cache_size` sets the size for the transaction cache only.

- `log_bin`

System Variable	Name	`log_bin`
	Scope	Global
	Dynamic	No

Whether the binary log is enabled. If the `--log-bin` option is used, then the value of this variable is `ON`; otherwise it is `OFF`. This variable reports only on the status of binary logging (enabled or disabled); it does not actually report the value to which `--log-bin` is set.

See Section 5.4.4, “The Binary Log”.

- `log_bin_use_v1_row_events`

Introduced	5.5.15-ndb-7.2.1	
Command-Line Format	`--log-bin-use-v1-row-events[={0|1}]`	
System Variable	Name	`log_bin_use_v1_row_events`
	Scope	Global
	Dynamic	No
Permitted Values (>= 5.5.15-ndb-7.2.1)	Type	boolean
	Default	`0`

Shows whether Version 2 binary logging, available beginning with MySQL NDB Cluster 7.2.1, is in use. A value of 1 shows that the server is writing the binary log using Version 1 logging events (the only version of binary log events used in previous releases), and thus producing a binary log that can be read by older slaves. 0 indicates that Version 2 binary log events are in use.

This variable is read-only. To switch between Version 1 and Version 2 binary event binary logging, it is necessary to restart `mysqld` with the `--log-bin-use-v1-row-events` option.

Other than when performing upgrades of NDB Cluster Replication, `--log-bin-use-v1-events` is chiefly of interest when setting up replication conflict detection and resolution using `NDB$EPOCH_TRANS()`, which requires Version 2 binary row event logging. Thus, this option and `--ndb-log-transaction-id` are not compatible.

Note

MySQL NDB Cluster 7.2.1 and later use Version 2 binary log row events by default (and so the default value for this variable changes to 0 in those versions). You should keep this mind when planning upgrades for setups using NDB Cluster Replication.

This variable is not supported in mainline MySQL Server 5.5.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `log_slave_updates`

Command-Line Format	`--log-slave-updates`	
System Variable	Name	`log_slave_updates`
	Scope	Global
	Dynamic	No
Permitted Values	Type	boolean
	Default	`FALSE`

Whether updates received by a slave server from a master server should be logged to the slave's own binary log. Binary logging must be enabled on the slave for this variable to have any effect. See Section 17.1.3, “Replication and Binary Logging Options and Variables”.

- `max_binlog_cache_size`

Command-Line Format	`--max-binlog-cache-size=#`	
System Variable	Name	`max_binlog_cache_size`
	Scope	Global
	Dynamic	Yes
Permitted Values (<= 5.5.2)	Type	integer
	Default	`18446744073709547520`
	Minimum	`4096`
	Maximum	`18446744073709547520`
Permitted Values (>= 5.5.3)	Type	integer
	Default	`18446744073709551615`
	Minimum	`4096`
	Maximum	`18446744073709551615`

If a transaction requires more than this many bytes of memory, the server generates a `Multi-statement transaction required more than 'max_binlog_cache_size' bytes of storage` error. The minimum value is 4096. The maximum possible value is 16EB (exabytes). The maximum recommended value is 4GB; this is due to the fact that MySQL currently cannot work with binary log positions greater than 4GB.

Note

Prior to MySQL 5.5.28, 64-bit Windows platforms truncated the stored value for this variable to 4G, even when it was set to a greater value (Bug #13961678).

In MySQL 5.5.3, a separate binary log cache (the binary log statement cache) was introduced for nontransactional statements and in MySQL 5.5.3 through 5.5.8, this variable sets.the upper limit for both caches. This means that, in these MySQL versions, the effective maximum for these caches is double the value set for `max_binlog_cache_size`.

Beginning with MySQL 5.5.9, `max_binlog_cache_size` sets the size for the transaction cache only, and the upper limit for the statement cache is governed by the `max_binlog_stmt_cache_size` system variable.

Also beginning with MySQL 5.5.9, the session visibility of the `max_binlog_cache_size` system variable matches that of the `binlog_cache_size` system variable: In MySQL 5.5.8 and earlier releases, a change in `max_binlog_cache_size` took immediate effect; in MySQL 5.5.9 and later,

a change in `max_binlog_cache_size` takes effect only for new sessions that started after the value is changed.

- `max_binlog_size`

Command-Line Format	`--max-binlog-size=#`	
System Variable	Name	`max_binlog_size`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`1073741824`
	Minimum	`4096`
	Maximum	`1073741824`

If a write to the binary log causes the current log file size to exceed the value of this variable, the server rotates the binary logs (closes the current file and opens the next one). The minimum value is 4096 bytes. The maximum and default value is 1GB.

A transaction is written in one chunk to the binary log, so it is never split between several binary logs. Therefore, if you have big transactions, you might see binary log files larger than `max_binlog_size`.

If `max_relay_log_size` is 0, the value of `max_binlog_size` applies to relay logs as well.

- `max_binlog_stmt_cache_size`

Introduced	5.5.9	
Command-Line Format	`--max-binlog-stmt-cache-size=#`	
System Variable	Name	`max_binlog_stmt_cache_size`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`18446744073709547520`
	Minimum	`4096`
	Maximum	`18446744073709547520`

If nontransactional statements within a transaction require more than this many bytes of memory, the server generates an error. The minimum value is 4096. The maximum and default values are 4GB on 32-bit platforms and 16EB (exabytes) on 64-bit platforms.

Note

Prior to MySQL 5.5.28, 64-bit Windows platforms truncated the stored value for this variable to 4G, even when it was set to a greater value (Bug #13961678).

In MySQL 5.5.3, a separate binary log cache (the binary log statement cache) was introduced for nontransactional statements and in MySQL 5.5.3 through 5.5.8, this variable sets.the upper limit for both caches. This means that, in these MySQL versions, the effective maximum for these caches is double the value set for `max_binlog_cache_size`.

Beginning with MySQL 5.5.9, `max_binlog_stmt_cache_size` sets the size for the statement cache only, and the upper limit for the transaction cache is governed exclusively by the `max_binlog_cache_size` system variable.

- `sync_binlog`

Command-Line Format	`--sync-binlog=#`	
System Variable	Name	`sync_binlog`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	integer
	Default	`0`
	Minimum	`0`
	Maximum	`4294967295`

If the value of this variable is greater than 0, the MySQL server synchronizes its binary log to disk (using `fdatasync()`) after every `sync_binlog` writes to the binary log. There is one write to the binary log per statement if autocommit is enabled, and one write per transaction otherwise. The default value of `sync_binlog` is 0, which does no synchronizing to disk—in this case, the server relies on the operating system to flush the binary log's contents from time to time as for any other file. A value of 1 is the safest choice because in the event of a crash you lose at most one statement or transaction from the binary log. However, it is also the slowest choice (unless the disk has a battery-backed cache, which makes synchronization very fast).

17.1.4 Common Replication Administration Tasks

Once replication has been started it should execute without requiring much regular administration. Depending on your replication environment, you will want to check the replication status of each slave periodically, daily, or even more frequently.

17.1.4.1 Checking Replication Status

The most common task when managing a replication process is to ensure that replication is taking place and that there have been no errors between the slave and the master. The primary statement for this is `SHOW SLAVE STATUS`, which you must execute on each slave:

```
mysql> SHOW SLAVE STATUS\G
*************************** 1. row ***************************
               Slave_IO_State: Waiting for master to send event
                  Master_Host: master1
                  Master_User: root
                  Master_Port: 3306
                Connect_Retry: 60
              Master_Log_File: mysql-bin.000004
          Read_Master_Log_Pos: 931
               Relay_Log_File: slave1-relay-bin.000056
                Relay_Log_Pos: 950
        Relay_Master_Log_File: mysql-bin.000004
             Slave_IO_Running: Yes
            Slave_SQL_Running: Yes
              Replicate_Do_DB:
          Replicate_Ignore_DB:
           Replicate_Do_Table:
       Replicate_Ignore_Table:
      Replicate_Wild_Do_Table:
  Replicate_Wild_Ignore_Table:
                   Last_Errno: 0
                   Last_Error:
                 Skip_Counter: 0
          Exec_Master_Log_Pos: 931
              Relay_Log_Space: 1365
              Until_Condition: None
               Until_Log_File:
                Until_Log_Pos: 0
           Master_SSL_Allowed: No
```

```
           Master_SSL_CA_File:
           Master_SSL_CA_Path:
              Master_SSL_Cert:
            Master_SSL_Cipher:
               Master_SSL_Key:
        Seconds_Behind_Master: 0
Master_SSL_Verify_Server_Cert: No
                Last_IO_Errno: 0
                Last_IO_Error:
               Last_SQL_Errno: 0
               Last_SQL_Error:
  Replicate_Ignore_Server_Ids: 0
```

The key fields from the status report to examine are:

- `Slave_IO_State`: The current status of the slave. See Section 8.14.6, “Replication Slave I/O Thread States”, and Section 8.14.7, “Replication Slave SQL Thread States”, for more information.
- `Slave_IO_Running`: Whether the I/O thread for reading the master's binary log is running. Normally, you want this to be `Yes` unless you have not yet started replication or have explicitly stopped it with `STOP SLAVE`.
- `Slave_SQL_Running`: Whether the SQL thread for executing events in the relay log is running. As with the I/O thread, this should normally be `Yes`.
- `Last_IO_Error`, `Last_SQL_Error`: The last errors registered by the I/O and SQL threads when processing the relay log. Ideally these should be blank, indicating no errors.
- `Seconds_Behind_Master`: The number of seconds that the slave SQL thread is behind processing the master binary log. A high number (or an increasing one) can indicate that the slave is unable to handle events from the master in a timely fashion.

  A value of 0 for `Seconds_Behind_Master` can usually be interpreted as meaning that the slave has caught up with the master, but there are some cases where this is not strictly true. For example, this can occur if the network connection between master and slave is broken but the slave I/O thread has not yet noticed this—that is, `slave_net_timeout` has not yet elapsed.

  It is also possible that transient values for `Seconds_Behind_Master` may not reflect the situation accurately. When the slave SQL thread has caught up on I/O, `Seconds_Behind_Master` displays 0; but when the slave I/O thread is still queuing up a new event, `Seconds_Behind_Master` may show a large value until the SQL thread finishes executing the new event. This is especially likely when the events have old timestamps; in such cases, if you execute `SHOW SLAVE STATUS` several times in a relatively short period, you may see this value change back and forth repeatedly between 0 and a relatively large value.

Several pairs of fields provide information about the progress of the slave in reading events from the master binary log and processing them in the relay log:

- (`Master_Log_file`, `Read_Master_Log_Pos`): Coordinates in the master binary log indicating how far the slave I/O thread has read events from that log.
- (`Relay_Master_Log_File`, `Exec_Master_Log_Pos`): Coordinates in the master binary log indicating how far the slave SQL thread has executed events received from that log.
- (`Relay_Log_File`, `Relay_Log_Pos`): Coordinates in the slave relay log indicating how far the slave SQL thread has executed the relay log. These correspond to the preceding coordinates, but are expressed in slave relay log coordinates rather than master binary log coordinates.

On the master, you can check the status of connected slaves using `SHOW PROCESSLIST` to examine the list of running processes. Slave connections have `Binlog Dump` in the `Command` field:

```
mysql> SHOW PROCESSLIST \G;
*************************** 4. row ***************************
```

```
     Id: 10
   User: root
   Host: slave1:58371
     db: NULL
Command: Binlog Dump
   Time: 777
  State: Has sent all binlog to slave; waiting for binlog to be updated
   Info: NULL
```

Because it is the slave that drives the replication process, very little information is available in this report.

For slaves that were started with the `--report-host` option and are connected to the master, the `SHOW SLAVE HOSTS` statement on the master shows basic information about the slaves. The output includes the ID of the slave server, the value of the `--report-host` option, the connecting port, and master ID:

```
mysql> SHOW SLAVE HOSTS;
+-----------+--------+------+------------------+-----------+
| Server_id | Host   | Port | Rpl_recovery_rank | Master_id |
+-----------+--------+------+------------------+-----------+
|        10 | slave1 | 3306 |                0 |         1 |
+-----------+--------+------+------------------+-----------+
1 row in set (0.00 sec)
```

17.1.4.2 Pausing Replication on the Slave

You can stop and start the replication of statements on the slave using the `STOP SLAVE` and `START SLAVE` statements.

To stop processing of the binary log from the master, use `STOP SLAVE`:

```
mysql> STOP SLAVE;
```

When replication is stopped, the slave I/O thread stops reading events from the master binary log and writing them to the relay log, and the SQL thread stops reading events from the relay log and executing them. You can pause the I/O or SQL thread individually by specifying the thread type:

```
mysql> STOP SLAVE IO_THREAD;
mysql> STOP SLAVE SQL_THREAD;
```

To start execution again, use the `START SLAVE` statement:

```
mysql> START SLAVE;
```

To start a particular thread, specify the thread type:

```
mysql> START SLAVE IO_THREAD;
mysql> START SLAVE SQL_THREAD;
```

For a slave that performs updates only by processing events from the master, stopping only the SQL thread can be useful if you want to perform a backup or other task. The I/O thread will continue to read events from the master but they are not executed. This makes it easier for the slave to catch up when you restart the SQL thread.

Stopping only the I/O thread enables the events in the relay log to be executed by the SQL thread up to the point where the relay log ends. This can be useful when you want to pause execution to catch up with events already received from the master, when you want to perform administration on the slave but also ensure that it has processed all updates to a specific point. This method can also be used to pause event receipt on the slave while you conduct administration on the master. Stopping the I/O

thread but permitting the SQL thread to run helps ensure that there is not a massive backlog of events to be executed when replication is started again.

17.2 Replication Implementation

Replication is based on the master server keeping track of all changes to its databases (updates, deletes, and so on) in its binary log. The binary log serves as a written record of all events that modify database structure or content (data) from the moment the server was started. Typically, `SELECT` statements are not recorded because they modify neither database structure nor content.

Each slave that connects to the master requests a copy of the binary log. That is, it pulls the data from the master, rather than the master pushing the data to the slave. The slave also executes the events from the binary log that it receives. This has the effect of repeating the original changes just as they were made on the master. Tables are created or their structure modified, and data is inserted, deleted, and updated according to the changes that were originally made on the master.

Because each slave is independent, the replaying of the changes from the master's binary log occurs independently on each slave that is connected to the master. In addition, because each slave receives a copy of the binary log only by requesting it from the master, the slave is able to read and update the copy of the database at its own pace and can start and stop the replication process at will without affecting the ability to update to the latest database status on either the master or slave side.

For more information on the specifics of the replication implementation, see Section 17.2.1, “Replication Implementation Details”.

Masters and slaves report their status in respect of the replication process regularly so that you can monitor them. See Section 8.14, “Examining Thread Information”, for descriptions of all replicated-related states.

The master binary log is written to a local relay log on the slave before it is processed. The slave also records information about the current position with the master's binary log and the local relay log. See Section 17.2.2, “Replication Relay and Status Logs”.

Database changes are filtered on the slave according to a set of rules that are applied according to the various configuration options and variables that control event evaluation. For details on how these rules are applied, see Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”.

17.2.1 Replication Implementation Details

MySQL replication capabilities are implemented using three threads, one on the master server and two on the slave:

- **Binlog dump thread.** The master creates a thread to send the binary log contents to a slave when the slave connects. This thread can be identified in the output of `SHOW PROCESSLIST` on the master as the `Binlog Dump` thread.

  The binary log dump thread acquires a lock on the master's binary log for reading each event that is to be sent to the slave. As soon as the event has been read, the lock is released, even before the event is sent to the slave.

- **Slave I/O thread.** When a `START SLAVE` statement is issued on a slave server, the slave creates an I/O thread, which connects to the master and asks it to send the updates recorded in its binary logs.

  The slave I/O thread reads the updates that the master's `Binlog Dump` thread sends (see previous item) and copies them to local files that comprise the slave's relay log.

  The state of this thread is shown as `Slave_IO_running` in the output of `SHOW SLAVE STATUS` or as `Slave_running` in the output of `SHOW STATUS`.

- **Slave SQL thread.** The slave creates an SQL thread to read the relay log that is written by the slave I/O thread and execute the events contained therein.

In the preceding description, there are three threads per master/slave connection. A master that has multiple slaves creates one binary log dump thread for each currently connected slave, and each slave has its own I/O and SQL threads.

A slave uses two threads to separate reading updates from the master and executing them into independent tasks. Thus, the task of reading statements is not slowed down if statement execution is slow. For example, if the slave server has not been running for a while, its I/O thread can quickly fetch all the binary log contents from the master when the slave starts, even if the SQL thread lags far behind. If the slave stops before the SQL thread has executed all the fetched statements, the I/O thread has at least fetched everything so that a safe copy of the statements is stored locally in the slave's relay logs, ready for execution the next time that the slave starts. This enables the master server to purge its binary logs sooner because it no longer needs to wait for the slave to fetch their contents.

The `SHOW PROCESSLIST` statement provides information that tells you what is happening on the master and on the slave regarding replication. For information on master states, see Section 8.14.5, “Replication Master Thread States”. For slave states, see Section 8.14.6, “Replication Slave I/O Thread States”, and Section 8.14.7, “Replication Slave SQL Thread States”.

The following example illustrates how the three threads show up in the output from `SHOW PROCESSLIST`.

On the master server, the output from `SHOW PROCESSLIST` looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 2
   User: root
   Host: localhost:32931
     db: NULL
Command: Binlog Dump
   Time: 94
  State: Has sent all binlog to slave; waiting for binlog to
         be updated
   Info: NULL
```

Here, thread 2 is a `Binlog Dump` replication thread that services a connected slave. The `State` information indicates that all outstanding updates have been sent to the slave and that the master is waiting for more updates to occur. If you see no `Binlog Dump` threads on a master server, this means that replication is not running; that is, no slaves are currently connected.

On a slave server, the output from `SHOW PROCESSLIST` looks like this:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 10
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Waiting for master to send event
   Info: NULL
*************************** 2. row ***************************
     Id: 11
   User: system user
   Host:
     db: NULL
Command: Connect
   Time: 11
  State: Has read all relay log; waiting for the slave I/O
```

```
        thread to update it
  Info: NULL
```

The `State` information indicates that thread 10 is the I/O thread that is communicating with the master server, and thread 11 is the SQL thread that is processing the updates stored in the relay logs. At the time that `SHOW PROCESSLIST` was run, both threads were idle, waiting for further updates.

The value in the `Time` column can show how late the slave is compared to the master. See Section A.13, “MySQL 5.5 FAQ: Replication”. If sufficient time elapses on the master side without activity on the `Binlog Dump` thread, the master determines that the slave is no longer connected. As for any other client connection, the timeouts for this depend on the values of `net_write_timeout` and `net_retry_count`; for more information about these, see Section 5.1.5, “Server System Variables”.

The `SHOW SLAVE STATUS` statement provides additional information about replication processing on a slave server. See Section 17.1.4.1, “Checking Replication Status”.

17.2.2 Replication Relay and Status Logs

During replication, a slave server creates several logs that hold the binary log events relayed from the master to the slave, and to record information about the current status and location within the relay log. There are three types of logs used in the process, listed here:

- The *relay log* consists of the events read from the binary log of the master and written by the slave I/O thread. Events in the relay log are executed on the slave as part of the SQL thread.
- The *master info log* contains status and current configuration information for the slave's connection to the master. This log holds information on the master host name, login credentials, and coordinates indicating how far the slave has read from the master's binary log.
- The *relay log info log* holds status information about the execution point within the slave's relay log.

17.2.2.1 The Slave Relay Log

The relay log, like the binary log, consists of a set of numbered files containing events that describe database changes, and an index file that contains the names of all used relay log files.

The term “relay log file” generally denotes an individual numbered file containing database events. The term “relay log” collectively denotes the set of numbered relay log files plus the index file.

Relay log files have the same format as binary log files and can be read using `mysqlbinlog` (see Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”).

By default, relay log file names have the form *`host_name`*`-relay-bin.`*`nnnnnn`* in the data directory, where *`host_name`* is the name of the slave server host and *`nnnnnn`* is a sequence number. Successive relay log files are created using successive sequence numbers, beginning with `000001`. The slave uses an index file to track the relay log files currently in use. The default relay log index file name is *`host_name`*`-relay-bin.index` in the data directory.

The default relay log file and relay log index file names can be overridden with, respectively, the `--relay-log` and `--relay-log-index` server options (see Section 17.1.3, “Replication and Binary Logging Options and Variables”).

If a slave uses the default host-based relay log file names, changing a slave's host name after replication has been set up can cause replication to fail with the errors `Failed to open the relay log` and `Could not find target log during relay log initialization`. This is a known issue (see Bug #2122). If you anticipate that a slave's host name might change in the future (for example, if networking is set up on the slave such that its host name can be modified using DHCP), you can avoid this issue entirely by using the `--relay-log` and `--relay-log-index` options to specify relay log file names explicitly when you initially set up the slave. This will make the names independent of server host name changes.

If you encounter the issue after replication has already begun, one way to work around it is to stop the slave server, prepend the contents of the old relay log index file to the new one, and then restart the slave. On a Unix system, this can be done as shown here:

```
shell> cat new_relay_log_name.index >> old_relay_log_name.index
shell> mv old_relay_log_name.index new_relay_log_name.index
```

A slave server creates a new relay log file under the following conditions:

- Each time the I/O thread starts.
- When the logs are flushed; for example, with `FLUSH LOGS` or `mysqladmin flush-logs`.
- When the size of the current relay log file becomes “too large,” determined as follows:
  - If the value of `max_relay_log_size` is greater than 0, that is the maximum relay log file size.
  - If the value of `max_relay_log_size` is 0, `max_binlog_size` determines the maximum relay log file size.

The SQL thread automatically deletes each relay log file after it has executed all events in the file and no longer needs it. There is no explicit mechanism for deleting relay logs because the SQL thread takes care of doing so. However, `FLUSH LOGS` rotates relay logs, which influences when the SQL thread deletes them.

17.2.2.2 Slave Status Logs

A replication slave server creates two logs. By default, these logs are files named `master.info` and `relay-log.info` and created in the data directory. The names and locations of these files can be changed by using the `--master-info-file` and `--relay-log-info-file` options, respectively. See Section 17.1.3, “Replication and Binary Logging Options and Variables”.

The two status logs contain information like that shown in the output of the `SHOW SLAVE STATUS` statement, which is discussed in Section 13.4.2, “SQL Statements for Controlling Slave Servers”. Because the status logs are stored on disk, they survive a slave server's shutdown. The next time the slave starts up, it reads the two logs to determine how far it has proceeded in reading binary logs from the master and in processing its own relay logs.

The master info log should be protected because it contains the password for connecting to the master. See Section 6.1.2.3, “Passwords and Logging”.

The slave I/O thread updates the master info log. The following table shows the correspondence between the lines in the `master.info` file and the columns displayed by `SHOW SLAVE STATUS`.

`master.info` File Line	`SHOW SLAVE STATUS` Column	Description
1		Number of lines in the file
2	`Master_Log_File`	The name of the master binary log currently being read from the master
3	`Read_Master_Log_Pos`	The current position within the master binary log that have been read from the master
4	`Master_Host`	The host name of the master
5	`Master_User`	The user name used to connect to the master
6	Password (not shown by `SHOW SLAVE STATUS`)	The password used to connect to the master

`master.info` File Line	`SHOW SLAVE STATUS` Column	Description
7	`Master_Port`	The network port used to connect to the master
8	`Connect_Retry`	The period (in seconds) that the slave will wait before trying to reconnect to the master
9	`Master_SSL_Allowed`	Indicates whether the server supports SSL connections
10	`Master_SSL_CA_File`	The file used for the Certificate Authority (CA) certificate
11	`Master_SSL_CA_Path`	The path to the Certificate Authority (CA) certificates
12	`Master_SSL_Cert`	The name of the SSL certificate file
13	`Master_SSL_Cipher`	The list of possible ciphers used in the handshake for the SSL connection
14	`Master_SSL_Key`	The name of the SSL key file
15	`Master_SSL_Verify_Server_Cert`	Whether to verify the server certificate
17	`Replicate_Ignore_Server_Ids`	The number of server IDs to be ignored, followed by the actual server IDs

The slave SQL thread updates the relay log info log. The following table shows the correspondence between the lines in the `relay-log.info` file and the columns displayed by `SHOW SLAVE STATUS`.

Line in `relay-log.info`	`SHOW SLAVE STATUS` Column	Description
1	`Relay_Log_File`	The name of the current relay log file
2	`Relay_Log_Pos`	The current position within the relay log file; events up to this position have been executed on the slave database
3	`Relay_Master_Log_File`	The name of the master binary log file from which the events in the relay log file were read
4	`Exec_Master_Log_Pos`	The equivalent position within the master's binary log file of events that have already been executed

The contents of the `relay-log.info` file and the states shown by the `SHOW SLAVE STATUS` statement might not match if the `relay-log.info` file has not been flushed to disk. Ideally, you should only view `relay-log.info` on a slave that is offline (that is, `mysqld` is not running). For a running system, `SHOW SLAVE STATUS` should be used.

When you back up the slave's data, you should back up these two status logs, along with the relay log files. The status logs are needed to resume replication after you restore the data from the slave. If you lose the relay logs but still have the relay log info log, you can check it to determine how far the SQL thread has executed in the master binary logs. Then you can use `CHANGE MASTER TO` with the `MASTER_LOG_FILE` and `MASTER_LOG_POS` options to tell the slave to re-read the binary logs from that point. Of course, this requires that the binary logs still exist on the master.

17.2.3 How Servers Evaluate Replication Filtering Rules

If a master server does not write a statement to its binary log, the statement is not replicated. If the server does log the statement, the statement is sent to all slaves and each slave determines whether to execute it or ignore it.

On the master, you can control which databases to log changes for by using the `--binlog-do-db` and `--binlog-ignore-db` options to control binary logging. For a description of the rules that servers use in evaluating these options, see Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”. You should not use these options to control which databases and tables are replicated. Instead, use filtering on the slave to control the events that are executed on the slave.

On the slave side, decisions about whether to execute or ignore statements received from the master are made according to the `--replicate-*` options that the slave was started with. (See Section 17.1.3, “Replication and Binary Logging Options and Variables”.)

In the simplest case, when there are no `--replicate-*` options, the slave executes all statements that it receives from the master. Otherwise, the result depends on the particular options given.

Database-level options (`--replicate-do-db`, `--replicate-ignore-db`) are checked first; see Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”, for a description of this process. If no database-level options are used, option checking proceeds to any table-level options that may be in use (see Section 17.2.3.2, “Evaluation of Table-Level Replication Options”, for a discussion of these). If one or more database-level options are used but none are matched, the statement is not replicated.

To make it easier to determine what effect an option set will have, it is recommended that you avoid mixing “do” and “ignore” options, or wildcard and nonwildcard options. An example of the latter that may have unintended effects is the use of `--replicate-do-db` and `--replicate-wild-do-table` together, where `--replicate-wild-do-table` uses a pattern for the database name that matches the name given for `--replicate-do-db`. Suppose a replication slave is started with `--replicate-do-db=dbx --replicate-wild-do-table=db%.t1`. Then, suppose that on the master, you issue the statement `CREATE DATABASE dbx`. Although you might expect it, this statement is not replicated because it does not reference a table named `t1`.

If any `--replicate-rewrite-db` options were specified, they are applied before the `--replicate-*` filtering rules are tested.

Note

Database-level filtering options are case-sensitive on platforms supporting case sensitivity in filenames, whereas table-level filtering options are not (regardless of platform). This is true regardless of the value of the `lower_case_table_names` system variable.

17.2.3.1 Evaluation of Database-Level Replication and Binary Logging Options

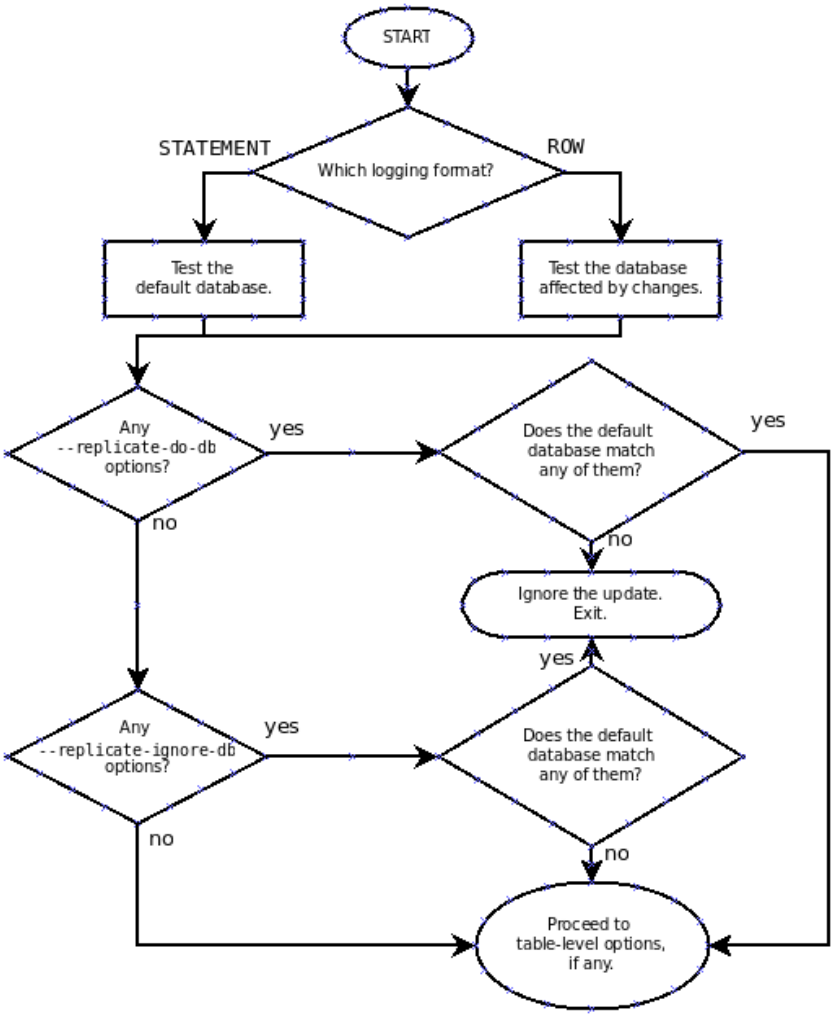
When evaluating replication options, the slave begins by checking to see whether there are any `--replicate-do-db` or `--replicate-ignore-db` options that apply. When using `--binlog-do-db` or `--binlog-ignore-db`, the process is similar, but the options are checked on the master.

The database that is checked for a match depends on the binary log format of the statement that is being handled. If the statement has been logged using the row format, the database where data is to be changed is the database that is checked. If the statement has been logged using the statement format, the default database (specified with a `USE` statement) is the database that is checked.

Note

Only DML statements can be logged using the row format. DDL statements are always logged as statements, even when `binlog_format=ROW`. All DDL statements are therefore always filtered according to the rules for statement-based replication. This means that you must select the default database explicitly with a `USE` statement in order for a DDL statement to be applied.

Checking of database-level options proceeds as shown in the following diagram:



For replication, the steps involved are listed here:

1. Are there any `--replicate-do-db` options?
   - **Yes.** Do any of them match the database?
     - **Yes.** Execute the statement and exit.
     - **No.** Ignore the statement and exit.
   - **No.** Continue to step 2.
2. Are there any `--replicate-ignore-db` options?
   - **Yes.** Do any of them match the database?
     - **Yes.** Ignore the statement and exit.
     - **No.** Continue to step 3.
   - **No.** Continue to step 3.
3. Proceed to checking the table-level replication options, if there are any. For a description of how these options are checked, see Section 17.2.3.2, “Evaluation of Table-Level Replication Options”.

Important

A statement that is still permitted at this stage is not yet actually executed. The statement is not executed until all table-level options (if any) have also been checked, and the outcome of that process permits execution of the statement.

For binary logging, the steps involved are listed here:

1. Are there any `--binlog-do-db` or `--binlog-ignore-db` options?
   - **Yes.** Continue to step 2.
   - **No.** Log the statement and exit.
2. Is there a default database (has any database been selected by `USE`)?
   - **Yes.** Continue to step 3.
   - **No.** Ignore the statement and exit.
3. There is a default database. Are there any `--binlog-do-db` options?
   - **Yes.** Do any of them match the database?
     - **Yes.** Log the statement and exit.
     - **No.** Ignore the statement and exit.
   - **No.** Continue to step 4.
4. Do any of the `--binlog-ignore-db` options match the database?
   - **Yes.** Ignore the statement and exit.
   - **No.** Log the statement and exit.

Important

For statement-based logging, an exception is made in the rules just given for the `CREATE DATABASE`, `ALTER DATABASE`, and `DROP DATABASE` statements. In those cases, the database being *created, altered, or dropped* replaces the default database when determining whether to log or ignore updates.

`--binlog-do-db` can sometimes mean “ignore other databases”. For example, when using statement-based logging, a server running with only `--binlog-do-db=sales` does not write to the binary log statements for which the default database differs from `sales`. When using row-based logging with the same option, the server logs only those updates that change data in `sales`.

17.2.3.2 Evaluation of Table-Level Replication Options

The slave checks for and evaluates table options only if either of the following two conditions is true:

- No matching database options were found.
- One or more database options were found, and were evaluated to arrive at an “execute” condition according to the rules described in the previous section (see Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”).

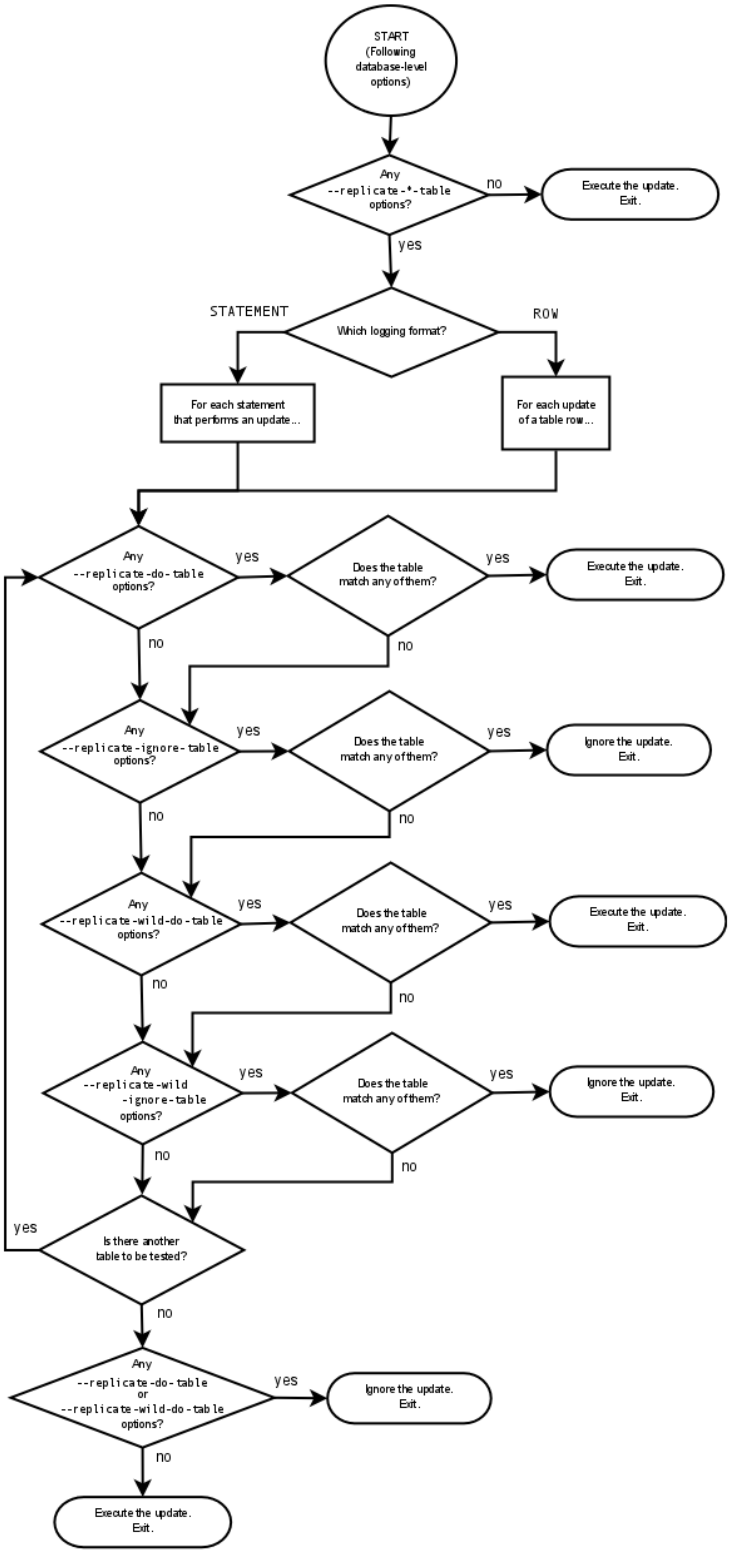
First, as a preliminary condition, the slave checks whether statement-based replication is enabled. If so, and the statement occurs within a stored function, the slave executes the statement and exits.

If row-based replication is enabled, the slave does not know whether a statement occurred within a stored function on the master, so this condition does not apply.

Note

For statement-based replication, replication events represent statements (all changes making up a given event are associated with a single SQL statement); for row-based replication, each event represents a change in a single table row (thus a single statement such as `UPDATE mytable SET mycol = 1` may yield many row-based events). When viewed in terms of events, the process of checking table options is the same for both row-based and statement-based replication.

Having reached this point, if there are no table options, the slave simply executes all events. If there are any `--replicate-do-table` or `--replicate-wild-do-table` options, the event must match one of these if it is to be executed; otherwise, it is ignored. If there are any `--replicate-ignore-table` or `--replicate-wild-ignore-table` options, all events are executed except those that match any of these options. This process is illustrated in the following diagram.



The following steps describe this evaluation in more detail:

1. Are there any table options?

   - **Yes.** Continue to step 2.
   - **No.** Execute the event and exit.

2. Are there any `--replicate-do-table` options?

- **Yes.** Does the table match any of them?
  - **Yes.** Execute the event and exit.
  - **No.** Continue to step 3.
- **No.** Continue to step 3.

3. Are there any `--replicate-ignore-table` options?
   - **Yes.** Does the table match any of them?
     - **Yes.** Ignore the event and exit.
     - **No.** Continue to step 4.
   - **No.** Continue to step 4.
4. Are there any `--replicate-wild-do-table` options?
   - **Yes.** Does the table match any of them?
     - **Yes.** Execute the event and exit.
     - **No.** Continue to step 5.
   - **No.** Continue to step 5.
5. Are there any `--replicate-wild-ignore-table` options?
   - **Yes.** Does the table match any of them?
     - **Yes.** Ignore the event and exit.
     - **No.** Continue to step 6.
   - **No.** Continue to step 6.
6. Are there any `--replicate-do-table` or `--replicate-wild-do-table` options?
   - **Yes.** Ignore the event and exit.
   - **No.** Execute the event and exit.

17.2.3.3 Replication Rule Application

This section provides additional explanation and examples of usage for different combinations of replication filtering options.

Some typical combinations of replication filter rule types are given in the following table:

Condition (Types of Options)	Outcome
No `--replicate-*` options at all:	The slave executes all events that it receives from the master.
`--replicate-*-db` options, but no table options:	The slave accepts or ignores events using the database options. It executes all events permitted by those options because there are no table restrictions.
`--replicate-*-table` options, but no database options:	All events are accepted at the database-checking stage because there are no database conditions. The slave

Condition (Types of Options)	Outcome
	executes or ignores events based solely on the table options.
A combination of database and table options:	The slave accepts or ignores events using the database options. Then it evaluates all events permitted by those options according to the table options. This can sometimes lead to results that seem counterintuitive, and that may be different depending on whether you are using statement-based or row-based replication; see the text for an example.

A more complex example follows, in which we examine the outcomes for both statement-based and row-based settings.

Suppose that we have two tables `mytbl1` in database `db1` and `mytbl2` in database `db2` on the master, and the slave is running with the following options (and no other replication filtering options):

```
replicate-ignore-db = db1
replicate-do-table  = db2.tbl2
```

Now we execute the following statements on the master:

```
USE db1;
INSERT INTO db2.tbl2 VALUES (1);
```

The results on the slave vary considerably depending on the binary log format, and may not match initial expectations in either case.

Statement-based replication. The `USE` statement causes `db1` to be the default database. Thus the `--replicate-ignore-db` option matches, *and the `INSERT` statement is ignored*. The table options are not checked.

Row-based replication. The default database has no effect on how the slave reads database options when using row-based replication. Thus, the `USE` statement makes no difference in how the `--replicate-ignore-db` option is handled: the database specified by this option does not match the database where the `INSERT` statement changes data, so the slave proceeds to check the table options. The table specified by `--replicate-do-table` matches the table to be updated, *and the row is inserted*.

17.3 Replication Solutions

Replication can be used in many different environments for a range of purposes. This section provides general notes and advice on using replication for specific solution types.

For information on using replication in a backup environment, including notes on the setup, backup procedure, and files to back up, see Section 17.3.1, “Using Replication for Backups”.

For advice and tips on using different storage engines on the master and slaves, see Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”.

Using replication as a scale-out solution requires some changes in the logic and operation of applications that use the solution. See Section 17.3.3, “Using Replication for Scale-Out”.

For performance or data distribution reasons, you may want to replicate different databases to different replication slaves. See Section 17.3.4, “Replicating Different Databases to Different Slaves”

As the number of replication slaves increases, the load on the master can increase and lead to reduced performance (because of the need to replicate the binary log to each slave). For tips on improving

your replication performance, including using a single secondary server as a replication master, see Section 17.3.5, “Improving Replication Performance”.

For guidance on switching masters, or converting slaves into masters as part of an emergency failover solution, see Section 17.3.6, “Switching Masters During Failover”.

To secure your replication communication, you can encrypt the communication channel. For step-by-step instructions, see Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”.

17.3.1 Using Replication for Backups

To use replication as a backup solution, replicate data from the master to a slave, and then back up the data slave. The slave can be paused and shut down without affecting the running operation of the master, so you can produce an effective snapshot of “live” data that would otherwise require the master to be shut down.

How you back up a database depends on its size and whether you are backing up only the data, or the data and the replication slave state so that you can rebuild the slave in the event of failure. There are therefore two choices:

- If you are using replication as a solution to enable you to back up the data on the master, and the size of your database is not too large, the `mysqldump` tool may be suitable. See Section 17.3.1.1, “Backing Up a Slave Using mysqldump”.
- For larger databases, where `mysqldump` would be impractical or inefficient, you can back up the raw data files instead. Using the raw data files option also means that you can back up the binary and relay logs that will enable you to recreate the slave in the event of a slave failure. For more information, see Section 17.3.1.2, “Backing Up Raw Data from a Slave”.

Another backup strategy, which can be used for either master or slave servers, is to put the server in a read-only state. The backup is performed against the read-only server, which then is changed back to its usual read/write operational status. See Section 17.3.1.3, “Backing Up a Master or Slave by Making It Read Only”.

17.3.1.1 Backing Up a Slave Using mysqldump

Using `mysqldump` to create a copy of a database enables you to capture all of the data in the database in a format that enables the information to be imported into another instance of MySQL Server (see Section 4.5.4, “`mysqldump` — A Database Backup Program”). Because the format of the information is SQL statements, the file can easily be distributed and applied to running servers in the event that you need access to the data in an emergency. However, if the size of your data set is very large, `mysqldump` may be impractical.

When using `mysqldump`, you should stop replication on the slave before starting the dump process to ensure that the dump contains a consistent set of data:

1. Stop the slave from processing requests. You can stop replication completely on the slave using `mysqladmin`:

   ```
   shell> mysqladmin stop-slave
   ```

   Alternatively, you can stop only the slave SQL thread to pause event execution:

   ```
   shell> mysql -e 'STOP SLAVE SQL_THREAD;'
   ```

   This enables the slave to continue to receive data change events from the master's binary log and store them in the relay logs using the I/O thread, but prevents the slave from executing these events and changing its data. Within busy replication environments, permitting the I/O thread to run during backup may speed up the catch-up process when you restart the slave SQL thread.

2. Run `mysqldump` to dump your databases. You may either dump all databases or select databases to be dumped. For example, to dump all databases:

```
shell> mysqldump --all-databases > fulldb.dump
```

3. Once the dump has completed, start slave operations again:

```
shell> mysqladmin start-slave
```

In the preceding example, you may want to add login credentials (user name, password) to the commands, and bundle the process up into a script that you can run automatically each day.

If you use this approach, make sure you monitor the slave replication process to ensure that the time taken to run the backup does not affect the slave's ability to keep up with events from the master. See Section 17.1.4.1, “Checking Replication Status”. If the slave is unable to keep up, you may want to add another slave and distribute the backup process. For an example of how to configure this scenario, see Section 17.3.4, “Replicating Different Databases to Different Slaves”.

17.3.1.2 Backing Up Raw Data from a Slave

To guarantee the integrity of the files that are copied, backing up the raw data files on your MySQL replication slave should take place while your slave server is shut down. If the MySQL server is still running, background tasks may still be updating the database files, particularly those involving storage engines with background processes such as `InnoDB`. With `InnoDB`, these problems should be resolved during crash recovery, but since the slave server can be shut down during the backup process without affecting the execution of the master it makes sense to take advantage of this capability.

To shut down the server and back up the files:

1. Shut down the slave MySQL server:

```
shell> mysqladmin shutdown
```

2. Copy the data files. You can use any suitable copying or archive utility, including `cp`, `tar` or `WinZip`. For example, assuming that the data directory is located under the current directory, you can archive the entire directory as follows:

```
shell> tar cf /tmp/dbbackup.tar ./data
```

3. Start the MySQL server again. Under Unix:

```
shell> mysqld_safe &
```

Under Windows:

```
C:\> "C:\Program Files\MySQL\MySQL Server 5.5\bin\mysqld"
```

Normally you should back up the entire data directory for the slave MySQL server. If you want to be able to restore the data and operate as a slave (for example, in the event of failure of the slave), then in addition to the slave's data, you should also back up the slave status files, `master.info` and `relay-log.info`, along with the relay log files. These files are needed to resume replication after you restore the slave's data.

If you lose the relay logs but still have the `relay-log.info` file, you can check it to determine how far the SQL thread has executed in the master binary logs. Then you can use `CHANGE MASTER TO` with the `MASTER_LOG_FILE` and `MASTER_LOG_POS` options to tell the slave to re-read the binary logs from that point. This requires that the binary logs still exist on the master server.

If your slave is replicating `LOAD DATA INFILE` statements, you should also back up any `SQL_LOAD-*` files that exist in the directory that the slave uses for this purpose. The slave needs these files to resume replication of any interrupted `LOAD DATA INFILE` operations. The location of this directory is the value of the `--slave-load-tmpdir` option. If the server was not started with that option, the directory location is the value of the `tmpdir` system variable.

17.3.1.3 Backing Up a Master or Slave by Making It Read Only

It is possible to back up either master or slave servers in a replication setup by acquiring a global read lock and manipulating the `read_only` system variable to change the read-only state of the server to be backed up:

1. Make the server read-only, so that it processes only retrievals and blocks updates.
2. Perform the backup.
3. Change the server back to its normal read/write state.

Note

The instructions in this section place the server to be backed up in a state that is safe for backup methods that get the data from the server, such as `mysqldump` (see Section 4.5.4, “`mysqldump` — A Database Backup Program”). You should not attempt to use these instructions to make a binary backup by copying files directly because the server may still have modified data cached in memory and not flushed to disk.

The following instructions describe how to do this for a master server and for a slave server. For both scenarios discussed here, suppose that you have the following replication setup:

- A master server M1
- A slave server S1 that has M1 as its master
- A client C1 connected to M1
- A client C2 connected to S1

In either scenario, the statements to acquire the global read lock and manipulate the `read_only` variable are performed on the server to be backed up and do not propagate to any slaves of that server.

Scenario 1: Backup with a Read-Only Master

Put the master M1 in a read-only state by executing these statements on it:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SET GLOBAL read_only = ON;
```

While M1 is in a read-only state, the following properties are true:

- Requests for updates sent by C1 to M1 will block because the server is in read-only mode.
- Requests for query results sent by C1 to M1 will succeed.
- Making a backup on M1 is safe.
- Making a backup on S1 is not safe. This server is still running, and might be processing the binary log or update requests coming from client C2

While M1 is read only, perform the backup. For example, you can use `mysqldump`.

After the backup operation on M1 completes, restore M1 to its normal operational state by executing these statements:

```
mysql> SET GLOBAL read_only = OFF;
```

```
mysql> UNLOCK TABLES;
```

Although performing the backup on M1 is safe (as far as the backup is concerned), it is not optimal for performance because clients of M1 are blocked from executing updates.

This strategy applies to backing up a master server in a replication setup, but can also be used for a single server in a nonreplication setting.

Scenario 2: Backup with a Read-Only Slave

Put the slave S1 in a read-only state by executing these statements on it:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SET GLOBAL read_only = ON;
```

While S1 is in a read-only state, the following properties are true:

- The master M1 will continue to operate, so making a backup on the master is not safe.
- The slave S1 is stopped, so making a backup on the slave S1 is safe.

These properties provide the basis for a popular backup scenario: Having one slave busy performing a backup for a while is not a problem because it does not affect the entire network, and the system is still running during the backup. In particular, clients can still perform updates on the master server, which remains unaffected by backup activity on the slave.

While S1 is read only, perform the backup. For example, you can use `mysqldump`.

After the backup operation on S1 completes, restore S1 to its normal operational state by executing these statements:

```
mysql> SET GLOBAL read_only = OFF;
mysql> UNLOCK TABLES;
```

After the slave is restored to normal operation, it again synchronizes to the master by catching up with any outstanding updates from the binary log of the master.

17.3.2 Using Replication with Different Master and Slave Storage Engines

It does not matter for the replication process whether the source table on the master and the replicated table on the slave use different engine types. In fact, the `default_storage_engine` and `storage_engine` system variables are not replicated.

This provides a number of benefits in the replication process in that you can take advantage of different engine types for different replication scenarios. For example, in a typical scale-out scenario (see Section 17.3.3, “Using Replication for Scale-Out”), you want to use `InnoDB` tables on the master to take advantage of the transactional functionality, but use `MyISAM` on the slaves where transaction support is not required because the data is only read. When using replication in a data-logging environment you may want to use the `Archive` storage engine on the slave.

Configuring different engines on the master and slave depends on how you set up the initial replication process:

- If you used `mysqldump` to create the database snapshot on your master, you could edit the dump file text to change the engine type used on each table.

  Another alternative for `mysqldump` is to disable engine types that you do not want to use on the slave before using the dump to build the data on the slave. For example, you can add the `--skip-innodb` option on your slave to disable the `InnoDB` engine. If a specific engine does not exist for a table to be created, MySQL will use the default engine type, usually `MyISAM`. (This requires that the

NO_ENGINE_SUBSTITUTION SQL mode is not enabled.) If you want to disable additional engines in this way, you may want to consider building a special binary to be used on the slave that only supports the engines you want.

- If you are using raw data files (a binary backup) to set up the slave, you will be unable to change the initial table format. Instead, use ALTER TABLE to change the table types after the slave has been started.
- For new master/slave replication setups where there are currently no tables on the master, avoid specifying the engine type when creating new tables.

If you are already running a replication solution and want to convert your existing tables to another engine type, follow these steps:

1. Stop the slave from running replication updates:

   ```
   mysql> STOP SLAVE;
   ```

   This will enable you to change engine types without interruptions.

2. Execute an ALTER TABLE ... ENGINE='*engine_type*' for each table to be changed.

3. Start the slave replication process again:

   ```
   mysql> START SLAVE;
   ```

Although the default_storage_engine variable is not replicated, be aware that CREATE TABLE and ALTER TABLE statements that include the engine specification will be correctly replicated to the slave. For example, if you have a CSV table and you execute:

```
mysql> ALTER TABLE csvtable Engine='MyISAM';
```

The above statement will be replicated to the slave and the engine type on the slave will be converted to MyISAM, even if you have previously changed the table type on the slave to an engine other than CSV. If you want to retain engine differences on the master and slave, you should be careful to use the default_storage_engine variable on the master when creating a new table. For example, instead of:

```
mysql> CREATE TABLE tablea (columna int) Engine=MyISAM;
```

Use this format:

```
mysql> SET default_storage_engine=MyISAM;
mysql> CREATE TABLE tablea (columna int);
```

When replicated, the default_storage_engine variable will be ignored, and the CREATE TABLE statement will execute on the slave using the slave's default engine.

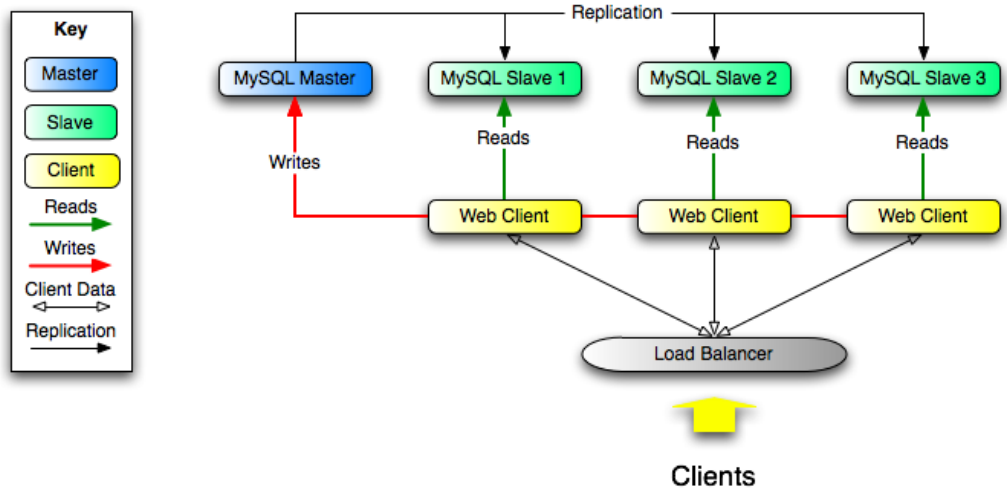
17.3.3 Using Replication for Scale-Out

You can use replication as a scale-out solution; that is, where you want to split up the load of database queries across multiple database servers, within some reasonable limitations.

Because replication works from the distribution of one master to one or more slaves, using replication for scale-out works best in an environment where you have a high number of reads and low number of writes/updates. Most Web sites fit into this category, where users are browsing the Web site, reading articles, posts, or viewing products. Updates only occur during session management, or when making a purchase or adding a comment/message to a forum.

Replication in this situation enables you to distribute the reads over the replication slaves, while still enabling your web servers to communicate with the replication master when a write is required. You can see a sample replication layout for this scenario in Figure 17.1, “Using Replication to Improve Performance During Scale-Out”.

Figure 17.1 Using Replication to Improve Performance During Scale-Out



If the part of your code that is responsible for database access has been properly abstracted/modularized, converting it to run with a replicated setup should be very smooth and easy. Change the implementation of your database access to send all writes to the master, and to send reads to either the master or a slave. If your code does not have this level of abstraction, setting up a replicated system gives you the opportunity and motivation to clean it up. Start by creating a wrapper library or module that implements the following functions:

- `safe_writer_connect()`
- `safe_reader_connect()`
- `safe_reader_statement()`
- `safe_writer_statement()`

`safe_` in each function name means that the function takes care of handling all error conditions. You can use different names for the functions. The important thing is to have a unified interface for connecting for reads, connecting for writes, doing a read, and doing a write.

Then convert your client code to use the wrapper library. This may be a painful and scary process at first, but it pays off in the long run. All applications that use the approach just described are able to take advantage of a master/slave configuration, even one involving multiple slaves. The code is much easier to maintain, and adding troubleshooting options is trivial. You need modify only one or two functions; for example, to log how long each statement took, or which statement among those issued gave you an error.

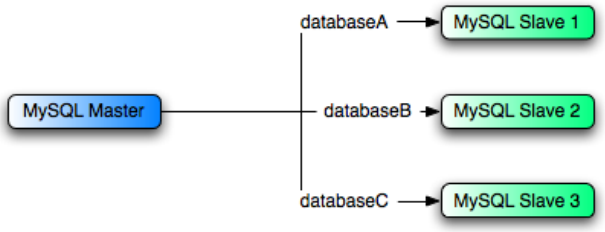
If you have written a lot of code, you may want to automate the conversion task by using the `replace` utility that comes with standard MySQL distributions, or write your own conversion script. Ideally, your code uses consistent programming style conventions. If not, then you are probably better off rewriting it anyway, or at least going through and manually regularizing it to use a consistent style.

17.3.4 Replicating Different Databases to Different Slaves

There may be situations where you have a single master and want to replicate different databases to different slaves. For example, you may want to distribute different sales data to different departments

to help spread the load during data analysis. A sample of this layout is shown in Figure 17.2, “Using Replication to Replicate Databases to Separate Replication Slaves”.

Figure 17.2 Using Replication to Replicate Databases to Separate Replication Slaves



You can achieve this separation by configuring the master and slaves as normal, and then limiting the binary log statements that each slave processes by using the `--replicate-wild-do-table` configuration option on each slave.

Important

You should *not* use `--replicate-do-db` for this purpose when using statement-based replication, since statement-based replication causes this option's affects to vary according to the database that is currently selected. This applies to mixed-format replication as well, since this enables some updates to be replicated using the statement-based format.

However, it should be safe to use `--replicate-do-db` for this purpose if you are using row-based replication only, since in this case the currently selected database has no effect on the option's operation.

For example, to support the separation as shown in Figure 17.2, “Using Replication to Replicate Databases to Separate Replication Slaves”, you should configure each replication slave as follows, before executing `START SLAVE`:

- Replication slave 1 should use `--replicate-wild-do-table=databaseA.%`.
- Replication slave 2 should use `--replicate-wild-do-table=databaseB.%`.
- Replication slave 3 should use `--replicate-wild-do-table=databaseC.%`.

Each slave in this configuration receives the entire binary log from the master, but executes only those events from the binary log that apply to the databases and tables included by the `--replicate-wild-do-table` option in effect on that slave.

If you have data that must be synchronized to the slaves before replication starts, you have a number of choices:

- Synchronize all the data to each slave, and delete the databases, tables, or both that you do not want to keep.
- Use `mysqldump` to create a separate dump file for each database and load the appropriate dump file on each slave.
- Use a raw data file dump and include only the specific files and databases that you need for each slave.

Note

This does not work with `InnoDB` databases unless you use `innodb_file_per_table`.

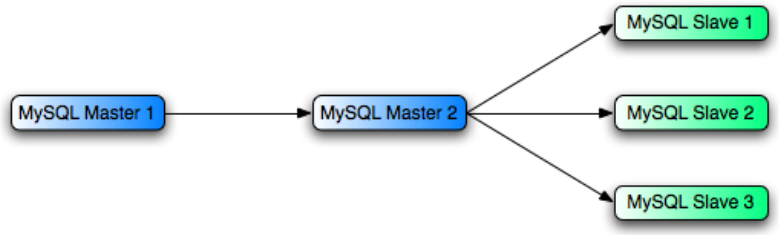
17.3.5 Improving Replication Performance

As the number of slaves connecting to a master increases, the load, although minimal, also increases, as each slave uses a client connection to the master. Also, as each slave must receive a full copy of the master binary log, the network load on the master may also increase and create a bottleneck.

If you are using a large number of slaves connected to one master, and that master is also busy processing requests (for example, as part of a scale-out solution), then you may want to improve the performance of the replication process.

One way to improve the performance of the replication process is to create a deeper replication structure that enables the master to replicate to only one slave, and for the remaining slaves to connect to this primary slave for their individual replication requirements. A sample of this structure is shown in Figure 17.3, “Using an Additional Replication Host to Improve Performance”.

Figure 17.3 Using an Additional Replication Host to Improve Performance



For this to work, you must configure the MySQL instances as follows:

- Master 1 is the primary master where all changes and updates are written to the database. Binary logging should be enabled on this machine.
- Master 2 is the slave to the Master 1 that provides the replication functionality to the remainder of the slaves in the replication structure. Master 2 is the only machine permitted to connect to Master 1. Master 2 also has binary logging enabled, and the `--log-slave-updates` option so that replication instructions from Master 1 are also written to Master 2's binary log so that they can then be replicated to the true slaves.
- Slave 1, Slave 2, and Slave 3 act as slaves to Master 2, and replicate the information from Master 2, which actually consists of the upgrades logged on Master 1.

The above solution reduces the client load and the network interface load on the primary master, which should improve the overall performance of the primary master when used as a direct database solution.

If your slaves are having trouble keeping up with the replication process on the master, there are a number of options available:

- If possible, put the relay logs and the data files on different physical drives. To do this, use the `--relay-log` option to specify the location of the relay log.
- If the slaves are significantly slower than the master, you may want to divide up the responsibility for replicating different databases to different slaves. See Section 17.3.4, “Replicating Different Databases to Different Slaves”.
- If your master makes use of transactions and you are not concerned about transaction support on your slaves, use `MyISAM` or another nontransactional engine on the slaves. See Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”.
- If your slaves are not acting as masters, and you have a potential solution in place to ensure that you can bring up a master in the event of failure, then you can switch off `--log-slave-updates`. This prevents “dumb” slaves from also logging events they have executed into their own binary log.

17.3.6 Switching Masters During Failover

There is in MySQL 5.5 no official solution for providing failover between master and slaves in the event of a failure. Instead, you must set up a master and one or more slaves; then, you need to write an application or script that monitors the master to check whether it is up, and instructs the slaves and applications to change master in case of failure. This section discusses some of the issues encountered when setting up failover in this fashion.

Note

The MySQL Utilities include a `mysqlfailover` tool that provides failover capability using GTIDs, support for which requires MySQL 5.6 or later. For more information, see `mysqlfailover` — Automatic replication health monitoring and failover, and Replication with Global Transaction Identifiers.

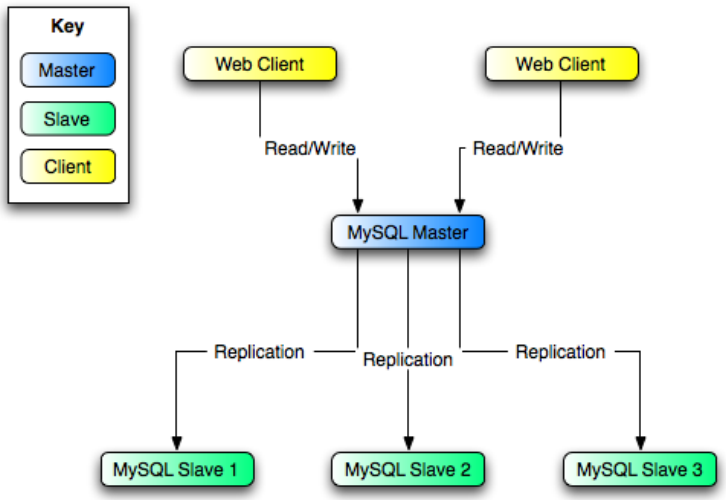
You can tell a slave to change to a new master using the `CHANGE MASTER TO` statement. The slave does not check whether the databases on the master are compatible with those on the slave; it simply begins reading and executing events from the specified coordinates in the new master's binary log. In a failover situation, all the servers in the group are typically executing the same events from the same binary log file, so changing the source of the events should not affect the structure or integrity of the database, provided that you exercise care in making the change.

Slaves should be run with the `--log-bin` option and without `--log-slave-updates`. In this way, the slave is ready to become a master without restarting the slave `mysqld`. Assume that you have the structure shown in Figure 17.4, “Redundancy Using Replication, Initial Structure”.

Remember that you can tell a slave to change its master at any time, using the `CHANGE MASTER TO` statement. The slave will not check whether the databases on the master are compatible with the slave, it will just start reading and executing events from the specified binary log coordinates on the new master. In a failover situation, all the servers in the group are typically executing the same events from the same binary log file, so changing the source of the events should not affect the database structure or integrity providing you are careful.

Run your slaves with the `--log-bin` option and without `--log-slave-updates`. In this way, the slave is ready to become a master as soon as you issue `STOP SLAVE`; `RESET MASTER`, and `CHANGE MASTER TO` statement on the other slaves. For example, assume that you have the structure shown in Figure 17.4, “Redundancy Using Replication, Initial Structure”.

Figure 17.4 Redundancy Using Replication, Initial Structure



In this diagram, the `MySQL Master` holds the master database, the `MySQL Slave` hosts are replication slaves, and the `Web Client` machines are issuing database reads and writes. Web clients that issue only reads (and would normally be connected to the slaves) are not shown, as they do not

need to switch to a new server in the event of failure. For a more detailed example of a read/write scale-out replication structure, see Section 17.3.3, “Using Replication for Scale-Out”.

Each MySQL Slave (`Slave 1`, `Slave 2`, and `Slave 3`) is a slave running with `--log-bin` and without `--log-slave-updates`. Because updates received by a slave from the master are not logged in the binary log unless `--log-slave-updates` is specified, the binary log on each slave is empty initially. If for some reason `MySQL Master` becomes unavailable, you can pick one of the slaves to become the new master. For example, if you pick `Slave 1`, all `Web Clients` should be redirected to `Slave 1`, which writes the updates to its binary log. `Slave 2` and `Slave 3` should then replicate from `Slave 1`.

The reason for running the slave without `--log-slave-updates` is to prevent slaves from receiving updates twice in case you cause one of the slaves to become the new master. If `Slave 1` has `--log-slave-updates` enabled, it writes any updates that it receives from `Master` in its own binary log. This means that, when `Slave 2` changes from `Master` to `Slave 1` as its master, it may receive updates from `Slave 1` that it has already received from `Master`.

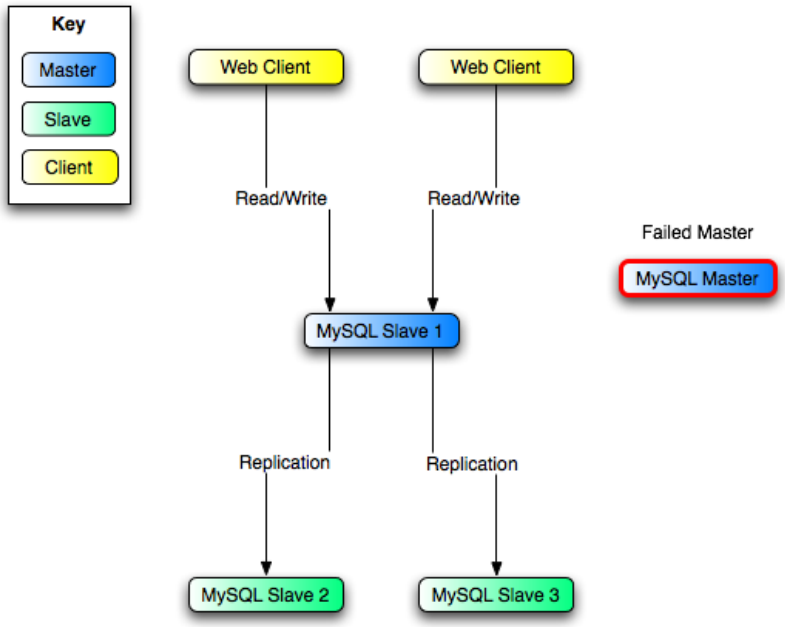
Make sure that all slaves have processed any statements in their relay log. On each slave, issue `STOP SLAVE IO_THREAD`, then check the output of `SHOW PROCESSLIST` until you see `Has read all relay log`. When this is true for all slaves, they can be reconfigured to the new setup. On the slave `Slave 1` being promoted to become the master, issue `STOP SLAVE` and `RESET MASTER`.

On the other slaves `Slave 2` and `Slave 3`, use `STOP SLAVE` and `CHANGE MASTER TO MASTER_HOST='Slave1'` (where `'Slave1'` represents the real host name of `Slave 1`). To use `CHANGE MASTER TO`, add all information about how to connect to `Slave 1` from `Slave 2` or `Slave 3` (*`user`*, *`password`*, *`port`*). When issuing the `CHANGE MASTER TO` statement in this, there is no need to specify the name of the `Slave 1` binary log file or log position to read from, since the first binary log file and position 4, are the defaults. Finally, execute `START SLAVE` on `Slave 2` and `Slave 3`.

Once the new replication setup is in place, you need to tell each `Web Client` to direct its statements to `Slave 1`. From that point on, all updates statements sent by `Web Client` to `Slave 1` are written to the binary log of `Slave 1`, which then contains every update statement sent to `Slave 1` since `Master` died.

The resulting server structure is shown in Figure 17.5, “Redundancy Using Replication, After Master Failure”.

Figure 17.5 Redundancy Using Replication, After Master Failure



When `Master` becomes available again, you should make it a slave of `Slave 1`. To do this, issue on `Master` the same `CHANGE MASTER TO` statement as that issued on `Slave 2` and `Slave 3` previously. `Master` then becomes a slave of `S1ave 1` and picks up the `Web Client` writes that it missed while it was offline.

To make `Master` a master again, use the preceding procedure as if `Slave 1` was unavailable and `Master` was to be the new master. During this procedure, do not forget to run `RESET MASTER` on `Master` before making `Slave 1`, `Slave 2`, and `Slave 3` slaves of `Master`. If you fail to do this, the slaves may pick up stale writes from the `Web Client` applications dating from before the point at which `Master` became unavailable.

You should be aware that there is no synchronization between slaves, even when they share the same master, and thus some slaves might be considerably ahead of others. This means that in some cases the procedure outlined in the previous example might not work as expected. In practice, however, relay logs on all slaves should be relatively close together.

One way to keep applications informed about the location of the master is to have a dynamic DNS entry for the master. With `bind` you can use `nsupdate` to update the DNS dynamically.

17.3.7 Setting Up Replication to Use Encrypted Connections

To use an encrypted connection for the transfer of the binary log required during replication, both the master and the slave servers must support encrypted network connections. If either server does not support encrypted connections (because it has not been compiled or configured for them), replication through an encrypted connection is not possible.

Setting up encrypted connections for replication is similar to doing so for client/server connections. You must obtain (or create) a suitable security certificate that you can use on the master, and a similar certificate (from the same certificate authority) on each slave. You must also obtain suitable key files.

For more information on setting up a server and client for encrypted connections, see Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”.

To enable encrypted connections on the master, you must create or obtain suitable certificate and key files, and then add the following configuration options to the master's configuration within the `[mysqld]` section of the master's `my.cnf` file, changing the file names as necessary:

```
[mysqld]
ssl-ca=cacert.pem
ssl-cert=server-cert.pem
ssl-key=server-key.pem
```

The paths to the files may be relative or absolute; we recommend that you always use complete paths for this purpose.

The options are as follows:

- `--ssl-ca`: The path name of the Certificate Authority (CA) certificate file. (`--ssl-capath` is similar but specifies the path name of a directory of CA certificate files.)
- `--ssl-cert`: The path name of the server public key certificate file. This can be sent to the client and authenticated against the CA certificate that it has.
- `--ssl-key`: The path name of the server private key file.

On the slave, there are two ways to specify the information required for connecting using encryption to the master. You can either name the slave certificate and key files in the `[client]` section of the slave's `my.cnf` file, or you can explicitly specify that information using the `CHANGE MASTER TO` statement:

- To name the slave certificate and key files using an option file, add the following lines to the `[client]` section of the slave's `my.cnf` file, changing the file names as necessary:

```
[client]
ssl-ca=cacert.pem
ssl-cert=client-cert.pem
ssl-key=client-key.pem
```

  Restart the slave server, using the `--skip-slave-start` option to prevent the slave from connecting to the master. Use `CHANGE MASTER TO` to specify the master configuration, using the `MASTER_SSL` option to connect using encryption:

```
mysql> CHANGE MASTER TO
    -> MASTER_HOST='master_hostname',
    -> MASTER_USER='replicate',
    -> MASTER_PASSWORD='password',
    -> MASTER_SSL=1;
```

- To specify the certificate and key names using the `CHANGE MASTER TO` statement, append the appropriate `MASTER_SSL_xxx` options:

```
mysql> CHANGE MASTER TO
    -> MASTER_HOST='master_hostname',
    -> MASTER_USER='replicate',
    -> MASTER_PASSWORD='password',
    -> MASTER_SSL=1,
    -> MASTER_SSL_CA = 'ca_file_name',
    -> MASTER_SSL_CAPATH = 'ca_directory_name',
    -> MASTER_SSL_CERT = 'cert_file_name',
    -> MASTER_SSL_KEY = 'key_file_name';
```

After the master information has been updated, start the slave replication process:

```
mysql> START SLAVE;
```

You can use the `SHOW SLAVE STATUS` statement to confirm that an encrypted connection was established successfully.

For more information on the `CHANGE MASTER TO` statement, see Section 13.4.2.1, “CHANGE MASTER TO Syntax”.

If you want to enforce the use of encrypted connections during replication, create a user with the `REPLICATION SLAVE` privilege and use the `REQUIRE SSL` option for that user. For example:

```
mysql> CREATE USER 'repl'@'%.mydomain.com' IDENTIFIED BY 'slavepass';
mysql> GRANT REPLICATION SLAVE ON *.*
    -> TO 'repl'@'%.mydomain.com' REQUIRE SSL;
```

If the account already exists, you can add `REQUIRE SSL` to it with this statement:

```
mysql> GRANT USAGE ON *.*
    -> TO 'repl'@'%.mydomain.com' REQUIRE SSL;
```

17.3.8 Semisynchronous Replication

In addition to the built-in asynchronous replication, MySQL 5.5 supports an interface to semisynchronous replication that is implemented by plugins. This section discusses what semisynchronous replication is and how it works. The following sections cover the administrative interface to semisynchronous replication and how to install, configure, and monitor it.

MySQL replication by default is asynchronous. The master writes events to its binary log but does not know whether or when a slave has retrieved and processed them. With asynchronous replication, if the master crashes, transactions that it has committed might not have been transmitted to any slave. Consequently, failover from master to slave in this case may result in failover to a server that is missing transactions relative to the master.

Semisynchronous replication can be used as an alternative to asynchronous replication:

- A slave indicates whether it is semisynchronous-capable when it connects to the master.
- If semisynchronous replication is enabled on the master side and there is at least one semisynchronous slave, a thread that performs a transaction commit on the master blocks after the commit is done and waits until at least one semisynchronous slave acknowledges that it has received all events for the transaction, or until a timeout occurs.
- The slave acknowledges receipt of a transaction's events only after the events have been written to its relay log and flushed to disk.
- If a timeout occurs without any slave having acknowledged the transaction, the master reverts to asynchronous replication. When at least one semisynchronous slave catches up, the master returns to semisynchronous replication.
- Semisynchronous replication must be enabled on both the master and slave sides. If semisynchronous replication is disabled on the master, or enabled on the master but on no slaves, the master uses asynchronous replication.

While the master is blocking (waiting for acknowledgment from a slave after having performed a commit), it does not return to the session that performed the transaction. When the block ends, the master returns to the session, which then can proceed to execute other statements. At this point, the transaction has committed on the master side, and receipt of its events has been acknowledged by at least one slave.

Blocking also occurs after rollbacks that are written to the binary log, which occurs when a transaction that modifies nontransactional tables is rolled back. The rolled-back transaction is logged even though it has no effect for transactional tables because the modifications to the nontransactional tables cannot be rolled back and must be sent to slaves.

For statements that do not occur in transactional context (that is, when no transaction has been started with `START TRANSACTION` or `SET autocommit = 0`), autocommit is enabled and each statement commits implicitly. With semisynchronous replication, the master blocks after committing each such statement, just as it does for explicit transaction commits.

To understand what the “semi” in “semisynchronous replication” means, compare it with asynchronous and fully synchronous replication:

- With asynchronous replication, the master writes events to its binary log and slaves request them when they are ready. There is no guarantee that any event will ever reach any slave.
- With fully synchronous replication, when a master commits a transaction, all slaves also will have committed the transaction before the master returns to the session that performed the transaction. The drawback of this is that there might be a lot of delay to complete a transaction.
- Semisynchronous replication falls between asynchronous and fully synchronous replication. The master waits after commit only until at least one slave has received and logged the events. It does not wait for all slaves to acknowledge receipt, and it requires only receipt, not that the events have been fully executed and committed on the slave side.

Compared to asynchronous replication, semisynchronous replication provides improved data integrity. When a commit returns successfully, it is known that the data exists in at least two places (on the master and at least one slave). If the master commits but a crash occurs while the master is waiting for acknowledgment from a slave, it is possible that the transaction may not have reached any slave.

Semisynchronous replication also places a rate limit on busy sessions by constraining the speed at which binary log events can be sent from master to slave. When one user is too busy, this will slow it down, which is useful in some deployment situations.

Semisynchronous replication does have some performance impact because commits are slower due to the need to wait for slaves. This is the tradeoff for increased data integrity. The amount of slowdown is at least the TCP/IP roundtrip time to send the commit to the slave and wait for the acknowledgment of receipt by the slave. This means that semisynchronous replication works best for close servers communicating over fast networks, and worst for distant servers communicating over slow networks.

17.3.8.1 Semisynchronous Replication Administrative Interface

The administrative interface to semisynchronous replication has several components:

- Two plugins implement semisynchronous capability. There is one plugin for the master side and one for the slave side.
- System variables control plugin behavior. Some examples:
  - `rpl_semi_sync_master_enabled`

    Controls whether semisynchronous replication is enabled on the master. To enable or disable the plugin, set this variable to 1 or 0, respectively. The default is 0 (off).
  - `rpl_semi_sync_master_timeout`

    A value in milliseconds that controls how long the master waits on a commit for acknowledgment from a slave before timing out and reverting to asynchronous replication. The default value is 10000 (10 seconds).
  - `rpl_semi_sync_slave_enabled`

    Similar to `rpl_semi_sync_master_enabled`, but controls the slave plugin.

  All `rpl_semi_sync_`*`xxx`* system variables are described at Section 5.1.5, “Server System Variables”.
- Status variables enable semisynchronous replication monitoring. Some examples:
  - `Rpl_semi_sync_master_clients`

    The number of semisynchronous slaves.
  - `Rpl_semi_sync_master_status`

    Whether semisynchronous replication currently is operational on the master. The value is 1 if the plugin has been enabled and a commit acknowledgment has occurred. It is 0 if the plugin is not enabled or the master has fallen back to asynchronous replication due to commit acknowledgment timeout.
  - `Rpl_semi_sync_master_no_tx`

    The number of commits that were not acknowledged successfully by a slave.
  - `Rpl_semi_sync_master_yes_tx`

    The number of commits that were acknowledged successfully by a slave.
  - `Rpl_semi_sync_slave_status`

    Whether semisynchronous replication currently is operational on the slave. This is 1 if the plugin has been enabled and the slave I/O thread is running, 0 otherwise.

All `Rpl_semi_sync_xxx` status variables are described at Section 5.1.7, “Server Status Variables”.

The system and status variables are available only if the appropriate master or slave plugin has been installed with `INSTALL PLUGIN`.

17.3.8.2 Semisynchronous Replication Installation and Configuration

Semisynchronous replication is implemented using plugins, so the plugins must be installed into the server to make them available. After a plugin has been installed, you control it by means of the system variables associated with it. These system variables are unavailable until the associated plugin has been installed.

This section describes how to install the semisynchronous replication plugins. For general information about installing plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To use semisynchronous replication, the following requirements must be satisfied:

- MySQL 5.5 or higher must be installed.
- The capability of installing plugins requires a MySQL server that supports dynamic loading. To verify this, check that the value of the `have_dynamic_loading` system variable is `YES`. Binary distributions should support dynamic loading.
- Replication must already be working. For information on creating a master/slave relationship, see Section 17.1.1, “How to Set Up Replication”.

To set up semisynchronous replication, use the following instructions. The `INSTALL PLUGIN`, `SET GLOBAL`, `STOP SLAVE`, and `START SLAVE` statements mentioned here require the `SUPER` privilege.

MySQL distributions include semisynchronous replication plugin files for the master side and the slave side.

To be usable by a master or slave server, the appropriate plugin library file must be located in the MySQL plugin directory (the directory named by the `plugin_dir` system variable). If necessary, set the value of `plugin_dir` at server startup to tell the server the plugin directory location.

The plugin library file base names are `semisync_master` and `semisync_slave`. The file name suffix differs per platform (for example, `.so` for Unix and Unix-like systems, `.dll` for Windows).

The master plugin library file must be present in the plugin directory of the master server. The slave plugin library file must be present in the plugin directory of each slave server.

To load the plugins, use the `INSTALL PLUGIN` statement on the master and on each slave that is to be semisynchronous (adjust the `.so` suffix for your platform as necessary).

On the master:

```
INSTALL PLUGIN rpl_semi_sync_master SONAME 'semisync_master.so';
```

On each slave:

```
INSTALL PLUGIN rpl_semi_sync_slave SONAME 'semisync_slave.so';
```

If an attempt to install a plugin results in an error on Linux similar to that shown here, you must install `libimf`:

```
mysql> INSTALL PLUGIN rpl_semi_sync_master SONAME 'semisync_master.so';
ERROR 1126 (HY000): Can't open shared library
'/usr/local/mysql/lib/plugin/semisync_master.so'
(errno: 22 libimf.so: cannot open shared object file:
No such file or directory)
```

You can obtain `libimf` from http://dev.mysql.com/downloads/os-linux.html.

To see which plugins are installed, use the `SHOW PLUGINS` statement, or query the `INFORMATION_SCHEMA.PLUGINS` table.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement (see Section 5.5.2, "Obtaining Server Plugin Information"). For example:

```
mysql> SELECT PLUGIN_NAME, PLUGIN_STATUS
       FROM INFORMATION_SCHEMA.PLUGINS
       WHERE PLUGIN_NAME LIKE '%semi%';
+----------------------+---------------+
| PLUGIN_NAME          | PLUGIN_STATUS |
+----------------------+---------------+
| rpl_semi_sync_master | ACTIVE        |
+----------------------+---------------+
```

If the plugin fails to initialize, check the server error log for diagnostic messages.

After a semisynchronous replication plugin has been installed, it is disabled by default. The plugins must be enabled both on the master side and the slave side to enable semisynchronous replication. If only one side is enabled, replication will be asynchronous.

To control whether an installed plugin is enabled, set the appropriate system variables. You can set these variables at runtime using `SET GLOBAL`, or at server startup on the command line or in an option file.

At runtime, these master-side system variables are available:

```
SET GLOBAL rpl_semi_sync_master_enabled = {0|1};
SET GLOBAL rpl_semi_sync_master_timeout = N;
```

On the slave side, this system variable is available:

```
SET GLOBAL rpl_semi_sync_slave_enabled = {0|1};
```

For `rpl_semi_sync_master_enabled` or `rpl_semi_sync_slave_enabled`, the value should be 1 to enable semisynchronous replication or 0 to disable it. By default, these variables are set to 0.

For `rpl_semi_sync_master_timeout`, the value *N* is given in milliseconds. The default value is 10000 (10 seconds).

If you enable semisynchronous replication on a slave at runtime, you must also start the slave I/O thread (stopping it first if it is already running) to cause the slave to connect to the master and register as a semisynchronous slave:

```
STOP SLAVE IO_THREAD;
START SLAVE IO_THREAD;
```

If the I/O thread is already running and you do not restart it, the slave continues to use asynchronous replication.

At server startup, the variables that control semisynchronous replication can be set as command-line options or in an option file. A setting listed in an option file takes effect each time the server starts. For example, you can set the variables in `my.cnf` files on the master and slave sides as follows.

On the master:

```
[mysqld]
rpl_semi_sync_master_enabled=1
rpl_semi_sync_master_timeout=1000 # 1 second
```

On each slave:

```
[mysqld]
rpl_semi_sync_slave_enabled=1
```

17.3.8.3 Semisynchronous Replication Monitoring

The plugins for the semisynchronous replication capability expose several system and status variables that you can examine to determine its configuration and operational state.

The system variable reflect how semisynchronous replication is configured. To check their values, use `SHOW VARIABLES`:

```
mysql> SHOW VARIABLES LIKE 'rpl_semi_sync%';
```

The status variables enable you to monitor the operation of semisynchronous replication. To check their values, use `SHOW STATUS`:

```
mysql> SHOW STATUS LIKE 'Rpl_semi_sync%';
```

When the master switches between asynchronous or semisynchronous replication due to commit-blocking timeout or a slave catching up, it sets the value of the `Rpl_semi_sync_master_status` status variable appropriately. Automatic fallback from semisynchronous to asynchronous replication on the master means that it is possible for the `rpl_semi_sync_master_enabled` system variable to have a value of 1 on the master side even when semisynchronous replication is in fact not operational at the moment. You can monitor the `Rpl_semi_sync_master_status` status variable to determine whether the master currently is using asynchronous or semisynchronous replication.

To see how many semisynchronous slaves are connected, check `Rpl_semi_sync_master_clients`.

The number of commits that have been acknowledged successfully or unsuccessfully by slaves are indicated by the `Rpl_semi_sync_master_yes_tx` and `Rpl_semi_sync_master_no_tx` variables.

On the slave side, `Rpl_semi_sync_slave_status` indicates whether semisynchronous replication currently is operational.

17.4 Replication Notes and Tips

17.4.1 Replication Features and Issues

The following sections provide information about what is supported and what is not in MySQL replication, and about specific issues and situations that may occur when replicating certain statements.

Statement-based replication depends on compatibility at the SQL level between the master and slave. In others, successful SBR requires that any SQL features used be supported by both the master and the slave servers. For example, if you use a feature on the master server that is available only in MySQL 5.5 (or later), you cannot replicate to a slave that uses MySQL 5.1 (or earlier).

Such incompatibilities also can occur within a release series when using pre-production releases of MySQL. For example, the `SLEEP()` function is available beginning with MySQL 5.0.12. If you use this function on the master, you cannot replicate to a slave that uses MySQL 5.0.11 or earlier.

For this reason, use Generally Available (GA) releases of MySQL for statement-based replication in a production setting, since we do not introduce new SQL statements or change their behavior within a given release series once that series reaches GA release status.

If you are planning to use statement-based replication between MySQL 5.5 and a previous MySQL release series, it is also a good idea to consult the edition of the *MySQL Reference Manual* corresponding to the earlier release series for information regarding the replication characteristics of that series.

With MySQL's statement-based replication, there may be issues with replicating stored routines or triggers. You can avoid these issues by using MySQL's row-based replication instead. For a detailed list of issues, see Section 20.7, “Binary Logging of Stored Programs”. For more information about row-based logging and row-based replication, see Section 5.4.4.1, “Binary Logging Formats”, and Section 17.1.2, “Replication Formats”.

For additional information specific to replication and `InnoDB`, see Section 14.22, “InnoDB and MySQL Replication”. For information relating to replication with NDB Cluster, see Section 18.6, “NDB Cluster Replication”.

17.4.1.1 Replication and AUTO_INCREMENT

Statement-based replication of `AUTO_INCREMENT`, `LAST_INSERT_ID()`, and `TIMESTAMP` values is done correctly, subject to the following exceptions:

- When using statement-based replication prior to MySQL 5.5.30, `AUTO_INCREMENT` columns in tables on the slave must match the same columns on the master; that is, `AUTO_INCREMENT` columns must be replicated to `AUTO_INCREMENT` columns. (Bug #12669186)
- A statement invoking a trigger or function that causes an update to an `AUTO_INCREMENT` column is not replicated correctly using statement-based replication. In MySQL 5.5, such statements are marked as unsafe. (Bug #45677)
- An `INSERT` into a table that has a composite primary key that includes an `AUTO_INCREMENT` column that is not the first column of this composite key is not safe for statement-based logging or replication. Beginning with MySQL 5.5.25, such statements are marked as unsafe. (Bug #11754117, Bug #45670)

  This issue does not affect tables using the `InnoDB` storage engine, since an `InnoDB` table with an AUTO_INCREMENT column requires at least one key where the auto-increment column is the only or leftmost column.
- Adding an `AUTO_INCREMENT` column to a table with `ALTER TABLE` might not produce the same ordering of the rows on the slave and the master. This occurs because the order in which the rows are numbered depends on the specific storage engine used for the table and the order in which the rows were inserted. If it is important to have the same order on the master and slave, the rows must be ordered before assigning an `AUTO_INCREMENT` number. Assuming that you want to add an `AUTO_INCREMENT` column to a table `t1` that has columns `col1` and `col2`, the following statements produce a new table `t2` identical to `t1` but with an `AUTO_INCREMENT` column:

```
CREATE TABLE t2 LIKE t1;
ALTER TABLE t2 ADD id INT AUTO_INCREMENT PRIMARY KEY;
INSERT INTO t2 SELECT * FROM t1 ORDER BY col1, col2;
```

Important

To guarantee the same ordering on both master and slave, the `ORDER BY` clause must name *all* columns of `t1`.

The instructions just given are subject to the limitations of `CREATE TABLE ... LIKE`: Foreign key definitions are ignored, as are the `DATA DIRECTORY` and `INDEX DIRECTORY` table options. If a table definition includes any of those characteristics, create `t2` using a `CREATE TABLE` statement that is identical to the one used to create `t1`, but with the addition of the `AUTO_INCREMENT` column.

Regardless of the method used to create and populate the copy having the `AUTO_INCREMENT` column, the final step is to drop the original table and then rename the copy:

```
DROP t1;
ALTER TABLE t2 RENAME t1;
```

See also Section B.5.6.1, “Problems with ALTER TABLE”.

17.4.1.2 Replication and BLACKHOLE Tables

The `BLACKHOLE` storage engine accepts data but discards it and does not store it. When performing binary logging, all inserts to such tables are always logged, regardless of the logging format in use. Updates and deletes are handled differently depending on whether statement based or row based logging is in use. With the statement based logging format, all statements affecting `BLACKHOLE` tables are logged, but their effects ignored. When using row-based logging, updates and deletes to such tables are simply skipped—they are not written to the binary log. In MySQL 5.5.32 and later, a warning is logged whenever this occurs (Bug #13004581)

For this reason we recommend when you replicate to tables using the `BLACKHOLE` storage engine that you have the `binlog_format` server variable set to `STATEMENT`, and not to either `ROW` or `MIXED`.

17.4.1.3 Replication and Character Sets

The following applies to replication between MySQL servers that use different character sets:

- If the master has databases with a character set different from the global `character_set_server` value, you should design your `CREATE TABLE` statements so that they do not implicitly rely on the database default character set. A good workaround is to state the character set and collation explicitly in `CREATE TABLE` statements.

17.4.1.4 Replication and CHECKSUM TABLE

`CHECKSUM TABLE` returns a checksum that is calculated row by row, using a method that depends on the table row storage format, which is not guaranteed to remain the same between MySQL release series. For example, the storage format for temporal types such as `TIME`, `DATETIME`, and `TIMESTAMP` changes in MySQL 5.6 prior to MySQL 5.6.5, so if a 5.5 table is upgraded to MySQL 5.6, the checksum value may change.

17.4.1.5 Replication of CREATE SERVER, ALTER SERVER, and DROP SERVER

In MySQL 5.5, the statements `CREATE SERVER`, `ALTER SERVER`, and `DROP SERVER` are not written to the binary log, regardless of the binary logging format that is in use.

17.4.1.6 Replication of CREATE ... IF NOT EXISTS Statements

MySQL applies these rules when various `CREATE ... IF NOT EXISTS` statements are replicated:

- Every `CREATE DATABASE IF NOT EXISTS` statement is replicated, whether or not the database already exists on the master.
- Similarly, every `CREATE TABLE IF NOT EXISTS` statement without a `SELECT` is replicated, whether or not the table already exists on the master. This includes `CREATE TABLE IF NOT EXISTS ... LIKE`. Replication of `CREATE TABLE IF NOT EXISTS ... SELECT` follows somewhat different rules; see Section 17.4.1.7, “Replication of CREATE TABLE ... SELECT Statements”, for more information.
- `CREATE EVENT IF NOT EXISTS` is always replicated in MySQL 5.5, whether or not the event named in the statement already exists on the master.

See also Bug #45574.

17.4.1.7 Replication of CREATE TABLE ... SELECT Statements

This section discusses how MySQL replicates `CREATE TABLE ... SELECT` statements.

These behaviors are not dependent on MySQL version:

- `CREATE TABLE ... SELECT` always performs an implicit commit (Section 13.3.3, “Statements That Cause an Implicit Commit”).
- If destination table does not exist, logging occurs as follows. It does not matter whether `IF NOT EXISTS` is present.
  - `STATEMENT` or `MIXED` format: The statement is logged as written.
  - `ROW` format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.
- If the statement fails, nothing is logged. This includes the case that the destination table exists and `IF NOT EXISTS` is not given.

When the destination table exists and `IF NOT EXISTS` is given, MySQL handles the statement in a version-dependent way.

In MySQL 5.1 before 5.1.51 and in MySQL 5.5 before 5.5.6 (this is the original behavior):

- `STATEMENT` or `MIXED` format: The statement is logged as written.
- `ROW` format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.

In MySQL 5.1 as of 5.1.51:

- `STATEMENT` or `MIXED` format: The statement is logged as the equivalent pair of `CREATE TABLE` and `INSERT INTO ... SELECT` statements.
- `ROW` format: The statement is logged as a `CREATE TABLE` statement followed by a series of insert-row events.

In MySQL 5.5 as of 5.5.6:

- Nothing is inserted or logged.

These version dependencies arise due to a change in MySQL 5.5.6 in handling of `CREATE TABLE ... SELECT` not to insert rows if the destination table already exists, and a change made in MySQL 5.1.51 to preserve forward compatibility in replication of such statements from a 5.1 master to a 5.5 slave. For details, see Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”.

When using statement-based replication between a MySQL 5.6 or later slave and a master running a previous version of MySQL, a `CREATE TABLE ... SELECT` statement causing changes in other tables on the master fails on the slave, causing replication to stop. This is due to the fact that MySQL 5.6 does not allow a `CREATE TABLE ... SELECT` statement to make any changes in tables other than the table that is created by the statement—a change in behavior from previous versions of MySQL, which permitted these statements to do so. To keep this from happening, you should use row-based replication, rewrite the offending statement before running it on the master, or upgrade the master to MySQL 5.6 (or later). (If you choose to upgrade the master, keep in mind that such a `CREATE TABLE ... SELECT` statement will fail there as well, following the upgrade, unless the statement is rewritten to remove any side effects on other tables.) This is not an issue when using row-based replication, because the statement is logged as a `CREATE TABLE` statement with any changes to table data logged as row-insert events (or possibly row-update events), rather than as the entire `CREATE TABLE ... SELECT` statement.

17.4.1.8 Replication of CURRENT_USER()

The following statements support use of the `CURRENT_USER()` function to take the place of the name of (and, possibly, the host for) an affected user or a definer; in such cases, `CURRENT_USER()` is expanded where and as needed:

- `DROP USER`
- `RENAME USER`
- `GRANT`
- `REVOKE`
- `CREATE FUNCTION`
- `CREATE PROCEDURE`
- `CREATE TRIGGER`
- `CREATE EVENT`
- `CREATE VIEW`
- `ALTER EVENT`
- `ALTER VIEW`
- `SET PASSWORD`

When `CURRENT_USER()` or `CURRENT_USER` is used as the definer in any of the statements `CREATE FUNCTION`, `CREATE PROCEDURE`, `CREATE TRIGGER`, `CREATE EVENT`, `CREATE VIEW`, or `ALTER VIEW` when binary logging is enabled, the function reference is expanded before it is written to the binary log, so that the statement refers to the same user on both the master and the slave when the statement is replicated. `CURRENT_USER()` or `CURRENT_USER` is also expanded prior to being written to the binary log when used in `DROP USER`, `RENAME USER`, `GRANT`, `REVOKE`, or `ALTER EVENT`.

17.4.1.9 Replication with Differing Table Definitions on Master and Slave

Source and target tables for replication do not have to be identical. A table on the master can have more or fewer columns than the slave's copy of the table. In addition, corresponding table columns on the master and the slave can use different data types, subject to certain conditions.

Note

Replication between tables which are partitioned differently from one another is not supported. See Section 17.4.1.23, “Replication and Partitioning”.

In all cases where the source and target tables do not have identical definitions, the database and table names must be the same on both the master and the slave. Additional conditions are discussed, with examples, in the following two sections.

Replication with More Columns on Master or Slave

You can replicate a table from the master to the slave such that the master and slave copies of the table have differing numbers of columns, subject to the following conditions:

- Columns common to both versions of the table must be defined in the same order on the master and the slave.

  (This is true even if both tables have the same number of columns.)

- Columns common to both versions of the table must be defined before any additional columns.

  This means that executing an `ALTER TABLE` statement on the slave where a new column is inserted into the table within the range of columns common to both tables causes replication to fail, as shown in the following example:

  Suppose that a table `t`, existing on the master and the slave, is defined by the following `CREATE TABLE` statement:

```
CREATE TABLE t (
    c1 INT,
    c2 INT,
    c3 INT
);
```

Suppose that the `ALTER TABLE` statement shown here is executed on the slave:

```
ALTER TABLE t ADD COLUMN cnew1 INT AFTER c3;
```

The previous `ALTER TABLE` is permitted on the slave because the columns `c1`, `c2`, and `c3` that are common to both versions of table `t` remain grouped together in both versions of the table, before any columns that differ.

However, the following `ALTER TABLE` statement cannot be executed on the slave without causing replication to break:

```
ALTER TABLE t ADD COLUMN cnew2 INT AFTER c2;
```

Replication fails after execution on the slave of the `ALTER TABLE` statement just shown, because the new column `cnew2` comes between columns common to both versions of `t`.

- Each “extra” column in the version of the table having more columns must have a default value.

Note

A column's default value is determined by a number of factors, including its type, whether it is defined with a `DEFAULT` option, whether it is declared as `NULL`, and the server SQL mode in effect at the time of its creation; for more information, see Section 11.6, “Data Type Default Values”).

In addition, when the slave's copy of the table has more columns than the master's copy, each column common to the tables must use the same data type in both tables.

Examples. The following examples illustrate some valid and invalid table definitions:

More columns on the master. The following table definitions are valid and replicate correctly:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT);
```

The following table definitions would raise an error because the definitions of the columns common to both versions of the table are in a different order on the slave than they are on the master:

```
master> CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
slave>  CREATE TABLE t1 (c2 INT, c1 INT);
```

The following table definitions would also raise an error because the definition of the extra column on the master appears before the definitions of the columns common to both versions of the table:

```
master> CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT);
```

More columns on the slave. The following table definitions are valid and replicate correctly:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
```

The following definitions raise an error because the columns common to both versions of the table are not defined in the same order on both the master and the slave:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c2 INT, c1 INT, c3 INT);
```

The following table definitions also raise an error because the definition for the extra column in the slave's version of the table appears before the definitions for the columns which are common to both versions of the table:

```
master> CREATE TABLE t1 (c1 INT, c2 INT);
slave>  CREATE TABLE t1 (c3 INT, c1 INT, c2 INT);
```

The following table definitions fail because the slave's version of the table has additional columns compared to the master's version, and the two versions of the table use different data types for the common column `c2`:

```
master> CREATE TABLE t1 (c1 INT, c2 BIGINT);
slave>  CREATE TABLE t1 (c1 INT, c2 INT, c3 INT);
```

Replication of Columns Having Different Data Types

Corresponding columns on the master's and the slave's copies of the same table ideally should have the same data type. However, beginning with MySQL 5.1.21, this is not always strictly enforced, as long as certain conditions are met.

All other things being equal, it is always possible to replicate from a column of a given data type to another column of the same type and same size or width, where applicable, or larger. For example, you can replicate from a `CHAR(10)` column to another `CHAR(10)`, or from a `CHAR(10)` column to a `CHAR(25)` column without any problems. In certain cases, it also possible to replicate from a column having one data type (on the master) to a column having a different data type (on the slave); when the data type of the master's version of the column is promoted to a type that is the same size or larger on the slave, this is known as *attribute promotion*.

Attribute promotion can be used with both statement-based and row-based replication, and is not dependent on the storage engine used by either the master or the slave. However, the choice of logging format does have an effect on the type conversions that are permitted; the particulars are discussed later in this section.

Important

Whether you use statement-based or row-based replication, the slave's copy of the table cannot contain more columns than the master's copy if you wish to employ attribute promotion.

Statement-based replication. When using statement-based replication, a simple rule of thumb to follow is, “If the statement run on the master would also execute successfully on the slave, it should also replicate successfully”. In other words, if the statement uses a value that is compatible with the type of a given column on the slave, the statement can be replicated. For example, you can insert any value that fits in a `TINYINT` column into a `BIGINT` column as well; it follows that, even if you change the type of a `TINYINT` column in the slave's copy of a table to `BIGINT`, any insert into that column on the master that succeeds should also succeed on the slave, since it is impossible to have a legal `TINYINT` value that is large enough to exceed a `BIGINT` column.

Prior to MySQL 5.5.30, when using statement-based replication, `AUTO_INCREMENT` columns were required to be the same on both the master and the slave; otherwise, updates could be applied to the wrong table on the slave. (Bug #12669186)

Row-based replication: attribute promotion and demotion. Formerly, due to the fact that in row-based replication changes rather than statements are replicated, and that these changes are

transmitted using formats that do not always map directly to MySQL server column data types, you could not replicate between different subtypes of the same general type (for example, from `TINYINT` to `BIGINT`, both `INT` subtypes). However, beginning with MySQL 5.5.3, MySQL Replication supports attribute promotion and demotion between smaller data types and larger types. It is also possible to specify whether or not to permit lossy (truncated) or non-lossy conversions of demoted column values, as explained later in this section.

Lossy and non-lossy conversions. In the event that the target type cannot represent the value being inserted, a decision must be made on how to handle the conversion. If we permit the conversion but truncate (or otherwise modify) the source value to achieve a “fit” in the target column, we make what is known as a *lossy conversion*. A conversion which does not require truncation or similar modifications to fit the source column value in the target column is a *non-lossy* conversion.

Type conversion modes (slave_type_conversions variable). The setting of the `slave_type_conversions` global server variable controls the type conversion mode used on the slave. This variable takes a set of values from the following table, which shows the effects of each mode on the slave's type-conversion behavior:

Mode	Effect
`ALL_LOSSY`	In this mode, type conversions that would mean loss of information are permitted. This does not imply that non-lossy conversions are permitted, merely that only cases requiring either lossy conversions or no conversion at all are permitted; for example, enabling *only* this mode permits an `INT` column to be converted to `TINYINT` (a lossy conversion), but not a `TINYINT` column to an `INT` column (non-lossy). Attempting the latter conversion in this case would cause replication to stop with an error on the slave.
`ALL_NON_LOSSY`	This mode permits conversions that do not require truncation or other special handling of the source value; that is, it permits conversions where the target type has a wider range than the source type. Setting this mode has no bearing on whether lossy conversions are permitted; this is controlled with the `ALL_LOSSY` mode. If only `ALL_NON_LOSSY` is set, but not `ALL_LOSSY`, then attempting a conversion that would result in the loss of data (such as `INT` to `TINYINT`, or `CHAR(25)` to `VARCHAR(20)`) causes the slave to stop with an error.
`ALL_LOSSY,ALL_NON_LOSSY`	When this mode is set, all supported type conversions are permitted, whether or not they are lossy conversions.
[*empty*]	When `slave_type_conversions` is not set, no attribute promotion or demotion is permitted; this means that all columns in the source and target tables must be of the same types. This mode is the default.

Changing the type conversion mode requires restarting the slave with the new `slave_type_conversions` setting.

Supported conversions. Supported conversions between different but similar data types are shown in the following list:

- Between any of the integer types `TINYINT`, `SMALLINT`, `MEDIUMINT`, `INT`, and `BIGINT`.

  This includes conversions between the signed and unsigned versions of these types.

Lossy conversions are made by truncating the source value to the maximum (or minimum) permitted by the target column. For insuring non-lossy conversions when going from unsigned to signed types, the target column must be large enough to accommodate the range of values in the source column. For example, you can demote `TINYINT UNSIGNED` non-lossily to `SMALLINT`, but not to `TINYINT`.

- Between any of the decimal types `DECIMAL`, `FLOAT`, `DOUBLE`, and `NUMERIC`.

  `FLOAT` to `DOUBLE` is a non-lossy conversion; `DOUBLE` to `FLOAT` can only be handled lossily. A conversion from `DECIMAL(M,D)` to `DECIMAL(M',D')` where `D' >= D` and `(M'-D') >= (M-D)` are non-lossy; for any case where `M' < M`, `D' < D`, or both, only a lossy conversion can be made.

  For any of the decimal types, if a value to be stored cannot be fit in the target type, the value is rounded down according to the rounding rules defined for the server elsewhere in the documentation. See Section 12.18.4, “Rounding Behavior”, for information about how this is done for decimal types.

- Between any of the string types `CHAR`, `VARCHAR`, and `TEXT`, including conversions between different widths.

  Conversion of a `CHAR`, `VARCHAR`, or `TEXT` to a `CHAR`, `VARCHAR`, or `TEXT` column the same size or larger is never lossy. Lossy conversion is handled by inserting only the first `N` characters of the string on the slave, where `N` is the width of the target column.

  Important

  Replication between columns using different character sets is not supported.

- Between any of the binary data types `BINARY`, `VARBINARY`, and `BLOB`, including conversions between different widths.

  Conversion of a `BINARY`, `VARBINARY`, or `BLOB` to a `BINARY`, `VARBINARY`, or `BLOB` column the same size or larger is never lossy. Lossy conversion is handled by inserting only the first `N` bytes of the string on the slave, where `N` is the width of the target column.

- Between any 2 `BIT` columns of any 2 sizes.

  When inserting a value from a `BIT(M)` column into a `BIT(M')` column, where `M' > M`, the most significant bits of the `BIT(M')` columns are cleared (set to zero) and the `M` bits of the `BIT(M)` value are set as the least significant bits of the `BIT(M')` column.

  When inserting a value from a source `BIT(M)` column into a target `BIT(M')` column, where `M' < M`, the maximum possible value for the `BIT(M')` column is assigned; in other words, an “all-set” value is assigned to the target column.

Conversions between types not in the previous list are not permitted.

Replication type conversions in MySQL 5.5.3 and earlier. Prior to MySQL 5.5.3, with row-based binary logging, you could not replicate between different `INT` subtypes, such as from `TINYINT` to `BIGINT`, because changes to columns of these types were represented differently from one another in the binary log when using row-based logging. (However, you could replicate from `BLOB` to `TEXT` using row-based replication because changes to `BLOB` and `TEXT` columns were represented using the same format in the binary log.)

Supported conversions for attribute promotion when using row-based replication prior to MySQL 5.5.3 are shown in the following table:

From (Master)	To (Slave)
`BINARY`	`CHAR`
`BLOB`	`TEXT`

From (Master)	To (Slave)
CHAR	BINARY
DECIMAL	NUMERIC
NUMERIC	DECIMAL
TEXT	BLOB
VARBINARY	VARCHAR
VARCHAR	VARBINARY

Note

In all cases, the size or width of the column on the slave must be equal to or greater than that of the column on the master. For example, you could replicate from a `CHAR(10)` column on the master to a column that used `BINARY(10)` or `BINARY(25)` on the slave, but you could not replicate from a `CHAR(10)` column on the master to `BINARY(5)` column on the slave.

Any unique index (including primary keys) having a prefix must use a prefix of the same length on both master and slave; in such cases, differing prefix lengths are disallowed. It is possible to use a nonunique index whose prefix length differs between master and slave, but this can cause serious performance issues, particularly when the prefix used on the master is longer. This is due to the fact that 2 unique prefixes of a given length may no longer be unique at a shorter length; for example, the words *catalogue* and *catamount* have the 5-character prefixes *catal* and *catam*, respectively, but share the same 4-character prefix (*cata*). This can lead to queries that use such indexes executing less efficiently on the slave, when a shorter prefix is employed in the slave' definition of the same index than on the master.

For `DECIMAL` and `NUMERIC` columns, both the mantissa (*M*) and the number of decimals (*D*) must be the same size or larger on the slave as compared with the master. For example, replication from a `NUMERIC(5,4)` to a `DECIMAL(6,4)` worked, but not from a `NUMERIC(5,4)` to a `DECIMAL(5,3)`.

Prior to MySQL 5.5.3, MySQL replication did not support attribute promotion of any of the following data types to or from any other data type when using row-based replication:

- `INT` (including `TINYINT`, `SMALLINT`, `MEDIUMINT`, `BIGINT`).

  Promotion between `INT` subtypes—for example, from `SMALLINT` to `BIGINT`—was also not supported prior to MySQL 5.5.3.

- `SET` or `ENUM`.
- `FLOAT` or `DOUBLE`.
- All of the data types relating to dates, times, or both: `DATE`, `TIME`, `DATETIME`, `TIMESTAMP`, and `YEAR`.

17.4.1.10 Replication and DIRECTORY Table Options

If a `DATA DIRECTORY` or `INDEX DIRECTORY` table option is used in a `CREATE TABLE` statement on the master server, the table option is also used on the slave. This can cause problems if no corresponding directory exists in the slave host file system or if it exists but is not accessible to the slave server. This can be overridden by using the `NO_DIR_IN_CREATE` server SQL mode on the slave, which causes the slave to ignore the `DATA DIRECTORY` and `INDEX DIRECTORY` table options when replicating `CREATE TABLE` statements. The result is that `MyISAM` data and index files are created in the table's database directory.

For more information, see Section 5.1.8, “Server SQL Modes”.

17.4.1.11 Replication of DROP ... IF EXISTS Statements

The `DROP DATABASE IF EXISTS`, `DROP TABLE IF EXISTS`, and `DROP VIEW IF EXISTS` statements are always replicated, even if the database, table, or view to be dropped does not exist on the master. This is to ensure that the object to be dropped no longer exists on either the master or the slave, once the slave has caught up with the master.

`DROP ... IF EXISTS` statements for stored programs (stored procedures and functions, triggers, and events) are also replicated, even if the stored program to be dropped does not exist on the master.

17.4.1.12 Replication and Floating-Point Values

With statement-based replication, values are converted from decimal to binary. Because conversions between decimal and binary representations of them may be approximate, comparisons involving floating-point values are inexact. This is true for operations that use floating-point values explicitly, or that use values that are converted to floating-point implicitly. Comparisons of floating-point values might yield different results on master and slave servers due to differences in computer architecture, the compiler used to build MySQL, and so forth. See Section 12.2, “Type Conversion in Expression Evaluation”, and Section B.5.4.8, “Problems with Floating-Point Values”.

17.4.1.13 Replication and FLUSH

Some forms of the `FLUSH` statement are not logged because they could cause problems if replicated to a slave: `FLUSH LOGS`, `FLUSH MASTER`, `FLUSH SLAVE`, and `FLUSH TABLES WITH READ LOCK`. For a syntax example, see Section 13.7.6.3, “FLUSH Syntax”. The `FLUSH TABLES`, `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` statements are written to the binary log and thus replicated to slaves. This is not normally a problem because these statements do not modify table data.

However, this behavior can cause difficulties under certain circumstances. If you replicate the privilege tables in the `mysql` database and update those tables directly without using `GRANT`, you must issue a `FLUSH PRIVILEGES` on the slaves to put the new privileges into effect. In addition, if you use `FLUSH TABLES` when renaming a `MyISAM` table that is part of a `MERGE` table, you must issue `FLUSH TABLES` manually on the slaves. These statements are written to the binary log unless you specify `NO_WRITE_TO_BINLOG` or its alias `LOCAL`.

17.4.1.14 Replication and System Functions

Certain functions do not replicate well under some conditions:

- The `USER()`, `CURRENT_USER()` (or `CURRENT_USER`), `UUID()`, `VERSION()`, and `LOAD_FILE()` functions are replicated without change and thus do not work reliably on the slave unless row-based replication is enabled. (See Section 17.1.2, “Replication Formats”.)

  `USER()` and `CURRENT_USER()` are automatically replicated using row-based replication when using `MIXED` mode, and generate a warning in `STATEMENT` mode. (Bug #28086) (See also Section 17.4.1.8, “Replication of CURRENT_USER()”.)

  Beginning with MySQL 5.5.1, `VERSION()` is also automatically replicated using row-based replication when using `MIXED` mode, and generates a warning in `STATEMENT` mode. (Bug #47995) Beginning with MySQL 5.5.2, this is also true with regard to the `RAND()` function. (Bug #49222)

- For `NOW()`, the binary log includes the timestamp. This means that the value *as returned by the call to this function on the master* is replicated to the slave. This can lead to a possibly unexpected result when replicating between MySQL servers in different time zones. Suppose that the master is located in New York, the slave is located in Stockholm, and both servers are using local time. Suppose further that, on the master, you create a table `mytable`, perform an `INSERT` statement on this table, and then select from the table, as shown here:

```
mysql> CREATE TABLE mytable (mycol TEXT);
Query OK, 0 rows affected (0.06 sec)

mysql> INSERT INTO mytable VALUES ( NOW() );
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM mytable;
+---------------------+
| mycol               |
+---------------------+
| 2009-09-01 12:00:00 |
+---------------------+
1 row in set (0.00 sec)
```

Local time in Stockholm is 6 hours later than in New York; so, if you issue `SELECT NOW()` on the slave at that exact same instant, the value `2009-09-01 18:00:00` is returned. For this reason, if you select from the slave's copy of `mytable` after the `CREATE TABLE` and `INSERT` statements just shown have been replicated, you might expect `mycol` to contain the value `2009-09-01 18:00:00`. However, this is not the case; when you select from the slave's copy of `mytable`, you obtain exactly the same result as on the master:

```
mysql> SELECT * FROM mytable;
+---------------------+
| mycol               |
+---------------------+
| 2009-09-01 12:00:00 |
+---------------------+
1 row in set (0.00 sec)
```

Unlike `NOW()`, the `SYSDATE()` function is not replication-safe because it is not affected by `SET TIMESTAMP` statements in the binary log and is nondeterministic if statement-based logging is used. This is not a problem if row-based logging is used.

An alternative is to use the `--sysdate-is-now` option to cause `SYSDATE()` to be an alias for `NOW()`. This must be done on the master and the slave to work correctly. In such cases, a warning is still issued by this function, but can safely be ignored as long as `--sysdate-is-now` is used on both the master and the slave.

Beginning with MySQL 5.5.1, `SYSDATE()` is automatically replicated using row-based replication when using `MIXED` mode, and generates a warning in `STATEMENT` mode. (Bug #47995)

See also Section 17.4.1.34, “Replication and Time Zones”.

- *The following restriction applies to statement-based replication only, not to row-based replication.* The `GET_LOCK()`, `RELEASE_LOCK()`, `IS_FREE_LOCK()`, and `IS_USED_LOCK()` functions that handle user-level locks are replicated without the slave knowing the concurrency context on the master. Therefore, these functions should not be used to insert into a master table because the content on the slave would differ. For example, do not issue a statement such as `INSERT INTO mytable VALUES(GET_LOCK(...))`.

  Beginning with MySQL 5.5.1, these functions are automatically replicated using row-based replication when using `MIXED` mode, and generate a warning in `STATEMENT` mode. (Bug #47995)

As a workaround for the preceding limitations when statement-based replication is in effect, you can use the strategy of saving the problematic function result in a user variable and referring to the variable in a later statement. For example, the following single-row `INSERT` is problematic due to the reference to the `UUID()` function:

```
INSERT INTO t VALUES(UUID());
```

To work around the problem, do this instead:

```
SET @my_uuid = UUID();
INSERT INTO t VALUES(@my_uuid);
```

That sequence of statements replicates because the value of `@my_uuid` is stored in the binary log as a user-variable event prior to the `INSERT` statement and is available for use in the `INSERT`.

The same idea applies to multiple-row inserts, but is more cumbersome to use. For a two-row insert, you can do this:

```
SET @my_uuid1 = UUID(); @my_uuid2 = UUID();
INSERT INTO t VALUES(@my_uuid1),(@my_uuid2);
```

However, if the number of rows is large or unknown, the workaround is difficult or impracticable. For example, you cannot convert the following statement to one in which a given individual user variable is associated with each row:

```
INSERT INTO t2 SELECT UUID(), * FROM t1;
```

Within a stored function, `RAND()` replicates correctly as long as it is invoked only once during the execution of the function. (You can consider the function execution timestamp and random number seed as implicit inputs that are identical on the master and slave.)

The `FOUND_ROWS()` and `ROW_COUNT()` functions are not replicated reliably using statement-based replication. A workaround is to store the result of the function call in a user variable, and then use that in the `INSERT` statement. For example, if you wish to store the result in a table named `mytable`, you might normally do so like this:

```
SELECT SQL_CALC_FOUND_ROWS FROM mytable LIMIT 1;
INSERT INTO mytable VALUES( FOUND_ROWS() );
```

However, if you are replicating `mytable`, you should use `SELECT ... INTO`, and then store the variable in the table, like this:

```
SELECT SQL_CALC_FOUND_ROWS INTO @found_rows FROM mytable LIMIT 1;
INSERT INTO mytable VALUES(@found_rows);
```

In this way, the user variable is replicated as part of the context, and applied on the slave correctly.

These functions are automatically replicated using row-based replication when using `MIXED` mode, and generate a warning in `STATEMENT` mode. (Bug #12092, Bug #30244)

Prior to MySQL 5.5.35, the value of `LAST_INSERT_ID()` was not replicated correctly if any filtering options such as `--replicate-ignore-db` and `--replicate-do-table` were enabled on the slave. (Bug #17234370, BUG# 69861)

17.4.1.15 Replication of Invoked Features

Replication of invoked features such as user-defined functions (UDFs) and stored programs (stored procedures and functions, triggers, and events) provides the following characteristics:

- The effects of the feature are always replicated.
- The following statements are replicated using statement-based replication:
  - `CREATE EVENT`
  - `ALTER EVENT`
  - `DROP EVENT`

- `CREATE PROCEDURE`
- `DROP PROCEDURE`
- `CREATE FUNCTION`
- `DROP FUNCTION`
- `CREATE TRIGGER`
- `DROP TRIGGER`

However, the *effects* of features created, modified, or dropped using these statements are replicated using row-based replication.

Note

Attempting to replicate invoked features using statement-based replication produces the warning `Statement is not safe to log in statement format`. For example, trying to replicate a UDF with statement-based replication generates this warning because it currently cannot be determined by the MySQL server whether the UDF is deterministic. If you are absolutely certain that the invoked feature's effects are deterministic, you can safely disregard such warnings.

- In the case of `CREATE EVENT` and `ALTER EVENT`:
  - The status of the event is set to `SLAVESIDE_DISABLED` on the slave regardless of the state specified (this does not apply to `DROP EVENT`).
  - The master on which the event was created is identified on the slave by its server ID. The `ORIGINATOR` column in `INFORMATION_SCHEMA.EVENTS` and the `originator` column in `mysql.event` store this information. See Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”, and Section 13.7.5.19, “SHOW EVENTS Syntax”, for more information.
- The feature implementation resides on the slave in a renewable state so that if the master fails, the slave can be used as the master without loss of event processing.

To determine whether there are any scheduled events on a MySQL server that were created on a different server (that was acting as a replication master), query the `INFORMATION_SCHEMA.EVENTS` table in a manner similar to what is shown here:

```
SELECT EVENT_SCHEMA, EVENT_NAME
    FROM INFORMATION_SCHEMA.EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED';
```

Alternatively, you can use the `SHOW EVENTS` statement, like this:

```
SHOW EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED';
```

When promoting a replication slave having such events to a replication master, you must enable each event using `ALTER EVENT event_name ENABLE`, where *`event_name`* is the name of the event.

If more than one master was involved in creating events on this slave, and you wish to identify events that were created only on a given master having the server ID *`master_id`*, modify the previous query on the `EVENTS` table to include the `ORIGINATOR` column, as shown here:

```
SELECT EVENT_SCHEMA, EVENT_NAME, ORIGINATOR
    FROM INFORMATION_SCHEMA.EVENTS
```

```
    WHERE STATUS = 'SLAVESIDE_DISABLED'
    AND   ORIGINATOR = 'master_id'
```

You can employ `ORIGINATOR` with the `SHOW EVENTS` statement in a similar fashion:

```
SHOW EVENTS
    WHERE STATUS = 'SLAVESIDE_DISABLED'
    AND   ORIGINATOR = 'master_id'
```

Before enabling events that were replicated from the master, you should disable the MySQL Event Scheduler on the slave (using a statement such as `SET GLOBAL event_scheduler = OFF;`), run any necessary `ALTER EVENT` statements, restart the server, then re-enable the Event Scheduler on the slave afterward (using a statement such as `SET GLOBAL event_scheduler = ON;`)-

If you later demote the new master back to being a replication slave, you must disable manually all events enabled by the `ALTER EVENT` statements. You can do this by storing in a separate table the event names from the `SELECT` statement shown previously, or using `ALTER EVENT` statements to rename the events with a common prefix such as `replicated_` to identify them.

If you rename the events, then when demoting this server back to being a replication slave, you can identify the events by querying the `EVENTS` table, as shown here:

```
SELECT CONCAT(EVENT_SCHEMA, '.', EVENT_NAME) AS 'Db.Event'
      FROM INFORMATION_SCHEMA.EVENTS
      WHERE INSTR(EVENT_NAME, 'replicated_') = 1;
```

17.4.1.16 Replication and LIMIT

Statement-based replication of `LIMIT` clauses in `DELETE`, `UPDATE`, and `INSERT ... SELECT` statements is unsafe since the order of the rows affected is not defined. (Such statements can be replicated correctly with statement-based replication only if they also contain an `ORDER BY` clause.) When such a statement is encountered:

- When using `STATEMENT` mode, a warning that the statement is not safe for statement-based replication is now issued.

  When using `STATEMENT` mode, warnings are issued for DML statements containing `LIMIT` even when they also have an `ORDER BY` clause (and so are made deterministic). This is a known issue. (Bug #42851)

- When using `MIXED` mode, the statement is now automatically replicated using row-based mode.

17.4.1.17 Replication and LOAD DATA INFILE

In MySQL 5.5.6 and later, `LOAD DATA INFILE` is considered unsafe (see Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”).

17.4.1.18 Replication and the Slow Query Log

In older versions of MySQL, replication slaves did not write replicated queries to the slow query log, even if the same queries were written to the slow query log on the master. This is no longer an issue in MySQL 5.5. (Bug #23300)

17.4.1.19 Replication and max_allowed_packet

`max_allowed_packet` sets an upper limit on the size of any single message between the MySQL server and clients, including replication slaves. If you are replicating large column values (such as might be found in `TEXT` or `BLOB` columns) and `max_allowed_packet` is too small on the master, the master fails with an error, and the slave shuts down the I/O thread. If `max_allowed_packet` is too small on the slave, this also causes the slave to stop the I/O thread.

Row-based replication currently sends all columns and column values for updated rows from the master to the slave, including values of columns that were not actually changed by the update. This means that, when you are replicating large column values using row-based replication, you must take care to set `max_allowed_packet` large enough to accommodate the largest row in any table to be replicated, even if you are replicating updates only, or you are inserting only relatively small values.

17.4.1.20 Replication and MEMORY Tables

When a master server shuts down and restarts, its `MEMORY` tables become empty. To replicate this effect to slaves, the first time that the master uses a given `MEMORY` table after startup, it logs an event that notifies slaves that the table must to be emptied by writing a `DELETE` statement for that table to the binary log.

When a slave server shuts down and restarts, its `MEMORY` tables become empty. This causes the slave to be out of synchrony with the master and may lead to other failures or cause the slave to stop:

- Row-format updates and deletes received from the master may fail with `Can't find record in 'memory_table'`.
- Statements such as `INSERT INTO ... SELECT FROM memory_table` may insert a different set of rows on the master and slave.

The safe way to restart a slave that is replicating `MEMORY` tables is to first drop or delete all rows from the `MEMORY` tables on the master and wait until those changes have replicated to the slave. Then it is safe to restart the slave.

An alternative restart method may apply in some cases. When `binlog_format=ROW`, you can prevent the slave from stopping if you set `slave_exec_mode=IDEMPOTENT` before you start the slave again. This allows the slave to continue to replicate, but its `MEMORY` tables will still be different from those on the master. This can be okay if the application logic is such that the contents of `MEMORY` tables can be safely lost (for example, if the `MEMORY` tables are used for caching). `slave_exec_mode=IDEMPOTENT` applies globally to all tables, so it may hide other replication errors in non-`MEMORY` tables.

(The method just described is not applicable in NDB Cluster, where `slave_exec_mode` is always `IDEMPOTENT`, and cannot be changed.)

The size of `MEMORY` tables is limited by the value of the `max_heap_table_size` system variable, which is not replicated (see Section 17.4.1.38, “Replication and Variables”). A change in `max_heap_table_size` takes effect for `MEMORY` tables that are created or updated using `ALTER TABLE ... ENGINE = MEMORY` or `TRUNCATE TABLE` following the change, or for all `MEMORY` tables following a server restart. If you increase the value of this variable on the master without doing so on the slave, it becomes possible for a table on the master to grow larger than its counterpart on the slave, leading to inserts that succeed on the master but fail on the slave with `Table is full` errors. This is a known issue (Bug #48666). In such cases, you must set the global value of `max_heap_table_size` on the slave as well as on the master, then restart replication. It is also recommended that you restart both the master and slave MySQL servers, to insure that the new value takes complete (global) effect on each of them.

See Section 15.4, “The MEMORY Storage Engine”, for more information about `MEMORY` tables.

17.4.1.21 Replication of the mysql System Database

Data modification statements made to tables in the `mysql` database are replicated according to the value of `binlog_format`; if this value is `MIXED`, these statements are replicated using row-based format. However, statements that would normally update this information indirectly—such `GRANT`, `REVOKE`, and statements manipulating triggers, stored routines, and views—are replicated to slaves using statement-based replication.

17.4.1.22 Replication and the Query Optimizer

It is possible for the data on the master and slave to become different if a statement is written in such a way that the data modification is nondeterministic; that is, left up the query optimizer. (In general, this is not a good practice, even outside of replication.) Examples of nondeterministic statements include `DELETE` or `UPDATE` statements that use `LIMIT` with no `ORDER BY` clause; see Section 17.4.1.16, "Replication and LIMIT", for a detailed discussion of these.

17.4.1.23 Replication and Partitioning

Replication is supported between partitioned tables as long as they use the same partitioning scheme and otherwise have the same structure except where an exception is specifically allowed (see Section 17.4.1.9, "Replication with Differing Table Definitions on Master and Slave").

Replication between tables having different partitioning is generally not supported. This because statements (such as `ALTER TABLE ... DROP PARTITION`) acting directly on partitions in such cases may produce different results on master and slave. In the case where a table is partitioned on the master but not on the slave, any statements operating on partitions on the master's copy of the slave fail on the slave. When the slave's copy of the table is partitioned but the master's copy is not, statements acting on partitions cannot be run on the master without causing errors there.

Due to these dangers of causing replication to fail entirely (on account of failed statements) and of inconsistencies (when the result of a partition-level SQL statement produces different results on master and slave), we recommend that insure that the partitioning of any tables to be replicated from the master is matched by the slave's versions of these tables.

17.4.1.24 Replication and REPAIR TABLE

When used on a corrupted or otherwise damaged table, it is possible for the `REPAIR TABLE` statement to delete rows that cannot be recovered. However, any such modifications of table data performed by this statement are not replicated, which can cause master and slave to lose synchronization. For this reason, in the event that a table on the master becomes damaged and you use `REPAIR TABLE` to repair it, you should first stop replication (if it is still running) before using `REPAIR TABLE`, then afterward compare the master's and slave's copies of the table and be prepared to correct any discrepancies manually, before restarting replication.

17.4.1.25 Replication and Reserved Words

You can encounter problems when you attempt to replicate from an older master to a newer slave and you make use of identifiers on the master that are reserved words in the newer MySQL version running on the slave. An example of this is using a table column named `range` on a 5.0 master that is replicating to a 5.1 or higher slave because `RANGE` is a reserved word beginning in MySQL 5.1. Replication can fail in such cases with Error 1064 `You have an error in your SQL syntax...`, *even if a database or table named using the reserved word or a table having a column named using the reserved word is excluded from replication*. This is due to the fact that each SQL event must be parsed by the slave prior to execution, so that the slave knows which database object or objects would be affected; only after the event is parsed can the slave apply any filtering rules defined by `--replicate-do-db`, `--replicate-do-table`, `--replicate-ignore-db`, and `--replicate-ignore-table`.

To work around the problem of database, table, or column names on the master which would be regarded as reserved words by the slave, do one of the following:

- Use one or more `ALTER TABLE` statements on the master to change the names of any database objects where these names would be considered reserved words on the slave, and change any SQL statements that use the old names to use the new names instead.
- In any SQL statements using these database object names, write the names as quoted identifiers using backtick characters (`` ` ``).

For listings of reserved words by MySQL version, see Reserved Words, in the *MySQL Server Version Reference*. For identifier quoting rules, see Section 9.2, "Schema Object Names".

17.4.1.26 Replication of Server-Side Help Tables

The server maintains tables in the `mysql` database that store information for the `HELP` statement (see Section 13.8.3, “HELP Syntax”. These tables can be loaded manually as described at Section 5.1.10, “Server-Side Help”.

Help table content is derived from the MySQL Reference Manual. There are versions of the manual specific to each MySQL release series, so help content is specific to each series as well. Normally, you load a version of help content that matches the server version. This has implications for replication. For example, you would load MySQL 5.5 help content into a MySQL 5.5 master server, but not necessarily replicate that content to a MySQL 5.6 slave server for which 5.6 help content is more appropriate.

This section describes how to manage help table content upgrades when your servers participate in replication. Server versions are one factor in this task. Another is that help table structure may differ between the master and the slave.

Assume that help content is stored in a file named `fill_help_tables.sql`. In MySQL distributions, this file is located under the `share` or `share/mysql` directory, and the most recent version is always available for download from http://dev.mysql.com/doc/index-other.html.

To upgrade help tables, using the following procedure. Connection parameters are not shown for the `mysql` commands discussed here; in all cases, connect to the server using an account such as `root` that has privileges for modifying tables in the `mysql` database.

1. Upgrade your servers by running `mysql_upgrade`, first on the slaves and then on the master. This is the usual principle of upgrading slaves first.

2. Decide whether you want to replicate help table content from the master to its slaves. If not, load the content on the master and each slave individually. Otherwise, check for and resolve any incompatibilities between help table structure on the master and its slaves, then load the content into the master and let it replicate to the slaves.

   More detail about these two methods of loading help table content follows.

Loading Help Table Content Without Replication to Slaves

To load help table content without replication, run this command on the master and each slave individually, using a `fill_help_tables.sql` file containing content appropriate to the server version (enter the command on one line):

```
mysql --init-command="SET sql_log_bin=0"
  mysql < fill_help_tables.sql
```

Use the `--init-command` option on each server, including the slaves, in case a slave also acts as a master to other slaves in your replication topology. The `SET` statement suppresses binary logging. After the command has been run on each server to be upgraded, you are done.

Loading Help Table Content With Replication to Slaves

If you do want to replicate help table content, check for help table incompatibilities between your master and its slaves. The `url` column in the `help_category` and `help_topic` tables was originally `CHAR(128)`, but is `TEXT` in newer MySQL versions to accommodate longer URLs. To check help table structure, use this statement:

```
SELECT TABLE_NAME, COLUMN_NAME, COLUMN_TYPE
FROM INFORMATION_SCHEMA.COLUMNS
WHERE TABLE_SCHEMA = 'mysql'
AND COLUMN_NAME = 'url';
```

For tables with the old structure, the statement produces this result:

```
+---------------+-------------+-------------+
| TABLE_NAME    | COLUMN_NAME | COLUMN_TYPE |
+---------------+-------------+-------------+
| help_category | url         | char(128)   |
| help_topic    | url         | char(128)   |
+---------------+-------------+-------------+
```

For tables with the new structure, the statement produces this result:

```
+---------------+-------------+-------------+
| TABLE_NAME    | COLUMN_NAME | COLUMN_TYPE |
+---------------+-------------+-------------+
| help_category | url         | text        |
| help_topic    | url         | text        |
+---------------+-------------+-------------+
```

If the master and slave both have the old structure or both have the new structure, they are compatible and you can replicate help table content by executing this command on the master:

```
mysql mysql < fill_help_tables.sql
```

The table content will load into the master, then replicate to the slaves.

If the master and slave have incompatible help tables (one server has the old structure and the other has the new), you have a choice between not replicating help table content after all, or making the table structures compatible so that you can replicate the content.

- If you decide not to replicate the content after all, upgrade the master and slaves individually using `mysql` with the `--init-command` option, as described previously.
- If instead you decide to make the table structures compatible, upgrade the tables on the server that has the old structure. Suppose that your master server has the old table structure. Upgrade its tables to the new structure manually by executing these statements (binary logging is disabled here to prevent replication of the changes to the slaves, which already have the new structure):

  ```
  SET sql_log_bin=0;
  ALTER TABLE mysql.help_category ALTER COLUMN url TEXT;
  ALTER TABLE mysql.help_topic ALTER COLUMN url TEXT;
  ```

  Then run this command on the master:

  ```
  mysql mysql < fill_help_tables.sql
  ```

  The table content will load into the master, then replicate to the slaves.

17.4.1.27 SET PASSWORD and Row-Based Replication

Row-based replication of `SET PASSWORD` statements from a MySQL 5.1 master to a MySQL 5.5 slave did not work correctly prior to MySQL 5.1.53 on the master and MySQL 5.5.7 on the slave (see Bug #57098, Bug #57357).

17.4.1.28 Replication and Master or Slave Shutdowns

It is safe to shut down a master server and restart it later. When a slave loses its connection to the master, the slave tries to reconnect immediately and retries periodically if that fails. The default is to retry every 60 seconds. This may be changed with the `CHANGE MASTER TO` statement. A slave also is able to deal with network connectivity outages. However, the slave notices the network outage only after receiving no data from the master for `slave_net_timeout` seconds. If your outages are short, you may want to decrease `slave_net_timeout`. See Section 5.1.5, “Server System Variables”.

An unclean shutdown (for example, a crash) on the master side can result in the master binary log having a final position less than the most recent position read by the slave, due to the master binary log file not being flushed. This can cause the slave not to be able to replicate when the master comes back up. Setting `sync_binlog=1` in the master `my.cnf` file helps to minimize this problem because it causes the master to flush its binary log more frequently.

Shutting down a slave cleanly is safe because it keeps track of where it left off. However, be careful that the slave does not have temporary tables open; see Section 17.4.1.31, “Replication and Temporary Tables”. Unclean shutdowns might produce problems, especially if the disk cache was not flushed to disk before the problem occurred:

- For transactions, the slave commits and then updates `relay-log.info`. If a crash occurs between these two operations, relay log processing will have proceeded further than the information file indicates and the slave will re-execute the events from the last transaction in the relay log after it has been restarted.
- A similar problem can occur if the slave updates `relay-log.info` but the server host crashes before the write has been flushed to disk. To minimize the chance of this occurring, set `sync_relay_log_info=1` in the slave `my.cnf` file. The default value of `sync_relay_log_info` is 0, which does not cause writes to be forced to disk; the server relies on the operating system to flush the file from time to time.

The fault tolerance of your system for these types of problems is greatly increased if you have a good uninterruptible power supply.

17.4.1.29 Slave Errors During Replication

If a statement produces the same error (identical error code) on both the master and the slave, the error is logged, but replication continues.

If a statement produces different errors on the master and the slave, the slave SQL thread terminates, and the slave writes a message to its error log and waits for the database administrator to decide what to do about the error. This includes the case that a statement produces an error on the master or the slave, but not both. To address the issue, connect to the slave manually and determine the cause of the problem. `SHOW SLAVE STATUS` is useful for this. Then fix the problem and run `START SLAVE`. For example, you might need to create a nonexistent table before you can start the slave again.

Note

If a temporary error is recorded in the slave's error log, you do not necessarily have to take any action suggested in the quoted error message. Temporary errors should be handled by the client retrying the transaction. For example, if the slave SQL thread records a temporary error relating to a deadlock, you do not need to restart the transaction manually on the slave, unless the slave SQL thread subsequently terminates with a non-temporary error message.

If this error code validation behavior is not desirable, some or all errors can be masked out (ignored) with the `--slave-skip-errors` option.

For nontransactional storage engines such as `MyISAM`, it is possible to have a statement that only partially updates a table and returns an error code. This can happen, for example, on a multiple-row insert that has one row violating a key constraint, or if a long update statement is killed after updating some of the rows. If that happens on the master, the slave expects execution of the statement to result in the same error code. If it does not, the slave SQL thread stops as described previously.

If you are replicating between tables that use different storage engines on the master and slave, keep in mind that the same statement might produce a different error when run against one version of the table, but not the other, or might cause an error for one version of the table, but not the other. For example, since `MyISAM` ignores foreign key constraints, an `INSERT` or `UPDATE` statement accessing an `InnoDB` table on the master might cause a foreign key violation but the same statement performed

on a MyISAM version of the same table on the slave would produce no such error, causing replication to stop.

17.4.1.30 Replication and Server SQL Mode

Using different server SQL mode settings on the master and the slave may cause the same INSERT statements to be handled differently on the master and the slave, leading the master and slave to diverge. For best results, you should always use the same server SQL mode on the master and on the slave. This advice applies whether you are using statement-based or row-based replication.

If you are replicating partitioned tables, using different SQL modes on the master and the slave is likely to cause issues. At a minimum, this is likely to cause the distribution of data among partitions to be different in the master's and slave's copies of a given table. It may also cause inserts into partitioned tables that succeed on the master to fail on the slave.

For more information, see Section 5.1.8, “Server SQL Modes”.

17.4.1.31 Replication and Temporary Tables

The discussion in the following paragraphs does not apply when binlog_format=ROW because, in that case, temporary tables are not replicated; this means that there are never any temporary tables on the slave to be lost in the event of an unplanned shutdown by the slave. The remainder of this section applies only when using statement-based or mixed-format replication. Loss of replicated temporary tables on the slave can be an issue, whenever binlog_format is STATEMENT or MIXED, for statements involving temporary tables that can be logged safely using statement-based format. For more information about row-based replication and temporary tables, see RBL, RBR, and temporary tables.

Safe slave shutdown when using temporary tables. Temporary tables are replicated except in the case where you stop the slave server (not just the slave threads) and you have replicated temporary tables that are open for use in updates that have not yet been executed on the slave. If you stop the slave server, the temporary tables needed by those updates are no longer available when the slave is restarted. To avoid this problem, do not shut down the slave while it has temporary tables open. Instead, use the following procedure:

1. Issue a STOP SLAVE SQL_THREAD statement.
2. Use SHOW STATUS to check the value of the Slave_open_temp_tables variable.
3. If the value is not 0, restart the slave SQL thread with START SLAVE SQL_THREAD and repeat the procedure later.
4. When the value is 0, issue a mysqladmin shutdown command to stop the slave.

Temporary tables and replication options. By default, all temporary tables are replicated; this happens whether or not there are any matching --replicate-do-db, --replicate-do-table, or --replicate-wild-do-table options in effect. However, the --replicate-ignore-table and --replicate-wild-ignore-table options are honored for temporary tables.

A recommended practice when using statement-based or mixed-format replication is to designate a prefix for exclusive use in naming temporary tables that you do not want replicated, then employ a --replicate-wild-ignore-table option to match that prefix. For example, you might give all such tables names beginning with norep (such as norepmytable, norepyourtable, and so on), then use --replicate-wild-ignore-table=norep% to prevent them from being replicated.

17.4.1.32 Replication Retries and Timeouts

The global system variable slave_transaction_retries affects replication as follows: If the slave SQL thread fails to execute a transaction because of an InnoDB deadlock or

because it exceeded the `InnoDB` `innodb_lock_wait_timeout` value, or the `NDBCLUSTER` `TransactionDeadlockDetectionTimeout` or `TransactionInactiveTimeout` value, the slave automatically retries the transaction `slave_transaction_retries` times before stopping with an error. The default value is 10. The total retry count can be seen in the output of `SHOW STATUS`; see Section 5.1.7, “Server Status Variables”.

17.4.1.33 Replication and TIMESTAMP

Older versions of MySQL (prior to 4.1) differed significantly in several ways in their handling of the `TIMESTAMP` data type from what is supported in MySQL versions 5.5 and newer; these include syntax extensions which are deprecated in MySQL 5.1, and that no longer supported in MySQL 5.5. This can cause problems (including replication failures) when replicating between MySQL Server versions, if you are using columns that are defined using the old `TIMESTAMP(N)` syntax. See Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”, for more information about the differences, how they can impact MySQL replication, and what you can do if you encounter such problems.

17.4.1.34 Replication and Time Zones

The same system time zone should be set for both master and slave. Otherwise, statements depending on the local time on the master are not replicated properly, such as statements that use the `NOW()` or `FROM_UNIXTIME()` functions. You can set the time zone in which MySQL server runs by using the `--timezone=`*`timezone_name`* option of the `mysqld_safe` script or by setting the `TZ` environment variable. See also Section 17.4.1.14, “Replication and System Functions”.

17.4.1.35 Replication and Transactions

Mixing transactional and nontransactional statements within the same transaction. In general, you should avoid transactions that update both transactional and nontransactional tables in a replication environment. You should also avoid using any statement that accesses both transactional (or temporary) and nontransactional tables and writes to any of them.

As of MySQL 5.5.2, the server uses these rules for binary logging:

- If the initial statements in a transaction are nontransactional, they are written to the binary log immediately. The remaining statements in the transaction are cached and not written to the binary log until the transaction is committed. (If the transaction is rolled back, the cached statements are written to the binary log only if they make nontransactional changes that cannot be rolled back. Otherwise, they are discarded.)

- For statement-based logging, logging of nontransactional statements is affected by the `binlog_direct_non_transactional_updates` system variable. When this variable is `OFF` (the default), logging is as just described. When this variable is `ON`, logging occurs immediately for nontransactional statements occurring anywhere in the transaction (not just initial nontransactional statements). Other statements are kept in the transaction cache and logged when the transaction commits. `binlog_direct_non_transactional_updates` has no effect for row-format or mixed-format binary logging.

Transactional, nontransactional, and mixed statements.
To apply those rules, the server considers a statement nontransactional if it changes only nontransactional tables, and transactional if it changes only transactional tables. Prior to MySQL 5.5.6, a statement that changed both nontransactional and transactional tables was considered “mixed”. Beginning with MySQL 5.5.6, a statement that references both nontransactional and transactional tables and updates *any* of the tables involved, is considered a mixed statement. Mixed statements, like transactional statements, are cached and logged when the transaction commits.

Beginning with MySQL 5.5.6, a mixed statement that updates a transactional table is considered unsafe if the statement also performs either of the following actions:

- Updates or reads a temporary table

- Reads a nontransactional table and the transaction isolation level is less than REPEATABLE_READ

Also beginning with MySQL 5.5.6, any mixed statement following the update of a transactional table within a transaction is considered unsafe if it performs either of the following actions:

- Updates any table and reads from any temporary table
- Updates a nontransactional table and `binlog_direct_non_transactional_updates` is OFF

For more information, see Section 17.1.2.3, "Determination of Safe and Unsafe Statements in Binary Logging".

Note

A mixed statement is unrelated to mixed binary logging format.

Before MySQL 5.5.2, the rules for binary logging are similar to those just described, except that there is no `binlog_direct_non_transactional_updates` system variable to affect logging of transactional statements. Thus, the server immediately logs only the initial nontransactional statements in a transaction and caches the rest until commit time.

In situations where transactions mix updates to transactional and nontransactional tables, the order of statements in the binary log is correct, and all needed statements are written to the binary log even in case of a `ROLLBACK`. However, when a second connection updates the nontransactional table before the first connection transaction is complete, statements can be logged out of order because the second connection update is written immediately after it is performed, regardless of the state of the transaction being performed by the first connection.

Using different storage engines on master and slave. It is possible to replicate transactional tables on the master using nontransactional tables on the slave. For example, you can replicate an `InnoDB` master table as a `MyISAM` slave table. However, if you do this, there are problems if the slave is stopped in the middle of a `BEGIN` ... `COMMIT` block because the slave restarts at the beginning of the `BEGIN` block.

Beginning with MySQL 5.5.0, it is also safe to replicate transactions from `MyISAM` tables on the master to transactional tables—such as tables that use the `InnoDB` storage engine—on the slave. In such cases (beginning with MySQL 5.5.0), an `AUTOCOMMIT=1` statement issued on the master is replicated, thus enforcing `AUTOCOMMIT` mode on the slave.

When the storage engine type of the slave is nontransactional, transactions on the master that mix updates of transactional and nontransactional tables should be avoided because they can cause inconsistency of the data between the master transactional table and the slave nontransactional table. That is, such transactions can lead to master storage engine-specific behavior with the possible effect of replication going out of synchrony. MySQL does not issue a warning about this currently, so extra care should be taken when replicating transactional tables from the master to nontransactional tables on the slaves.

Changing the binary logging format within transactions. Beginning with MySQL 5.5.3, the `binlog_format` system variable is read-only as long as a transaction is in progress. (Bug #47863)

Every transaction (including `autocommit` transactions) is recorded in the binary log as though it starts with a `BEGIN` statement, and ends with either a `COMMIT` or a `ROLLBACK` statement. In MySQL 5.5, this true is even for statements affecting tables that use a nontransactional storage engine (such as `MyISAM`).

17.4.1.36 Replication and Triggers

With statement-based replication, triggers executed on the master also execute on the slave. With row-based replication, triggers executed on the master do not execute on the slave. Instead, the row changes on the master resulting from trigger execution are replicated and applied on the slave.

This behavior is by design. If under row-based replication the slave applied the triggers as well as the row changes caused by them, the changes would in effect be applied twice on the slave, leading to different data on the master and the slave.

If you want triggers to execute on both the master and the slave—perhaps because you have different triggers on the master and slave—you must use statement-based replication. However, to enable slave-side triggers, it is not necessary to use statement-based replication exclusively. It is sufficient to switch to statement-based replication only for those statements where you want this effect, and to use row-based replication the rest of the time.

A statement invoking a trigger (or function) that causes an update to an `AUTO_INCREMENT` column is not replicated correctly using statement-based replication. MySQL 5.5 marks such statements as unsafe. (Bug #45677)

17.4.1.37 Replication and TRUNCATE TABLE

`TRUNCATE TABLE` is normally regarded as a DML statement, and so would be expected to be logged and replicated using row-based format when the binary logging mode is `ROW` or `MIXED`. However this caused issues when logging or replicating, in `STATEMENT` or `MIXED` mode, tables that used transactional storage engines such as `InnoDB` when the transaction isolation level was `READ COMMITTED` or `READ UNCOMMITTED`, which precludes statement-based logging.

`TRUNCATE TABLE` is treated for purposes of logging and replication as DDL rather than DML so that it can be logged and replicated as a statement. However, the effects of the statement as applicable to `InnoDB` and other transactional tables on replication slaves still follow the rules described in Section 13.1.33, “TRUNCATE TABLE Syntax” governing such tables. (Bug #36763)

17.4.1.38 Replication and Variables

System variables are not replicated correctly when using `STATEMENT` mode, except for the following variables when they are used with session scope:

- `auto_increment_increment`
- `auto_increment_offset`
- `character_set_client`
- `character_set_connection`
- `character_set_database`
- `character_set_server`
- `collation_connection`
- `collation_database`
- `collation_server`
- `foreign_key_checks`
- `identity`
- `last_insert_id`
- `lc_time_names`
- `pseudo_thread_id`
- `sql_auto_is_null`

- `time_zone`
- `timestamp`
- `unique_checks`

When `MIXED` mode is used, the variables in the preceding list, when used with session scope, cause a switch from statement-based to row-based logging. See Section 5.4.4.3, “Mixed Binary Logging Format”.

`sql_mode` is also replicated except for the `NO_DIR_IN_CREATE` mode; the slave always preserves its own value for `NO_DIR_IN_CREATE`, regardless of changes to it on the master. This is true for all replication formats.

However, when `mysqlbinlog` parses a `SET @@sql_mode = mode` statement, the full *`mode`* value, including `NO_DIR_IN_CREATE`, is passed to the receiving server. For this reason, replication of such a statement may not be safe when `STATEMENT` mode is in use.

The `default_storage_engine` and `storage_engine` system variables are not replicated, regardless of the logging mode; this is intended to facilitate replication between different storage engines.

The `read_only` system variable is not replicated. In addition, the enabling this variable has different effects with regard to temporary tables, table locking, and the `SET PASSWORD` statement in different MySQL versions.

The `max_heap_table_size` system variable is not replicated. Increasing the value of this variable on the master without doing so on the slave can lead eventually to `Table is full` errors on the slave when trying to execute `INSERT` statements on a `MEMORY` table on the master that is thus permitted to grow larger than its counterpart on the slave. For more information, see Section 17.4.1.20, “Replication and MEMORY Tables”.

In statement-based replication, session variables are not replicated properly when used in statements that update tables. For example, the following sequence of statements will not insert the same data on the master and the slave:

```
SET max_join_size=1000;
INSERT INTO mytable VALUES(@@max_join_size);
```

This does not apply to the common sequence:

```
SET time_zone=...;
INSERT INTO mytable VALUES(CONVERT_TZ(..., ..., @@time_zone));
```

Replication of session variables is not a problem when row-based replication is being used, in which case, session variables are always replicated safely. See Section 17.1.2, “Replication Formats”.

In MySQL 5.5, the following session variables are written to the binary log and honored by the replication slave when parsing the binary log, regardless of the logging format:

- `sql_mode`
- `foreign_key_checks`
- `unique_checks`
- `character_set_client`
- `collation_connection`
- `collation_database`

- `collation_server`
- `sql_auto_is_null`

Important

Even though session variables relating to character sets and collations are written to the binary log, replication between different character sets is not supported.

It is strongly recommended that you always use the same setting for the `lower_case_table_names` system variable on both master and slave. In particular, when a case-sensitive file system is used, setting this variable to 1 on the slave, but to a different value on the master, can cause two types of problems: Names of databases are not converted to lowercase; in addition, when using row-based replication names of tables are also not converted. Either of these problems can cause replication to fail. This is a known issue, which is fixed in MySQL 5.6.

17.4.1.39 Replication and Views

Views are always replicated to slaves. Views are filtered by their own name, not by the tables they refer to. This means that a view can be replicated to the slave even if the view contains a table that would normally be filtered out by `replication-ignore-table` rules. Care should therefore be taken to ensure that views do not replicate table data that would normally be filtered for security reasons.

Replication from a table to a samed-named view is supported using statement-based logging, but not when using row-based logging. In MySQL 5.5.31 and later, trying to do so when row-based logging is in effect causes an error. (Bug #11752707, Bug #43975)

17.4.2 Replication Compatibility Between MySQL Versions

MySQL supports replication from one release series to the next higher release series. For example, you can replicate from a master running MySQL 5.1 to a slave running MySQL 5.5, from a master running MySQL 5.5 to a slave running MySQL 5.6, and so on.

However, one may encounter difficulties when replicating from an older master to a newer slave if the master uses statements or relies on behavior no longer supported in the version of MySQL used on the slave. For example, in MySQL 5.5, `CREATE TABLE ... SELECT` statements are permitted to change tables other than the one being created, but are no longer allowed to do so in MySQL 5.6 (see Section 17.4.1.7, “Replication of CREATE TABLE ... SELECT Statements”).

The use of more than two MySQL Server versions is not supported in replication setups involving multiple masters, regardless of the number of master or slave MySQL servers. This restriction applies not only to release series, but to version numbers within the same release series as well. For example, if you are using a chained or circular replication setup, you cannot use MySQL 5.5.1, MySQL 5.5.2, and MySQL 5.5.4 concurrently, although you could use any two of these releases together.

Important

It is strongly recommended to use the most recent release available within a given MySQL release series because replication (and other) capabilities are continually being improved. It is also recommended to upgrade masters and slaves that use early releases of a release series of MySQL to GA (production) releases when the latter become available for that release series.

Replication from newer masters to older slaves may be possible, but is generally not supported. This is due to a number of factors:

- **Binary log format changes.** The binary log format can change between major releases. While we attempt to maintain backward compatibility, this is not always possible. For example, the binary log format implemented in MySQL 5.0 changed considerably from that used in previous versions, especially with regard to handling of character sets, `LOAD DATA INFILE`, and time zones. This

means that replication from a MySQL 5.0 (or later) master to a MySQL 4.1 (or earlier) slave is generally not supported.

This also has significant implications for upgrading replication servers; see Section 17.4.3, “Upgrading a Replication Setup”, for more information.

- **Use of row-based replication.** Row-based replication was implemented in MySQL 5.1.5, so you cannot replicate using row-based replication from any MySQL 5.5 or later master to a slave older than MySQL 5.1.5.

  For more information about row-based replication, see Section 17.1.2, “Replication Formats”.

- **SQL incompatibilities.** You cannot replicate from a newer master to an older slave using statement-based replication if the statements to be replicated use SQL features available on the master but not on the slave.

  However, if both the master and the slave support row-based replication, and there are no data definition statements to be replicated that depend on SQL features found on the master but not on the slave, you can use row-based replication to replicate the effects of data modification statements even if the DDL run on the master is not supported on the slave.

For more information on potential replication issues, see Section 17.4.1, “Replication Features and Issues”.

17.4.3 Upgrading a Replication Setup

When you upgrade servers that participate in a replication setup, the procedure for upgrading depends on the current server versions and the version to which you are upgrading. This section provides information about how upgrading affects replication. For general information about upgrading MySQL, see Section 2.11.1, “Upgrading MySQL”

When you upgrade a master to 5.5 from an earlier MySQL release series, you should first ensure that all the slaves of this master are using the same 5.5.x release. If this is not the case, you should first upgrade the slaves. To upgrade each slave, shut it down, upgrade it to the appropriate 5.5.x version, restart it, and restart replication. The 5.5 slave is able to read the old relay logs written prior to the upgrade and to execute the statements they contain. Relay logs created by the slave after the upgrade are in 5.5 format.

After the slaves have been upgraded, shut down the master, upgrade it to the same 5.5.x release as the slaves, and restart it. The 5.5 master is able to read the old binary logs written prior to the upgrade and to send them to the 5.5 slaves. The slaves recognize the old format and handle it properly. Binary logs created by the master subsequent to the upgrade are in 5.5 format. These too are recognized by the 5.5 slaves.

In other words, when upgrading to MySQL 5.5, the slaves must be MySQL 5.5 before you can upgrade the master to 5.5. Note that downgrading from 5.5 to older versions does not work so simply: You must ensure that any 5.5 binary log or relay log has been fully processed, so that you can remove it before proceeding with the downgrade.

Some upgrades may require that you drop and re-create database objects when you move from one MySQL series to the next. For example, collation changes might require that table indexes be rebuilt. Such operations, if necessary, are detailed at Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”. It is safest to perform these operations separately on the slaves and the master, and to disable replication of these operations from the master to the slave. To achieve this, use the following procedure:

1. Stop all the slaves and upgrade them. Restart them with the `--skip-slave-start` option so that they do not connect to the master. Perform any table repair or rebuilding operations needed to re-create database objects, such as use of `REPAIR TABLE` or `ALTER TABLE`, or dumping and reloading tables or triggers.

2. Disable the binary log on the master. To do this without restarting the master, execute a `SET sql_log_bin = 0` statement. Alternatively, stop the master and restart it without the `--log-bin` option. If you restart the master, you might also want to disallow client connections. For example, if all clients connect using TCP/IP, use the `--skip-networking` option when you restart the master.

3. With the binary log disabled, perform any table repair or rebuilding operations needed to re-create database objects. The binary log must be disabled during this step to prevent these operations from being logged and sent to the slaves later.

4. Re-enable the binary log on the master. If you set `sql_log_bin` to 0 earlier, execute a `SET sql_log_bin = 1` statement. If you restarted the master to disable the binary log, restart it with `--log-bin`, and without `--skip-networking` so that clients and slaves can connect.

5. Restart the slaves, this time without the `--skip-slave-start` option.

17.4.4 Troubleshooting Replication

If you have followed the instructions but your replication setup is not working, the first thing to do is *check the error log for messages*. Many users have lost time by not doing this soon enough after encountering problems.

If you cannot tell from the error log what the problem was, try the following techniques:

- Verify that the master has binary logging enabled by issuing a `SHOW MASTER STATUS` statement. If logging is enabled, `Position` is nonzero. If binary logging is not enabled, verify that you are running the master with the `--log-bin` option.

- Verify that the master and slave both were started with the `--server-id` option and that the ID value is unique on each server.

- Verify that the slave is running. Use `SHOW SLAVE STATUS` to check whether the `Slave_IO_Running` and `Slave_SQL_Running` values are both `Yes`. If not, verify the options that were used when starting the slave server. For example, `--skip-slave-start` prevents the slave threads from starting until you issue a `START SLAVE` statement.

- If the slave is running, check whether it established a connection to the master. Use `SHOW PROCESSLIST`, find the I/O and SQL threads and check their `State` column to see what they display. See Section 17.2.1, “Replication Implementation Details”. If the I/O thread state says `Connecting to master`, check the following:

  - Verify the privileges for the user being used for replication on the master.

  - Check that the host name of the master is correct and that you are using the correct port to connect to the master. The port used for replication is the same as used for client network communication (the default is `3306`). For the host name, ensure that the name resolves to the correct IP address.

  - Check that networking has not been disabled on the master or slave. Look for the `skip-networking` option in the configuration file. If present, comment it out or remove it.

  - If the master has a firewall or IP filtering configuration, ensure that the network port being used for MySQL is not being filtered.

  - Check that you can reach the master by using `ping` or `traceroute`/`tracert` to reach the host.

- If the slave was running previously but has stopped, the reason usually is that some statement that succeeded on the master failed on the slave. This should never happen if you have taken a proper snapshot of the master, and never modified the data on the slave outside of the slave thread. If the slave stops unexpectedly, it is a bug or you have encountered one of the known replication limitations described in Section 17.4.1, “Replication Features and Issues”. If it is a bug,

see Section 17.4.5, “How to Report Replication Bugs or Problems”, for instructions on how to report it.

- If a statement that succeeded on the master refuses to run on the slave, try the following procedure if it is not feasible to do a full database resynchronization by deleting the slave's databases and copying a new snapshot from the master:

  1. Determine whether the affected table on the slave is different from the master table. Try to understand how this happened. Then make the slave's table identical to the master's and run `START SLAVE`.

  2. If the preceding step does not work or does not apply, try to understand whether it would be safe to make the update manually (if needed) and then ignore the next statement from the master.

  3. If you decide that the slave can skip the next statement from the master, issue the following statements:

     ```
     mysql> SET GLOBAL sql_slave_skip_counter = N;
     mysql> START SLAVE;
     ```

     The value of *`N`* should be 1 if the next statement from the master does not use `AUTO_INCREMENT` or `LAST_INSERT_ID()`. Otherwise, the value should be 2. The reason for using a value of 2 for statements that use `AUTO_INCREMENT` or `LAST_INSERT_ID()` is that they take two events in the binary log of the master.

     See also Section 13.4.2.4, “SET GLOBAL sql_slave_skip_counter Syntax”.

  4. If you are sure that the slave started out perfectly synchronized with the master, and that no one has updated the tables involved outside of the slave thread, then presumably the discrepancy is the result of a bug. If you are running the most recent version of MySQL, please report the problem. If you are running an older version, try upgrading to the latest production release to determine whether the problem persists.

17.4.5 How to Report Replication Bugs or Problems

When you have determined that there is no user error involved, and replication still either does not work at all or is unstable, it is time to send us a bug report. We need to obtain as much information as possible from you to be able to track down the bug. Please spend some time and effort in preparing a good bug report.

If you have a repeatable test case that demonstrates the bug, please enter it into our bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”. If you have a “phantom” problem (one that you cannot duplicate at will), use the following procedure:

1. Verify that no user error is involved. For example, if you update the slave outside of the slave thread, the data goes out of synchrony, and you can have unique key violations on updates. In this case, the slave thread stops and waits for you to clean up the tables manually to bring them into synchrony. *This is not a replication problem. It is a problem of outside interference causing replication to fail.*

2. Run the slave with the `--log-slave-updates` and `--log-bin` options. These options cause the slave to log the updates that it receives from the master into its own binary logs.

3. Save all evidence before resetting the replication state. If we have no information or only sketchy information, it becomes difficult or impossible for us to track down the problem. The evidence you should collect is:

   - All binary log files from the master

   - All binary log files from the slave

- The output of `SHOW MASTER STATUS` from the master at the time you discovered the problem
- The output of `SHOW SLAVE STATUS` from the slave at the time you discovered the problem
- Error logs from the master and the slave

4. Use `mysqlbinlog` to examine the binary logs. The following should be helpful to find the problem statement. *`log_file`* and *`log_pos`* are the `Master_Log_File` and `Read_Master_Log_Pos` values from `SHOW SLAVE STATUS`.

```
shell> mysqlbinlog --start-position=log_pos log_file | head
```

After you have collected the evidence for the problem, try to isolate it as a separate test case first. Then enter the problem with as much information as possible into our bugs database using the instructions at Section 1.6, “How to Report Bugs or Problems”.

Chapter 18 MySQL NDB Cluster 7.2

Table of Contents

18.1 NDB Cluster Overview 2012
18.1.1 NDB Cluster Core Concepts 2014
18.1.2 NDB Cluster Nodes, Node Groups, Replicas, and Partitions 2016
18.1.3 NDB Cluster Hardware, Software, and Networking Requirements 2019
18.1.4 What is New in MySQL NDB Cluster 7.2 2020
18.1.5 MySQL Server Using InnoDB Compared with NDB Cluster 2023
18.1.6 Known Limitations of NDB Cluster 2026
18.2 NDB Cluster Installation 2038
18.2.1 Installing NDB Cluster on Linux 2040
18.2.2 Installing NDB Cluster on Windows 2046
18.2.3 Initial Configuration of NDB Cluster 2055
18.2.4 Initial Startup of NDB Cluster 2057
18.2.5 NDB Cluster Example with Tables and Data 2058
18.2.6 Safe Shutdown and Restart of NDB Cluster 2061
18.2.7 Upgrading and Downgrading NDB Cluster 2062
18.3 Configuration of NDB Cluster 2064
18.3.1 Quick Test Setup of NDB Cluster 2064
18.3.2 Overview of NDB Cluster Configuration Parameters, Options, and Variables 2066
18.3.3 NDB Cluster Configuration Files 2108
18.3.4 Using High-Speed Interconnects with NDB Cluster 2232
18.4 NDB Cluster Programs 2232
18.4.1 `ndbd` — The NDB Cluster Data Node Daemon 2232
18.4.2 `ndbinfo_select_all` — Select From ndbinfo Tables 2239
18.4.3 `ndbmtd` — The NDB Cluster Data Node Daemon (Multi-Threaded) 2240
18.4.4 `ndb_mgmd` — The NDB Cluster Management Server Daemon 2241
18.4.5 `ndb_mgm` — The NDB Cluster Management Client 2249
18.4.6 `ndb_blob_tool` — Check and Repair BLOB and TEXT columns of NDB Cluster Tables 2250
18.4.7 `ndb_config` — Extract NDB Cluster Configuration Information 2253
18.4.8 `ndb_cpcd` — Automate Testing for NDB Development 2260
18.4.9 `ndb_delete_all` — Delete All Rows from an NDB Table 2260
18.4.10 `ndb_desc` — Describe NDB Tables 2261
18.4.11 `ndb_drop_index` — Drop Index from an NDB Table 2265
18.4.12 `ndb_drop_table` — Drop an NDB Table 2266
18.4.13 `ndb_error_reporter` — NDB Error-Reporting Utility 2267
18.4.14 `ndb_index_stat` — NDB Index Statistics Utility 2268
18.4.15 `ndb_move_data` — NDB Data Copy Utility 2273
18.4.16 `ndb_print_backup_file` — Print NDB Backup File Contents 2276
18.4.17 `ndb_print_file` — Print NDB Disk Data File Contents 2276
18.4.18 `ndb_print_schema_file` — Print NDB Schema File Contents 2277
18.4.19 `ndb_print_sys_file` — Print NDB System File Contents 2277
18.4.20 `ndb_redo_log_reader` — Check and Print Content of Cluster Redo Log 2277
18.4.21 `ndb_restore` — Restore an NDB Cluster Backup 2280
18.4.22 `ndb_select_all` — Print Rows from an NDB Table 2299
18.4.23 `ndb_select_count` — Print Row Counts for NDB Tables 2302
18.4.24 `ndb_show_tables` — Display List of NDB Tables 2303
18.4.25 `ndb_size.pl` — NDBCLUSTER Size Requirement Estimator 2304
18.4.26 `ndb_waiter` — Wait for NDB Cluster to Reach a Given Status 2307
18.4.27 Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs 2309
18.5 Management of NDB Cluster 2313
18.5.1 Summary of NDB Cluster Start Phases 2313

18.5.2 Commands in the NDB Cluster Management Client 2315
18.5.3 Online Backup of NDB Cluster 2319
18.5.4 MySQL Server Usage for NDB Cluster 2324
18.5.5 Performing a Rolling Restart of an NDB Cluster 2325
18.5.6 Event Reports Generated in NDB Cluster 2327
18.5.7 NDB Cluster Log Messages 2337
18.5.8 NDB Cluster Single User Mode 2351
18.5.9 Quick Reference: NDB Cluster SQL Statements 2352
18.5.10 ndbinfo: The NDB Cluster Information Database 2355
18.5.11 NDB Cluster Security Issues 2376
18.5.12 NDB Cluster Disk Data Tables 2383
18.5.13 Adding NDB Cluster Data Nodes Online 2390
18.5.14 Distributed MySQL Privileges for NDB Cluster 2401
18.5.15 NDB API Statistics Counters and Variables 2404
18.6 NDB Cluster Replication 2416
18.6.1 NDB Cluster Replication: Abbreviations and Symbols 2417
18.6.2 General Requirements for NDB Cluster Replication 2417
18.6.3 Known Issues in NDB Cluster Replication 2419
18.6.4 NDB Cluster Replication Schema and Tables 2425
18.6.5 Preparing the NDB Cluster for Replication 2428
18.6.6 Starting NDB Cluster Replication (Single Replication Channel) 2429
18.6.7 Using Two Replication Channels for NDB Cluster Replication 2431
18.6.8 Implementing Failover with NDB Cluster Replication 2432
18.6.9 NDB Cluster Backups With NDB Cluster Replication 2434
18.6.10 NDB Cluster Replication: Multi-Master and Circular Replication 2440
18.6.11 NDB Cluster Replication Conflict Resolution 2444
18.7 NDB Cluster Release Notes 2453

MySQL *NDB Cluster* is a high-availability, high-redundancy version of MySQL adapted for the distributed computing environment. Recent releases of NDB Cluster use version 7 of the `NDBCLUSTER` storage engine (also known as `NDB`) to enable running several computers with MySQL servers and other software in a cluster. NDB Cluster 7.5, now available as a General Availability (GA) release beginning with version 7.5.4, incorporates version 7.5 of the `NDB` storage engine. NDB Cluster 7.6, currently under development and available for evaluation and testing as a Developer Preview release, uses version 7.6 of `NDB`. Previous GA releases still available for production, NDB Cluster 7.3 and NDB Cluster 7.4, incorporate `NDB` versions 7.3 and 7.4, respectively.

Support for the `NDBCLUSTER` storage engine is not included in standard MySQL Server 5.5 binaries built by Oracle. Instead, users of NDB Cluster binaries from Oracle should upgrade to the most recent binary release of NDB Cluster for supported platforms—these include RPMs that should work with most Linux distributions. NDB Cluster users who build from source should use the sources provided for NDB Cluster. (Locations where the sources can be obtained are listed later in this section.)

This chapter contains information about NDB Cluster 7.2 releases through 5.5.58-ndb-7.2.32. Currently, NDB Cluster 7.5 is available as a General Availability release, and recommended for new deployments. The NDB Cluster 7.4 and NDB Cluster 7.3 release series are previous GA releases still supported in production. NDB Cluster 7.2 is a previous GA release series which is still supported, although we recommend that new deployments for production use NDB Cluster 7.5 (see MySQL NDB Cluster 7.5 and NDB Cluster 7.6). For more information about NDB Cluster 7.4 and NDB Cluster 7.3, see MySQL NDB Cluster 7.3 and NDB Cluster 7.4. NDB Cluster 7.6, currently under development, is now available for evaluation and testing as a Developer Preview release; for information about NDB Cluster 7.6, see What is New in NDB Cluster 7.6.

Release notes for the changes in each release of NDB Cluster are located at NDB Cluster 7.2 Release Notes.

Supported Platforms. NDB Cluster is currently available and supported on a number of platforms. For exact levels of support available for on specific combinations of operating system versions,

operating system distributions, and hardware platforms, please refer to http://www.mysql.com/support/supportedplatforms/cluster.html.

Availability. NDB Cluster binary and source packages are available for supported platforms from http://dev.mysql.com/downloads/cluster/.

NDB Cluster release numbers. NDB Cluster follows a somewhat different release pattern from the mainline MySQL Server 5.5 series of releases. In this *Manual* and other MySQL documentation, we identify these and later NDB Cluster releases employing a version number that begins with "NDB". This version number is that of the `NDBCLUSTER` storage engine used in the release, and not of the MySQL server version on which the NDB Cluster release is based.

Version strings used in NDB Cluster software. The version string displayed by NDB Cluster programs uses this format:

```
mysql-mysql_server_version-ndb-ndb_engine_version
```

`mysql_server_version` represents the version of the MySQL Server on which the NDB Cluster release is based. For all NDB Cluster 6.x and 7.x releases, this is "5.1". *`ndb_engine_version`* is the version of the `NDB` storage engine used by this release of the NDB Cluster software. You can see this format used in the `mysql` client, as shown here:

```
shell> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 2
Server version: 5.5.58-ndb-7.2.32 Source distribution

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SELECT VERSION()\G
*************************** 1. row ***************************
VERSION(): 5.5.58-ndb-7.2.32
1 row in set (0.00 sec)
```

This version string is also displayed in the output of the `SHOW` command in the `ndb_mgm` client:

```
ndb_mgm> SHOW
Connected to Management Server at: localhost:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @10.0.10.6  (5.5.58-ndb-7.2.32, Nodegroup: 0, *)
id=2    @10.0.10.8  (5.5.58-ndb-7.2.32, Nodegroup: 0)

[ndb_mgmd(MGM)] 1 node(s)
id=3    @10.0.10.2  (5.5.58-ndb-7.2.32)

[mysqld(API)]   2 node(s)
id=4    @10.0.10.10  (5.5.58-ndb-7.2.32)
id=5 (not connected, accepting connect from any host)
```

The version string identifies the mainline MySQL version from which the NDB Cluster release was branched and the version of the `NDBCLUSTER` storage engine used. For example, the full version string for NDB 7.2.4 (the first NDB Cluster production release based on MySQL Server 5.5) is `mysql-5.5.19-ndb-7.2.4`. From this we can determine the following:

- Since the portion of the version string preceding `-ndb-` is the base MySQL Server version, this means that NDB 7.2.4 derives from the MySQL 5.5.19, and contains all feature enhancements and bugfixes from MySQL 5.5 up to and including MySQL 5.5.19.
- Since the portion of the version string following `-ndb-` represents the version number of the `NDB` (or `NDBCLUSTER`) storage engine, NDB 7.2.4 uses version 7.2.4 of the `NDBCLUSTER` storage engine.

New NDB Cluster releases are numbered according to updates in the NDB storage engine, and do not necessarily correspond in a one-to-one fashion with mainline MySQL Server releases. For example, NDB 7.2.4 (as previously noted) is based on MySQL 5.5.19, while NDB 7.2.0 was based on MySQL 5.1.51 (version string: `mysql-5.1.51-ndb-7.2.0`).

Compatibility with standard MySQL 5.5 releases. While many standard MySQL schemas and applications can work using NDB Cluster, it is also true that unmodified applications and database schemas may be slightly incompatible or have suboptimal performance when run using NDB Cluster (see Section 18.1.6, "Known Limitations of NDB Cluster"). Most of these issues can be overcome, but this also means that you are very unlikely to be able to switch an existing application datastore—that currently uses, for example, MyISAM or InnoDB—to use the NDB storage engine without allowing for the possibility of changes in schemas, queries, and applications. In addition, the MySQL Server and NDB Cluster codebases diverge considerably, so that the standard `mysqld` cannot function as a drop-in replacement for the version of `mysqld` supplied with NDB Cluster.

NDB Cluster development source trees. NDB Cluster development trees can also be accessed from https://github.com/mysql/mysql-server.

The NDB Cluster development sources maintained at https://github.com/mysql/mysql-server are licensed under the GPL. For information about obtaining MySQL sources using Git and building them yourself, see Section 2.9.3, "Installing MySQL Using a Development Source Tree".

Note

As with MySQL Server 5.5, NDB Cluster 7.2 is built using CMake.

Currently, NDB Cluster 7.3 and NDB Cluster 7.4 releases are Generally Available (GA). We recommend that new deployments use NDB Cluster 7.4. NDB Cluster 7.1 and earlier versions are no longer in active development. For an overview of major features added in NDB Cluster 7.4, see What is New in NDB Cluster 7.4. For similar information about NDB Cluster 7.3, see What is New in NDB Cluster 7.3. For an overview of major features added in past NDB Cluster releases, see the *MySQL 5.1 Reference Manual*. NDB Cluster 7.5 is also available as a Developer Preview for testing of new features; for more information, see MySQL NDB Cluster 7.5 and NDB Cluster 7.6.

This chapter represents a work in progress, and its contents are subject to revision as NDB Cluster continues to evolve. Additional information regarding NDB Cluster can be found on the MySQL Web site at http://www.mysql.com/products/cluster/.

Additional Resources. More information about NDB Cluster can be found in the following places:

- For answers to some commonly asked questions about NDB Cluster, see Section A.10, "MySQL FAQ: MySQL 5.5 and NDB Cluster".
- The NDB Cluster mailing list: http://lists.mysql.com/cluster.
- The NDB Cluster Forum: http://forums.mysql.com/list.php?25.
- Many NDB Cluster users and developers blog about their experiences with NDB Cluster, and make feeds of these available through PlanetMySQL.

18.1 NDB Cluster Overview

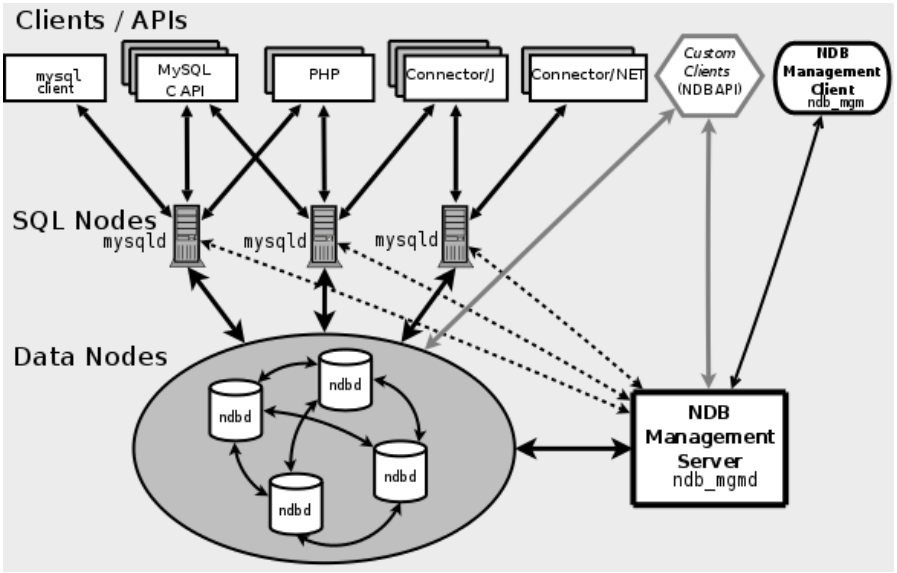
NDB Cluster is a technology that enables clustering of in-memory databases in a shared-nothing system. The shared-nothing architecture enables the system to work with very inexpensive hardware, and with a minimum of specific requirements for hardware or software.

NDB Cluster is designed not to have any single point of failure. In a shared-nothing system, each component is expected to have its own memory and disk, and the use of shared storage mechanisms such as network shares, network file systems, and SANs is not recommended or supported.

NDB Cluster integrates the standard MySQL server with an in-memory clustered storage engine called NDB (which stands for "*N*etwork *D*ata*B*ase"). In our documentation, the term NDB refers to the part of the setup that is specific to the storage engine, whereas "MySQL NDB Cluster" refers to the combination of one or more MySQL servers with the NDB storage engine.

An NDB Cluster consists of a set of computers, known as *hosts*, each running one or more processes. These processes, known as *nodes*, may include MySQL servers (for access to NDB data), data nodes (for storage of the data), one or more management servers, and possibly other specialized data access programs. The relationship of these components in an NDB Cluster is shown here:

Figure 18.1 NDB Cluster Components



All these programs work together to form an NDB Cluster (see Section 18.4, "NDB Cluster Programs". When data is stored by the NDB storage engine, the tables (and table data) are stored in the data nodes. Such tables are directly accessible from all other MySQL servers (SQL nodes) in the cluster. Thus, in a payroll application storing data in a cluster, if one application updates the salary of an employee, all other MySQL servers that query this data can see this change immediately.

Although an NDB Cluster SQL node uses the `mysqld` server daemon, it differs in a number of critical respects from the `mysqld` binary supplied with the MySQL 5.5 distributions, and the two versions of `mysqld` are not interchangeable.

In addition, a MySQL server that is not connected to an NDB Cluster cannot use the NDB storage engine and cannot access any NDB Cluster data.

The data stored in the data nodes for NDB Cluster can be mirrored; the cluster can handle failures of individual data nodes with no other impact than that a small number of transactions are aborted due to losing the transaction state. Because transactional applications are expected to handle transaction failure, this should not be a source of problems.

Individual nodes can be stopped and restarted, and can then rejoin the system (cluster). Rolling restarts (in which all nodes are restarted in turn) are used in making configuration changes and software upgrades (see Section 18.5.5, "Performing a Rolling Restart of an NDB Cluster"). Rolling restarts are also used as part of the process of adding new data nodes online (see Section 18.5.13, "Adding NDB Cluster Data Nodes Online"). For more information about data nodes, how they are organized in an NDB Cluster, and how they handle and store NDB Cluster data, see Section 18.1.2, "NDB Cluster Nodes, Node Groups, Replicas, and Partitions".

Backing up and restoring NDB Cluster databases can be done using the NDB-native functionality found in the NDB Cluster management client and the `ndb_restore` program included in the NDB Cluster distribution. For more information, see Section 18.5.3, "Online Backup of NDB Cluster", and Section 18.4.21, "`ndb_restore` — Restore an NDB Cluster Backup". You can also use the

standard MySQL functionality provided for this purpose in `mysqldump` and the MySQL server. See Section 4.5.4, “`mysqldump` — A Database Backup Program”, for more information.

NDB Cluster nodes can employ different transport mechanisms for inter-node communications; TCP/IP over standard 100 Mbps or faster Ethernet hardware is used in most real-world deployments.

18.1.1 NDB Cluster Core Concepts

`NDBCLUSTER` (also known as `NDB`) is an in-memory storage engine offering high-availability and data-persistence features.

The `NDBCLUSTER` storage engine can be configured with a range of failover and load-balancing options, but it is easiest to start with the storage engine at the cluster level. NDB Cluster's `NDB` storage engine contains a complete set of data, dependent only on other data within the cluster itself.

The “Cluster” portion of NDB Cluster is configured independently of the MySQL servers. In an NDB Cluster, each part of the cluster is considered to be a *node*.

Note

In many contexts, the term “node” is used to indicate a computer, but when discussing NDB Cluster it means a *process*. It is possible to run multiple nodes on a single computer; for a computer on which one or more cluster nodes are being run we use the term *cluster host*.

There are three types of cluster nodes, and in a minimal NDB Cluster configuration, there will be at least three nodes, one of each of these types:

- *Management node*: The role of this type of node is to manage the other nodes within the NDB Cluster, performing such functions as providing configuration data, starting and stopping nodes, and running backups. Because this node type manages the configuration of the other nodes, a node of this type should be started first, before any other node. An MGM node is started with the command `ndb_mgmd`.

- *Data node*: This type of node stores cluster data. There are as many data nodes as there are replicas, times the number of fragments (see Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”). For example, with two replicas, each having two fragments, you need four data nodes. One replica is sufficient for data storage, but provides no redundancy; therefore, it is recommended to have 2 (or more) replicas to provide redundancy, and thus high availability. A data node is started with the command `ndbd` (see Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”) or `ndbmtd` (see Section 18.4.3, “`ndbmtd` — The NDB Cluster Data Node Daemon (Multi-Threaded)”).

  NDB Cluster tables are normally stored completely in memory rather than on disk (this is why we refer to NDB Cluster as an *in-memory* database). However, some NDB Cluster data can be stored on disk; see Section 18.5.12, “NDB Cluster Disk Data Tables”, for more information.

- *SQL node*: This is a node that accesses the cluster data. In the case of NDB Cluster, an SQL node is a traditional MySQL server that uses the `NDBCLUSTER` storage engine. An SQL node is a `mysqld` process started with the `--ndbcluster` and `--ndb-connectstring` options, which are explained elsewhere in this chapter, possibly with additional MySQL server options as well.

  An SQL node is actually just a specialized type of *API node*, which designates any application which accesses NDB Cluster data. Another example of an API node is the `ndb_restore` utility that is used to restore a cluster backup. It is possible to write such applications using the NDB API. For basic information about the NDB API, see Getting Started with the NDB API.

Important

It is not realistic to expect to employ a three-node setup in a production environment. Such a configuration provides no redundancy; to benefit from NDB

Cluster's high-availability features, you must use multiple data and SQL nodes. The use of multiple management nodes is also highly recommended.

For a brief introduction to the relationships between nodes, node groups, replicas, and partitions in NDB Cluster, see Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”.

Configuration of a cluster involves configuring each individual node in the cluster and setting up individual communication links between nodes. NDB Cluster is currently designed with the intention that data nodes are homogeneous in terms of processor power, memory space, and bandwidth. In addition, to provide a single point of configuration, all configuration data for the cluster as a whole is located in one configuration file.

The management server manages the cluster configuration file and the cluster log. Each node in the cluster retrieves the configuration data from the management server, and so requires a way to determine where the management server resides. When interesting events occur in the data nodes, the nodes transfer information about these events to the management server, which then writes the information to the cluster log.

In addition, there can be any number of cluster client processes or applications. These include standard MySQL clients, `NDB`-specific API programs, and management clients. These are described in the next few paragraphs.

Standard MySQL clients. NDB Cluster can be used with existing MySQL applications written in PHP, Perl, C, C++, Java, Python, Ruby, and so on. Such client applications send SQL statements to and receive responses from MySQL servers acting as NDB Cluster SQL nodes in much the same way that they interact with standalone MySQL servers.

MySQL clients using an NDB Cluster as a data source can be modified to take advantage of the ability to connect with multiple MySQL servers to achieve load balancing and failover. For example, Java clients using Connector/J 5.0.6 and later can use `jdbc:mysql:loadbalance://` URLs (improved in Connector/J 5.1.7) to achieve load balancing transparently; for more information about using Connector/J with NDB Cluster, see Using Connector/J with NDB Cluster.

NDB client programs. Client programs can be written that access NDB Cluster data directly from the `NDBCLUSTER` storage engine, bypassing any MySQL Servers that may be connected to the cluster, using the *NDB API*, a high-level C++ API. Such applications may be useful for specialized purposes where an SQL interface to the data is not needed. For more information, see The NDB API.

`NDB`-specific Java applications can also be written for NDB Cluster using the *NDB Cluster Connector for Java*. This NDB Cluster Connector includes *ClusterJ*, a high-level database API similar to object-relational mapping persistence frameworks such as Hibernate and JPA that connect directly to `NDBCLUSTER`, and so does not require access to a MySQL Server. Support is also provided in NDB Cluster for *ClusterJPA*, an OpenJPA implementation for NDB Cluster that leverages the strengths of ClusterJ and JDBC; ID lookups and other fast operations are performed using ClusterJ (bypassing the MySQL Server), while more complex queries that can benefit from MySQL's query optimizer are sent through the MySQL Server, using JDBC. See Java and NDB Cluster, and The ClusterJ API and Data Object Model, for more information.

The Memcache API for NDB Cluster, implemented as the loadable *ndbmemcache* storage engine for memcached version 1.6 and later, is available beginning with NDB 7.2.2. This API can be used to provide a persistent NDB Cluster data store, accessed using the memcache protocol.

The standard `memcached` caching engine is included in the NDB Cluster 7.2 distribution (7.2.2 and later). Each `memcached` server has direct access to data stored in NDB Cluster, but is also able to cache data locally and to serve (some) requests from this local cache.

For more information, see ndbmemcache—Memcache API for NDB Cluster.

Management clients. These clients connect to the management server and provide commands for starting and stopping nodes gracefully, starting and stopping message tracing (debug versions

only), showing node versions and status, starting and stopping backups, and so on. An example of this type of program is the `ndb_mgm` management client supplied with NDB Cluster (see Section 18.4.5, “`ndb_mgm` — The NDB Cluster Management Client”). Such applications can be written using the *MGM API*, a C-language API that communicates directly with one or more NDB Cluster management servers. For more information, see The MGM API.

Oracle also makes available MySQL Cluster Manager, which provides an advanced command-line interface simplifying many complex NDB Cluster management tasks, such restarting an NDB Cluster with a large number of nodes. The MySQL Cluster Manager client also supports commands for getting and setting the values of most node configuration parameters as well as `mysqld` server options and variables relating to NDB Cluster. See MySQL™ Cluster Manager 1.3.6 User Manual, for more information.

Event logs. NDB Cluster logs events by category (startup, shutdown, errors, checkpoints, and so on), priority, and severity. A complete listing of all reportable events may be found in Section 18.5.6, “Event Reports Generated in NDB Cluster”. Event logs are of the two types listed here:

- *Cluster log*: Keeps a record of all desired reportable events for the cluster as a whole.
- *Node log*: A separate log which is also kept for each individual node.

Note

Under normal circumstances, it is necessary and sufficient to keep and examine only the cluster log. The node logs need be consulted only for application development and debugging purposes.

Checkpoint. Generally speaking, when data is saved to disk, it is said that a *checkpoint* has been reached. More specific to NDB Cluster, a checkpoint is a point in time where all committed transactions are stored on disk. With regard to the `NDB` storage engine, there are two types of checkpoints which work together to ensure that a consistent view of the cluster's data is maintained. These are shown in the following list:

- *Local Checkpoint (LCP)*: This is a checkpoint that is specific to a single node; however, LCPs take place for all nodes in the cluster more or less concurrently. An LCP involves saving all of a node's data to disk, and so usually occurs every few minutes. The precise interval varies, and depends upon the amount of data stored by the node, the level of cluster activity, and other factors.
- *Global Checkpoint (GCP)*: A GCP occurs every few seconds, when transactions for all nodes are synchronized and the redo-log is flushed to disk.

For more information about the files and directories created by local checkpoints and global checkpoints, see NDB Cluster Data Node File System Directory Files.

18.1.2 NDB Cluster Nodes, Node Groups, Replicas, and Partitions

This section discusses the manner in which NDB Cluster divides and duplicates data for storage.

A number of concepts central to an understanding of this topic are discussed in the next few paragraphs.

Data node. An `ndbd` or `ndbmtd` process, which stores one or more *replicas*—that is, copies of the *partitions* (discussed later in this section) assigned to the node group of which the node is a member.

Each data node should be located on a separate computer. While it is also possible to host multiple data node processes on a single computer, such a configuration is not usually recommended.

It is common for the terms “node” and “data node” to be used interchangeably when referring to an `ndbd` or `ndbmtd` process; where mentioned, management nodes (`ndb_mgmd` processes) and SQL nodes (`mysqld` processes) are specified as such in this discussion.

Node group. A node group consists of one or more nodes, and stores partitions, or sets of *replicas* (see next item).

The number of node groups in an NDB Cluster is not directly configurable; it is a function of the number of data nodes and of the number of replicas (`NoOfReplicas` configuration parameter), as shown here:

```
[# of node groups] = [# of data nodes] / NoOfReplicas
```

Thus, an NDB Cluster with 4 data nodes has 4 node groups if `NoOfReplicas` is set to 1 in the `config.ini` file, 2 node groups if `NoOfReplicas` is set to 2, and 1 node group if `NoOfReplicas` is set to 4. Replicas are discussed later in this section; for more information about `NoOfReplicas`, see Section 18.3.3.6, “Defining NDB Cluster Data Nodes”.

Note

All node groups in an NDB Cluster must have the same number of data nodes.

You can add new node groups (and thus new data nodes) online, to a running NDB Cluster; see Section 18.5.13, “Adding NDB Cluster Data Nodes Online”, for more information.

Partition. This is a portion of the data stored by the cluster. Each node is responsible for keeping at least one copy of any partitions assigned to it (that is, at least one replica) available to the cluster.

The number of partitions used by default by NDB Cluster depends on the number of data nodes and the number of LDM threads in use by the data nodes, as shown here:

```
[# of partitions] = [# of data nodes] * [# of LDM threads]
```

When using data nodes running `ndbmtd`, the number of LDM threads is controlled by the setting for `MaxNoOfExecutionThreads`. When using `ndbd` there is a single LDM thread, which means that there are as many cluster partitions as nodes participating in the cluster. This is also the case when using `ndbmtd` with `MaxNoOfExecutionThreads` set to 3 or less. (You should be aware that the number of LDM threads increases with the value of this parameter, but not in a strictly linear fashion, and that there are additional constraints on setting it; see the description of `MaxNoOfExecutionThreads` for more information.)

NDB and user-defined partitioning. NDB Cluster normally partitions `NDBCLUSTER` tables automatically. However, it is also possible to employ user-defined partitioning with `NDBCLUSTER` tables. This is subject to the following limitations:

1. Only the `KEY` and `LINEAR KEY` partitioning schemes are supported in production with `NDB` tables.

2. The maximum number of partitions that may be defined explicitly for any `NDB` table is `8 * MaxNoOfExecutionThreads * [number of node groups]`, the number of node groups in an NDB Cluster being determined as discussed previously in this section. When using `ndbd` for data node processes, setting `MaxNoOfExecutionThreads` has no effect; in such a case, it can be treated as though it were equal to 1 for purposes of performing this calculation.

   See Section 18.4.3, “`ndbmtd` — The NDB Cluster Data Node Daemon (Multi-Threaded)”, for more information.

For more information relating to NDB Cluster and user-defined partitioning, see Section 18.1.6, “Known Limitations of NDB Cluster”, and Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”.

Replica. This is a copy of a cluster partition. Each node in a node group stores a replica. Also sometimes known as a *partition replica*. The number of replicas is equal to the number of nodes per node group.

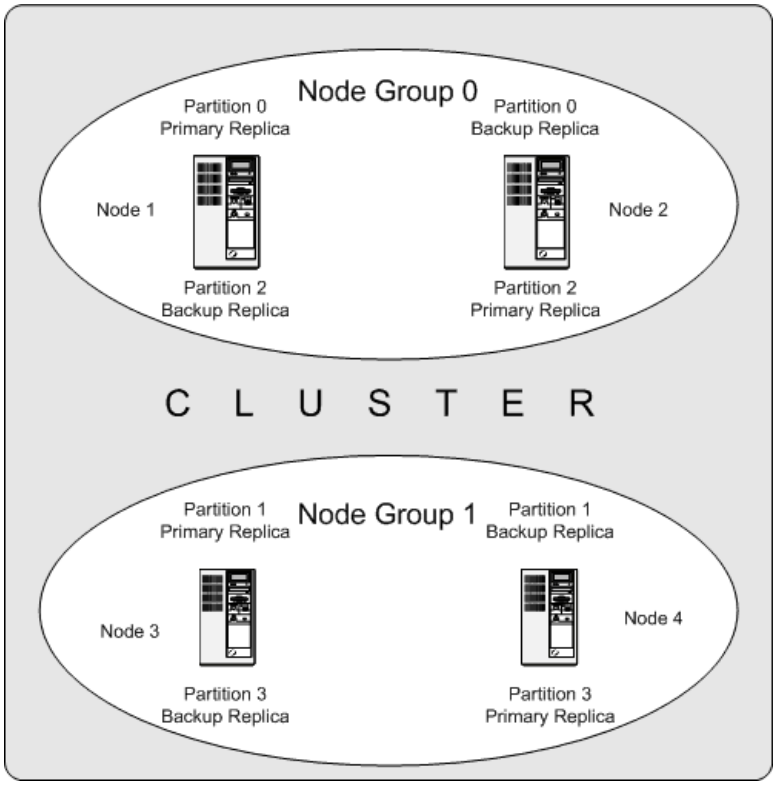
A replica belongs entirely to a single node; a node can (and usually does) store several replicas.

The following diagram illustrates an NDB Cluster with four data nodes running ndbd, arranged in two node groups of two nodes each; nodes 1 and 2 belong to node group 0, and nodes 3 and 4 belong to node group 1.

Note

Only data nodes are shown here; although a working NDB Cluster requires an ndb_mgmd process for cluster management and at least one SQL node to access the data stored by the cluster, these have been omitted from the figure for clarity.

Figure 18.2 NDB Cluster with Two Node Groups

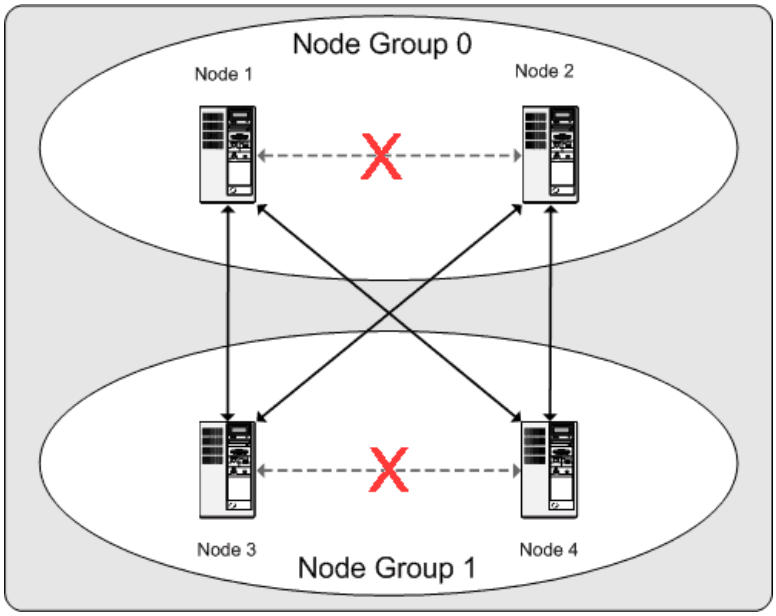


The data stored by the cluster is divided into four partitions, numbered 0, 1, 2, and 3. Each partition is stored—in multiple copies—on the same node group. Partitions are stored on alternate node groups as follows:

- Partition 0 is stored on node group 0; a *primary replica* (primary copy) is stored on node 1, and a *backup replica* (backup copy of the partition) is stored on node 2.
- Partition 1 is stored on the other node group (node group 1); this partition's primary replica is on node 3, and its backup replica is on node 4.
- Partition 2 is stored on node group 0. However, the placing of its two replicas is reversed from that of Partition 0; for Partition 2, the primary replica is stored on node 2, and the backup on node 1.
- Partition 3 is stored on node group 1, and the placement of its two replicas are reversed from those of partition 1. That is, its primary replica is located on node 4, with the backup on node 3.

What this means regarding the continued operation of an NDB Cluster is this: so long as each node group participating in the cluster has at least one node operating, the cluster has a complete copy of all data and remains viable. This is illustrated in the next diagram.

Figure 18.3 Nodes Required for a 2x2 NDB Cluster



In this example, where the cluster consists of two node groups of two data nodes, each running an instance of ndbd, any combination of at least one node in node group 0 and at least one node in node group 1 is sufficient to keep the cluster “alive” (indicated by arrows in the diagram). However, if *both* nodes from *either* node group fail, the remaining two nodes are not sufficient (shown by the arrows marked out with an **X**); in either case, the cluster has lost an entire partition and so can no longer provide access to a complete set of all NDB Cluster data.

18.1.3 NDB Cluster Hardware, Software, and Networking Requirements

One of the strengths of NDB Cluster is that it can be run on commodity hardware and has no unusual requirements in this regard, other than for large amounts of RAM, due to the fact that all live data storage is done in memory. (It is possible to reduce this requirement using Disk Data tables—see Section 18.5.12, “NDB Cluster Disk Data Tables”, for more information about these.) Naturally, multiple and faster CPUs can enhance performance. Memory requirements for other NDB Cluster processes are relatively small.

The software requirements for NDB Cluster are also modest. Host operating systems do not require any unusual modules, services, applications, or configuration to support NDB Cluster. For supported operating systems, a standard installation should be sufficient. The MySQL software requirements are simple: all that is needed is a production release of NDB Cluster. It is not strictly necessary to compile MySQL yourself merely to be able to use NDB Cluster. We assume that you are using the binaries appropriate to your platform, available from the NDB Cluster software downloads page at http://dev.mysql.com/downloads/cluster/.

For communication between nodes, NDB Cluster supports TCP/IP networking in any standard topology, and the minimum expected for each host is a standard 100 Mbps Ethernet card, plus a switch, hub, or router to provide network connectivity for the cluster as a whole. We strongly recommend that an NDB Cluster be run on its own subnet which is not shared with machines not forming part of the cluster for the following reasons:

- **Security.** Communications between NDB Cluster nodes are not encrypted or shielded in any way. The only means of protecting transmissions within an NDB Cluster is to run your NDB Cluster on a protected network. If you intend to use NDB Cluster for Web applications, the cluster should definitely reside behind your firewall and not in your network's De-Militarized Zone (DMZ) or elsewhere.

  See Section 18.5.11.1, “NDB Cluster Security and Networking Issues”, for more information.

- **Efficiency.** Setting up an NDB Cluster on a private or protected network enables the cluster to make exclusive use of bandwidth between cluster hosts. Using a separate switch for your NDB Cluster not only helps protect against unauthorized access to NDB Cluster data, it also ensures that NDB Cluster nodes are shielded from interference caused by transmissions between other computers on the network. For enhanced reliability, you can use dual switches and dual cards to remove the network as a single point of failure; many device drivers support failover for such communication links.

Network communication and latency. NDB Cluster requires communication between data nodes and API nodes (including SQL nodes), as well as between data nodes and other data nodes, to execute queries and updates. Communication latency between these processes can directly affect the observed performance and latency of user queries. In addition, to maintain consistency and service despite the silent failure of nodes, NDB Cluster uses heartbeating and timeout mechanisms which treat an extended loss of communication from a node as node failure. This can lead to reduced redundancy. Recall that, to maintain data consistency, an NDB Cluster shuts down when the last node in a node group fails. Thus, to avoid increasing the risk of a forced shutdown, breaks in communication between nodes should be avoided wherever possible.

The failure of a data or API node results in the abort of all uncommitted transactions involving the failed node. Data node recovery requires synchronization of the failed node's data from a surviving data node, and re-establishment of disk-based redo and checkpoint logs, before the data node returns to service. This recovery can take some time, during which the Cluster operates with reduced redundancy.

Heartbeating relies on timely generation of heartbeat signals by all nodes. This may not be possible if the node is overloaded, has insufficient machine CPU due to sharing with other programs, or is experiencing delays due to swapping. If heartbeat generation is sufficiently delayed, other nodes treat the node that is slow to respond as failed.

This treatment of a slow node as a failed one may or may not be desirable in some circumstances, depending on the impact of the node's slowed operation on the rest of the cluster. When setting timeout values such as `HeartbeatIntervalDbDb` and `HeartbeatIntervalDbApi` for NDB Cluster, care must be taken care to achieve quick detection, failover, and return to service, while avoiding potentially expensive false positives.

Where communication latencies between data nodes are expected to be higher than would be expected in a LAN environment (on the order of 100 µs), timeout parameters must be increased to ensure that any allowed periods of latency periods are well within configured timeouts. Increasing timeouts in this way has a corresponding effect on the worst-case time to detect failure and therefore time to service recovery.

LAN environments can typically be configured with stable low latency, and such that they can provide redundancy with fast failover. Individual link failures can be recovered from with minimal and controlled latency visible at the TCP level (where NDB Cluster normally operates). WAN environments may offer a range of latencies, as well as redundancy with slower failover times. Individual link failures may require route changes to propagate before end-to-end connectivity is restored. At the TCP level this can appear as large latencies on individual channels. The worst-case observed TCP latency in these scenarios is related to the worst-case time for the IP layer to reroute around the failures.

SCI support. It is also possible to use the high-speed Scalable Coherent Interface (SCI) with NDB Cluster, but this is not a requirement. See Section 18.3.4, “Using High-Speed Interconnects with NDB Cluster”, for more about this protocol and its use with NDB Cluster.

18.1.4 What is New in MySQL NDB Cluster 7.2

In this section, we discuss changes in the implementation of NDB Cluster in MySQL NDB Cluster 7.2, as compared to NDB Cluster 7.1 and earlier releases. Changes and features most likely to be of interest are shown in the following table:

NDB Cluster 7.2
NDB Cluster 7.2 is based on MySQL 5.5. For more information about new features in MySQL Server 5.5, see Section 1.4, “What Is New in MySQL 5.5”.
Version 2 binary log row events, to provide support for improvements in NDB Cluster Replication conflict detection (see next item). A given `mysqld` can be made to use Version 1 or Version 2 binary logging row events with the `--log-bin-use-v1-row-events` option.
Two new “primary wins” conflict detection and resolution functions `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` for use in replication setups with 2 NDB Clusters. For more information, see Section 18.6, “NDB Cluster Replication”.
Distribution of MySQL users and privileges across NDB Cluster SQL nodes is now supported—see Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”.
Improved support for distributed pushed-down joins, which greatly improve performance for many joins that can be executed in parallel on the data nodes.
Default values for a number of data node configuration parameters such as `HeartbeatIntervalDbDb` and `ArbitrationTimeout` have been improved.
Support for the Memcache API using the loadable ndbmemcache storage engine. See ndbmemcache—Memcache API for NDB Cluster.

This section contains information about NDB Cluster 7.2 releases through 5.5.58-ndb-7.2.32, which is a previous GA release but still supported, as is NDB Cluster 7.3. NDB Cluster 7.1, NDB Cluster 7.0, and NDB Cluster 6.3 are previous GA release series which are no longer supported. We recommend that new deployments use NDB Cluster 7.4 or NDB Cluster 7.5, both of which are available as General Availability releases. NDB Cluster 7.6, currently under development, is available for evaluation and testing as a Developer Preview release. For information about NDB Cluster 7.1 and previous releases, see the *MySQL 5.1 Reference Manual*.

The following improvements to NDB Cluster have been made in NDB Cluster 7.2:

- **Based on MySQL Server 5.5.** Previous NDB Cluster release series, including NDB Cluster 7.1, used MySQL 5.1 as a base. Beginning with NDB 7.2.1, NDB Cluster 7.2 is based on MySQL Server 5.5, so that NDB Cluster users can benefit from MySQL 5.5's improvements in scalability and performance monitoring. As with MySQL 5.5, NDB 7.2.1 and later use `CMake` for configuring and building from source in place of GNU Autotools (used in MySQL 5.1 and NDB Cluster releases based on MySQL 5.1). For more information about changes and improvements in MySQL 5.5, see Section 1.4, “What Is New in MySQL 5.5”.

- **Conflict detection using GCI Reflection.** NDB Cluster Replication implements a new “primary wins” conflict detection and resolution mechanism. *GCI Reflection* applies in two-cluster circulation “active-active” replication setups, tracking the order in which changes are applied on the NDB Cluster designated as primary relative to changes originating on the other NDB Cluster (referred to as the secondary). This relative ordering is used to determine whether changes originating on the slave are concurrent with any changes that originate locally, and are therefore potentially in conflict. Two new conflict detection functions are added: When using `NDB$EPOCH()`, rows that are out of sync on the secondary are realigned with those on the primary; with `NDB$EPOCH_TRANS()`, this realignment is applied to transactions. For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- **Version 2 binary log row events.** A new format for binary log row events, known as Version 2 binary log row events, provides support for improvements in NDB Cluster Replication conflict detection (see previous item) and is intended to facilitate further improvements in MySQL Replication. You can cause a given `mysqld` use Version 1 or Version 2 binary logging row events with the `--log-bin-use-v1-row-events` option. For backward compatibility, Version 2 binary log row events are also available in NDB Cluster 7.0 (7.0.27 and later) and NDB Cluster 7.1 (7.1.16 and later). However, NDB Cluster 7.0 and NDB Cluster 7.1 continue to use Version 1 binary log row events as the default, whereas the default in NDB 7.2.1 and later is use Version 2 row events for binary logging.

- **Distribution of MySQL users and privileges.** Automatic distribution of MySQL users and privileges across all SQL nodes in a given NDB Cluster is now supported. To enable this support, you must first import an SQL script `share/mysql/ndb_dist_priv.sql` that is included with the NDB Cluster 7.2 distribution. This script creates several stored procedures which you can use to enable privilege distribution and perform related tasks.

  When a new MySQL Server joins an NDB Cluster where privilege distribution is in effect, it also participates in the privilege distribution automatically.

  Once privilege distribution is enabled, all changes to the grant tables made on any `mysqld` attached to the cluster are immediately available on any other attached MySQL Servers. This is true whether the changes are made using `CREATE USER`, `GRANT`, or any of the other statements described elsewhere in this Manual (see Section 13.7.1, “Account Management Statements”.) This includes privileges relating to stored routines and views; however, automatic distribution of the views or stored routines themselves is not currently supported.

  For more information, see Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”.

- **Distributed pushed-down joins.** Many joins can now be pushed down to the NDB kernel for processing on NDB Cluster data nodes. Previously, a join was handled in NDB Cluster by means of repeated accesses of `NDB` by the SQL node; however, when pushed-down joins are enabled, a pushable join is sent in its entirety to the data nodes, where it can be distributed among the data nodes and executed in parallel on multiple copies of the data, with a single, merged result being returned to `mysqld`. This can reduce greatly the number of round trips between an SQL node and the data nodes required to handle such a join, leading to greatly improved performance of join processing.

  It is possible to determine when joins can be pushed down to the data nodes by examining the join with `EXPLAIN`. A number of new system status variables (`Ndb_pushed_queries_defined`, `Ndb_pushed_queries_dropped`, `Ndb_pushed_queries_executed`, and `Ndb_pushed_reads`) and additions to the `counters` table (in the `ndbinfo` information database) can also be helpful in determining when and how well joins are being pushed down.

  More information and examples are available in the description of the `ndb_join_pushdown` server system variable. See also the description of the status variables referenced in the previous paragraph, as well as Section 18.5.10.7, “The ndbinfo counters Table”.

- **Improved default values for data node configuration parameters.** In order to provide more resiliency to environmental issues and better handling of some potential failure scenarios, and to perform more reliably with increases in memory and other resource requirements brought about by recent improvements in join handling by `NDB`, the default values for a number of NDB Cluster data node configuration parameters have been changed. The parameters and changes are described in the following list:

  - `HeartbeatIntervalDbDb`: Default increased from 1500 ms to 5000 ms.
  - `ArbitrationTimeout`: Default increased from 3000 ms to 7500 ms.
  - `TimeBetweenEpochsTimeout`: Now effectively disabled by default (default changed from 4000 ms to 0).
  - `SharedGlobalMemory`: Default increased from 20 MB to 128 MB.
  - `MaxParallelScansPerFragment`: Default increased from 32 to 256.
  - `CrashOnCorruptedTuple` changed from `FALSE` to `TRUE`.
  - Beginning with NDB 7.2.10, `DefaultOperationRedoProblemAction` changed from `ABORT` to `QUEUE`.

In addition, the value computed for `MaxNoOfLocalScans` when this parameter is not set in `config.ini` has been increased by a factor of 4.

- **Fail-fast data nodes.** Beginning with NDB 7.2.1, data nodes handle corrupted tuples in a fail-fast manner by default. This is a change from previous versions of NDB Cluster where this behavior had to be enabled explicitly by enabling the `CrashOnCorruptedTuple` configuration parameter. In NDB 7.2.1 and later, this parameter is enabled by default and must be explicitly disabled, in which case data nodes merely log a warning whenever they detect a corrupted tuple.

- **Memcache API support (ndbmemcache).** The Memcached server is a distributed in-memory caching server that uses a simple text-based protocol. It is often employed with key-value stores. The Memcache API for NDB Cluster, available beginning with NDB 7.2.2, is implemented as a loadable storage engine for memcached version 1.6 and later. This API can be used to access a persistent NDB Cluster data store employing the memcache protocol. It is also possible for the `memcached` server to provide a strictly defined interface to existing NDB Cluster tables.

  Each memcache server can both cache data locally and access data stored in NDB Cluster directly. Caching policies are configurable. For more information, see ndbmemcache—Memcache API for NDB Cluster, in the *NDB Cluster API Developers Guide*.

- **Rows per partition limit removed.** Previously it was possible to store a maximum of 46137488 rows in a single NDB Cluster partition—that is, per data node. Beginning with NDB 7.2.9, this limitation has been lifted, and there is no longer any practical upper limit to this number. (Bug #13844405, Bug #14000373)

NDB Cluster 7.2 is also supported by MySQL Cluster Manager, which provides an advanced command-line interface that can simplify many complex NDB Cluster management tasks. See MySQL™ Cluster Manager 1.3.6 User Manual, for more information.

18.1.5 MySQL Server Using InnoDB Compared with NDB Cluster

MySQL Server offers a number of choices in storage engines. Since both `NDB` and `InnoDB` can serve as transactional MySQL storage engines, users of MySQL Server sometimes become interested in NDB Cluster. They see `NDB` as a possible alternative or upgrade to the default `InnoDB` storage engine in MySQL 5.5. While `NDB` and `InnoDB` share common characteristics, there are differences in architecture and implementation, so that some existing MySQL Server applications and usage scenarios can be a good fit for NDB Cluster, but not all of them.

In this section, we discuss and compare some characteristics of the `NDB` storage engine used by NDB Cluster 7.2 with `InnoDB` used in MySQL 5.5. The next few sections provide a technical comparison. In many instances, decisions about when and where to use NDB Cluster must be made on a case-by-case basis, taking all factors into consideration. While it is beyond the scope of this documentation to provide specifics for every conceivable usage scenario, we also attempt to offer some very general guidance on the relative suitability of some common types of applications for `NDB` as opposed to `InnoDB` back ends.

Recent NDB Cluster 7.2 releases use a `mysqld` based on MySQL 5.5, including support for `InnoDB` 1.1. While it is possible to use `InnoDB` tables with NDB Cluster, such tables are not clustered. It is also not possible to use programs or libraries from an NDB Cluster 7.2 distribution with MySQL Server 5.5, or the reverse.

While it is also true that some types of common business applications can be run either on NDB Cluster or on MySQL Server (most likely using the `InnoDB` storage engine), there are some important architectural and implementation differences. Section 18.1.5.1, “Differences Between the NDB and InnoDB Storage Engines”, provides a summary of the these differences. Due to the differences, some usage scenarios are clearly more suitable for one engine or the other; see Section 18.1.5.2, “NDB and InnoDB Workloads”. This in turn has an impact on the types of applications that better suited for use with `NDB` or `InnoDB`. See Section 18.1.5.3, “NDB and InnoDB Feature Usage Summary”, for a comparison of the relative suitability of each for use in common types of database applications.

For information about the relative characteristics of the NDB and MEMORY storage engines, see When to Use MEMORY or NDB Cluster.

See Chapter 15, *Alternative Storage Engines*, for additional information about MySQL storage engines.

18.1.5.1 Differences Between the NDB and InnoDB Storage Engines

The NDB storage engine is implemented using a distributed, shared-nothing architecture, which causes it to behave differently from InnoDB in a number of ways. For those unaccustomed to working with NDB, unexpected behaviors can arise due to its distributed nature with regard to transactions, foreign keys, table limits, and other characteristics. These are shown in the following table:

Feature	InnoDB 1.1	NDB 7.2
MySQL Server Version	5.5	5.5
InnoDB Version	InnoDB 1.1	InnoDB 1.1
NDB Cluster Version	N/A	NDB 7.2.32
Storage Limits	64TB	3TB (Practical upper limit based on 48 data nodes with 64GB RAM each; can be increased with disk-based data and BLOBs)
Foreign Keys	Yes	Not in NDB 7.2, where they are ignored as by MyISAM (Available in NDB Cluster 7.3 and later=
Transactions	All standard types	READ COMMITTED
MVCC	Yes	No
Data Compression	Yes	No (NDB checkpoint and backup files can be compressed)
Large Row Support (> 14K)	Supported for VARBINARY, VARCHAR, BLOB, and TEXT columns	Supported for BLOB and TEXT columns only (Using these types to store very large amounts of data can lower NDB performance)
Replication Support	Asynchronous and semisynchronous replication using MySQL Replication	Automatic synchronous replication within an NDB Cluster; asynchronous replication between NDB Clusters, using MySQL Replication (Semisynchronous replication is not supported)
Scaleout for Read Operations	Yes (MySQL Replication)	Yes (Automatic partitioning in NDB Cluster; NDB Cluster Replication)
Scaleout for Write Operations	Requires application-level partitioning (sharding)	Yes (Automatic partitioning in NDB Cluster is transparent to applications)
High Availability (HA)	Requires additional software	Yes (Designed for 99.999% uptime)
Node Failure Recovery and Failover	Requires additional software	Automatic (Key element in NDB architecture)
Time for Node Failure Recovery	30 seconds or longer	Typically < 1 second
Real-Time Performance	No	Yes

Feature	InnoDB 1.1	NDB 7.2
In-Memory Tables	No	Yes (Some data can optionally be stored on disk; both in-memory and disk data storage are durable)
NoSQL Access to Storage Engine	Yes	Yes (Multiple APIs, including Memcached, Node.js/JavaScript, Java, JPA, C++, and HTTP/REST)
Concurrent and Parallel Writes	Not supported	Up to 48 writers, optimized for concurrent writes
Conflict Detection and Resolution (Multiple Replication Masters)	No	Yes
Hash Indexes	No	Yes
Online Addition of Nodes	Read-only replicas using MySQL Replication	Yes (all node types)
Online Upgrades	No	Yes
Online Schema Modifications	No	Yes

18.1.5.2 NDB and InnoDB Workloads

NDB Cluster has a range of unique attributes that make it ideal to serve applications requiring high availability, fast failover, high throughput, and low latency. Due to its distributed architecture and multi-node implementation, NDB Cluster also has specific constraints that may keep some workloads from performing well. A number of major differences in behavior between the NDB and InnoDB storage engines with regard to some common types of database-driven application workloads are shown in the following table::

Workload	InnoDB	NDB Cluster (NDB)
High-Volume OLTP Applications	Yes	Yes
DSS Applications (data marts, analytics)	Yes	Limited (Join operations across OLTP datasets not exceeding 3TB in size)
Custom Applications	Yes	Yes
Packaged Applications	Yes	Limited (should be mostly primary key access) **Note** NDB Cluster 7.3 adds support for foreign keys.
In-Network Telecoms Applications (HLR, HSS, SDP)	No	Yes
Session Management and Caching	Yes	Yes
E-Commerce Applications	Yes	Yes
User Profile Management, AAA Protocol	Yes	Yes

18.1.5.3 NDB and InnoDB Feature Usage Summary

When comparing application feature requirements to the capabilities of `InnoDB` with `NDB`, some are clearly more compatible with one storage engine than the other.

The following table lists supported application features according to the storage engine to which each feature is typically better suited.

Preferred application requirements for `InnoDB`	Preferred application requirements for `NDB`
• Foreign keys **Note** NDB Cluster 7.3 adds support support for foreign keys. • Full table scans • Very large databases, rows, or transactions • Transactions other than `READ COMMITTED`	• Write scaling • 99.999% uptime • Online addition of nodes and online schema operations • Multiple SQL and NoSQL APIs (see NDB Cluster APIs: Overview and Concepts) • Real-time performance • Limited use of `BLOB` columns

18.1.6 Known Limitations of NDB Cluster

In the sections that follow, we discuss known limitations in current releases of NDB Cluster as compared with the features available when using the `MyISAM` and `InnoDB` storage engines. If you check the “Cluster” category in the MySQL bugs database at http://bugs.mysql.com, you can find known bugs in the following categories under “MySQL Server:” in the MySQL bugs database at http://bugs.mysql.com, which we intend to correct in upcoming releases of NDB Cluster:

- NDB Cluster
- Cluster Direct API (NDBAPI)
- Cluster Disk Data
- Cluster Replication
- ClusterJ

This information is intended to be complete with respect to the conditions just set forth. You can report any discrepancies that you encounter to the MySQL bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”. If we do not plan to fix the problem in NDB Cluster 7.2, we will add it to the list.

See Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x” for a list of issues in NDB Cluster in MySQL 5.1 that have been resolved in the current version.

Note

Limitations and other issues specific to NDB Cluster Replication are described in Section 18.6.3, “Known Issues in NDB Cluster Replication”.

18.1.6.1 Noncompliance with SQL Syntax in NDB Cluster

Some SQL statements relating to certain MySQL features produce errors when used with `NDB` tables, as described in the following list:

- **Temporary tables.** Temporary tables are not supported. Trying either to create a temporary table that uses the `NDB` storage engine or to alter an existing temporary table to use `NDB` fails with the

error `Table storage engine 'ndbcluster' does not support the create option 'TEMPORARY'`.

- **Indexes and keys in NDB tables.** Keys and indexes on NDB Cluster tables are subject to the following limitations:

  - **Column width.** Attempting to create an index on an `NDB` table column whose width is greater than 3072 bytes succeeds, but only the first 3072 bytes are actually used for the index. In such cases, a warning `Specified key was too long; max key length is 3072 bytes` is issued, and a `SHOW CREATE TABLE` statement shows the length of the index as 3072.

  - **TEXT and BLOB columns.** You cannot create indexes on `NDB` table columns that use any of the `TEXT` or `BLOB` data types.

  - **FULLTEXT indexes.** The `NDB` storage engine does not support `FULLTEXT` indexes, which are possible for `MyISAM` tables only.

    However, you can create indexes on `VARCHAR` columns of `NDB` tables.

  - **USING HASH keys and NULL.** Using nullable columns in unique keys and primary keys means that queries using these columns are handled as full table scans. To work around this issue, make the column `NOT NULL`, or re-create the index without the `USING HASH` option.

  - **Prefixes.** There are no prefix indexes; only entire columns can be indexed. (The size of an `NDB` column index is always the same as the width of the column in bytes, up to and including 3072 bytes, as described earlier in this section. Also see Section 18.1.6.6, “Unsupported or Missing Features in NDB Cluster”, for additional information.)

  - **BIT columns.** A `BIT` column cannot be a primary key, unique key, or index, nor can it be part of a composite primary key, unique key, or index.

  - **AUTO_INCREMENT columns.** Like other MySQL storage engines, the `NDB` storage engine can handle a maximum of one `AUTO_INCREMENT` column per table, and this column must be indexed. However, in the case of an NDB table with no explicit primary key, an `AUTO_INCREMENT` column is automatically defined and used as a “hidden” primary key. For this reason, you cannot create an `NDB` table having an `AUTO_INCREMENT` column and no explicit primary key.

- **NDB Cluster and geometry data types.**
  Geometry data types (`WKT` and `WKB`) are supported for `NDB` tables. However, spatial indexes are not supported.

- **Character sets and binary log files.** Currently, the `ndb_apply_status` and `ndb_binlog_index` tables are created using the `latin1` (ASCII) character set. Because names of binary logs are recorded in this table, binary log files named using non-Latin characters are not referenced correctly in these tables. This is a known issue, which we are working to fix. (Bug #50226)

  To work around this problem, use only Latin-1 characters when naming binary log files or setting any the `--basedir`, `--log-bin`, or `--log-bin-index` options.

- **Creating NDB tables with user-defined partitioning.** Support for user-defined partitioning in NDB Cluster is restricted to [`LINEAR`] `KEY` partitioning. Using any other partitioning type with `ENGINE=NDB` or `ENGINE=NDBCLUSTER` in a `CREATE TABLE` statement results in an error.

  It is possible to override this restriction, but doing so is not supported for use in production settings. For details, see User-defined partitioning and the NDB storage engine (NDB Cluster).

  Default partitioning scheme. All NDB Cluster tables are by default partitioned by `KEY` using the table's primary key as the partitioning key. If no primary key is explicitly set for the table, the “hidden” primary key automatically created by the `NDB` storage engine is used instead. For additional discussion of these and related issues, see Section 19.2.5, “KEY Partitioning”.

`CREATE TABLE` and `ALTER TABLE` statements that would cause a user-partitioned `NDBCLUSTER` table not to meet either or both of the following two requirements are not permitted, and fail with an error:

1. The table must have an explicit primary key.

2. All columns listed in the table's partitioning expression must be part of the primary key.

Exception. If a user-partitioned `NDBCLUSTER` table is created using an empty column-list (that is, using `PARTITION BY [LINEAR] KEY()`), then no explicit primary key is required.

Maximum number of partitions for NDBCLUSTER tables. The maximum number of partitions that can defined for a `NDBCLUSTER` table when employing user-defined partitioning is 8 per node group. (See Section 18.1.2, "NDB Cluster Nodes, Node Groups, Replicas, and Partitions", for more information about NDB Cluster node groups.

DROP PARTITION not supported. It is not possible to drop partitions from `NDB` tables using `ALTER TABLE ... DROP PARTITION`. The other partitioning extensions to `ALTER TABLE`—`ADD PARTITION`, `REORGANIZE PARTITION`, and `COALESCE PARTITION`—are supported for NDB tables, but use copying and so are not optimized. See Section 19.3.1, "Management of RANGE and LIST Partitions" and Section 13.1.7, "ALTER TABLE Syntax".

- **Row-based replication.**
  When using row-based replication with NDB Cluster, binary logging cannot be disabled. That is, the `NDB` storage engine ignores the value of `sql_log_bin`. (Bug #16680)

18.1.6.2 Limits and Differences of NDB Cluster from Standard MySQL Limits

In this section, we list limits found in NDB Cluster that either differ from limits found in, or that are not found in, standard MySQL.

Memory usage and recovery. Memory consumed when data is inserted into an `NDB` table is not automatically recovered when deleted, as it is with other storage engines. Instead, the following rules hold true:

- A `DELETE` statement on an `NDB` table makes the memory formerly used by the deleted rows available for re-use by inserts on the same table only. However, this memory can be made available for general re-use by performing `OPTIMIZE TABLE`.

  A rolling restart of the cluster also frees any memory used by deleted rows. See Section 18.5.5, "Performing a Rolling Restart of an NDB Cluster".

- A `DROP TABLE` or `TRUNCATE TABLE` operation on an `NDB` table frees the memory that was used by this table for re-use by any `NDB` table, either by the same table or by another `NDB` table.

Note

Recall that `TRUNCATE TABLE` drops and re-creates the table. See Section 13.1.33, "TRUNCATE TABLE Syntax".

- **Limits imposed by the cluster's configuration.**
  A number of hard limits exist which are configurable, but available main memory in the cluster sets limits. See the complete list of configuration parameters in Section 18.3.3, "NDB Cluster Configuration Files". Most configuration parameters can be upgraded online. These hard limits include:

  - Database memory size and index memory size (`DataMemory` and `IndexMemory`, respectively).

    `DataMemory` is allocated as 32KB pages. As each `DataMemory` page is used, it is assigned to a specific table; once allocated, this memory cannot be freed except by dropping the table.

See Section 18.3.3.6, “Defining NDB Cluster Data Nodes”, for more information.

- The maximum number of operations that can be performed per transaction is set using the configuration parameters `MaxNoOfConcurrentOperations` and `MaxNoOfLocalOperations`.

  Note

  Bulk loading, `TRUNCATE TABLE`, and `ALTER TABLE` are handled as special cases by running multiple transactions, and so are not subject to this limitation.

- Different limits related to tables and indexes. For example, the maximum number of ordered indexes in the cluster is determined by `MaxNoOfOrderedIndexes`, and the maximum number of ordered indexes per table is 16.

- **Node and data object maximums.** The following limits apply to numbers of cluster nodes and metadata objects:

  - The maximum number of data nodes is 48.

    A data node must have a node ID in the range of 1 to 48, inclusive. (Management and API nodes may use node IDs in the range 1 to 255, inclusive.)

  - The total maximum number of nodes in an NDB Cluster is 255. This number includes all SQL nodes (MySQL Servers), API nodes (applications accessing the cluster other than MySQL servers), data nodes, and management servers.

  - The maximum number of metadata objects in current versions of NDB Cluster is 20320. This limit is hard-coded.

  See Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”, for more information.

18.1.6.3 Limits Relating to Transaction Handling in NDB Cluster

A number of limitations exist in NDB Cluster with regard to the handling of transactions. These include the following:

- **Transaction isolation level.** The `NDBCLUSTER` storage engine supports only the `READ COMMITTED` transaction isolation level. (`InnoDB`, for example, supports `READ COMMITTED`, `READ UNCOMMITTED`, `REPEATABLE READ`, and `SERIALIZABLE`.) You should keep in mind that `NDB` implements `READ COMMITTED` on a per-row basis; when a read request arrives at the data node storing the row, what is returned is the last committed version of the row at that time.

  Uncommitted data is never returned, but when a transaction modifying a number of rows commits concurrently with a transaction reading the same rows, the transaction performing the read can observe “before” values, “after” values, or both, for different rows among these, due to the fact that a given row read request can be processed either before or after the commit of the other transaction.

  To ensure that a given transaction reads only before or after values, you can impose row locks using `SELECT ... LOCK IN SHARE MODE`. In such cases, the lock is held until the owning transaction is committed. Using row locks can also cause the following issues:

  - Increased frequency of lock wait timeout errors, and reduced concurrency

  - Increased transaction processing overhead due to reads requiring a commit phase

  - Possibility of exhausting the available number of concurrent locks, which is limited by `MaxNoOfConcurrentOperations`

NDB uses READ COMMITTED for all reads unless a modifier such as LOCK IN SHARE MODE or FOR UPDATE is used. LOCK IN SHARE MODE causes shared row locks to be used; FOR UPDATE causes exclusive row locks to be used. Unique key reads have their locks upgraded automatically by NDB to ensure a self-consistent read; BLOB reads also employ extra locking for consistency.

See Section 18.5.3.4, “NDB Cluster Backup Troubleshooting”, for information on how NDB Cluster's implementation of transaction isolation level can affect backup and restoration of NDB databases.

- **Transactions and BLOB or TEXT columns.** NDBCLUSTER stores only part of a column value that uses any of MySQL's BLOB or TEXT data types in the table visible to MySQL; the remainder of the BLOB or TEXT is stored in a separate internal table that is not accessible to MySQL. This gives rise to two related issues of which you should be aware whenever executing SELECT statements on tables that contain columns of these types:

  1. For any SELECT from an NDB Cluster table: If the SELECT includes a BLOB or TEXT column, the READ COMMITTED transaction isolation level is converted to a read with read lock. This is done to guarantee consistency.

  2. For any SELECT which uses a unique key lookup to retrieve any columns that use any of the BLOB or TEXT data types and that is executed within a transaction, a shared read lock is held on the table for the duration of the transaction—that is, until the transaction is either committed or aborted.

     This issue does not occur for queries that use index or table scans, even against NDB tables having BLOB or TEXT columns.

     For example, consider the table t defined by the following CREATE TABLE statement:

     ```
     CREATE TABLE t (
         a INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
         b INT NOT NULL,
         c INT NOT NULL,
         d TEXT,
         INDEX i(b),
         UNIQUE KEY u(c)
     ) ENGINE = NDB,
     ```

     Either of the following queries on t causes a shared read lock, because the first query uses a primary key lookup and the second uses a unique key lookup:

     ```
     SELECT * FROM t WHERE a = 1;

     SELECT * FROM t WHERE c = 1;
     ```

     However, none of the four queries shown here causes a shared read lock:

     ```
     SELECT * FROM t WHERE b = 1;

     SELECT * FROM t WHERE d = '1';

     SELECT * FROM t;

     SELECT b,c WHERE a = 1;
     ```

     This is because, of these four queries, the first uses an index scan, the second and third use table scans, and the fourth, while using a primary key lookup, does not retrieve the value of any BLOB or TEXT columns.

You can help minimize issues with shared read locks by avoiding queries that use unique key lookups that retrieve `BLOB` or `TEXT` columns, or, in cases where such queries are not avoidable, by committing transactions as soon as possible afterward.

- **Rollbacks.** There are no partial transactions, and no partial rollbacks of transactions. A duplicate key or similar error causes the entire transaction to be rolled back.

  This behavior differs from that of other transactional storage engines such as `InnoDB` that may roll back individual statements.

- **Transactions and memory usage.**
  As noted elsewhere in this chapter, NDB Cluster does not handle large transactions well; it is better to perform a number of small transactions with a few operations each than to attempt a single large transaction containing a great many operations. Among other considerations, large transactions require very large amounts of memory. Because of this, the transactional behavior of a number of MySQL statements is affected as described in the following list:

  - `TRUNCATE TABLE` is not transactional when used on `NDB` tables. If a `TRUNCATE TABLE` fails to empty the table, then it must be re-run until it is successful.

  - `DELETE FROM` (even with no `WHERE` clause) *is* transactional. For tables containing a great many rows, you may find that performance is improved by using several `DELETE FROM ... LIMIT ...` statements to "chunk" the delete operation. If your objective is to empty the table, then you may wish to use `TRUNCATE TABLE` instead.

  - **LOAD DATA statements.** `LOAD DATA INFILE` is not transactional when used on `NDB` tables.

    Important

    When executing a `LOAD DATA INFILE` statement, the `NDB` engine performs commits at irregular intervals that enable better utilization of the communication network. It is not possible to know ahead of time when such commits take place.

  - **ALTER TABLE and transactions.** When copying an `NDB` table as part of an `ALTER TABLE`, the creation of the copy is nontransactional. (In any case, this operation is rolled back when the copy is deleted.)

- **Transactions and the COUNT() function.** When using NDB Cluster Replication, it is not possible to guarantee the transactional consistency of the `COUNT()` function on the slave. In other words, when performing on the master a series of statements (`INSERT`, `DELETE`, or both) that changes the number of rows in a table within a single transaction, executing `SELECT COUNT(*) FROM table` queries on the slave may yield intermediate results. This is due to the fact that `SELECT COUNT(...)` may perform dirty reads, and is not a bug in the `NDB` storage engine. (See Bug #31321 for more information.)

18.1.6.4 NDB Cluster Error Handling

Starting, stopping, or restarting a node may give rise to temporary errors causing some transactions to fail. These include the following cases:

- **Temporary errors.** When first starting a node, it is possible that you may see Error 1204 `Temporary failure, distribution changed` and similar temporary errors.

- **Errors due to node failure.** The stopping or failure of any data node can result in a number of different node failure errors. (However, there should be no aborted transactions when performing a planned shutdown of the cluster.)

In either of these cases, any errors that are generated must be handled within the application. This should be done by retrying the transaction.

See also Section 18.1.6.2, “Limits and Differences of NDB Cluster from Standard MySQL Limits”.

18.1.6.5 Limits Associated with Database Objects in NDB Cluster

Some database objects such as tables and indexes have different limitations when using the `NDBCLUSTER` storage engine:

- **Database and table names.** When using the `NDB` storage engine, the maximum allowed length both for database names and for table names is 63 characters.
- **Number of database objects.** The maximum number of *all* `NDB` database objects in a single NDB Cluster—including databases, tables, and indexes—is limited to 20320.
- **Attributes per table.** The maximum number of attributes (that is, columns and indexes) that can belong to a given table is 512.
- **Attributes per key.** The maximum number of attributes per key is 32.
- **Row size.** The maximum permitted size of any one row is 14000 bytes. Each `BLOB` or `TEXT` column contributes 256 + 8 = 264 bytes to this total.
- **BIT column storage per table.** The maximum combined width for all `BIT` columns used in a given `NDB` table is 4096.
- **FIXED column storage.** NDB Cluster supports a maximum of 16 GB per fragment of data in `FIXED` columns.

18.1.6.6 Unsupported or Missing Features in NDB Cluster

A number of features supported by other storage engines are not supported for `NDB` tables. Trying to use any of these features in NDB Cluster does not cause errors in or of itself; however, errors may occur in applications that expects the features to be supported or enforced. Statements referencing such features, even if effectively ignored by `NDB`, must be syntactically and otherwise valid.

- **Foreign key constraints.** Prior to NDB Cluster 7.3, the foreign key construct is ignored, just as it is by `MyISAM` tables. Foreign keys are supported in NDB Cluster 7.3 and later.
- **Index prefixes.** Prefixes on indexes are not supported for `NDB` tables. If a prefix is used as part of an index specification in a statement such as `CREATE TABLE`, `ALTER TABLE`, or `CREATE INDEX`, the prefix is not created by `NDB`.

  A statement containing an index prefix, and creating or modifying an `NDB` table, must still be syntactically valid. For example, the following statement always fails with Error 1089 `Incorrect prefix key; the used key part isn't a string, the used length is longer than the key part, or the storage engine doesn't support unique prefix keys`, regardless of storage engine:

  ```
  CREATE TABLE t1 (
      c1 INT NOT NULL,
      c2 VARCHAR(100),
      INDEX i1 (c2(500))
  );
  ```

  This happens on account of the SQL syntax rule that no index may have a prefix larger than itself.
- **Savepoints and rollbacks.** Savepoints and rollbacks to savepoints are ignored as in `MyISAM`.
- **Durability of commits.** There are no durable commits on disk. Commits are replicated, but there is no guarantee that logs are flushed to disk on commit.
- **Replication.** Statement-based replication is not supported. Use `--binlog-format=ROW` (or `--binlog-format=MIXED`) when setting up cluster replication. See Section 18.6, “NDB Cluster Replication”, for more information.

Semisynchronous replication is not supported in NDB Cluster.

Note

See Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”, for more information relating to limitations on transaction handling in `NDB`.

18.1.6.7 Limitations Relating to Performance in NDB Cluster

The following performance issues are specific to or especially pronounced in NDB Cluster:

- **Range scans.** There are query performance issues due to sequential access to the `NDB` storage engine; it is also relatively more expensive to do many range scans than it is with either `MyISAM` or `InnoDB`.
- **Reliability of Records in range.** The `Records in range` statistic is available but is not completely tested or officially supported. This may result in nonoptimal query plans in some cases. If necessary, you can employ `USE INDEX` or `FORCE INDEX` to alter the execution plan. See Section 8.9.3, “Index Hints”, for more information on how to do this.
- **Unique hash indexes.** Unique hash indexes created with `USING HASH` cannot be used for accessing a table if `NULL` is given as part of the key.

18.1.6.8 Issues Exclusive to NDB Cluster

The following are limitations specific to the `NDB` storage engine:

- **Machine architecture.** All machines used in the cluster must have the same architecture. That is, all machines hosting nodes must be either big-endian or little-endian, and you cannot use a mixture of both. For example, you cannot have a management node running on a PowerPC which directs a data node that is running on an x86 machine. This restriction does not apply to machines simply running `mysql` or other clients that may be accessing the cluster's SQL nodes.
- **Binary logging.**
  NDB Cluster has the following limitations or restrictions with regard to binary logging:
  - `sql_log_bin` has no effect on data operations; however, it is supported for schema operations.
  - NDB Cluster cannot produce a binary log for tables having `BLOB` columns but no primary key.
  - Only the following schema operations are logged in a cluster binary log which is *not* on the `mysqld` executing the statement:
    - `CREATE TABLE`
    - `ALTER TABLE`
    - `DROP TABLE`
    - `CREATE DATABASE` / `CREATE SCHEMA`
    - `DROP DATABASE` / `DROP SCHEMA`
    - `CREATE TABLESPACE`
    - `ALTER TABLESPACE`
    - `DROP TABLESPACE`
    - `CREATE LOGFILE GROUP`

- `ALTER LOGFILE GROUP`
- `DROP LOGFILE GROUP`

- Schema operations (DDL statements) are rejected while any data node restarts.
- **Number of replicas.** The number of replicas, as determined by the `NoOfReplicas` data node configuration parameter, is the number of copies of all data stored by NDB Cluster. Setting this parameter to 1 means there is only a single copy; in this case, no redundancy is provided, and the loss of a data node entails loss of data. To guarantee redundancy, and thus preservation of data even if a data node fails, set this parameter to 2, which is the default and recommended value in production.

  Setting `NoOfReplicas` to a value greater than 2 is possible (to a maximum of 4) but unnecessary to guard against loss of data. In addition, *values greater than 2 for this parameter are not supported in production*.

See also Section 18.1.6.10, “Limitations Relating to Multiple NDB Cluster Nodes”.

18.1.6.9 Limitations Relating to NDB Cluster Disk Data Storage

Disk Data object maximums and minimums. Disk data objects are subject to the following maximums and minimums:

- Maximum number of tablespaces: 2^{32} (4294967296)
- Maximum number of data files per tablespace: 2^{16} (65536)
- The minimum and maximum possible sizes of extents for tablespace data files are 32K and 2G, respectively. See Section 13.1.18, “CREATE TABLESPACE Syntax”, for more information.

In addition, when working with NDB Disk Data tables, you should be aware of the following issues regarding data files and extents:

- Data files use `DataMemory`. Usage is the same as for in-memory data.
- Data files use file descriptors. It is important to keep in mind that data files are always open, which means the file descriptors are always in use and cannot be re-used for other system tasks.
- Extents require sufficient `DiskPageBufferMemory`; you must reserve enough for this parameter to account for all memory used by all extents (number of extents times size of extents).

Disk Data tables and diskless mode. Use of Disk Data tables is not supported when running the cluster in diskless mode. Beginning with MySQL 5.1.12, it is prohibited altogether. (Bug #20008)

18.1.6.10 Limitations Relating to Multiple NDB Cluster Nodes

Multiple SQL nodes.
The following are issues relating to the use of multiple MySQL servers as NDB Cluster SQL nodes, and are specific to the `NDBCLUSTER` storage engine:

- **No distributed table locks.** A `LOCK TABLES` works only for the SQL node on which the lock is issued; no other SQL node in the cluster “sees” this lock. This is also true for a lock issued by any statement that locks tables as part of its operations. (See next item for an example.)
- **ALTER TABLE operations.** `ALTER TABLE` is not fully locking when running multiple MySQL servers (SQL nodes). (As discussed in the previous item, NDB Cluster does not support distributed table locks.)

Multiple management nodes.

When using multiple management servers:

- If any of the management servers are running on the same host, you must give nodes explicit IDs in connection strings because automatic allocation of node IDs does not work across multiple management servers on the same host. This is not required if every management server resides on a different host.
- When a management server starts, it first checks for any other management server in the same NDB Cluster, and upon successful connection to the other management server uses its configuration data. This means that the management server `--reload` and `--initial` startup options are ignored unless the management server is the only one running. It also means that, when performing a rolling restart of an NDB Cluster with multiple management nodes, the management server reads its own configuration file if (and only if) it is the only management server running in this NDB Cluster. See Section 18.5.5, "Performing a Rolling Restart of an NDB Cluster", for more information.

Multiple network addresses. Multiple network addresses per data node are not supported. Use of these is liable to cause problems: In the event of a data node failure, an SQL node waits for confirmation that the data node went down but never receives it because another route to that data node remains open. This can effectively make the cluster inoperable.

Note

It is possible to use multiple network hardware *interfaces* (such as Ethernet cards) for a single data node, but these must be bound to the same address. This also means that it not possible to use more than one `[tcp]` section per connection in the `config.ini` file. See Section 18.3.3.9, "NDB Cluster TCP/IP Connections", for more information.

18.1.6.11 Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x

A number of limitations and related issues existing in earlier versions of NDB Cluster have been resolved:

- **Variable-length column support.** The `NDBCLUSTER` storage engine now supports variable-length column types for in-memory tables.

  Previously, for example, any Cluster table having one or more `VARCHAR` fields which contained only relatively small values, much more memory and disk space were required when using the `NDBCLUSTER` storage engine than would have been the case for the same table and data using the `MyISAM` engine. In other words, in the case of a `VARCHAR` column, such a column required the same amount of storage as a `CHAR` column of the same size. In MySQL 5.1, this is no longer the case for in-memory tables, where storage requirements for variable-length column types such as `VARCHAR` and `BINARY` are comparable to those for these column types when used in `MyISAM` tables (see Section 11.7, "Data Type Storage Requirements").

  Important

  For NDB Cluster Disk Data tables, the fixed-width limitation continues to apply. See Section 18.5.12, "NDB Cluster Disk Data Tables".

- **Replication with NDB Cluster.** It is now possible to use MySQL replication with Cluster databases. For details, see Section 18.6, "NDB Cluster Replication".

  Circular Replication. Circular replication is also supported with NDB Cluster, beginning with MySQL 5.1.18. See Section 18.6.10, "NDB Cluster Replication: Multi-Master and Circular Replication".

- **auto_increment_increment and auto_increment_offset.** The `auto_increment_increment` and `auto_increment_offset` server system variables are supported for NDB Cluster Replication.

- **Backup and restore between architectures.** It is possible to perform a Cluster backup and restore between different architectures. Previously—for example—you could not back up a cluster running on a big-endian platform and then restore from that backup to a cluster running on a little-endian system. (Bug #19255)

- **Multiple data nodes, multi-threaded data nodes.** NDB Cluster 7.2 supports multiple data node processes on a single host as well as multi-threaded data node processes. See Section 18.4.3, “ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded)”, for more information.

- **Identifiers.** Formerly (in MySQL 5.0 and earlier), database names, table names and attribute names could not be as long for NDB tables as tables using other storage engines, because attribute names were truncated internally. In MySQL 5.1 and later, names of NDB Cluster databases, tables, and table columns follow the same rules regarding length as they do for any other storage engine.

- **Length of CREATE TABLE statements.** CREATE TABLE statements may be no more than 4096 characters in length. *This limitation affects MySQL 5.1.6, 5.1.7, and 5.1.8 only*. (See Bug #17813)

- **IGNORE and REPLACE functionality.** In MySQL 5.1.7 and earlier, INSERT IGNORE, UPDATE IGNORE, and REPLACE were supported only for primary keys, but not for unique keys. It was possible to work around this issue by removing the constraint, then dropping the unique index, performing any inserts, and then adding the unique index again.

  This limitation was removed for INSERT IGNORE and REPLACE in MySQL 5.1.8. (See Bug #17431.)

- **AUTO_INCREMENT columns.** In MySQL 5.1.10 and earlier versions, the maximum number of tables having AUTO_INCREMENT columns—including those belonging to hidden primary keys—was 2048.

  This limitation was lifted in MySQL 5.1.11.

- **Maximum number of cluster nodes.** The total maximum number of nodes in an NDB Cluster is 255, including all SQL nodes (MySQL Servers), API nodes (applications accessing the cluster other than MySQL servers), data nodes, and management servers. The total number of data nodes and management nodes is 63, of which up to 48 can be data nodes.

  Note

  A data node cannot have a node ID greater than 49.

- **Recovery of memory from deleted rows.** Memory can be reclaimed from an NDB table for reuse with any NDB table by employing OPTIMIZE TABLE, subject to the following limitations:

  - Only in-memory tables are supported; the OPTIMIZE TABLE statement has no effect on NDB Cluster Disk Data tables.

  - Only variable-length columns (such as those declared as VARCHAR, TEXT, or BLOB) are supported.

    However, you can force columns defined using fixed-length data types (such as CHAR) to be dynamic using the ROW_FORMAT or COLUMN_FORMAT option with a CREATE TABLE or ALTER TABLE statement.

    See Section 13.1.17, “CREATE TABLE Syntax”, and Section 13.1.7, “ALTER TABLE Syntax”, for information on these options.

  You can regulate the effects of OPTIMIZE on performance by adjusting the value of the global system variable ndb_optimization_delay, which sets the number of milliseconds to wait between batches of rows being processed by OPTIMIZE. The default value is 10 milliseconds. It is possible to set a lower value (to a minimum of 0), but not recommended. The maximum is 100000 milliseconds (that is, 100 seconds).

- **Number of tables.** The maximum number of `NDBCLUSTER` tables in a single NDB Cluster is included in the total maximum number of `NDBCLUSTER` database objects (20320). (See Section 18.1.6.5, “Limits Associated with Database Objects in NDB Cluster”.)

- **Adding and dropping of data nodes.** In NDB Cluster 7.2 (NDB Cluster 7.0 and later), it is possible to add new data nodes to a running NDB Cluster by performing a rolling restart, so that the cluster and the data stored in it remain available to applications.

  When planning to increase the number of data nodes in the cluster online, you should be aware of and take into account the following issues:

  - New data nodes can be added online to an NDB Cluster only as part of a new node group.

  - New data nodes can be added online, but cannot be dropped online. Reducing the number of data nodes requires a system restart of the cluster.

  - As in previous NDB Cluster releases, it is not possible to change online either the number of replicas (`NoOfReplicas` configuration parameter) or the number of data nodes per node group. These changes require a system restart.

  - Redistribution of existing cluster data using the new data nodes is not automatic; however, this can be accomplished using simple SQL statements in the `mysql` client or other MySQL client application once the nodes have been added. During this procedure, it is not possible to perform DDL operations, although DML operations can continue as normal.

    The distribution of new cluster data (that is, data stored in the cluster *after* the new nodes have been added) uses the new nodes without manual intervention.

  For more information, see Section 18.5.13, “Adding NDB Cluster Data Nodes Online”.

- **Native support for default column values.** Starting with NDB 7.1.0, default values for table columns are stored by `NDBCLUSTER`, rather than by the MySQL server as was previously the case. Because less data must be sent from an SQL node to the data nodes, inserts on tables having column value defaults can be performed more efficiently than before.

  Tables created using previous NDB Cluster releases can still be used in NDB 7.1.0 and later, although they do not support native default values and continue to use defaults supplied by the MySQL server until they are upgraded. This can be done by means of an offline `ALTER TABLE` statement.

  Important

  You cannot set or change a table column's default value using an online `ALTER TABLE` operation

- **Distribution of MySQL users and privileges.** Previously, MySQL users and privileges created on one SQL node were unique to that SQL node, due to the fact that the MySQL grant tables were restricted to using the `MyISAM` storage engine. Beginning with NDB 7.2.0, it is possible, following installation of the NDB Cluster software and setup of the desired users and privileges on one SQL node, to convert the grant tables to use `NDB` and thus to distribute the users and privileges across all SQL nodes connected to the cluster. You can do this by loading and making use of a set of stored procedures defined in an SQL script supplied with the NDB Cluster distribution. For more information, see Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”.

- **Number of rows per partition.** Previously, a single NDB Cluster partition could hold a maximum of 46137488 rows. This limitation was removed in NDB 7.2.9. (Bug #13844405, Bug #14000373)

  If you are still using a previous NDB Cluster release, you can work around this limitation by taking advantage of the fact that the number of partitions is the same as the number of data nodes in the cluster (see Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”). This

means that, by increasing the number of data nodes, you can increase the available space for storing data.

NDB Cluster 7.2 also supports increasing the number of data nodes in the cluster while the cluster remains in operation. See Section 18.5.13, “Adding NDB Cluster Data Nodes Online”, for more information.

It is also possible to increase the number of partitions for `NDB` tables by using explicit `KEY` or `LINEAR KEY` partitioning (see Section 19.2.5, “KEY Partitioning”).

18.2 NDB Cluster Installation

This section describes the basics for planning, installing, configuring, and running an NDB Cluster. Whereas the examples in Section 18.3, “Configuration of NDB Cluster” provide more in-depth information on a variety of clustering options and configuration, the result of following the guidelines and procedures outlined here should be a usable NDB Cluster which meets the *minimum* requirements for availability and safeguarding of data.

For information about upgrading or downgrading an NDB Cluster between release versions, see Section 18.2.7, “Upgrading and Downgrading NDB Cluster”.

This section covers hardware and software requirements; networking issues; installation of NDB Cluster; configuration issues; starting, stopping, and restarting the cluster; loading of a sample database; and performing queries.

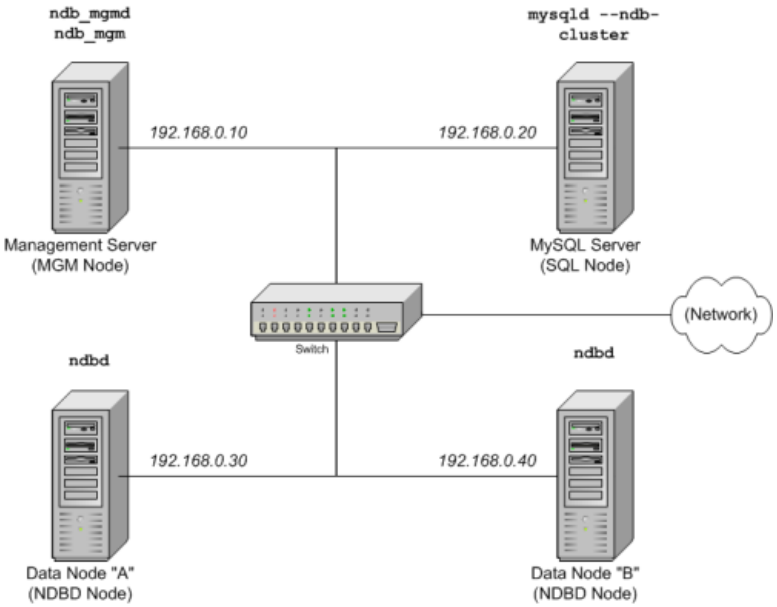
Assumptions. The following sections make a number of assumptions regarding the cluster's physical and network configuration. These assumptions are discussed in the next few paragraphs.

Cluster nodes and host computers. The cluster consists of four nodes, each on a separate host computer, and each with a fixed network address on a typical Ethernet network as shown here:

Node	IP Address
Management node (`mgmd`)	198.51.100.10
SQL node (`mysqld`)	198.51.100.20
Data node "A" (`ndbd`)	198.51.100.30
Data node "B" (`ndbd`)	198.51.100.40

This may be made clearer by the following diagram:

Figure 18.4 NDB Cluster Multi-Computer Setup



Network addressing. In the interest of simplicity (and reliability), this *How-To* uses only numeric IP addresses. However, if DNS resolution is available on your network, it is possible to use host names in lieu of IP addresses in configuring Cluster. Alternatively, you can use the `hosts` file (typically `/etc/hosts` for Linux and other Unix-like operating systems, `C:\WINDOWS\system32\drivers\etc\hosts` on Windows, or your operating system's equivalent) for providing a means to do host lookup if such is available.

Potential hosts file issues. A common problem when trying to use host names for Cluster nodes arises because of the way in which some operating systems (including some Linux distributions) set up the system's own host name in the `/etc/hosts` during installation. Consider two machines with the host names `ndb1` and `ndb2`, both in the `cluster` network domain. Red Hat Linux (including some derivatives such as CentOS and Fedora) places the following entries in these machines' `/etc/hosts` files:

```
#  ndb1 /etc/hosts:
127.0.0.1   ndb1.cluster ndb1 localhost.localdomain localhost
```

```
#  ndb2 /etc/hosts:
127.0.0.1   ndb2.cluster ndb2 localhost.localdomain localhost
```

SUSE Linux (including OpenSUSE) places these entries in the machines' `/etc/hosts` files:

```
#  ndb1 /etc/hosts:
127.0.0.1       localhost
127.0.0.2       ndb1.cluster ndb1
```

```
#  ndb2 /etc/hosts:
127.0.0.1       localhost
127.0.0.2       ndb2.cluster ndb2
```

In both instances, `ndb1` routes `ndb1.cluster` to a loopback IP address, but gets a public IP address from DNS for `ndb2.cluster`, while `ndb2` routes `ndb2.cluster` to a loopback address and obtains a public address for `ndb1.cluster`. The result is that each data node connects to the management server, but cannot tell when any other data nodes have connected, and so the data nodes appear to hang while starting.

Caution

You cannot mix `localhost` and other host names or IP addresses in `config.ini`. For these reasons, the solution in such cases (other than to use IP addresses for *all* `config.ini` `HostName` entries) is to remove the fully qualified host names from `/etc/hosts` and use these in `config.ini` for all cluster hosts.

Host computer type. Each host computer in our installation scenario is an Intel-based desktop PC running a supported operating system installed to disk in a standard configuration, and running no unnecessary services. The core operating system with standard TCP/IP networking capabilities should be sufficient. Also for the sake of simplicity, we also assume that the file systems on all hosts are set up identically. In the event that they are not, you should adapt these instructions accordingly.

Network hardware. Standard 100 Mbps or 1 gigabit Ethernet cards are installed on each machine, along with the proper drivers for the cards, and that all four hosts are connected through a standard-issue Ethernet networking appliance such as a switch. (All machines should use network cards with the same throughput. That is, all four machines in the cluster should have 100 Mbps cards *or* all four machines should have 1 Gbps cards.) NDB Cluster works in a 100 Mbps network; however, gigabit Ethernet provides better performance.

Important

NDB Cluster is *not* intended for use in a network for which throughput is less than 100 Mbps or which experiences a high degree of latency. For this reason (among others), attempting to run an NDB Cluster over a wide area network such as the Internet is not likely to be successful, and is not supported in production.

Sample data. We use the `world` database which is available for download from the MySQL Web site (see http://dev.mysql.com/doc/index-other.html). We assume that each machine has sufficient memory for running the operating system, required NDB Cluster processes, and (on the data nodes) storing the database.

For general information about installing MySQL, see Chapter 2, *Installing and Upgrading MySQL*. For information about installation of NDB Cluster on Linux and other Unix-like operating systems, see Section 18.2.1, “Installing NDB Cluster on Linux”. For information about installation of NDB Cluster on Windows operating systems, see Section 18.2.2, “Installing NDB Cluster on Windows”.

For general information about NDB Cluster hardware, software, and networking requirements, see Section 18.1.3, “NDB Cluster Hardware, Software, and Networking Requirements”.

18.2.1 Installing NDB Cluster on Linux

This section covers installation of NDB Cluster on Linux and other Unix-like operating systems. While the next few sections refer to a Linux operating system, the instructions and procedures given there should be easily adaptable to other supported Unix-like platforms.

NDB Cluster 7.2 is also available for Windows operating systems; for installation and setup instructions specific to Windows, see Section 18.2.2, “Installing NDB Cluster on Windows”.

Each NDB Cluster host computer must have the correct executable programs installed. A host running an SQL node must have installed on it a MySQL Server binary (`mysqld`). Management nodes require the management server daemon (`ndb_mgmd`); data nodes require the data node daemon (`ndbd` or `ndbmtd`). It is not necessary to install the MySQL Server binary on management node hosts and data node hosts. It is recommended that you also install the management client (`ndb_mgm`) on the management server host.

Installation of NDB Cluster on Linux can be done using precompiled binaries from Oracle (downloaded as a .tar.gz archive), with RPM packages (also available from Oracle), or from source code. All three of these installation methods are described in the section that follow.

Regardless of the method used, it is still necessary following installation of the NDB Cluster binaries to create configuration files for all cluster nodes, before you can start the cluster. See Section 18.2.3, “Initial Configuration of NDB Cluster”.

18.2.1.1 Installing an NDB Cluster Binary Release on Linux

This section covers the steps necessary to install the correct executables for each type of Cluster node from precompiled binaries supplied by Oracle.

For setting up a cluster using precompiled binaries, the first step in the installation process for each cluster host is to download the latest NDB Cluster 7.2 binary archive (`mysql-cluster-gpl-7.2.32-linux-i686-glibc23.tar.gz`) from the NDB Cluster downloads area. We assume that you have placed this file in each machine's `/var/tmp` directory. (If you do require a custom binary, see Section 2.9.3, “Installing MySQL Using a Development Source Tree”.)

Note

After completing the installation, do not yet start any of the binaries. We show you how to do so following the configuration of the nodes (see Section 18.2.3, “Initial Configuration of NDB Cluster”).

SQL nodes. On each of the machines designated to host SQL nodes, perform the following steps as the system `root` user:

1. Check your `/etc/passwd` and `/etc/group` files (or use whatever tools are provided by your operating system for managing users and groups) to see whether there is already a `mysql` group and `mysql` user on the system. Some OS distributions create these as part of the operating system installation process. If they are not already present, create a new `mysql` user group, and then add a `mysql` user to this group:

   ```
   shell> groupadd mysql
   shell> useradd -g mysql -s /bin/false mysql
   ```

   The syntax for `useradd` and `groupadd` may differ slightly on different versions of Unix, or they may have different names such as `adduser` and `addgroup`.

2. Change location to the directory containing the downloaded file, unpack the archive, and create a symbolic link named `mysql` to the `mysql` directory.

   Note

   The actual file and directory names vary according to the NDB Cluster version number.

   ```
   shell> cd /var/tmp
   shell> tar -C /usr/local -xzvf mysql-cluster-gpl-7.2.32-linux2.6.tar.gz
   shell> ln -s /usr/local/mysql-cluster-gpl-7.2.32-linux2.6-i686 /usr/local/mysql
   ```

3. Change location to the `mysql` directory and run the supplied script for creating the system databases:

   ```
   shell> cd mysql
   shell> scripts/mysql_install_db --user=mysql
   ```

4. Set the necessary permissions for the MySQL server and data directories:

   ```
   shell> chown -R root .
   shell> chown -R mysql data
   shell> chgrp -R mysql .
   ```

5. Copy the MySQL startup script to the appropriate directory, make it executable, and set it to start when the operating system is booted up:

```
shell> cp support-files/mysql.server /etc/rc.d/init.d/
shell> chmod +x /etc/rc.d/init.d/mysql.server
shell> chkconfig --add mysql.server
```

   (The startup scripts directory may vary depending on your operating system and version—for example, in some Linux distributions, it is `/etc/init.d`.)

   Here we use Red Hat's `chkconfig` for creating links to the startup scripts; use whatever means is appropriate for this purpose on your platform, such as `update-rc.d` on Debian.

Remember that the preceding steps must be repeated on each machine where an SQL node is to reside.

Data nodes. Installation of the data nodes does not require the `mysqld` binary. Only the NDB Cluster data node executable `ndbd` (single-threaded) or `ndbmtd` (multi-threaded) is required. These binaries can also be found in the `.tar.gz` archive. Again, we assume that you have placed this archive in `/var/tmp`.

As system `root` (that is, after using `sudo`, `su root`, or your system's equivalent for temporarily assuming the system administrator account's privileges), perform the following steps to install the data node binaries on the data node hosts:

1. Change location to the `/var/tmp` directory, and extract the `ndbd` and `ndbmtd` binaries from the archive into a suitable directory such as `/usr/local/bin`:

```
shell> cd /var/tmp
shell> tar -zxvf mysql-5.5.58-ndb-7.2.32-linux-i686-glibc23.tar.gz
shell> cd mysql-5.5.58-ndb-7.2.32-linux-i686-glibc23
shell> cp bin/ndbd /usr/local/bin/ndbd
shell> cp bin/ndbmtd /usr/local/bin/ndbmtd
```

   (You can safely delete the directory created by unpacking the downloaded archive, and the files it contains, from `/var/tmp` once `ndb_mgm` and `ndb_mgmd` have been copied to the executables directory.)

2. Change location to the directory into which you copied the files, and then make both of them executable:

```
shell> cd /usr/local/bin
shell> chmod +x ndb*
```

The preceding steps should be repeated on each data node host.

Although only one of the data node executables is required to run an NDB Cluster data node, we have shown you how to install both `ndbd` and `ndbmtd` in the preceding instructions. We recommend that you do this when installing or upgrading NDB Cluster, even if you plan to use only one of them, since this will save time and trouble in the event that you later decide to change from one to the other.

Note

The data directory on each machine hosting a data node is `/usr/local/mysql/data`. This piece of information is essential when configuring the management node. (See Section 18.2.3, “Initial Configuration of NDB Cluster”.)

Management nodes. Installation of the management node does not require the `mysqld` binary. Only the NDB Cluster management server (`ndb_mgmd`) is required; you most likely want to install the management client (`ndb_mgm`) as well. Both of these binaries also be found in the `.tar.gz` archive. Again, we assume that you have placed this archive in `/var/tmp`.

As system `root`, perform the following steps to install `ndb_mgmd` and `ndb_mgm` on the management node host:

1. Change location to the `/var/tmp` directory, and extract the `ndb_mgm` and `ndb_mgmd` from the archive into a suitable directory such as `/usr/local/bin`:

   ```
   shell> cd /var/tmp
   shell> tar -zxvf mysql-5.5.58-ndb-7.2.32-linux2.6-i686.tar.gz
   shell> cd mysql-5.5.58-ndb-7.2.32-linux2.6-i686
   shell> cp bin/ndb_mgm* /usr/local/bin
   ```

   (You can safely delete the directory created by unpacking the downloaded archive, and the files it contains, from `/var/tmp` once `ndb_mgm` and `ndb_mgmd` have been copied to the executables directory.)

2. Change location to the directory into which you copied the files, and then make both of them executable:

   ```
   shell> cd /usr/local/bin
   shell> chmod +x ndb_mgm*
   ```

In Section 18.2.3, “Initial Configuration of NDB Cluster”, we create configuration files for all of the nodes in our example NDB Cluster.

18.2.1.2 Installing NDB Cluster from RPM

This section covers the steps necessary to install the correct executables for each type of NDB Cluster node using RPM packages supplied by Oracle.

RPMs are available for both 32-bit and 64-bit Linux platforms. The filenames for these RPMs use the following pattern:

```
MySQL-Cluster-component-producttype-ndbversion.distribution.architecture.rpm

component:= {server | client [| other]}

producttype:= {gpl | advanced}

ndbversion:= major.minor.release

distribution:= {sles10 | rhel5 | el6}

architecture:= {i386 | x86_64}
```

The *`component`* can be `server` or `client`. (Other values are possible, but since only the `server` and `client` components are required for a working NDB Cluster installation, we do not discuss them here.) The *`producttype`* for Community RPMs downloaded from http://dev.mysql.com/downloads/cluster/ is always `gpl`; `advanced` is used to indicate commercial releases. *`ndbversion`* represents the three-part `NDB` storage engine version number in 7.2.*x* format. The *`distribution`* can be one of `sles11` (SUSE Enterprise Linux 11), `rhel5` (Oracle Linux 5, Red Hat Enterprise Linux 4 and 5), or `el6` (Oracle Linux 6, Red Hat Enterprise Linux 6) The *`architecture`* is `i386` for 32-bit RPMs and `x86_64` for 64-bit versions.

For an NDB Cluster, one and possibly two RPMs are required:

- The `server` RPM (for example, `MySQL-Cluster-server-gpl-7.2.32-1.sles11.i386.rpm`), which supplies the core files needed to run a MySQL Server with `NDBCLUSTER` storage engine support (that is, as an NDB Cluster SQL node) as well as all NDB Cluster executables, including the management node, data node, and `ndb_mgm` client binaries. This RPM is always required for installing NDB Cluster 7.2.

- If you do not have your own client application capable of administering a MySQL server, you should also obtain and install the `client` RPM (for example, `MySQL-Cluster-client-gpl-7.2.32-1.sles11.i386.rpm`), which supplies the `mysql` client

The NDB Cluster version number in the RPM file names (shown here as `7.2.32`) can vary according to the version which you are actually using. *It is very important that all of the Cluster RPMs to be installed have the same version number*. The *`architecture`* designation should be appropriate to the machine on which the RPM is to be installed; in particular, you should keep in mind that 64-bit RPMs cannot be used with 32-bit operating systems.

Data nodes. On a computer that is to host a cluster data node it is necessary to install only the `server` RPM. To do so, copy this RPM to the data node host, and run the following command as the system root user, replacing the name shown for the RPM as necessary to match that of the RPM downloaded from the MySQL web site:

```
shell> rpm -Uhv MySQL-Cluster-server-gpl-7.2.32-1.sles11.i386.rpm
```

Although this installs all NDB Cluster binaries, only the program `ndbd` or `ndbmtd` (both in `/usr/sbin`) is actually needed to run an NDB Cluster data node.

SQL nodes. On each machine to be used for hosting a cluster SQL node, install the `server` RPM by executing the following command as the system root user, replacing the name shown for the RPM as necessary to match the name of the RPM downloaded from the MySQL web site:

```
shell> rpm -Uhv MySQL-Cluster-server-gpl-7.2.32-1.sles11.i386.rpm
```

This installs the MySQL server binary (`mysqld`) with `NDB` storage engine support in the `/usr/sbin` directory, as well as all needed MySQL Server support files. It also installs the `mysql.server` and `mysqld_safe` startup scripts (in `/usr/share/mysql` and `/usr/bin`, respectively). The RPM installer should take care of general configuration issues (such as creating the `mysql` user and group, if needed) automatically.

To administer the SQL node (MySQL server), you should also install the `client` RPM, as shown here:

```
shell> rpm -Uhv MySQL-Cluster-client-gpl-7.2.32-1.sles11.i386.rpm
```

This installs the `mysql` client program.

Management nodes. To install the NDB Cluster management server, it is necessary only to use the `server` RPM. Copy this RPM to the computer intended to host the management node, and then install it by running the following command as the system root user (replace the name shown for the RPM as necessary to match that of the `server` RPM downloaded from the MySQL web site):

```
shell> rpm -Uhv MySQL-Cluster-server-gpl-7.2.32-1.sles11.i386.rpm
```

Although this RPM installs many other files, only the management server binary `ndb_mgmd` (in the `/usr/sbin` directory) is actually required for running a management node. The `server` RPM also installs `ndb_mgm`, the `NDB` management client.

See Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”, for general information about installing MySQL using RPMs supplied by Oracle.

After installing from RPM, you still need to configure the cluster as discussed in Section 18.2.3, “Initial Configuration of NDB Cluster”.

Note

A number of RPMs used by NDB Cluster 7.1 were made obsolete and discontinued in NDB Cluster 7.2. These include the former `MySQL-Cluster-clusterj`, `MySQL-Cluster-extra`, `MySQL-Cluster-management`, `MySQL-Cluster-storage`, and `NDB Cluster-tools` RPMs; all of these

have been merged into the `MySQL-Cluster-server` RPM. When upgrading from an NDB Cluster 7.1 RPM installation to NDB 7.2.3 or an earlier NDB Cluster 7.2 release, it was necessary to remove these packages manually before installing the NDB Cluster 7.2 `MySQL-Cluster-server` RPM. This issue is fixed in NDB 7.2.4 and later, where the `MySQL-Cluster-server` package specifically obsoletes the discontinued packages (BUG #13545589).

18.2.1.3 Installing NDB Cluster Using .deb Files

The section provides information about installing NDB Cluster on Debian and related Linux distributions such Ubuntu using the .deb files supplied by Oracle for this purpose.

Oracle provides `.deb` installer files for NDB Cluster 7.2 for 32-bit and 64-bit platforms. For a Debian-based system, only a single installer file is necessary. This file is named using the pattern shown here, according to the applicable NDB Cluster version, Debian version, and architecture:

```
mysql-cluster-gpl-ndbver-debiandebianver-arch.deb
```

Here, *`ndbver`* is the 3-part `NDB` engine version number, *`debianver`* is the major version of Debian (for NDB Cluster 7.2, this is always `6.0`), and *`arch`* is one of `i686` or `x86_64`. In the examples that follow, we assume you wish to install NDB 7.2.21 on a 64-bit Debian 6 system; in this case, the installer file is named `mysql-cluster-gpl-7.2.21-debian6.0-x86_64.deb`.

Once you have downloaded the appropriate `.deb` file, you can install it from the command line using `dpkg`, like this:

```
shell> dpkg -i mysql-cluster-gpl-7.2.21-debian6.0-i686.deb
```

You can also remove it using `dpkg` as shown here:

```
shell> dpkg -r mysql
```

The installer file should also be compatible with most graphical package managers that work with `.deb` files, such as `GDebi` for the Gnome desktop.

The `.deb` file installs NDB Cluster under `/opt/mysql/server-version/`, where *`version`* is the 2-part release series version for the included MySQL server. For NDB Cluster 7.2, this is always `5.5`. The directory layout is the same as that for the generic Linux binary distribution (see Table 2.3, “MySQL Installation Layout for Generic Unix/Linux Binary Package”), with the exception that startup scripts and configuration files are found in `support-files` instead of `share`. All NDB Cluster executables, such as `ndb_mgm`, `ndbd`, and `ndb_mgmd`, are placed in the `bin` directory.

18.2.1.4 Building NDB Cluster from Source on Linux

This section provides information about compiling NDB Cluster on Linux and other Unix-like platforms. Building NDB Cluster from source is similar to building the standard MySQL Server, although it differs in a few key respects discussed here. For general information about building MySQL from source, see Section 2.9, “Installing MySQL from Source”. For information about compiling NDB Cluster on Windows platforms, see Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”.

Building NDB Cluster requires using the NDB Cluster sources. These are available from the NDB Cluster downloads page at http://dev.mysql.com/downloads/cluster/. The archived source file should have a name similar to `mysql-cluster-gpl-7.2.32.tar.gz`. You can also obtain MySQL development sources from launchpad.net. Attempting to build NDB Cluster from standard MySQL Server 5.5 sources is not supported.

The `WITH_NDBCLUSTER_STORAGE_ENGINE` option for `CMake` causes the binaries for the management nodes, data nodes, and other NDB Cluster programs to be built; it also causes `mysqld` to be compiled with `NDB` storage engine support. This option (or its alias `WITH_NDBCLUSTER`) is required when building NDB Cluster.

Important

Beginning with NDB 7.2.9, the `WITH_NDB_JAVA` option is enabled by default. This means that, by default, if `CMake` cannot find the location of Java on your system, the configuration process fails; if you do not wish to enable Java and ClusterJ support, you must indicate this explicitly by configuring the build using `-DWITH_NDB_JAVA=OFF`. (Bug #12379735) Use `WITH_CLASSPATH` to provide the Java classpath if needed.

For more information about `CMake` options specific to building NDB Cluster, see Options for Compiling NDB Cluster.

After you have run `make && make install` (or your system's equivalent), the result is similar to what is obtained by unpacking a precompiled binary to the same location.

Management nodes. When building from source and running the default `make install`, the management server and management client binaries (`ndb_mgmd` and `ndb_mgm`) can be found in `/usr/local/mysql/bin`. Only `ndb_mgmd` is required to be present on a management node host; however, it is also a good idea to have `ndb_mgm` present on the same host machine. Neither of these executables requires a specific location on the host machine's file system.

Data nodes. The only executable required on a data node host is the data node binary `ndbd` or `ndbmtd`. (`mysqld`, for example, does not have to be present on the host machine.) By default, when building from source, this file is placed in the directory `/usr/local/mysql/bin`. For installing on multiple data node hosts, only `ndbd` or `ndbmtd` need be copied to the other host machine or machines. (This assumes that all data node hosts use the same architecture and operating system; otherwise you may need to compile separately for each different platform.) The data node binary need not be in any particular location on the host's file system, as long as the location is known.

When compiling NDB Cluster from source, no special options are required for building multi-threaded data node binaries. Configuring the build with `NDB` storage engine support causes `ndbmtd` to be built automatically; `make install` places the `ndbmtd` binary in the installation `bin` directory along with `mysqld`, `ndbd`, and `ndb_mgm`.

SQL nodes. If you compile MySQL with clustering support, and perform the default installation (using `make install` as the system `root` user), `mysqld` is placed in `/usr/local/mysql/bin`. Follow the steps given in Section 2.9, “Installing MySQL from Source” to make `mysqld` ready for use. If you want to run multiple SQL nodes, you can use a copy of the same `mysqld` executable and its associated support files on several machines. The easiest way to do this is to copy the entire `/usr/local/mysql` directory and all directories and files contained within it to the other SQL node host or hosts, then repeat the steps from Section 2.9, “Installing MySQL from Source” on each machine. If you configure the build with a nondefault `PREFIX` option, you must adjust the directory accordingly.

In Section 18.2.3, “Initial Configuration of NDB Cluster”, we create configuration files for all of the nodes in our example NDB Cluster.

18.2.2 Installing NDB Cluster on Windows

NDB Cluster 7.2 binaries for Windows can be obtained from http://dev.mysql.com/downloads/cluster/. For information about installing NDB Cluster on Windows from a binary release provided by Oracle, see Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”.

It is also possible to compile and install NDB Cluster from source on Windows using Microsoft Visual Studio. For more information, see Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”.

18.2.2.1 Installing NDB Cluster on Windows from a Binary Release

This section describes a basic installation of NDB Cluster on Windows using a binary `no-install` NDB Cluster release provided by Oracle, using the same 4-node setup outlined in the beginning of this section (see Section 18.2, “NDB Cluster Installation”), as shown in the following table:

Node	IP Address
Management (MGMD) node	198.51.100.10
MySQL server (SQL) node	198.51.100.20
Data (NDBD) node "A"	198.51.100.30
Data (NDBD) node "B"	198.51.100.40

As on other platforms, the NDB Cluster host computer running an SQL node must have installed on it a MySQL Server binary (`mysqld.exe`). You should also have the MySQL client (`mysql.exe`) on this host. For management nodes and data nodes, it is not necessary to install the MySQL Server binary; however, each management node requires the management server daemon (`ndb_mgmd.exe`); each data node requires the data node daemon (`ndbd.exe` or `ndbmtd.exe`). For this example, we refer to `ndbd.exe` as the data node executable, but you can install `ndbmtd.exe`, the multi-threaded version of this program, instead, in exactly the same way. You should also install the management client (`ndb_mgm.exe`) on the management server host. This section covers the steps necessary to install the correct Windows binaries for each type of NDB Cluster node.

Note

As with other Windows programs, NDB Cluster executables are named with the `.exe` file extension. However, it is not necessary to include the `.exe` extension when invoking these programs from the command line. Therefore, we often simply refer to these programs in this documentation as `mysqld`, `mysql`, `ndb_mgmd`, and so on. You should understand that, whether we refer (for example) to `mysqld` or `mysqld.exe`, either name means the same thing (the MySQL Server program).

For setting up an NDB Cluster using Oracles's `no-install` binaries, the first step in the installation process is to download the latest NDB Cluster Windows binary archive from http://dev.mysql.com/downloads/cluster/. This archive has a filename of the form `mysql-cluster-gpl-noinstall-`*`ver`*`-win`*`arch`*`.zip`, where *`ver`* is the `NDB` storage engine version (such as `7.2.1`), and *`arch`* is the architecture (`32` for 32-bit binaries, and `64` for 64-bit binaries). For example, the NDB 7.2.1 `no-install` archive for 32-bit Windows systems is named `mysql-cluster-gpl-noinstall-7.2.1-win32.zip`.

You can run 32-bit NDB Cluster binaries on both 32-bit and 64-bit versions of Windows; however, 64-bit NDB Cluster binaries can be used only on 64-bit versions of Windows. If you are using a 32-bit version of Windows on a computer that has a 64-bit CPU, then you must use the 32-bit NDB Cluster binaries.

To minimize the number of files that need to be downloaded from the Internet or copied between machines, we start with the computer where you intend to run the SQL node.

SQL node. We assume that you have placed a copy of the `no-install` archive in the directory `C:\Documents and Settings\`*`username`*`\My Documents\Downloads` on the computer having the IP address 198.51.100.20, where *`username`* is the name of the current user. (You can obtain this name using `ECHO %USERNAME%` on the command line.) To install and run NDB Cluster executables as Windows services, this user should be a member of the `Administrators` group.

Extract all the files from the archive. The Extraction Wizard integrated with Windows Explorer is adequate for this task. (If you use a different archive program, be sure that it extracts all files and directories from the archive, and that it preserves the archive's directory structure.) When you are asked for a destination directory, enter `C:\`, which causes the Extraction Wizard to extract the archive to the directory `C:\mysql-cluster-gpl-noinstall-`*`ver`*`-win`*`arch`*. Rename this directory to `C:\mysql`.

It is possible to install the NDB Cluster binaries to directories other than `C:\mysql\bin`; however, if you do so, you must modify the paths shown in this procedure accordingly. In particular, if the MySQL Server (SQL node) binary is installed to a location other than `C:\mysql` or `C:\Program Files\MySQL\MySQL Server 5.5`, or if the SQL node's data directory is in a location other than `C:`

`\mysql\data` or `C:\Program Files\MySQL\MySQL Server 5.5\data`, extra configuration options must be used on the command line or added to the `my.ini` or `my.cnf` file when starting the SQL node. For more information about configuring a MySQL Server to run in a nonstandard location, see Section 2.3.7, "Installing MySQL on Microsoft Windows Using a `noinstall` ZIP Archive".

For a MySQL Server with NDB Cluster support to run as part of an NDB Cluster, it must be started with the options `--ndbcluster` and `--ndb-connectstring`. While you can specify these options on the command line, it is usually more convenient to place them in an option file. To do this, create a new text file in Notepad or another text editor. Enter the following configuration information into this file:

```
[mysqld]
# Options for mysqld process:
ndbcluster                      # run NDB storage engine
ndb-connectstring=198.51.100.10  # location of management server
```

You can add other options used by this MySQL Server if desired (see Section 2.3.7.2, "Creating an Option File"), but the file must contain the options shown, at a minimum. Save this file as `C:\mysql\my.ini`. This completes the installation and setup for the SQL node.

Data nodes. An NDB Cluster data node on a Windows host requires only a single executable, one of either `ndbd.exe` or `ndbmtd.exe`. For this example, we assume that you are using `ndbd.exe`, but the same instructions apply when using `ndbmtd.exe`. On each computer where you wish to run a data node (the computers having the IP addresses 198.51.100.30 and 198.51.100.40), create the directories `C:\mysql`, `C:\mysql\bin`, and `C:\mysql\cluster-data`; then, on the computer where you downloaded and extracted the `no-install` archive, locate `ndbd.exe` in the `C:\mysql\bin` directory. Copy this file to the `C:\mysql\bin` directory on each of the two data node hosts.

To function as part of an NDB Cluster, each data node must be given the address or hostname of the management server. You can supply this information on the command line using the `--ndb-connectstring` or `-c` option when starting each data node process. However, it is usually preferable to put this information in an option file. To do this, create a new text file in Notepad or another text editor and enter the following text:

```
[mysql_cluster]
# Options for data node process:
ndb-connectstring=198.51.100.10  # location of management server
```

Save this file as `C:\mysql\my.ini` on the data node host. Create another text file containing the same information and save it on as `C:mysql\my.ini` on the other data node host, or copy the my.ini file from the first data node host to the second one, making sure to place the copy in the second data node's `C:\mysql` directory. Both data node hosts are now ready to be used in the NDB Cluster, which leaves only the management node to be installed and configured.

Management node. The only executable program required on a computer used for hosting an NDB Cluster management node is the management server program `ndb_mgmd.exe`. However, in order to administer the NDB Cluster once it has been started, you should also install the NDB Cluster management client program `ndb_mgm.exe` on the same machine as the management server. Locate these two programs on the machine where you downloaded and extracted the `no-install` archive; this should be the directory `C:\mysql\bin` on the SQL node host. Create the directory `C:\mysql\bin` on the computer having the IP address 198.51.100.10, then copy both programs to this directory.

You should now create two configuration files for use by `ndb_mgmd.exe`:

1. A local configuration file to supply configuration data specific to the management node itself. Typically, this file needs only to supply the location of the NDB Cluster global configuration file (see item 2).

   To create this file, start a new text file in Notepad or another text editor, and enter the following information:

   ```
   [mysql_cluster]
   ```

```
# Options for management node process
config-file=C:/mysql/bin/config.ini
```

Save this file as the text file `C:\mysql\bin\my.ini`.

2. A global configuration file from which the management node can obtain configuration information governing the NDB Cluster as a whole. At a minimum, this file must contain a section for each node in the NDB Cluster, and the IP addresses or hostnames for the management node and all data nodes (`HostName` configuration parameter). It is also advisable to include the following additional information:

   - The IP address or hostname of any SQL nodes
   - The data memory and index memory allocated to each data node (`DataMemory` and `IndexMemory` configuration parameters)
   - The number of replicas, using the `NoOfReplicas` configuration parameter (see Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”)
   - The directory where each data node stores it data and log file, and the directory where the management node keeps its log files (in both cases, the `DataDir` configuration parameter)

   Create a new text file using a text editor such as Notepad, and input the following information:

```
[ndbd default]
# Options affecting ndbd processes on all data nodes:
NoOfReplicas=2                      # Number of replicas
DataDir=C:/mysql/cluster-data       # Directory for each data node's data files
                                    # Forward slashes used in directory path,
                                    # rather than backslashes. This is correct;
                                    # see Important note in text
DataMemory=80M    # Memory allocated to data storage
IndexMemory=18M   # Memory allocated to index storage
                  # For DataMemory and IndexMemory, we have used the
                  # default values. Since the "world" database takes up
                  # only about 500KB, this should be more than enough for
                  # this example Cluster setup.

[ndb_mgmd]
# Management process options:
HostName=198.51.100.10              # Hostname or IP address of management node
DataDir=C:/mysql/bin/cluster-logs   # Directory for management node log files

[ndbd]
# Options for data node "A":
                                # (one [ndbd] section per data node)
HostName=198.51.100.30          # Hostname or IP address

[ndbd]
# Options for data node "B":
HostName=198.51.100.40          # Hostname or IP address

[mysqld]
# SQL node options:
HostName=198.51.100.20          # Hostname or IP address
```

Save this file as the text file `C:\mysql\bin\config.ini`.

Important

A single backslash character (`\`) cannot be used when specifying directory paths in program options or configuration files used by NDB Cluster on Windows. Instead, you must either escape each backslash character with a second backslash (`\\`), or replace the backslash with a forward slash character (`/`). For example, the following line from the `[ndb_mgmd]` section of an NDB Cluster `config.ini` file does not work:

```
DataDir=C:\mysql\bin\cluster-logs
```

Instead, you may use either of the following:

```
DataDir=C:\\mysql\\bin\\cluster-logs  # Escaped backslashes
```

```
DataDir=C:/mysql/bin/cluster-logs     # Forward slashes
```

For reasons of brevity and legibility, we recommend that you use forward slashes in directory paths used in NDB Cluster program options and configuration files on Windows.

18.2.2.2 Compiling and Installing NDB Cluster from Source on Windows

Oracle provides precompiled NDB Cluster binaries for Windows which should be adequate for most users. However, if you wish, it is also possible to compile NDB Cluster for Windows from source code. The procedure for doing this is almost identical to the procedure used to compile the standard MySQL Server binaries for Windows, and uses the same tools. However, there are two major differences:

- To build NDB Cluster, you must use the NDB Cluster sources, which you can obtain from http://dev.mysql.com/downloads/cluster/.

  Attempting to build NDB Cluster from the source code for the standard MySQL Server is likely not to be successful, and is not supported by Oracle.

- You must configure the build using the `WITH_NDBCLUSTER_STORAGE_ENGINE` or `WITH_NDBCLUSTER` option in addition to any other build options you wish to use with `CMake`. (`WITH_NDBCLUSTER` is supported as an alias for `WITH_NDBCLUSTER_STORAGE_ENGINE`, and works in exactly the same way.)

Important

Beginning with NDB 7.2.9, the `WITH_NDB_JAVA` option is enabled by default. This means that, by default, if `CMake` cannot find the location of Java on your system, the configuration process fails; if you do not wish to enable Java and ClusterJ support, you must indicate this explicitly by configuring the build using `-DWITH_NDB_JAVA=OFF`. (Bug #12379735) Use `WITH_CLASSPATH` to provide the Java classpath if needed.

For more information about `CMake` options specific to building NDB Cluster, see Options for Compiling NDB Cluster.

Once the build process is complete, you can create a Zip archive containing the compiled binaries; Section 2.9.2, “Installing MySQL Using a Standard Source Distribution” provides the commands needed to perform this task on Windows systems. The NDB Cluster binaries can be found in the `bin` directory of the resulting archive, which is equivalent to the `no-install` archive, and which can be installed and configured in the same manner. For more information, see Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”.

18.2.2.3 Initial Startup of NDB Cluster on Windows

Once the NDB Cluster executables and needed configuration files are in place, performing an initial start of the cluster is simply a matter of starting the NDB Cluster executables for all nodes in the cluster. Each cluster node process must be started separately, and on the host computer where it resides. The management node should be started first, followed by the data nodes, and then finally by any SQL nodes.

1. On the management node host, issue the following command from the command line to start the management node process:

```
C:\mysql\bin> ndb_mgmd
2010-06-23 07:53:34 [MgmtSrvr] INFO -- NDB Cluster Management Server. mysql-5.5.58-ndb-7.2.32
2010-06-23 07:53:34 [MgmtSrvr] INFO -- Reading cluster configuration from 'config.ini'
```

The management node process continues to print logging output to the console. This is normal, because the management node is not running as a Windows service. (If you have used NDB Cluster on a Unix-like platform such as Linux, you may notice that the management node's default behavior in this regard on Windows is effectively the opposite of its behavior on Unix systems, where it runs by default as a Unix daemon process. This behavior is also true of NDB Cluster data node processes running on Windows.) For this reason, do not close the window in which `ndb_mgmd.exe` is running; doing so kills the management node process. (See Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”, where we show how to install and run NDB Cluster processes as Windows services.)

The required `-f` option tells the management node where to find the global configuration file (`config.ini`). The long form of this option is `--config-file`.

Important

An NDB Cluster management node caches the configuration data that it reads from `config.ini`; once it has created a configuration cache, it ignores the `config.ini` file on subsequent starts unless forced to do otherwise. This means that, if the management node fails to start due to an error in this file, you must make the management node re-read `config.ini` after you have corrected any errors in it. You can do this by starting `ndb_mgmd.exe` with the `--reload` or `--initial` option on the command line. Either of these options works to refresh the configuration cache.

It is not necessary or advisable to use either of these options in the management node's `my.ini` file.

For additional information about options which can be used with `ndb_mgmd`, see Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”, as well as Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

2. On each of the data node hosts, run the command shown here to start the data node processes:

```
C:\mysql\bin> ndbd
2010-06-23 07:53:46 [ndbd] INFO -- Configuration fetched from 'localhost:1186', generation: 1
```

In each case, the first line of output from the data node process should resemble what is shown in the preceding example, and is followed by additional lines of logging output. As with the management node process, this is normal, because the data node is not running as a Windows service. For this reason, do not close the console window in which the data node process is running; doing so kills `ndbd.exe`. (For more information, see Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”.)

3. Do not start the SQL node yet; it cannot connect to the cluster until the data nodes have finished starting, which may take some time. Instead, in a new console window on the management node host, start the NDB Cluster management client `ndb_mgm.exe`, which should be in `C:\mysql\bin` on the management node host. (Do not try to re-use the console window where `ndb_mgmd.exe` is running by typing **CTRL**+**C**, as this kills the management node.) The resulting output should look like this:

```
C:\mysql\bin> ndb_mgm
-- NDB Cluster -- Management Client --
ndb_mgm>
```

When the prompt `ndb_mgm>` appears, this indicates that the management client is ready to receive NDB Cluster management commands. You can observe the status of the data nodes as they start by entering `ALL STATUS` at the management client prompt. This command causes a running report of the data nodes's startup sequence, which should look something like this:

```
ndb_mgm> ALL STATUS
Connected to Management Server at: localhost:1186
Node 2: starting (Last completed phase 3) (mysql-5.5.58-ndb-7.2.32)
Node 3: starting (Last completed phase 3) (mysql-5.5.58-ndb-7.2.32)

Node 2: starting (Last completed phase 4) (mysql-5.5.58-ndb-7.2.32)
Node 3: starting (Last completed phase 4) (mysql-5.5.58-ndb-7.2.32)

Node 2: Started (version 7.2.32)
Node 3: Started (version 7.2.32)

ndb_mgm>
```

Note

Commands issued in the management client are not case-sensitive; we use uppercase as the canonical form of these commands, but you are not required to observe this convention when inputting them into the `ndb_mgm` client. For more information, see Section 18.5.2, “Commands in the NDB Cluster Management Client”.

The output produced by `ALL STATUS` is likely to vary from what is shown here, according to the speed at which the data nodes are able to start, the release version number of the NDB Cluster software you are using, and other factors. What is significant is that, when you see that both data nodes have started, you are ready to start the SQL node.

You can leave `ndb_mgm.exe` running; it has no negative impact on the performance of the NDB Cluster, and we use it in the next step to verify that the SQL node is connected to the cluster after you have started it.

4. On the computer designated as the SQL node host, open a console window and navigate to the directory where you unpacked the NDB Cluster binaries (if you are following our example, this is `C:\mysql\bin`).

   Start the SQL node by invoking `mysqld.exe` from the command line, as shown here:

   ```
   C:\mysql\bin> mysqld --console
   ```

   The `--console` option causes logging information to be written to the console, which can be helpful in the event of problems. (Once you are satisfied that the SQL node is running in a satisfactory manner, you can stop it and restart it out without the `--console` option, so that logging is performed normally.)

   In the console window where the management client (`ndb_mgm.exe`) is running on the management node host, enter the `SHOW` command, which should produce output similar to what is shown here:

   ```
   ndb_mgm> SHOW
   Connected to Management Server at: localhost:1186
   Cluster Configuration
   ---------------------
   [ndbd(NDB)]     2 node(s)
   id=2    @198.51.100.30  (Version: 5.5.58-ndb-7.2.32, Nodegroup: 0, *)
   id=3    @198.51.100.40  (Version: 5.5.58-ndb-7.2.32, Nodegroup: 0)

   [ndb_mgmd(MGM)] 1 node(s)
   ```

```
id=1    @198.51.100.10  (Version: 5.5.58-ndb-7.2.32)

[mysqld(API)]   1 node(s)
id=4    @198.51.100.20  (Version: 5.5.58-ndb-7.2.32)
```

You can also verify that the SQL node is connected to the NDB Cluster in the `mysql` client (`mysql.exe`) using the `SHOW ENGINE NDB STATUS` statement.

You should now be ready to work with database objects and data using NDB Cluster's `NDBCLUSTER` storage engine. See Section 18.2.5, “NDB Cluster Example with Tables and Data”, for more information and examples.

You can also install `ndb_mgmd.exe`, `ndbd.exe`, and `ndbmtd.exe` as Windows services. For information on how to do this, see Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”).

18.2.2.4 Installing NDB Cluster Processes as Windows Services

Once you are satisfied that NDB Cluster is running as desired, you can install the management nodes and data nodes as Windows services, so that these processes are started and stopped automatically whenever Windows is started or stopped. This also makes it possible to control these processes from the command line with the appropriate `NET START` or `NET STOP` command, or using the Windows graphical `Services` utility.

Installing programs as Windows services usually must be done using an account that has Administrator rights on the system.

To install the management node as a service on Windows, invoke `ndb_mgmd.exe` from the command line on the machine hosting the management node, using the `--install` option, as shown here:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --install
Installing service 'NDB Cluster Management Server'
  as '"C:\mysql\bin\ndbd.exe" "--service=ndb_mgmd"'
Service successfully installed.
```

Important

When installing an NDB Cluster program as a Windows service, you should always specify the complete path; otherwise the service installation may fail with the error `The system cannot find the file specified`.

The `--install` option must be used first, ahead of any other options that might be specified for `ndb_mgmd.exe`. However, it is preferable to specify such options in an options file instead. If your options file is not in one of the default locations as shown in the output of `ndb_mgmd.exe --help`, you can specify the location using the `--config-file` option.

Now you should be able to start and stop the management server like this:

```
C:\> NET START ndb_mgmd
The NDB Cluster Management Server service is starting.
The NDB Cluster Management Server service was started successfully.

C:\> NET STOP ndb_mgmd
The NDB Cluster Management Server service is stopping..
The NDB Cluster Management Server service was stopped successfully.
```

You can also start or stop the management server as a Windows service using the descriptive name, as shown here:

```
C:\> NET START 'NDB Cluster Management Server'
The NDB Cluster Management Server service is starting.
The NDB Cluster Management Server service was started successfully.
```

```
C:\> NET STOP  'NDB Cluster Management Server'
The NDB Cluster Management Server service is stopping..
The NDB Cluster Management Server service was stopped successfully.
```

However, it is usually simpler to specify a short service name or to permit the default service name to be used when installing the service, and then reference that name when starting or stopping the service. To specify a service name other than `ndb_mgmd`, append it to the `--install` option, as shown in this example:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --install=mgmd1
Installing service 'NDB Cluster Management Server'
  as '"C:\mysql\bin\ndb_mgmd.exe" "--service=mgmd1"'
Service successfully installed.
```

Now you should be able to start or stop the service using the name you have specified, like this:

```
C:\> NET START mgmd1
The NDB Cluster Management Server service is starting.
The NDB Cluster Management Server service was started successfully.

C:\> NET STOP mgmd1
The NDB Cluster Management Server service is stopping..
The NDB Cluster Management Server service was stopped successfully.
```

To remove the management node service, invoke `ndb_mgmd.exe` with the `--remove` option, as shown here:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --remove
Removing service 'NDB Cluster Management Server'
Service successfully removed.
```

If you installed the service using a service name other than the default, you can remove the service by passing this name as the value of the `--remove` option, like this:

```
C:\> C:\mysql\bin\ndb_mgmd.exe --remove=mgmd1
Removing service 'mgmd1'
Service successfully removed.
```

Installation of an NDB Cluster data node process as a Windows service can be done in a similar fashion, using the `--install` option for `ndbd.exe` (or `ndbmtd.exe`), as shown here:

```
C:\> C:\mysql\bin\ndbd.exe --install
Installing service 'NDB Cluster Data Node Daemon' as '"C:\mysql\bin\ndbd.exe" "--service=ndbd"'
Service successfully installed.
```

Now you can start or stop the data node using either the default service name or the descriptive name with `net start` or `net stop`, as shown in the following example:

```
C:\> NET START ndbd
The NDB Cluster Data Node Daemon service is starting.
The NDB Cluster Data Node Daemon service was started successfully.

C:\> NET STOP ndbd
The NDB Cluster Data Node Daemon service is stopping..
The NDB Cluster Data Node Daemon service was stopped successfully.

C:\> NET START 'NDB Cluster Data Node Daemon'
The NDB Cluster Data Node Daemon service is starting.
The NDB Cluster Data Node Daemon service was started successfully.

C:\> NET STOP 'NDB Cluster Data Node Daemon'
The NDB Cluster Data Node Daemon service is stopping..
The NDB Cluster Data Node Daemon service was stopped successfully.
```

To remove the data node service, invoke `ndbd.exe` with the `--remove` option, as shown here:

```
C:\> C:\mysql\bin\ndbd.exe --remove
Removing service 'NDB Cluster Data Node Daemon'
Service successfully removed.
```

As with `ndb_mgmd.exe` (and `mysqld.exe`), when installing `ndbd.exe` as a Windows service, you can also specify a name for the service as the value of `--install`, and then use it when starting or stopping the service, like this:

```
C:\> C:\mysql\bin\ndbd.exe --install=dnode1
Installing service 'dnode1' as '"C:\mysql\bin\ndbd.exe" "--service=dnode1"'
Service successfully installed.

C:\> NET START dnode1
The NDB Cluster Data Node Daemon service is starting.
The NDB Cluster Data Node Daemon service was started successfully.

C:\> NET STOP dnode1
The NDB Cluster Data Node Daemon service is stopping..
The NDB Cluster Data Node Daemon service was stopped successfully.
```

If you specified a service name when installing the data node service, you can use this name when removing it as well, by passing it as the value of the `--remove` option, as shown here:

```
C:\> C:\mysql\bin\ndbd.exe --remove=dnode1
Removing service 'dnode1'
Service successfully removed.
```

Installation of the SQL node as a Windows service, starting the service, stopping the service, and removing the service are done in a similar fashion, using `mysqld --install`, `NET START`, `NET STOP`, and `mysqld --remove`. For additional information, see Section 2.3.7.7, “Starting MySQL as a Windows Service”.

18.2.3 Initial Configuration of NDB Cluster

For our four-node, four-host NDB Cluster, it is necessary to write four configuration files, one per node host.

- Each data node or SQL node requires a `my.cnf` file that provides two pieces of information: a *connection string* that tells the node where to find the management node, and a line telling the MySQL server on this host (the machine hosting the data node) to enable the `NDBCLUSTER` storage engine.

  For more information on connection strings, see Section 18.3.3.3, “NDB Cluster Connection Strings”.

- The management node needs a `config.ini` file telling it how many replicas to maintain, how much memory to allocate for data and indexes on each data node, where to find the data nodes, where to save data to disk on each data node, and where to find any SQL nodes.

Configuring the data nodes and SQL nodes. The `my.cnf` file needed for the data nodes is fairly simple. The configuration file should be located in the `/etc` directory and can be edited using any text editor. (Create the file if it does not exist.) For example:

```
shell> vi /etc/my.cnf
```

Note

We show `vi` being used here to create the file, but any text editor should work just as well.

For each data node and SQL node in our example setup, `my.cnf` should look like this:

```
[mysqld]
# Options for mysqld process:
ndbcluster                      # run NDB storage engine

[mysql_cluster]
# Options for NDB Cluster processes:
ndb-connectstring=198.51.100.10  # location of management server
```

After entering the preceding information, save this file and exit the text editor. Do this for the machines hosting data node “A”, data node “B”, and the SQL node.

Important

Once you have started a `mysqld` process with the `ndbcluster` and `ndb-connectstring` parameters in the `[mysqld]` and `[mysql_cluster]` sections of the `my.cnf` file as shown previously, you cannot execute any `CREATE TABLE` or `ALTER TABLE` statements without having actually started the cluster. Otherwise, these statements will fail with an error. This is by design.

Configuring the management node. The first step in configuring the management node is to create the directory in which the configuration file can be found and then to create the file itself. For example (running as `root`):

```
shell> mkdir /var/lib/mysql-cluster
shell> cd /var/lib/mysql-cluster
shell> vi config.ini
```

For our representative setup, the `config.ini` file should read as follows:

```
[ndbd default]
# Options affecting ndbd processes on all data nodes:
NoOfReplicas=2    # Number of replicas
DataMemory=80M    # How much memory to allocate for data storage
IndexMemory=18M   # How much memory to allocate for index storage
                  # For DataMemory and IndexMemory, we have used the
                  # default values. Since the "world" database takes up
                  # only about 500KB, this should be more than enough for
                  # this example Cluster setup.

[tcp default]
# TCP/IP options:
PortNumber=2202   # This the default; however, you can use any
                  # port that is free for all the hosts in the cluster
                  # Note: It is recommended that you do not specify the port
                  # number at all and simply allow the default value to be used
                  # instead

[ndb_mgmd]
# Management process options:
HostName=198.51.100.10          # Hostname or IP address of MGM node
DataDir=/var/lib/mysql-cluster  # Directory for MGM node log files

[ndbd]
# Options for data node "A":
                                # (one [ndbd] section per data node)
HostName=198.51.100.30          # Hostname or IP address
NodeId=2                        # Node ID for this data node
DataDir=/usr/local/mysql/data   # Directory for this data node's data files

[ndbd]
# Options for data node "B":
HostName=198.51.100.40          # Hostname or IP address
NodeId=3                        # Node ID for this data node
DataDir=/usr/local/mysql/data   # Directory for this data node's data files

[mysqld]
# SQL node options:
```

```
HostName=198.51.100.20          # Hostname or IP address
                                # (additional mysqld connections can be
                                # specified for this node for various
                                # purposes such as running ndb_restore)
```

Note

The `world` database can be downloaded from http://dev.mysql.com/doc/index-other.html.

After all the configuration files have been created and these minimal options have been specified, you are ready to proceed with starting the cluster and verifying that all processes are running. We discuss how this is done in Section 18.2.4, “Initial Startup of NDB Cluster”.

For more detailed information about the available NDB Cluster configuration parameters and their uses, see Section 18.3.3, “NDB Cluster Configuration Files”, and Section 18.3, “Configuration of NDB Cluster”. For configuration of NDB Cluster as relates to making backups, see Section 18.5.3.3, “Configuration for NDB Cluster Backups”.

Note

The default port for Cluster management nodes is 1186; the default port for data nodes is 2202. However, the cluster can automatically allocate ports for data nodes from those that are already free.

18.2.4 Initial Startup of NDB Cluster

Starting the cluster is not very difficult after it has been configured. Each cluster node process must be started separately, and on the host where it resides. The management node should be started first, followed by the data nodes, and then finally by any SQL nodes:

1. On the management host, issue the following command from the system shell to start the management node process:

   ```
   shell> ndb_mgmd -f /var/lib/mysql-cluster/config.ini
   ```

   The first time that it is started, `ndb_mgmd` must be told where to find its configuration file, using the `-f` or `--config-file` option. (See Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”, for details.)

   For additional options which can be used with `ndb_mgmd`, see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

2. On each of the data node hosts, run this command to start the `ndbd` process:

   ```
   shell> ndbd
   ```

3. If you used RPM files to install MySQL on the cluster host where the SQL node is to reside, you can (and should) use the supplied startup script to start the MySQL server process on the SQL node.

If all has gone well, and the cluster has been set up correctly, the cluster should now be operational. You can test this by invoking the `ndb_mgm` management node client. The output should look like that shown here, although you might see some slight differences in the output depending upon the exact version of MySQL that you are using:

```
shell> ndb_mgm
-- NDB Cluster -- Management Client --
ndb_mgm> SHOW
Connected to Management Server at: localhost:1186
Cluster Configuration
---------------------
```

```
[ndbd(NDB)]     2 node(s)
id=2    @198.51.100.30  (Version: 5.5.58-ndb-7.2.32, Nodegroup: 0, *)
id=3    @198.51.100.40  (Version: 5.5.58-ndb-7.2.32, Nodegroup: 0)

[ndb_mgmd(MGM)] 1 node(s)
id=1    @198.51.100.10  (Version: 5.5.58-ndb-7.2.32)

[mysqld(API)]   1 node(s)
id=4    @198.51.100.20  (Version: 5.5.58-ndb-7.2.32)
```

The SQL node is referenced here as `[mysqld(API)]`, which reflects the fact that the `mysqld` process is acting as an NDB Cluster API node.

Note

The IP address shown for a given NDB Cluster SQL or other API node in the output of `SHOW` is the address used by the SQL or API node to connect to the cluster data nodes, and not to any management node.

You should now be ready to work with databases, tables, and data in NDB Cluster. See Section 18.2.5, “NDB Cluster Example with Tables and Data”, for a brief discussion.

18.2.5 NDB Cluster Example with Tables and Data

Note

The information in this section applies to NDB Cluster running on both Unix and Windows platforms.

Working with database tables and data in NDB Cluster is not much different from doing so in standard MySQL. There are two key points to keep in mind:

- For a table to be replicated in the cluster, it must use the `NDBCLUSTER` storage engine. To specify this, use the `ENGINE=NDBCLUSTER` or `ENGINE=NDB` option when creating the table:

  ```
  CREATE TABLE tbl_name (col_name column_definitions) ENGINE=NDBCLUSTER;
  ```

  Alternatively, for an existing table that uses a different storage engine, use `ALTER TABLE` to change the table to use `NDBCLUSTER`:

  ```
  ALTER TABLE tbl_name ENGINE=NDBCLUSTER;
  ```

- Every `NDBCLUSTER` table has a primary key. If no primary key is defined by the user when a table is created, the `NDBCLUSTER` storage engine automatically generates a hidden one. Such a key takes up space just as does any other table index. (It is not uncommon to encounter problems due to insufficient memory for accommodating these automatically created indexes.)

If you are importing tables from an existing database using the output of `mysqldump`, you can open the SQL script in a text editor and add the `ENGINE` option to any table creation statements, or replace any existing `ENGINE` options. Suppose that you have the `world` sample database on another MySQL server that does not support NDB Cluster, and you want to export the `City` table:

```
shell> mysqldump --add-drop-table world City > city_table.sql
```

The resulting `city_table.sql` file will contain this table creation statement (and the `INSERT` statements necessary to import the table data):

```
DROP TABLE IF EXISTS `City`;
CREATE TABLE `City` (
  `ID` int(11) NOT NULL auto_increment,
  `Name` char(35) NOT NULL default '',
  `CountryCode` char(3) NOT NULL default '',
```

```
  `District` char(20) NOT NULL default '',
  `Population` int(11) NOT NULL default '0',
  PRIMARY KEY  (`ID`)
) ENGINE=MyISAM DEFAULT CHARSET=latin1;

INSERT INTO `City` VALUES (1,'Kabul','AFG','Kabol',1780000);
INSERT INTO `City` VALUES (2,'Qandahar','AFG','Qandahar',237500);
INSERT INTO `City` VALUES (3,'Herat','AFG','Herat',186800);
(remaining INSERT statements omitted)
```

You need to make sure that MySQL uses the `NDBCLUSTER` storage engine for this table. There are two ways that this can be accomplished. One of these is to modify the table definition *before* importing it into the Cluster database. Using the `City` table as an example, modify the `ENGINE` option of the definition as follows:

```
DROP TABLE IF EXISTS `City`;
CREATE TABLE `City` (
  `ID` int(11) NOT NULL auto_increment,
  `Name` char(35) NOT NULL default '',
  `CountryCode` char(3) NOT NULL default '',
  `District` char(20) NOT NULL default '',
  `Population` int(11) NOT NULL default '0',
  PRIMARY KEY  (`ID`)
) ENGINE=NDBCLUSTER DEFAULT CHARSET=latin1;

INSERT INTO `City` VALUES (1,'Kabul','AFG','Kabol',1780000);
INSERT INTO `City` VALUES (2,'Qandahar','AFG','Qandahar',237500);
INSERT INTO `City` VALUES (3,'Herat','AFG','Herat',186800);
(remaining INSERT statements omitted)
```

This must be done for the definition of each table that is to be part of the clustered database. The easiest way to accomplish this is to do a search-and-replace on the file that contains the definitions and replace all instances of `TYPE=engine_name` or `ENGINE=engine_name` with `ENGINE=NDBCLUSTER`. If you do not want to modify the file, you can use the unmodified file to create the tables, and then use `ALTER TABLE` to change their storage engine. The particulars are given later in this section.

Assuming that you have already created a database named `world` on the SQL node of the cluster, you can then use the `mysql` command-line client to read `city_table.sql`, and create and populate the corresponding table in the usual manner:

```
shell> mysql world < city_table.sql
```

It is very important to keep in mind that the preceding command must be executed on the host where the SQL node is running (in this case, on the machine with the IP address `198.51.100.20`).

To create a copy of the entire `world` database on the SQL node, use `mysqldump` on the noncluster server to export the database to a file named `world.sql`; for example, in the `/tmp` directory. Then modify the table definitions as just described and import the file into the SQL node of the cluster like this:

```
shell> mysql world < /tmp/world.sql
```

If you save the file to a different location, adjust the preceding instructions accordingly.

Running `SELECT` queries on the SQL node is no different from running them on any other instance of a MySQL server. To run queries from the command line, you first need to log in to the MySQL Monitor in the usual way (specify the `root` password at the `Enter password:` prompt):

```
shell> mysql -u root -p
Enter password:
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 1 to server version: 5.5.58-ndb-7.2.32

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.
```

```
mysql>
```

We simply use the MySQL server's `root` account and assume that you have followed the standard security precautions for installing a MySQL server, including setting a strong `root` password. For more information, see Section 2.10.4, “Securing the Initial MySQL Accounts”.

It is worth taking into account that Cluster nodes do *not* make use of the MySQL privilege system when accessing one another. Setting or changing MySQL user accounts (including the `root` account) effects only applications that access the SQL node, not interaction between nodes. See Section 18.5.11.2, “NDB Cluster and MySQL Privileges”, for more information.

If you did not modify the `ENGINE` clauses in the table definitions prior to importing the SQL script, you should run the following statements at this point:

```
mysql> USE world;
mysql> ALTER TABLE city ENGINE=NDBCLUSTER;
mysql> ALTER TABLE country ENGINE=NDBCLUSTER;
mysql> ALTER TABLE countrylanguage ENGINE=NDBCLUSTER;
```

Selecting a database and running a `SELECT` query against a table in that database is also accomplished in the usual manner, as is exiting the MySQL Monitor:

```
mysql> USE world;
mysql> SELECT Name, Population FROM city ORDER BY Population DESC LIMIT 5;
+-----------+------------+
| Name      | Population |
+-----------+------------+
| Bombay    |   10500000 |
| Seoul     |    9981619 |
| São Paulo |    9968485 |
| Shanghai  |    9696300 |
| Jakarta   |    9604900 |
+-----------+------------+
5 rows in set (0.34 sec)

mysql> \q
Bye

shell>
```

Applications that use MySQL can employ standard APIs to access `NDB` tables. It is important to remember that your application must access the SQL node, and not the management or data nodes. This brief example shows how we might execute the `SELECT` statement just shown by using the PHP 5.X `mysqli` extension running on a Web server elsewhere on the network:

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
  "http://www.w3.org/TR/html4/loose.dtd">
<html>
<head>
  <meta http-equiv="Content-Type"
          content="text/html; charset=iso-8859-1">
  <title>SIMPLE mysqli SELECT</title>
</head>
<body>
<?php
  # connect to SQL node:
  $link = new mysqli('198.51.100.20', 'root', 'root_password', 'world');
  # parameters for mysqli constructor are:
  #   host, user, password, database

  if( mysqli_connect_errno() )
    die("Connect failed: " . mysqli_connect_error());

  $query = "SELECT Name, Population
            FROM City
```

```
            ORDER BY Population DESC
            LIMIT 5";

  # if no errors...
  if( $result = $link->query($query) )
  {
?>
<table border="1" width="40%" cellpadding="4" cellspacing ="1">
  <tbody>
  <tr>
    <th width="10%">City</th>
    <th>Population</th>
  </tr>
<?
    # then display the results...
    while($row = $result->fetch_object())
      printf("<tr>\n  <td align=\"center\">%s</td><td>%d</td>\n</tr>\n",
              $row->Name, $row->Population);
?>
  </tbody
</table>
<?
  # ...and verify the number of rows that were retrieved
    printf("<p>Affected rows: %d</p>\n", $link->affected_rows);
  }
  else
    # otherwise, tell us what went wrong
    echo mysqli_error();

  # free the result set and the mysqli connection object
  $result->close();
  $link->close();
?>
</body>
</html>
```

We assume that the process running on the Web server can reach the IP address of the SQL node.

In a similar fashion, you can use the MySQL C API, Perl-DBI, Python-mysql, or MySQL Connectors to perform the tasks of data definition and manipulation just as you would normally with MySQL.

18.2.6 Safe Shutdown and Restart of NDB Cluster

To shut down the cluster, enter the following command in a shell on the machine hosting the management node:

```
shell> ndb_mgm -e shutdown
```

The `-e` option here is used to pass a command to the `ndb_mgm` client from the shell. (See Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”, for more information about this option.) The command causes the `ndb_mgm`, `ndb_mgmd`, and any `ndbd` or `ndbmtd` processes to terminate gracefully. Any SQL nodes can be terminated using `mysqladmin shutdown` and other means. On Windows platforms, assuming that you have installed the SQL node as a Windows service, you can use `NET STOP MYSQL`.

To restart the cluster on Unix platforms, run these commands:

- On the management host (`198.51.100.10` in our example setup):

  ```
  shell> ndb_mgmd -f /var/lib/mysql-cluster/config.ini
  ```

- On each of the data node hosts (`198.51.100.30` and `198.51.100.40`):

  ```
  shell> ndbd
  ```

- Use the `ndb_mgm` client to verify that both data nodes have started successfully.

- On the SQL host (198.51.100.20):

```
shell> mysqld_safe &
```

On Windows platforms, assuming that you have installed all NDB Cluster processes as Windows services using the default service names (see Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”), you can restart the cluster as follows:

- On the management host (198.51.100.10 in our example setup), execute the following command:

```
C:\> NET START ndb_mgmd
```

- On each of the data node hosts (198.51.100.30 and 198.51.100.40), execute the following command:

```
C:\> NET START ndbd
```

- On the management node host, use the ndb_mgm client to verify that the management node and both data nodes have started successfully (see Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”).

- On the SQL node host (198.51.100.20), execute the following command:

```
C:\> NET START mysql
```

In a production setting, it is usually not desirable to shut down the cluster completely. In many cases, even when making configuration changes, or performing upgrades to the cluster hardware or software (or both), which require shutting down individual host machines, it is possible to do so without shutting down the cluster as a whole by performing a *rolling restart* of the cluster. For more information about doing this, see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”.

18.2.7 Upgrading and Downgrading NDB Cluster

This section provides information about NDB Cluster software and table file compatibility between different NDB Cluster 7.2 releases with regard to performing upgrades and downgrades as well as compatibility matrices and notes. You are expected already to be familiar with installing and configuring an NDB Cluster prior to attempting an upgrade or downgrade. See Section 18.3, “Configuration of NDB Cluster”.

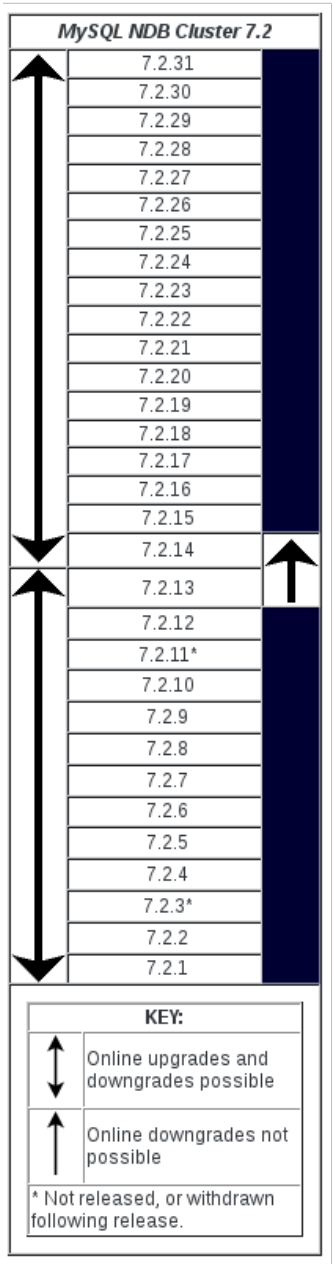
For information regarding the rolling restart procedure used to perform an online upgrade, see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”.

Important

Only compatibility between MySQL versions with regard to NDBCLUSTER is taken into account in this section, and there are likely other issues to be considered. *As with any other MySQL software upgrade or downgrade, you are strongly encouraged to review the relevant portions of the MySQL Manual for the MySQL versions from which and to which you intend to migrate, before attempting an upgrade or downgrade of the NDB Cluster software*. This is especially true when planning a migration from NDB Cluster 7.1 (or earlier) to NDB Cluster 7.2, since the version of the underlying MySQL Server also changes from MySQL 5.1 to MySQL 5.5. See Section 2.11.1, “Upgrading MySQL”.

The table shown here provides information on NDB Cluster upgrade and downgrade compatibility among different releases of NDB Cluster 7.2. Additional notes about upgrades and downgrades to, from, or within the NDB Cluster 7.2 release series can be found immediately following the table.

Figure 18.5 NDB Cluster Upgrade and Downgrade Compatibility, NDB Cluster 7.2



Notes: NDB Cluster 7.2

Versions supported. The following versions of NDB Cluster are supported for upgrades to NDB Cluster 7.2 (7.2.4 and later):

- NDB Cluster 7.1 GA releases (7.1.3 and later)
- NDB Cluster 7.0 GA releases (7.0.5 and later)
- NDB Cluster 6.3 GA releases (6.3.8 and later) that can be upgraded to NDB Cluster 7.1

For information about upgrades to and downgrades from NDB Cluster 7.3, see Upgrading and Downgrading NDB Cluster. For information about upgrades and downgrades in previous NDB Cluster release series, see the *MySQL 5.1 Reference Manual*.

NDB API, ClusterJ, and other applications used with recent releases of NDB Cluster 6.3 and later should continue to work with NDB 7.2.4 and later without rewriting or recompiling.

In NDB Cluster 7.2, the default values for a number of node configuration parameters have changed. See Improved default values for data node configuration parameters, for a listing of these.

Other known issues include the following:

- In NDB 7.2.7 and later, the size of the hash map is 3840 LDM threads, an increase from 240 in previous versions. When upgrading an NDB Cluster from NDB 7.2.6 and earlier to NDB 7.2.9 or later, you can modify existing tables online to take advantage of the new size: following the upgrade, increase the number of fragments by (for example) adding new data nodes to the cluster, and then execute `ALTER ONLINE TABLE ... REORGANIZE PARTITION` on any tables that were created in the older version. Following this, these tables can use the larger hash map size. (Bug #14645319)

  Due to this change, it was not possible to downgrade online to NDB 7.2.6 or earlier. This issue was resolved in NDB 7.2.11, where the size is made configurable using the `DefaultHashMapSize` parameter. (Bug #14800539) See the description of this parameter for more information.

- It is not possible to downgrade online to NDB 7.2.13 or earlier from NDB 7.2.14 or later. Online upgrades from NDB 7.2.13 to later NDB Cluster 7.2 releases are supported.

18.3 Configuration of NDB Cluster

A MySQL server that is part of an NDB Cluster differs in one chief respect from a normal (nonclustered) MySQL server, in that it employs the `NDB` storage engine. This engine is also referred to sometimes as `NDBCLUSTER`, although `NDB` is preferred.

To avoid unnecessary allocation of resources, the server is configured by default with the `NDB` storage engine disabled. To enable `NDB`, you must modify the server's `my.cnf` configuration file, or start the server with the `--ndbcluster` option.

This MySQL server is a part of the cluster, so it also must know how to access a management node to obtain the cluster configuration data. The default behavior is to look for the management node on `localhost`. However, should you need to specify that its location is elsewhere, this can be done in `my.cnf`, or with the `mysql` client. Before the `NDB` storage engine can be used, at least one management node must be operational, as well as any desired data nodes.

For more information about `--ndbcluster` and other `mysqld` options specific to NDB Cluster, see MySQL Server Options for NDB Cluster.

For information about installing NDB Cluster, see Section 18.2, “NDB Cluster Installation”.

18.3.1 Quick Test Setup of NDB Cluster

To familiarize you with the basics, we will describe the simplest possible configuration for a functional NDB Cluster. After this, you should be able to design your desired setup from the information provided in the other relevant sections of this chapter.

First, you need to create a configuration directory such as `/var/lib/mysql-cluster`, by executing the following command as the system `root` user:

```
shell> mkdir /var/lib/mysql-cluster
```

In this directory, create a file named `config.ini` that contains the following information. Substitute appropriate values for `HostName` and `DataDir` as necessary for your system.

```
# file "config.ini" - showing minimal setup consisting of 1 data node,
# 1 management server, and 3 MySQL servers.
# The empty default sections are not required, and are shown only for
# the sake of completeness.
# Data nodes must provide a hostname but MySQL Servers are not required
# to do so.
# If you don't know the hostname for your machine, use localhost.
# The DataDir parameter also has a default value, but it is recommended to
```

```
# set it explicitly.
# Note: [db], [api], and [mgm] are aliases for [ndbd], [mysqld], and [ndb_mgmd],
# respectively. [db] is deprecated and should not be used in new installations.

[ndbd default]
NoOfReplicas= 1

[mysqld  default]
[ndb_mgmd default]
[tcp default]

[ndb_mgmd]
HostName= myhost.example.com

[ndbd]
HostName= myhost.example.com
DataDir= /var/lib/mysql-cluster

[mysqld]
[mysqld]
[mysqld]
```

You can now start the `ndb_mgmd` management server. By default, it attempts to read the `config.ini` file in its current working directory, so change location into the directory where the file is located and then invoke `ndb_mgmd`:

```
shell> cd /var/lib/mysql-cluster
shell> ndb_mgmd
```

Then start a single data node by running `ndbd`:

```
shell> ndbd
```

For command-line options which can be used when starting `ndbd`, see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

By default, `ndbd` looks for the management server at `localhost` on port 1186.

Note

If you have installed MySQL from a binary tarball, you will need to specify the path of the `ndb_mgmd` and `ndbd` servers explicitly. (Normally, these will be found in `/usr/local/mysql/bin`.)

Finally, change location to the MySQL data directory (usually `/var/lib/mysql` or `/usr/local/mysql/data`), and make sure that the `my.cnf` file contains the option necessary to enable the NDB storage engine:

```
[mysqld]
ndbcluster
```

You can now start the MySQL server as usual:

```
shell> mysqld_safe --user=mysql &
```

Wait a moment to make sure the MySQL server is running properly. If you see the notice `mysql ended`, check the server's `.err` file to find out what went wrong.

If all has gone well so far, you now can start using the cluster. Connect to the server and verify that the `NDBCLUSTER` storage engine is enabled:

```
shell> mysql
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 1 to server version: 5.5.60
```

```
Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SHOW ENGINES\G
...
*************************** 12. row ***************************
Engine: NDBCLUSTER
Support: YES
Comment: Clustered, fault-tolerant, memory-based tables
*************************** 13. row ***************************
Engine: NDB
Support: YES
Comment: Alias for NDBCLUSTER
...
```

The row numbers shown in the preceding example output may be different from those shown on your system, depending upon how your server is configured.

Try to create an `NDBCLUSTER` table:

```
shell> mysql
mysql> USE test;
Database changed

mysql> CREATE TABLE ctest (i INT) ENGINE=NDBCLUSTER;
Query OK, 0 rows affected (0.09 sec)

mysql> SHOW CREATE TABLE ctest \G
*************************** 1. row ***************************
       Table: ctest
Create Table: CREATE TABLE `ctest` (
  `i` int(11) default NULL
) ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.00 sec)
```

To check that your nodes were set up properly, start the management client:

```
shell> ndb_mgm
```

Use the `SHOW` command from within the management client to obtain a report on the cluster's status:

```
ndb_mgm> SHOW
Cluster Configuration
---------------------
[ndbd(NDB)]     1 node(s)
id=2    @127.0.0.1  (Version: 5.5.58-ndb-7.2.32, Nodegroup: 0, *)

[ndb_mgmd(MGM)] 1 node(s)
id=1    @127.0.0.1  (Version: 5.5.58-ndb-7.2.32)

[mysqld(API)]   3 node(s)
id=3    @127.0.0.1  (Version: 5.5.58-ndb-7.2.32)
id=4 (not connected, accepting connect from any host)
id=5 (not connected, accepting connect from any host)
```

At this point, you have successfully set up a working NDB Cluster. You can now store data in the cluster by using any table created with `ENGINE=NDBCLUSTER` or its alias `ENGINE=NDB`.

18.3.2 Overview of NDB Cluster Configuration Parameters, Options, and Variables

The next several sections provide summary tables of NDB Cluster node configuration parameters used in the `config.ini` file to govern various aspects of node behavior, as well as of options and variables read by `mysqld` from a `my.cnf` file or from the command line when run as an NDB Cluster process. Each of the node parameter tables lists the parameters for a given type (`ndbd`, `ndb_mgmd`, `mysqld`,

`computer`, `tcp`, `shm`, or `sci`). All tables include the data type for the parameter, option, or variable, as well as its default, mimimum, and maximum values as applicable.

Considerations when restarting nodes. For node parameters, these tables also indicate what type of restart is required (node restart or system restart)—and whether the restart must be done with `--initial`—to change the value of a given configuration parameter. When performing a node restart or an initial node restart, all of the cluster's data nodes must be restarted in turn (also referred to as a *rolling restart*). It is possible to update cluster configuration parameters marked as `node` online—that is, without shutting down the cluster—in this fashion. An initial node restart requires restarting each `ndbd` process with the `--initial` option.

A system restart requires a complete shutdown and restart of the entire cluster. An initial system restart requires taking a backup of the cluster, wiping the cluster file system after shutdown, and then restoring from the backup following the restart.

In any cluster restart, all of the cluster's management servers must be restarted for them to read the updated configuration parameter values.

Important

Values for numeric cluster parameters can generally be increased without any problems, although it is advisable to do so progressively, making such adjustments in relatively small increments. Many of these can be increased online, using a rolling restart.

However, decreasing the values of such parameters—whether this is done using a node restart, node initial restart, or even a complete system restart of the cluster—is not to be undertaken lightly; it is recommended that you do so only after careful planning and testing. This is especially true with regard to those parameters that relate to memory usage and disk space, such as `MaxNoOfTables`, `MaxNoOfOrderedIndexes`, and `MaxNoOfUniqueHashIndexes`. In addition, it is the generally the case that configuration parameters relating to memory and disk usage can be raised using a simple node restart, but they require an initial node restart to be lowered.

Because some of these parameters can be used for configuring more than one type of cluster node, they may appear in more than one of the tables.

Note

`4294967039` often appears as a maximum value in these tables. This value is defined in the `NDBCLUSTER` sources as `MAX_INT_RNIL` and is equal to `0xFFFFFEFF`, or $2^{32} - 2^8 - 1$.

18.3.2.1 NDB Cluster Data Node Configuration Parameters

The summary table in this section provides information about parameters used in the `[ndbd]` or `[ndbd default]` sections of a `config.ini` file for configuring NDB Cluster data nodes. For detailed descriptions and other additional information about each of these parameters, see Section 18.3.3.6, “Defining NDB Cluster Data Nodes”.

These parameters also apply to `ndbmtd`, the multi-threaded version of `ndbd`. For more information, see Section 18.4.3, “`ndbmtd` — The NDB Cluster Data Node Daemon (Multi-Threaded)”.

Restart types. Changes in NDB Cluster configuration parameters do not take effect until the cluster is restarted. The type of restart required to change a given parameter is indicated in the summary table as follows:

- `N`—Node restart: The parameter can be updated using a rolling restart (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”).

- S—System restart: The cluster must be shut down completely, then restarted, to effect a change in this parameter.
- I—Initial restart: Data nodes must be restarted using the `--initial` option.

For more information about restart types, see Section 18.3.2, “Overview of NDB Cluster Configuration Parameters, Options, and Variables”.

NDB Cluster 7.2 supports the addition of new data node groups online, to a running cluster. For more information, see Section 18.5.13, “Adding NDB Cluster Data Nodes Online”.

Table 18.1 Data Node Configuration Parameters

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
`Arbitration`	enumeration Default Default, Disabled, WaitExternal	N	NDB 7.2.0
`ArbitrationTimeout`	milliseconds 7500 10 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
`BackupDataBufferSize`	bytes 16M 512K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
`BackupDataDir`	path FileSystemPath ...	IN	NDB 7.2.0
`BackupLogBufferSize`	bytes 16M 2M / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
`BackupMaxWriteSize`	bytes 1M 2K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.1
`BackupMemory`	bytes 32M	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	0 / 4294967039 (0xFFFFFEFF)		
BackupReportFrequency	seconds 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
BackupWriteSize	bytes 256K 32K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
BatchSizePerLocalScan	integer 256 1 / 992	N	NDB 7.2.1
BuildIndexThreads	numeric 0 0 / 128	S	NDB 7.2.0
CompressedBackup	boolean false true, false	N	NDB 7.2.0
CompressedLCP	boolean false true, false	N	NDB 7.2.0
ConnectCheckIntervalDelay	milliseconds 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.1
CrashOnCorruptedTuple	boolean true true, false	S	NDB 7.2.1
DataDir	path	IN	NDB 7.2.0
DataMemory	bytes 80M 1M / 1024G	N	NDB 7.2.0

Parameter Name	Type or Units	Default Value	Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
DefaultHashMapSize	LDM threads	3840	0 / 3840	N	NDB 7.2.11
DictTrace	bytes	undefined	0 / 100	N	NDB 7.2.0
DiskCheckpointSpeed	bytes	10M	1M / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
DiskCheckpointSpeedInRestart	bytes	100M	1M / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
DiskIOThreadPool	threads	2	0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
Diskless	true|false (1|0)	false	true, false	IS	NDB 7.2.0
DiskPageBufferEntries	32K pages	10	1 / 1000	N	NDB 7.2.19
DiskPageBufferMemory	bytes	64M	4M / 1T	N	NDB 7.2.0
DiskSyncSize	bytes	4M	32K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
ExecuteOnComputer	name	[none]	...	S	NDB 7.2.0
ExtraSendBufferMemory	bytes			N	NDB 7.2.5

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	0 0 / 32G		
FileSystemPath	path DataDir ...	IN	NDB 7.2.0
FileSystemPathDataFiles	filename [see text] ...	IN	NDB 7.2.0
FileSystemPathDD	filename FileSystemPath ...	IN	NDB 7.2.0
FileSystemPathUndoFiles	filename [see text] ...	IN	NDB 7.2.0
FragmentLogFileSize	bytes 16M 4M / 1G	IN	NDB 7.2.0
HeartbeatIntervalDbApi	milliseconds 1500 100 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
HeartbeatIntervalDbDb	milliseconds 5000 10 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
HeartbeatOrder	numeric 0 0 / 65535	S	NDB 7.2.0
HostName	name or IP address localhost ...	N	NDB 7.2.0
Id	unsigned [none] 1 / 48	IS	NDB 7.2.0
IndexMemory	bytes	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	18M 1M / 1T		
IndexStatAutoCreate	boolean false false, true	S	NDB 7.2.1
IndexStatAutoUpdate	boolean false false, true	S	NDB 7.2.1
IndexStatSaveScale	percentage 100 0 / 4294967039 (0xFFFFFEFF)	IN	NDB 7.2.1
IndexStatSaveSize	bytes 32768 0 / 4294967039 (0xFFFFFEFF)	IN	NDB 7.2.1
IndexStatTriggerPct	percentage 100 0 / 4294967039 (0xFFFFFEFF)	IN	NDB 7.2.1
IndexStatTriggerScale	percentage 100 0 / 4294967039 (0xFFFFFEFF)	IN	NDB 7.2.1
IndexStatUpdateDelay	seconds 60 0 / 4294967039 (0xFFFFFEFF)	IN	NDB 7.2.1
InitFragmentLogFiles	[see values] SPARSE SPARSE, FULL	IN	NDB 7.2.0
InitialLogFileGroup	string [see text] ...	S	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
InitialNoOfOpenFiles	files 27 20 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
InitialTablespace	string [see text] ...	S	NDB 7.2.0
LateAlloc	numeric 1 0 / 1	N	NDB 7.2.0
LcpScanProgressTimeout	second 60 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.14
LockExecuteThreadToCPU	set of CPU IDs 0 ...	N	NDB 7.2.0
LockMaintThreadsToCPU	CPU ID 0 0 / 64K	N	NDB 7.2.0
LockPagesInMainMemory	numeric 0 0 / 2	N	NDB 7.2.0
LogLevelCheckpoint	log level 0 0 / 15	N	NDB 7.2.0
LogLevelCongestion	levelr 0 0 / 15	N	NDB 7.2.0
LogLevelConnection	integer 0 0 / 15	N	NDB 7.2.0
LogLevelError	integer 0 0 / 15	N	NDB 7.2.0
LogLevelInfo	integer	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	0 0 / 15		
LogLevelNodeRestart	integer 0 0 / 15	N	NDB 7.2.0
LogLevelShutdown	integer 0 0 / 15	N	NDB 7.2.0
LogLevelStartup	integer 1 0 / 15	N	NDB 7.2.0
LogLevelStatistic	integer 0 0 / 15	N	NDB 7.2.0
LongMessageBuffer	bytes 64M 512K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.16
MaxAllocate	unsigned 32M 1M / 1G	N	NDB 7.2.0
MaxBufferedEpochs	epochs 100 0 / 100000	N	NDB 7.2.0
MaxBufferedEpochBytes	bytes 26214400 26214400 (0x01900000) / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.13
MaxDMLOperationsPerTransaction	operations (DML) 4294967295 32 / 4294967295	N	NDB 7.2.0
MaxLCPStartDelay	seconds 0 0 / 600	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
MaxNoOfAttributes	integer 1000 32 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfConcurrentIndexOperations	integer 8K 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfConcurrentOperations	integer 32K 32 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfConcurrentScans	integer 256 2 / 500	N	NDB 7.2.0
MaxNoOfConcurrentSubOperations	unsigned 256 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfConcurrentTransactions	integer 4096 32 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfFiredTriggers	integer 4000 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfLocalOperations	integer UNDEFINED 32 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfLocalScans	integer [see text]	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	32 / 4294967039 (0xFFFFFEFF)		
MaxNoOfOpenFiles	unsigned 0 20 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfOrderedIndexes	integer 128 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfSavedMessages	integer 25 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfSubscribers	unsigned 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfSubscriptions	unsigned 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfTables	integer 128 8 / 20320	N	NDB 7.2.0
MaxNoOfTriggers	integer 768 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxNoOfUniqueHashIndexes	integer 64 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
MaxParallelScansPerFragment	bytes 256 1 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MaxStartFailRetries	unsigned 3 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MemReportFrequency	unsigned 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
MinFreePct	unsigned 5 0 / 100	N	NDB 7.2.3
NodeGroup	 [none] 0 / 65536	IS	NDB 7.2.0
NodeId	unsigned [none] 1 / 48	IS	NDB 7.2.0
NoOfFragmentLogFiles	integer 16 3 / 4294967039 (0xFFFFFEFF)	IN	NDB 7.2.0
NoOfReplicas	integer 2 1 / 4	IS	NDB 7.2.0
Numa	integer 1 0 - 1	N	NDB 7.2.0
ODirect	boolean false true, false	N	NDB 7.2.0
RealtimeScheduler	boolean	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	false true, false		
RedoBuffer	bytes 32M 1M / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
RedoOverCommitCounter	numeric 3 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
RedoOverCommitLimit	seconds 20 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
ReservedSendBufferMemory	bytes 256K 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
RestartOnErrorInsert	error code 2 0 / 4	N	NDB 7.2.0
SchedulerExecutionTimer	µs 50 0 / 11000	N	NDB 7.2.0
SchedulerSpinTimer	µs 0 0 / 500	N	NDB 7.2.0
ServerPort	unsigned [none] 1 / 64K	S	NDB 7.2.0
SharedGlobalMemory	bytes 128M 0 / 64T	N	NDB 7.2.0
StartFailRetryDelay	unsigned 0	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	0 / 4294967039 (0xFFFFFEFF)		
StartFailureTimeout	milliseconds 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
StartNoNodeGroupTimeout	milliseconds 15000 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
StartPartialTimeout	milliseconds 30000 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
StartPartitionedTimeout	milliseconds 60000 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
StartupStatusReportFrequency	seconds 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
StopOnError	boolean 1 0, 1	N	NDB 7.2.0
StringMemory	% or bytes 25 0 / 4294967039 (0xFFFFFEFF)	S	NDB 7.2.1
TcpBind_INADDR_ANY	boolean false true, false	N	NDB 7.2.0
TimeBetweenEpochs	milliseconds	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	100 0 / 32000		
TimeBetweenEpochsTimeout	milliseconds 0 0 / 256000	N	NDB 7.2.0
TimeBetweenGlobalCheckpoints	milliseconds 2000 20 / 32000	N	NDB 7.2.0
TimeBetweenGlobalCheckpointsTimeout	milliseconds 120000 10 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.20
TimeBetweenInactiveTransactionAbortCheck	milliseconds 1000 1000 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
TimeBetweenLocalCheckpoints	number of 4-byte words, as a base-2 logarithm 20 0 / 31	N	NDB 7.2.0
TimeBetweenWatchDogCheck	milliseconds 6000 70 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
TimeBetweenWatchDogCheckInitial	milliseconds 6000 70 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
TotalSendBufferMemory	bytes 0 256K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
TransactionBufferMemory	bytes	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	1M 1K / 4294967039 (0xFFFFFEFF)		
TransactionDeadlockDetectionTimeout	milliseconds 1200 50 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
TransactionInactiveTimeout	milliseconds [see text] 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
TwoPassInitialNodeRestartCopy	boolean false true, false	N	NDB 7.2.0
UndoDataBuffer	unsigned 16M 1M / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
UndoIndexBuffer	unsigned 2M 1M / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0

Table 18.2 Multi-Threaded Data Node Configuration Parameters

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
MaxNoOfExecutionThreads	integer 2 2 / 36	IS	NDB 7.2.5
NoOfFragmentLogParts	numeric 4 4, 8, 12, 16	IN	NDB 7.2.5

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
ThreadConfig	string '' ...	IS	NDB 7.2.3

18.3.2.2 NDB Cluster Management Node Configuration Parameters

The summary table in this section provides information about parameters used in the [ndb_mgmd] or [mgm] sections of a config.ini file for configuring NDB Cluster management nodes. For detailed descriptions and other additional information about each of these parameters, see Section 18.3.3.5, "Defining an NDB Cluster Management Server".

Restart types. Changes in NDB Cluster configuration parameters do not take effect until the cluster is restarted. The type of restart required to change a given parameter is indicated in the summary table as follows:

- N—Node restart: The parameter can be updated using a rolling restart (see Section 18.5.5, "Performing a Rolling Restart of an NDB Cluster").
- S—System restart: The cluster must be shut down completely, then restarted, to effect a change in this parameter.
- I—Initial restart: Data nodes must be restarted using the --initial option.

For more information about restart types, see Section 18.3.2, "Overview of NDB Cluster Configuration Parameters, Options, and Variables".

Table 18.3 Management Node Configuration Parameters

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
ArbitrationDelay	milliseconds 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
ArbitrationRank	0-2 1 0 / 2	N	NDB 7.2.0
DataDir	path	N	NDB 7.2.0
ExecuteOnComputer	name [none]	S	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	...		
ExtraSendBufferMemory	bytes 0 0 / 32G	N	NDB 7.2.14
HeartbeatIntervalMgmdMgmd	milliseconds 1500 100 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.12
HeartbeatThreadPriority	string [none] ...	S	NDB 7.2.0
HostName	name or IP address [none] ...	N	NDB 7.2.0
Id	unsigned [none] 1 / 255	IS	NDB 7.2.0
LogDestination	{CONSOLE|SYSLOG|FILE} [see text] ...	N	NDB 7.2.0
MaxNoOfSavedEvents	unsigned 100 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
NodeId	unsigned [none] 1 / 255	IS	NDB 7.2.0
PortNumber	unsigned 1186 0 / 64K	S	NDB 7.2.0
PortNumberStats	unsigned [none] 0 / 64K	N	NDB 7.2.0
TotalSendBufferMemory	bytes	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	0 256K / 4294967039 (0xFFFFFEFF)		
wan	boolean false true, false	N	NDB 7.2.0

Note

After making changes in a management node's configuration, it is necessary to perform a rolling restart of the cluster for the new configuration to take effect. See Section 18.3.3.5, "Defining an NDB Cluster Management Server", for more information.

To add new management servers to a running NDB Cluster, it is also necessary perform a rolling restart of all cluster nodes after modifying any existing `config.ini` files. For more information about issues arising when using multiple management nodes, see Section 18.1.6.10, "Limitations Relating to Multiple NDB Cluster Nodes".

18.3.2.3 NDB Cluster SQL Node and API Node Configuration Parameters

The summary table in this section provides information about parameters used in the `[mysqld]` and `[api]` sections of a `config.ini` file for configuring NDB Cluster SQL nodes and API nodes. For detailed descriptions and other additional information about each of these parameters, see Section 18.3.3.7, "Defining SQL and Other API Nodes in an NDB Cluster".

Note

For a discussion of MySQL server options for NDB Cluster, see MySQL Server Options for NDB Cluster; for information about MySQL server system variables relating to NDB Cluster, see NDB Cluster System Variables.

Restart types. Changes in NDB Cluster configuration parameters do not take effect until the cluster is restarted. The type of restart required to change a given parameter is indicated in the summary table as follows:

- `N`—Node restart: The parameter can be updated using a rolling restart (see Section 18.5.5, "Performing a Rolling Restart of an NDB Cluster").
- `S`—System restart: The cluster must be shut down completely, then restarted, to effect a change in this parameter.
- `I`—Initial restart: Data nodes must be restarted using the `--initial` option.

For more information about restart types, see Section 18.3.2, "Overview of NDB Cluster Configuration Parameters, Options, and Variables".

Table 18.4 SQL Node / API Node Configuration Parameters

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
ArbitrationDelay	milliseconds 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
ArbitrationRank	0-2 0 0 / 2	N	NDB 7.2.0
AutoReconnect	boolean false true, false	N	NDB 7.2.0
BatchByteSize	bytes 16K 1K / 1M	N	NDB 7.2.1
BatchSize	records 256 1 / 992	N	NDB 7.2.1
ConnectBackoffMaxTime	integer 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.18
ConnectionMap	string [none] ...	N	NDB 7.2.0
DefaultHashMapSize	buckets 3840 0 / 3840	N	NDB 7.2.11
DefaultOperationRedoProblemAction	enumeration QUEUE ABORT, QUEUE	S	NDB 7.2.10
EventLogBufferSize	bytes 8192 0 / 64K	S	NDB 7.2.0
ExecuteOnComputer	name [none]	S	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	...		
ExtraSendBufferMemory	bytes 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.14
HeartbeatThreadPriority	string [none] ...	S	NDB 7.2.0
HostName	name or IP address [none] ...	N	NDB 7.2.0
Id	unsigned [none] 1 / 255	IS	NDB 7.2.0
MaxScanBatchSize	bytes 256K 32K / 16M	N	NDB 7.2.0
NodeId	unsigned [none] 1 / 255	IS	NDB 7.2.0
StartConnectBackoffMaxTime	integer 1500 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.18
TotalSendBufferMemory	bytes 0 256K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
wan	boolean false true, false	N	NDB 7.2.0

Note

To add new SQL or API nodes to the configuration of a running NDB Cluster, it is necessary to perform a rolling restart of all cluster nodes after adding new `[mysqld]` or `[api]` sections to the `config.ini` file (or files, if you are using

more than one management server). This must be done before the new SQL or API nodes can connect to the cluster.

It is *not* necessary to perform any restart of the cluster if new SQL or API nodes can employ previously unused API slots in the cluster configuration to connect to the cluster.

18.3.2.4 Other NDB Cluster Configuration Parameters

The summary tables in this section provide information about parameters used in the `[computer]`, `[tcp]`, `[shm]`, and `[sci]` sections of a `config.ini` file for configuring NDB Cluster management nodes. For detailed descriptions and other additional information about individual parameters, see Section 18.3.3.9, “NDB Cluster TCP/IP Connections”, Section 18.3.3.11, “NDB Cluster Shared-Memory Connections”, or Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”, as appropriate.

Restart types. Changes in NDB Cluster configuration parameters do not take effect until the cluster is restarted. The type of restart required to change a given parameter is indicated in the summary tables as follows:

- `N`—Node restart: The parameter can be updated using a rolling restart (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”).
- `S`—System restart: The cluster must be shut down completely, then restarted, to effect a change in this parameter.
- `I`—Initial restart: Data nodes must be restarted using the `--initial` option.

For more information about restart types, see Section 18.3.2, “Overview of NDB Cluster Configuration Parameters, Options, and Variables”.

Table 18.5 Computer Configuration Parameters

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
`HostName`	name or IP address [none] ...	N	NDB 7.2.0
`Id`	string [none] ...	IS	NDB 7.2.0

Table 18.6 TCP Configuration Parameters

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
`Checksum`	boolean false true, false	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
Group	unsigned 55 0 / 200	N	NDB 7.2.0
NodeId1	numeric [none] ...	N	NDB 7.2.0
NodeId2	numeric [none] ...	N	NDB 7.2.0
NodeIdServer	numeric [none] ...	N	NDB 7.2.0
OverloadLimit	bytes 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
PortNumber	unsigned [none] 0 / 64K	S	NDB 7.2.0
Proxy	string [none] ...	N	NDB 7.2.0
ReceiveBufferMemory	bytes 2M 16K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
SendBufferMemory	unsigned 2M 256K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
SendSignalId	boolean [see text] true, false	N	NDB 7.2.0
TCP_MAXSEG_SIZE	unsigned 0	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	0 / 2G		
TCP_RCV_BUF_SIZE	unsigned 0 0 / 2G	N	NDB 7.2.0
TCP_SND_BUF_SIZE	unsigned 0 0 / 2G	N	NDB 7.2.0
TcpBind_INADDR_ANY	boolean false true, false	N	NDB 7.2.0

Table 18.7 Shared Memory Configuration Parameters

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
Checksum	boolean true true, false	N	NDB 7.2.0
Group	unsigned 35 0 / 200	N	NDB 7.2.0
NodeId1	numeric [none] ...	N	NDB 7.2.0
NodeId2	numeric [none] ...	N	NDB 7.2.0
NodeIdServer	numeric [none] ...	N	NDB 7.2.0
OverloadLimit	bytes 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
PortNumber	unsigned	S	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	[none] 0 / 64K		
SendSignalId	boolean false true, false	N	NDB 7.2.0
ShmKey	unsigned [none] 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
ShmSize	bytes 1M 64K / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
Signum	unsigned [none] 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0

Table 18.8 SCI Configuration Parameters

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
Checksum	boolean false true, false	N	NDB 7.2.0
Group	unsigned 15 0 / 200	N	NDB 7.2.0
Host1SciId0	unsigned [none] 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
Host1SciId1	unsigned	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	0 0 / 4294967039 (0xFFFFFEFF)		
Host2SciId0	unsigned [none] 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
Host2SciId1	unsigned 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
NodeId1	numeric [none] ...	N	NDB 7.2.0
NodeId2	numeric [none] ...	N	NDB 7.2.0
NodeIdServer	numeric [none] ...	N	NDB 7.2.0
OverloadLimit	bytes 0 0 / 4294967039 (0xFFFFFEFF)	N	NDB 7.2.0
PortNumber	unsigned [none] 0 / 64K	S	NDB 7.2.0
SendLimit	unsigned 8K 128 / 32K	N	NDB 7.2.0
SendSignalId	boolean true true, false	N	NDB 7.2.0
SharedBufferSize	unsigned 10M	N	NDB 7.2.0

Parameter Name	Type or Units Default Value Minimum/ Maximum or Permitted Values	Restart Type	In Version ... (and later)
	64K / 4294967039 (0xFFFFFEFF)		

18.3.2.5 NDB Cluster mysqld Option and Variable Reference

The following table provides a list of the command-line options, server and status variables applicable within `mysqld` when it is running as an SQL node in an NDB Cluster. For a table showing *all* command-line options, server and status variables available for use with `mysqld`, see Section 5.1.3, “Server Option and Variable Reference”.

Table 18.9 MySQL Server Options and Variables for NDB Cluster: MySQL Cluster NDB 7.2

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
`Com_show_ndb_status`		
No	No	Yes
No	Both	No
DESCRIPTION: Count of SHOW NDB STATUS statements.		
`Handler_discover`		
No	No	Yes
No	Both	No
DESCRIPTION: Number of times that tables have been discovered.		
`have_ndbcluster`		
No	Yes	No
No	Global	No
DESCRIPTION: Whether mysqld supports NDB Cluster tables (set by --ndbcluster option).		
`ndb-batch-size`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Size (in bytes) to use for NDB transaction batches.		
`ndb-blob-read-batch-bytes`		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies size in bytes that large BLOB reads should be batched into. 0 = no limit..		
`ndb-blob-write-batch-bytes`		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies size in bytes that large BLOB writes should be batched into. 0 = no limit..		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
ndb-cluster-connection-pool		
Yes	Yes	Yes
Yes	Global	No
DESCRIPTION: Number of connections to the cluster used by MySQL.		
ndb-connectstring		
Yes	No	No
Yes		No
DESCRIPTION: Point to the management server that distributes the cluster configuration.		
ndb-deferred-constraints		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies that constraint checks on unique indexes (where these are supported) should be deferred until commit time. Not normally needed or used; for testing purposes only..		
ndb-distribution		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH).		
ndb-log-apply-status		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Cause a MySQL server acting as a slave to log mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID. Effective only if the server is started with the --ndbcluster option..		
ndb-log-empty-epochs		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: When enabled, causes epochs in which there were no changes to be written to the ndb_apply_status and ndb_binlog_index tables, even when --log-slave-updates is enabled..		
ndb-log-empty-update		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: When enabled, causes updates that produced no changes to be written to the ndb_apply_status and ndb_binlog_index tables, even when --log-slave-updates is enabled..		
ndb-log-orig		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Log originating server id and epoch in mysql.ndb_binlog_index table.		
ndb-log-transaction-id		
Yes	Yes	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Global	No
DESCRIPTION: Write NDB transaction IDs in the binary log. Requires --log-bin-v1-events=OFF..		
ndb-log-update-as-write		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Toggles logging of updates on the master between updates (OFF) and writes (ON).		
ndb-mgmd-host		
Yes	No	No
Yes		No
DESCRIPTION: Set the host (and port, if desired) for connecting to management server.		
ndb-nodeid		
Yes	No	Yes
Yes	Global	No
DESCRIPTION: NDB Cluster node ID for this MySQL server.		
ndb-transid-mysql-connection-map		
Yes	No	No
No		No
DESCRIPTION: Enable or disable the ndb_transid_mysql_connection_map plugin; that is, enable or disable the INFORMATION_SCHEMA table having that name.		
ndb-wait-connected		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Time (in seconds) for the MySQL server to wait for connection to cluster management and data nodes before accepting MySQL client connections.		
ndb-wait-setup		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Time (in seconds) for the MySQL server to wait for NDB engine setup to complete.		
Ndb_api_bytes_received_count		
No	No	Yes
No	Global	No
DESCRIPTION: Amount of data (in bytes) received from the data nodes by this MySQL Server (SQL node).		
Ndb_api_bytes_received_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Amount of data (in bytes) received from the data nodes in this client session.		
Ndb_api_bytes_received_count_slave		
No	No	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	Global	No
DESCRIPTION: Amount of data (in bytes) received from the data nodes by this slave.		
`Ndb_api_bytes_sent_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Amount of data (in bytes) sent to the data nodes by this MySQL Server (SQL node).		
`Ndb_api_bytes_sent_count_session`		
No	No	Yes
No	Session	No
DESCRIPTION: Amount of data (in bytes) sent to the data nodes in this client session.		
`Ndb_api_bytes_sent_count_slave`		
No	No	Yes
No	Global	No
DESCRIPTION: Amount of data (in bytes) sent to the data nodes by this slave.		
`Ndb_api_event_bytes_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of bytes of events received by this MySQL Server (SQL node).		
`Ndb_api_event_bytes_count_injector`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of bytes of events received by the NDB binary log injector thread.		
`Ndb_api_event_data_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of row change events received by this MySQL Server (SQL node).		
`Ndb_api_event_data_count_injector`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of row change events received by the NDB binary log injector thread.		
`Ndb_api_event_nondata_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of events received, other than row change events, by this MySQL Server (SQL node).		
`Ndb_api_event_nondata_count_injector`		
No	No	Yes
No	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of events received, other than row change events, by the NDB binary log injector thread. `Ndb_api_pk_op_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of operations based on or using primary keys by this MySQL Server (SQL node). `Ndb_api_pk_op_count_session`		
No	No	Yes
No	Session	No
DESCRIPTION: Number of operations based on or using primary keys in this client session. `Ndb_api_pk_op_count_slave`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of operations based on or using primary keys by this slave. `Ndb_api_pruned_scan_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of scans that have been pruned to a single partition by this MySQL Server (SQL node). `Ndb_api_pruned_scan_count_session`		
No	No	Yes
No	Session	No
DESCRIPTION: Number of scans that have been pruned to a single partition in this client session. `Ndb_api_pruned_scan_count_slave`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of scans that have been pruned to a single partition by this slave. `Ndb_api_range_scan_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of range scans that have been started by this MySQL Server (SQL node). `Ndb_api_range_scan_count_session`		
No	No	Yes
No	Session	No
DESCRIPTION: Number of range scans that have been started in this client session. `Ndb_api_range_scan_count_slave`		
No	No	Yes
No	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of range scans that have been started by this slave. Ndb_api_read_row_count		
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows that have been read by this MySQL Server (SQL node). Ndb_api_read_row_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Total number of rows that have been read in this client session. Ndb_api_read_row_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows that have been read by this slave. Ndb_api_scan_batch_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of batches of rows received by this MySQL Server (SQL node). Ndb_api_scan_batch_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of batches of rows received in this client session. Ndb_api_scan_batch_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of batches of rows received by this slave. Ndb_api_table_scan_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of table scans that have been started, including scans of internal tables, by this MySQL Server (SQL node). Ndb_api_table_scan_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of table scans that have been started, including scans of internal tables, in this client session. Ndb_api_table_scan_count_slave		
No	No	Yes
No	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of table scans that have been started, including scans of internal tables, by this slave.		
`Ndb_api_trans_abort_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions aborted by this MySQL Server (SQL node).		
`Ndb_api_trans_abort_count_session`		
No	No	Yes
No	Session	No
DESCRIPTION: Number of transactions aborted in this client session.		
`Ndb_api_trans_abort_count_slave`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions aborted by this slave.		
`Ndb_api_trans_close_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions aborted (may be greater than the sum of TransCommitCount and TransAbortCount) by this MySQL Server (SQL node).		
`Ndb_api_trans_close_count_session`		
No	No	Yes
No	Session	No
DESCRIPTION: Number of transactions aborted (may be greater than the sum of TransCommitCount and TransAbortCount) in this client session.		
`Ndb_api_trans_close_count_slave`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions aborted (may be greater than the sum of TransCommitCount and TransAbortCount) by this slave.		
`Ndb_api_trans_commit_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions committed by this MySQL Server (SQL node).		
`Ndb_api_trans_commit_count_session`		
No	No	Yes
No	Session	No
DESCRIPTION: Number of transactions committed in this client session.		
`Ndb_api_trans_commit_count_slave`		
No	No	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	Global	No
DESCRIPTION: Number of transactions committed by this slave.		
Ndb_api_trans_local_read_row_count		
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows that have been read by this MySQL Server (SQL node).		
Ndb_api_trans_local_read_row_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Total number of rows that have been read in this client session.		
Ndb_api_trans_local_read_row_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows that have been read by this slave.		
Ndb_api_trans_start_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions started by this MySQL Server (SQL node).		
Ndb_api_trans_start_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of transactions started in this client session.		
Ndb_api_trans_start_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of transactions started by this slave.		
Ndb_api_uk_op_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of operations based on or using unique keys by this MySQL Server (SQL node).		
Ndb_api_uk_op_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of operations based on or using unique keys in this client session.		
Ndb_api_uk_op_count_slave		
No	No	Yes
No	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of operations based on or using unique keys by this slave. `Ndb_api_wait_exec_complete_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked while waiting for execution of an operation to complete by this MySQL Server (SQL node). `Ndb_api_wait_exec_complete_count_session`		
No	No	Yes
No	Session	No
DESCRIPTION: Number of times thread has been blocked while waiting for execution of an operation to complete in this client session. `Ndb_api_wait_exec_complete_count_slave`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked while waiting for execution of an operation to complete by this slave. `Ndb_api_wait_meta_request_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked waiting for a metadata-based signal by this MySQL Server (SQL node). `Ndb_api_wait_meta_request_count_session`		
No	No	Yes
No	Session	No
DESCRIPTION: Number of times thread has been blocked waiting for a metadata-based signal in this client session. `Ndb_api_wait_meta_request_count_slave`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked waiting for a metadata-based signal by this slave. `Ndb_api_wait_nanos_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Total time (in nanoseconds) spent waiting for some type of signal from the data nodes by this MySQL Server (SQL node). `Ndb_api_wait_nanos_count_session`		
No	No	Yes
No	Session	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Total time (in nanoseconds) spent waiting for some type of signal from the data nodes in this client session.		
Ndb_api_wait_nanos_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Total time (in nanoseconds) spent waiting for some type of signal from the data nodes by this slave.		
Ndb_api_wait_scan_result_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked while waiting for a scan-based signal by this MySQL Server (SQL node).		
Ndb_api_wait_scan_result_count_session		
No	No	Yes
No	Session	No
DESCRIPTION: Number of times thread has been blocked while waiting for a scan-based signal in this client session.		
Ndb_api_wait_scan_result_count_slave		
No	No	Yes
No	Global	No
DESCRIPTION: Number of times thread has been blocked while waiting for a scan-based signal by this slave.		
ndb_autoincrement_prefetch_sz		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: NDB auto-increment prefetch size.		
ndb_cache_check_time		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Number of milliseconds between checks of cluster SQL nodes made by the MySQL query cache.		
Ndb_cluster_node_id		
No	No	Yes
No	Both	No
DESCRIPTION: If the server is acting as an NDB Cluster node, then the value of this variable its node ID in the cluster.		
Ndb_config_from_host		
No	No	Yes
No	Both	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: The host name or IP address of the Cluster management server Formerly Ndb_connected_host. `Ndb_config_from_port`		
No	No	Yes
No	Both	No
DESCRIPTION: The port for connecting to Cluster management server. Formerly Ndb_connected_port. `Ndb_conflict_fn_epoch`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of rows that have been found in conflict by the NDB$EPOCH() conflict detection function. `Ndb_conflict_fn_epoch_trans`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of rows that have been found in conflict by the NDB$EPOCH_TRANS() conflict detection function. `Ndb_conflict_fn_max`		
No	No	Yes
No	Global	No
DESCRIPTION: If the server is part of an NDB Cluster involved in cluster replication, the value of this variable indicates the number of times that conflict resolution based on "greater timestamp wins" has been applied. `Ndb_conflict_fn_old`		
No	No	Yes
No	Global	No
DESCRIPTION: If the server is part of an NDB Cluster involved in cluster replication, the value of this variable indicates the number of times that "same timestamp wins" conflict resolution has been applied. `Ndb_conflict_trans_conflict_commit_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of epoch transactions committed after requiring transactional conflict handling. `Ndb_conflict_trans_detect_iter_count`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of internal iterations required to commit an epoch transaction. Should be (slightly) greater than or equal to Ndb_conflict_trans_conflict_commit_count. `Ndb_conflict_trans_reject_count`		
No	No	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
No	Global	No
DESCRIPTION: Number of transactions rejected after being found in conflict by a transactional conflict function.		
Ndb_conflict_trans_row_reject_count		
No	No	Yes
No	Global	No
DESCRIPTION: Total number of rows realigned after being found in conflict by a transactional conflict function. Includes Ndb_conflict_trans_row_conflict_count and any rows included in or dependent on conflicting transactions..		
ndb_deferred_constraints		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Specifies that constraint checks should be deferred (where these are supported). Not normally needed or used; for testing purposes only..		
ndb_distribution		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH).		
ndb_eventbuffer_max_alloc		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Maximum memory that can be allocated for buffering events by the NDB API. Defaults to 0 (no limit)..		
Ndb_execute_count		
No	No	Yes
No	Global	No
DESCRIPTION: Provides the number of round trips to the NDB kernel made by operations.		
ndb_extra_logging		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Controls logging of NDB Cluster schema, connection, and data distribution events in the MySQL error log.		
ndb_force_send		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Forces sending of buffers to NDB immediately, without waiting for other threads.		
ndb_index_stat_cache_entries		
Yes	Yes	No
Yes	Both	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Sets the granularity of the statistics by determining the number of starting and ending keys.		
ndb_index_stat_enable		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Use NDB index statistics in query optimization.		
ndb_index_stat_option		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Comma-separated list of tunable options for NDB index statistics; the list should contain no spaces.		
ndb_index_stat_update_freq		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: How often to query data nodes instead of the statistics cache.		
ndb_join_pushdown		
No	Yes	No
No	Both	Yes
DESCRIPTION: Enables pushing down of joins to data nodes.		
ndb_log_apply_status		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Whether or not a MySQL server acting as a slave logs mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID.		
ndb_log_bin		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: Write updates to NDB tables in the binary log. Effective only if binary logging is enabled with --log-bin..		
ndb_log_binlog_index		
Yes	Yes	No
No	Global	Yes
DESCRIPTION: Insert mapping between epochs and binary log positions into the ndb_binlog_index table. Defaults to ON. Effective only if binary logging is enabled on the server..		
ndb_log_empty_epochs		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: When enabled, epochs in which there were no changes are written to the ndb_apply_status and ndb_binlog_index tables, even when log_slave_updates is enabled.		
ndb_log_empty_update		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: When enabled, updates which produce no changes are written to the ndb_apply_status and ndb_binlog_index tables, even when log_slave_updates is enabled.		
ndb_log_orig		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Whether the id and epoch of the originating server are recorded in the mysql.ndb_binlog_index table. Set using the --ndb-log-orig option when starting mysqld..		
ndb_log_transaction_id		
No	Yes	No
No	Global	No
DESCRIPTION: Whether NDB transaction IDs are written into the binary log (Read-only.).		
ndb_log_updated_only		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Log complete rows (ON) or updates only (OFF).		
Ndb_number_of_data_nodes		
No	No	Yes
No	Global	No
DESCRIPTION: If the server is part of an NDB Cluster, the value of this variable is the number of data nodes in the cluster.		
ndb_optimization_delay		
No	Yes	No
No	Global	Yes
DESCRIPTION: Sets the number of milliseconds to wait between processing sets of rows by OPTIMIZE TABLE on NDB tables.		
ndb_optimized_node_selection		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Determines how an SQL node chooses a cluster data node to use as transaction coordinator.		
Ndb_pruned_scan_count		
No	No	Yes
No	Global	No
DESCRIPTION: Number of scans executed by NDB since the cluster was last started where partition pruning could be used.		
Ndb_pushed_queries_defined		
No	No	Yes
No	Global	No

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Number of joins that API nodes have attempted to push down to the data nodes.		
`Ndb_pushed_queries_dropped`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of joins that API nodes have tried to push down, but failed.		
`Ndb_pushed_queries_executed`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of joins successfully pushed down and executed on the data nodes.		
`Ndb_pushed_reads`		
No	No	Yes
No	Global	No
DESCRIPTION: Number of reads executed on the data nodes by pushed-down joins.		
`ndb_report_thresh_binlog_epoch_slip`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: NDB 7.5.4 and later: Threshold for number of epochs completely buffered, but not yet consumed by binlog injector thread which when exceeded generates BUFFERED_EPOCHS_OVER_THRESHOLD event buffer status message; prior to NDB 7.5.4: Threshold for number of epochs to lag behind before reporting binary log status.		
`ndb_report_thresh_binlog_mem_usage`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: This is a threshold on the percentage of free memory remaining before reporting binary log status.		
`Ndb_scan_count`		
No	No	Yes
No	Global	No
DESCRIPTION: The total number of scans executed by NDB since the cluster was last started.		
`ndb_table_no_logging`		
No	Yes	No
No	Session	Yes
DESCRIPTION: NDB tables created when this setting is enabled are not checkpointed to disk (although table schema files are created). The setting in effect when the table is created with or altered to use NDBCLUSTER persists for the lifetime of the table..		
`ndb_table_temporary`		
No	Yes	No
No	Session	Yes
DESCRIPTION: NDB tables are not persistent on disk: no schema files are created and the tables are not logged.		

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
ndb_use_exact_count		
No	Yes	No
No	Both	Yes
DESCRIPTION: Use exact row count when planning queries.		
ndb_use_transactions		
Yes	Yes	No
Yes	Both	Yes
DESCRIPTION: Forces NDB to use a count of records during SELECT COUNT(*) query planning to speed up this type of query.		
ndb_version		
No	Yes	No
No	Global	No
DESCRIPTION: Shows build and NDB engine version as an integer.		
ndb_version_string		
No	Yes	No
No	Global	No
DESCRIPTION: Shows build information including NDB engine version in ndb-x.y.z format.		
ndbcluster		
Yes	No	No
Yes		No
DESCRIPTION: Enable NDB Cluster (if this version of MySQL supports it). Disabled by --skip-ndbcluster.		
ndbinfo_database		
No	Yes	No
No	Global	No
DESCRIPTION: The name used for the NDB information database; read only.		
ndbinfo_max_bytes		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: Used for debugging only.		
ndbinfo_max_rows		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: Used for debugging only.		
ndbinfo_offline		
No	Yes	No
No	Global	Yes

Option or Variable Name		
Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
Notes		
DESCRIPTION: Put the ndbinfo database into offline mode, in which no rows are returned from tables or views.		
`ndbinfo_show_hidden`		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: Whether to show ndbinfo internal base tables in the mysql client. The default is OFF..		
`ndbinfo_table_prefix`		
Yes	Yes	No
No	Both	Yes
DESCRIPTION: The prefix to use for naming ndbinfo internal base tables.		
`ndbinfo_version`		
No	Yes	No
No	Global	No
DESCRIPTION: The version of the ndbinfo engine; read only.		
`server-id-bits`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: Sets the number of least significant bits in the server_id actually used for identifying the server, permitting NDB API applications to store application data in the most significant bits. server_id must be less than 2 to the power of this value..		
`server_id_bits`		
Yes	Yes	No
Yes	Global	No
DESCRIPTION: The effective value of server_id if the server was started with the --server-id-bits option set to a nondefault value.		
`slave_allow_batching`		
Yes	Yes	No
Yes	Global	Yes
DESCRIPTION: Turns update batching on and off for a replication slave.		
`transaction_allow_batching`		
No	Yes	No
No	Session	Yes
DESCRIPTION: Allows batching of statements within a transaction. Disable AUTOCOMMIT to use..		

18.3.3 NDB Cluster Configuration Files

Configuring NDB Cluster requires working with two files:

- `my.cnf`: Specifies options for all NDB Cluster executables. This file, with which you should be familiar with from previous work with MySQL, must be accessible by each executable running in the cluster.

- `config.ini`: This file, sometimes known as the *global configuration file*, is read only by the NDB Cluster management server, which then distributes the information contained therein to all processes participating in the cluster. `config.ini` contains a description of each node involved in the cluster. This includes configuration parameters for data nodes and configuration parameters for connections between all nodes in the cluster. For a quick reference to the sections that can appear in this file, and what sorts of configuration parameters may be placed in each section, see Sections of the `config.ini` File.

Caching of configuration data. In NDB Cluster 7.2, NDB Cluster uses *stateful configuration*. Rather than reading the global configuration file every time the management server is restarted, the management server caches the configuration the first time it is started, and thereafter, the global configuration file is read only when one of the following conditions is true:

- **The management server is started using the --initial option.** When `--initial` is used, the global configuration file is re-read, any existing cache files are deleted, and the management server creates a new configuration cache.
- **The management server is started using the --reload option.** The `--reload` option causes the management server to compare its cache with the global configuration file. If they differ, the management server creates a new configuration cache; any existing configuration cache is preserved, but not used. If the management server's cache and the global configuration file contain the same configuration data, then the existing cache is used, and no new cache is created.
- **The management server is started using --config-cache=FALSE.** This disables `--config-cache` (enabled by default), and can be used to force the management server to bypass configuration caching altogether. In this case, the management server ignores any configuration files that may be present, always reading its configuration data from the `config.ini` file instead.
- **No configuration cache is found.** In this case, the management server reads the global configuration file and creates a cache containing the same configuration data as found in the file.

Configuration cache files. The management server by default creates configuration cache files in a directory named `mysql-cluster` in the MySQL installation directory. (If you build NDB Cluster from source on a Unix system, the default location is `/usr/local/mysql-cluster`.) This can be overridden at runtime by starting the management server with the `--configdir` option. Configuration cache files are binary files named according to the pattern `ndb_node_id_config.bin.seq_id`, where *`node_id`* is the management server's node ID in the cluster, and *`seq_id`* is a cache idenitifer. Cache files are numbered sequentially using *`seq_id`*, in the order in which they are created. The management server uses the latest cache file as determined by the *`seq_id`*.

Note

It is possible to roll back to a previous configuration by deleting later configuration cache files, or by renaming an earlier cache file so that it has a higher *`seq_id`*. However, since configuration cache files are written in a binary format, you should not attempt to edit their contents by hand.

For more information about the `--configdir`, `--config-cache`, `--initial`, and `--reload` options for the NDB Cluster management server, see Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”.

We are continuously making improvements in Cluster configuration and attempting to simplify this process. Although we strive to maintain backward compatibility, there may be times when introduce an incompatible change. In such cases we will try to let Cluster users know in advance if a change is not backward compatible. If you find such a change and we have not documented it, please report it in the MySQL bugs database using the instructions given in Section 1.6, “How to Report Bugs or Problems”.

18.3.3.1 NDB Cluster Configuration: Basic Example

To support NDB Cluster, you will need to update `my.cnf` as shown in the following example. You may also specify these parameters on the command line when invoking the executables.

Note

The options shown here should not be confused with those that are used in `config.ini` global configuration files. Global configuration options are discussed later in this section.

```
# my.cnf
# example additions to my.cnf for NDB Cluster
# (valid in MySQL 5.5)

# enable ndbcluster storage engine, and provide connection string for
# management server host (default port is 1186)
[mysqld]
ndbcluster
ndb-connectstring=ndb_mgmd.mysql.com


# provide connection string for management server host (default port: 1186)
[ndbd]
connect-string=ndb_mgmd.mysql.com

# provide connection string for management server host (default port: 1186)
[ndb_mgm]
connect-string=ndb_mgmd.mysql.com

# provide location of cluster configuration file
[ndb_mgmd]
config-file=/etc/config.ini
```

(For more information on connection strings, see Section 18.3.3.3, “NDB Cluster Connection Strings”.)

```
# my.cnf
# example additions to my.cnf for NDB Cluster
# (will work on all versions)

# enable ndbcluster storage engine, and provide connection string for management
# server host to the default port 1186
[mysqld]
ndbcluster
ndb-connectstring=ndb_mgmd.mysql.com:1186
```

Important

Once you have started a `mysqld` process with the `NDBCLUSTER` and `ndb-connectstring` parameters in the `[mysqld]` in the `my.cnf` file as shown previously, you cannot execute any `CREATE TABLE` or `ALTER TABLE` statements without having actually started the cluster. Otherwise, these statements will fail with an error. *This is by design*.

You may also use a separate `[mysql_cluster]` section in the cluster `my.cnf` file for settings to be read and used by all executables:

```
# cluster-specific settings
[mysql_cluster]
ndb-connectstring=ndb_mgmd.mysql.com:1186
```

For additional `NDB` variables that can be set in the `my.cnf` file, see NDB Cluster System Variables.

The NDB Cluster global configuration file is by convention named `config.ini` (but this is not required). If needed, it is read by `ndb_mgmd` at startup and can be placed in any location that can be read by it. The location and name of the configuration are specified using `--config-file=path_name` with `ndb_mgmd` on the command line. This option has no default value, and is ignored if `ndb_mgmd` uses the configuration cache.

The global configuration file for NDB Cluster uses INI format, which consists of sections preceded by section headings (surrounded by square brackets), followed by the appropriate parameter names and values. One deviation from the standard INI format is that the parameter name and value can be separated by a colon (`:`) as well as the equal sign (`=`); however, the equal sign is preferred. Another deviation is that sections are not uniquely identified by section name. Instead, unique sections (such as two different nodes of the same type) are identified by a unique ID specified as a parameter within the section.

Default values are defined for most parameters, and can also be specified in `config.ini`. To create a default value section, simply add the word `default` to the section name. For example, an `[ndbd]` section contains parameters that apply to a particular data node, whereas an `[ndbd default]` section contains parameters that apply to all data nodes. Suppose that all data nodes should use the same data memory size. To configure them all, create an `[ndbd default]` section that contains a `DataMemory` line to specify the data memory size.

Note

In some older releases of NDB Cluster, there was no default value for `NoOfReplicas`, which always had to be specified explicitly in the `[ndbd default]` section. Although this parameter now has a default value of 2, which is the recommended setting in most common usage scenarios, it is still recommended practice to set this parameter explicitly.

The global configuration file must define the computers and nodes involved in the cluster and on which computers these nodes are located. An example of a simple configuration file for a cluster consisting of one management server, two data nodes and two MySQL servers is shown here:

```
# file "config.ini" - 2 data nodes and 2 SQL nodes
# This file is placed in the startup directory of ndb_mgmd (the
# management server)
# The first MySQL Server can be started from any host. The second
# can be started only on the host mysqld_5.mysql.com

[ndbd default]
NoOfReplicas= 2
DataDir= /var/lib/mysql-cluster

[ndb_mgmd]
Hostname= ndb_mgmd.mysql.com
DataDir= /var/lib/mysql-cluster

[ndbd]
HostName= ndbd_2.mysql.com

[ndbd]
HostName= ndbd_3.mysql.com

[mysqld]
[mysqld]
HostName= mysqld_5.mysql.com
```

Note

The preceding example is intended as a minimal starting configuration for purposes of familiarization with NDB Cluster, and is almost certain not to be sufficient for production settings. See Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”, which provides a more complete example starting configuration.

Each node has its own section in the `config.ini` file. For example, this cluster has two data nodes, so the preceding configuration file contains two `[ndbd]` sections defining these nodes.

Note

Do not place comments on the same line as a section heading in the `config.ini` file; this causes the management server not to start because it cannot parse the configuration file in such cases.

Sections of the config.ini File

There are six different sections that you can use in the `config.ini` configuration file, as described in the following list:

- `[computer]`: Defines cluster hosts. This is not required to configure a viable NDB Cluster, but be may used as a convenience when setting up a large cluster. See Section 18.3.3.4, “Defining Computers in an NDB Cluster”, for more information.
- `[ndbd]`: Defines a cluster data node (`ndbd` process). See Section 18.3.3.6, “Defining NDB Cluster Data Nodes”, for details.
- `[mysqld]`: Defines the cluster's MySQL server nodes (also called SQL or API nodes). For a discussion of SQL node configuration, see Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”.
- `[mgm]` or `[ndb_mgmd]`: Defines a cluster management server (MGM) node. For information concerning the configuration of management nodes, see Section 18.3.3.5, “Defining an NDB Cluster Management Server”.
- `[tcp]`: Defines a TCP/IP connection between cluster nodes, with TCP/IP being the default connection protocol. Normally, `[tcp]` or `[tcp default]` sections are not required to set up an NDB Cluster, as the cluster handles this automatically; however, it may be necessary in some situations to override the defaults provided by the cluster. See Section 18.3.3.9, “NDB Cluster TCP/IP Connections”, for information about available TCP/IP configuration parameters and how to use them. (You may also find Section 18.3.3.10, “NDB Cluster TCP/IP Connections Using Direct Connections” to be of interest in some cases.)
- `[shm]`: Defines shared-memory connections between nodes. In MySQL 5.5, it is enabled by default, but should still be considered experimental. For a discussion of SHM interconnects, see Section 18.3.3.11, “NDB Cluster Shared-Memory Connections”.
- `[sci]`: Defines Scalable Coherent Interface connections between cluster data nodes. Not supported in NDB 7.2 or later.

You can define `default` values for each section. NDB Cluster parameter names are case-insensitive, unless specified in MySQL Server `my.cnf` or `my.ini` files.

18.3.3.2 Recommended Starting Configuration for NDB Cluster

Achieving the best performance from an NDB Cluster depends on a number of factors including the following:

- NDB Cluster software version
- Numbers of data nodes and SQL nodes
- Hardware
- Operating system
- Amount of data to be stored
- Size and type of load under which the cluster is to operate

Therefore, obtaining an optimum configuration is likely to be an iterative process, the outcome of which can vary widely with the specifics of each NDB Cluster deployment. Changes in configuration

are also likely to be indicated when changes are made in the platform on which the cluster is run, or in applications that use the NDB Cluster's data. For these reasons, it is not possible to offer a single configuration that is ideal for all usage scenarios. However, in this section, we provide a recommended base configuration.

Starting config.ini file. The following `config.ini` file is a recommended starting point for configuring a cluster running NDB Cluster 7.2:

```
# TCP PARAMETERS

[tcp default]
SendBufferMemory=2M
ReceiveBufferMemory=2M

# Increasing the sizes of these 2 buffers beyond the default values
# helps prevent bottlenecks due to slow disk I/O.

# MANAGEMENT NODE PARAMETERS

[ndb_mgmd default]
DataDir=path/to/management/server/data/directory

# It is possible to use a different data directory for each management
# server, but for ease of administration it is preferable to be
# consistent.

[ndb_mgmd]
HostName=management-server-A-hostname
# NodeId=management-server-A-nodeid

[ndb_mgmd]
HostName=management-server-B-hostname
# NodeId=management-server-B-nodeid

# Using 2 management servers helps guarantee that there is always an
# arbitrator in the event of network partitioning, and so is
# recommended for high availability. Each management server must be
# identified by a HostName. You may for the sake of convenience specify
# a NodeId for any management server, although one will be allocated
# for it automatically; if you do so, it must be in the range 1-255
# inclusive and must be unique among all IDs specified for cluster
# nodes.

# DATA NODE PARAMETERS

[ndbd default]
NoOfReplicas=2

# Using 2 replicas is recommended to guarantee availability of data;
# using only 1 replica does not provide any redundancy, which means
# that the failure of a single data node causes the entire cluster to
# shut down. We do not recommend using more than 2 replicas, since 2 is
# sufficient to provide high availability, and we do not currently test
# with greater values for this parameter.

LockPagesInMainMemory=1

# On Linux and Solaris systems, setting this parameter locks data node
# processes into memory. Doing so prevents them from swapping to disk,
# which can severely degrade cluster performance.

DataMemory=3072M
IndexMemory=384M

# The values provided for DataMemory and IndexMemory assume 4 GB RAM
# per data node. However, for best results, you should first calculate
# the memory that would be used based on the data you actually plan to
# store (you may find the ndb_size.pl utility helpful in estimating
# this), then allow an extra 20% over the calculated values. Naturally,
# you should ensure that each data node host has at least as much
```

```
# physical memory as the sum of these two values.

# ODirect=1

# Enabling this parameter causes NDBCLUSTER to try using O_DIRECT
# writes for local checkpoints and redo logs; this can reduce load on
# CPUs. We recommend doing so when using NDB Cluster on systems running
# Linux kernel 2.6 or later.

NoOfFragmentLogFiles=300
DataDir=path/to/data/node/data/directory
MaxNoOfConcurrentOperations=100000

SchedulerSpinTimer=400
SchedulerExecutionTimer=100
RealTimeScheduler=1
# Setting these parameters allows you to take advantage of real-time scheduling
# of NDB threads to achieve increased throughput when using ndbd. They
# are not needed when using ndbmtd; in particular, you should not set
# RealTimeScheduler for ndbmtd data nodes.

TimeBetweenGlobalCheckpoints=1000
TimeBetweenEpochs=200
DiskCheckpointSpeed=10M
DiskCheckpointSpeedInRestart=100M
RedoBuffer=32M

# CompressedLCP=1
# CompressedBackup=1
# Enabling CompressedLCP and CompressedBackup causes, respectively, local
checkpoint files and backup files to be compressed, which can result in a space
savings of up to 50% over noncompressed LCPs and backups.

# MaxNoOfLocalScans=64
MaxNoOfTables=1024
MaxNoOfOrderedIndexes=256

[ndbd]
HostName=data-node-A-hostname
# NodeId=data-node-A-nodeid

LockExecuteThreadToCPU=1
LockMaintThreadsToCPU=0
# On systems with multiple CPUs, these parameters can be used to lock NDBCLUSTER
# threads to specific CPUs

[ndbd]
HostName=data-node-B-hostname
# NodeId=data-node-B-nodeid

LockExecuteThreadToCPU=1
LockMaintThreadsToCPU=0

# You must have an [ndbd] section for every data node in the cluster;
# each of these sections must include a HostName. Each section may
# optionally include a NodeId for convenience, but in most cases, it is
# sufficient to allow the cluster to allocate node IDs dynamically. If
# you do specify the node ID for a data node, it must be in the range 1
# to 48 inclusive and must be unique among all IDs specified for
# cluster nodes.

# SQL NODE / API NODE PARAMETERS

[mysqld]
# HostName=sql-node-A-hostname
# NodeId=sql-node-A-nodeid

[mysqld]

[mysqld]

# Each API or SQL node that connects to the cluster requires a [mysqld]
```

```
# or [api] section of its own. Each such section defines a connection
# “slot”; you should have at least as many of these sections in the
# config.ini file as the total number of API nodes and SQL nodes that
# you wish to have connected to the cluster at any given time. There is
# no performance or other penalty for having extra slots available in
# case you find later that you want or need more API or SQL nodes to
# connect to the cluster at the same time.
# If no HostName is specified for a given [mysqld] or [api] section,
# then any API or SQL node may use that slot to connect to the
# cluster. You may wish to use an explicit HostName for one connection slot
# to guarantee that an API or SQL node from that host can always
# connect to the cluster. If you wish to prevent API or SQL nodes from
# connecting from other than a desired host or hosts, then use a
# HostName for every [mysqld] or [api] section in the config.ini file.
# You can if you wish define a node ID (NodeId parameter) for any API or
# SQL node, but this is not necessary; if you do so, it must be in the
# range 1 to 255 inclusive and must be unique among all IDs specified
# for cluster nodes.
```

Recommended my.cnf options for SQL nodes. MySQL Servers acting as NDB Cluster SQL nodes must always be started with the `--ndbcluster` and `--ndb-connectstring` options, either on the command line or in `my.cnf`. In addition, set the following options for all `mysqld` processes in the cluster, unless your setup requires otherwise:

- `--ndb-use-exact-count=0`
- `--ndb-index-stat-enable=0`
- `--ndb-force-send=1`
- `--engine-condition-pushdown=1`

18.3.3.3 NDB Cluster Connection Strings

With the exception of the NDB Cluster management server (`ndb_mgmd`), each node that is part of an NDB Cluster requires a *connection string* that points to the management server's location. This connection string is used in establishing a connection to the management server as well as in performing other tasks depending on the node's role in the cluster. The syntax for a connection string is as follows:

```
[nodeid=node_id, ]host-definition[, host-definition[, ...]]

host-definition:
    host_name[:port_number]
```

`node_id` is an integer greater than or equal to 1 which identifies a node in `config.ini`. *`host_name`* is a string representing a valid Internet host name or IP address. *`port_number`* is an integer referring to a TCP/IP port number.

```
example 1 (long):    "nodeid=2,myhost1:1100,myhost2:1100,198.51.100.3:1200"
example 2 (short):   "myhost1"
```

`localhost:1186` is used as the default connection string value if none is provided. If *`port_num`* is omitted from the connection string, the default port is 1186. This port should always be available on the network because it has been assigned by IANA for this purpose (see http://www.iana.org/assignments/port-numbers for details).

By listing multiple host definitions, it is possible to designate several redundant management servers. An NDB Cluster data or API node attempts to contact successive management servers on each host in the order specified, until a successful connection has been established.

It is also possible to specify in a connection string one or more bind addresses to be used by nodes having multiple network interfaces for connecting to management servers. A bind address consists of

a hostname or network address and an optional port number. This enhanced syntax for connection strings is shown here:

```
[nodeid=node_id, ]
    [bind-address=host-definition, ]
    host-definition[; bind-address=host-definition]
    host-definition[; bind-address=host-definition]
    [, ...]]

host-definition:
    host_name[:port_number]
```

If a single bind address is used in the connection string *prior* to specifying any management hosts, then this address is used as the default for connecting to any of them (unless overridden for a given management server; see later in this section for an example). For example, the following connection string causes the node to use `198.51.100.242` regardless of the management server to which it connects:

```
bind-address=198.51.100.242, poseidon:1186, perch:1186
```

If a bind address is specified *following* a management host definition, then it is used only for connecting to that management node. Consider the following connection string:

```
poseidon:1186;bind-address=localhost, perch:1186;bind-address=198.51.100.242
```

In this case, the node uses `localhost` to connect to the management server running on the host named `poseidon` and `198.51.100.242` to connect to the management server running on the host named `perch`.

You can specify a default bind address and then override this default for one or more specific management hosts. In the following example, `localhost` is used for connecting to the management server running on host `poseidon`; since `198.51.100.242` is specified first (before any management server definitions), it is the default bind address and so is used for connecting to the management servers on hosts `perch` and `orca`:

```
bind-address=198.51.100.242,poseidon:1186;bind-address=localhost,perch:1186,orca:2200
```

There are a number of different ways to specify the connection string:

- Each executable has its own command-line option which enables specifying the management server at startup. (See the documentation for the respective executable.)
- It is also possible to set the connection string for all nodes in the cluster at once by placing it in a `[mysql_cluster]` section in the management server's `my.cnf` file.
- For backward compatibility, two other options are available, using the same syntax:

  1. Set the `NDB_CONNECTSTRING` environment variable to contain the connection string.
  2. Write the connection string for each executable into a text file named `Ndb.cfg` and place this file in the executable's startup directory.

  However, these are now deprecated and should not be used for new installations.

The recommended method for specifying the connection string is to set it on the command line or in the `my.cnf` file for each executable.

18.3.3.4 Defining Computers in an NDB Cluster

The `[computer]` section has no real significance other than serving as a way to avoid the need of defining host names for each node in the system. All parameters mentioned here are required.

- `Id`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	string	[none]	...	IS

This is a unique identifier, used to refer to the host computer elsewhere in the configuration file.

Important

The computer ID is *not* the same as the node ID used for a management, API, or data node. Unlike the case with node IDs, you cannot use `NodeId` in place of `Id` in the `[computer]` section of the `config.ini` file.

- `HostName`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	[none]	...	N

This is the computer's hostname or IP address.

18.3.3.5 Defining an NDB Cluster Management Server

The `[ndb_mgmd]` section is used to configure the behavior of the management server. If multiple management servers are employed, you can specify parameters common to all of them in an `[ndb_mgmd default]` section. `[mgm]` and `[mgm default]` are older aliases for these, supported for backward compatibility.

All parameters in the following list are optional and assume their default values if omitted.

Note

If neither the `ExecuteOnComputer` nor the `HostName` parameter is present, the default value `localhost` will be assumed for both.

- `Id`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	1 - 255	IS

Each node in the cluster has a unique identity. For a management node, this is represented by an integer value in the range 1 to 255, inclusive. This ID is used by all internal cluster messages for addressing the node, and so must be unique for each NDB Cluster node, regardless of the type of node.

Note

Data node IDs must be less than 49. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for management nodes (and API nodes) to values greater than 48.

The use of the `Id` parameter for identifying management nodes is deprecated in favor of `NodeId`. Although `Id` continues to be supported for backward compatibility, it now generates a warning and is subject to removal in a future version of NDB Cluster.

- `NodeId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	1 - 255	IS

Each node in the cluster has a unique identity. For a management node, this is represented by an integer value in the range 1 to 255 inclusive. This ID is used by all internal cluster messages for addressing the node, and so must be unique for each NDB Cluster node, regardless of the type of node.

Note

Data node IDs must be less than 49. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for management nodes (and API nodes) to values greater than 48.

`NodeId` is the preferred parameter name to use when identifying management nodes. Although the older `Id` continues to be supported for backward compatibility, it is now deprecated and generates a warning when used; it is also subject to removal in a future NDB Cluster release.

- `ExecuteOnComputer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name	[none]	...	S

This refers to the `Id` set for one of the computers defined in a `[computer]` section of the `config.ini` file.

- `PortNumber`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	1186	0 - 64K	S

This is the port number on which the management server listens for configuration requests and management commands.

- `HostName`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	[none]	...	N

Specifying this parameter defines the hostname of the computer on which the management node is to reside. To specify a hostname other than `localhost`, either this parameter or `ExecuteOnComputer` is required.

- `LogDestination`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	{CONSOLE|SYSLOG|FILE}	[see text]	...	N

This parameter specifies where to send cluster logging information. There are three options in this regard—`CONSOLE`, `SYSLOG`, and `FILE`—with `FILE` being the default:

- `CONSOLE` outputs the log to `stdout`:

```
CONSOLE
```

- `SYSLOG` sends the log to a `syslog` facility, possible values being one of `auth`, `authpriv`, `cron`, `daemon`, `ftp`, `kern`, `lpr`, `mail`, `news`, `syslog`, `user`, `uucp`, `local0`, `local1`, `local2`, `local3`, `local4`, `local5`, `local6`, or `local7`.

Note

Not every facility is necessarily supported by every operating system.

```
SYSLOG:facility=syslog
```

- `FILE` pipes the cluster log output to a regular file on the same machine. The following values can be specified:
  - `filename`: The name of the log file.

    In NDB 7.2.6 and earlier, the log file's default name, used if `FILE` was specified without also setting `filename`, was `logger.log`. Beginning with NDB 7.2.7, the default log file name used in such cases is `ndb_nodeid_cluster.log`.
  - `maxsize`: The maximum size (in bytes) to which the file can grow before logging rolls over to a new file. When this occurs, the old log file is renamed by appending `.N` to the file name, where `N` is the next number not yet used with this name.
  - `maxfiles`: The maximum number of log files.

  ```
  FILE:filename=cluster.log,maxsize=1000000,maxfiles=6
  ```

  The default value for the `FILE` parameter is `FILE:filename=ndb_node_id_cluster.log,maxsize=1000000,maxfiles=6`, where `node_id` is the ID of the node.

It is possible to specify multiple log destinations separated by semicolons as shown here:

```
CONSOLE;SYSLOG:facility=local0;FILE:filename=/var/log/mgmd
```

- `ArbitrationRank`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	0-2	1	0 - 2	N

This parameter is used to define which nodes can act as arbitrators. Only management nodes and SQL nodes can be arbitrators. `ArbitrationRank` can take one of the following values:

- `0`: The node will never be used as an arbitrator.
- `1`: The node has high priority; that is, it will be preferred as an arbitrator over low-priority nodes.
- `2`: Indicates a low-priority node which be used as an arbitrator only if a node with a higher priority is not available for that purpose.

Normally, the management server should be configured as an arbitrator by setting its `ArbitrationRank` to 1 (the default for management nodes) and those for all SQL nodes to 0 (the default for SQL nodes).

You can disable arbitration completely either by setting `ArbitrationRank` to 0 on all management and SQL nodes, or by setting the `Arbitration` parameter in the `[ndbd default]` section of the `config.ini` global configuration file. Setting `Arbitration` causes any settings for `ArbitrationRank` to be disregarded.

- `ArbitrationDelay`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	0	0 - 4294967039 (0xFFFFFEFF)	N

An integer value which causes the management server's responses to arbitration requests to be delayed by that number of milliseconds. By default, this value is 0; it is normally not necessary to change it.

- `DataDir`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	path	.	...	N

This specifies the directory where output files from the management server will be placed. These files include cluster log files, process output files, and the daemon's process ID (PID) file. (For log files, this location can be overridden by setting the `FILE` parameter for `LogDestination` as discussed previously in this section.)

The default value for this parameter is the directory in which `ndb_mgmd` is located.

- `PortNumberStats`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	0 - 64K	N

This parameter specifies the port number used to obtain statistical information from an NDB Cluster management server. It has no default value.

- `Wan`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

Use WAN TCP setting as default.

- `HeartbeatThreadPriority`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	string	[none]	...	S

Set the scheduling policy and priority of heartbeat threads for management and API nodes.

The syntax for setting this parameter is shown here:

```
HeartbeatThreadPriority = policy[, priority]

policy:
  {FIFO | RR}
```

When setting this parameter, you must specify a policy. This is one of `FIFO` (first in, first out) or `RR` (round robin). The policy value is followed optionally by the priority (an integer).

- `ExtraSendBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.14	bytes	0	0 - 32G	N

This parameter specifies the amount of transporter send buffer memory to allocate in addition to any that has been set using `TotalSendBufferMemory`, `SendBufferMemory`, or both.

This parameter was added in NDB 7.2.14. (Bug #14555359)

- `TotalSendBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	0	256K - 4294967039 (0xFFFFFEFF)	N

This parameter is used to determine the total amount of memory to allocate on this node for shared send buffer memory among all configured transporters.

If this parameter is set, its minimum permitted value is 256KB; 0 indicates that the parameter has not been set. For more detailed information, see Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

- `HeartbeatIntervalMgmdMgmd`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.12	milliseconds	1500	100 - 4294967039 (0xFFFFFEFF)	N

Specify the interval between heartbeat messages used to determine whether another management node is on contact with this one. The management node waits after 3 of these intervals to declare the connection dead; thus, the default setting of 1500 milliseconds causes the management node to wait for approximately 1600 ms before timing out.

This parameter was added in NDB 7.2.12. (Bug #16426805, Bug #17807768)

Note

After making changes in a management node's configuration, it is necessary to perform a rolling restart of the cluster for the new configuration to take effect.

To add new management servers to a running NDB Cluster, it is also necessary to perform a rolling restart of all cluster nodes after modifying any existing `config.ini` files. For more information about issues arising when using multiple management nodes, see Section 18.1.6.10, “Limitations Relating to Multiple NDB Cluster Nodes”.

18.3.3.6 Defining NDB Cluster Data Nodes

The `[ndbd]` and `[ndbd default]` sections are used to configure the behavior of the cluster's data nodes.

`[ndbd]` and `[ndbd default]` are always used as the section names whether you are using `ndbd` or `ndbmtd` binaries for the data node processes.

There are many parameters which control buffer sizes, pool sizes, timeouts, and so forth. The only mandatory parameter is either one of `ExecuteOnComputer` or `HostName`; this must be defined in the local `[ndbd]` section.

The parameter `NoOfReplicas` should be defined in the `[ndbd default]` section, as it is common to all Cluster data nodes. It is not strictly necessary to set `NoOfReplicas`, but it is good practice to set it explicitly.

Most data node parameters are set in the `[ndbd default]` section. Only those parameters explicitly stated as being able to set local values are permitted to be changed in the `[ndbd]` section. Where present, `HostName`, `NodeId` and `ExecuteOnComputer` *must* be defined in the local `[ndbd]` section, and not in any other section of `config.ini`. In other words, settings for these parameters are specific to one data node.

For those parameters affecting memory usage or buffer sizes, it is possible to use `K`, `M`, or `G` as a suffix to indicate units of 1024, 1024×1024, or 1024×1024×1024. (For example, `100K` means 100 × 1024 = 102400.)

Parameter names and values are case-insensitive, unless used in a MySQL Server `my.cnf` or `my.ini` file, in which case they are case sensitive.

Information about configuration parameters specific to NDB Cluster Disk Data tables can be found later in this section (see Disk Data Configuration Parameters).

All of these parameters also apply to `ndbmtd` (the multi-threaded version of `ndbd`). Three additional data node configuration parameters—`MaxNoOfExecutionThreads`, `ThreadConfig`, and `NoOfFragmentLogParts`—apply to `ndbmtd` only; these have no effect when used with `ndbd`. For more information, see Multi-Threading Configuration Parameters (ndbmtd). See also Section 18.4.3, “`ndbmtd` — The NDB Cluster Data Node Daemon (Multi-Threaded)”.

Identifying data nodes. The `NodeId` or `Id` value (that is, the data node identifier) can be allocated on the command line when the node is started or in the configuration file.

- `Id`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	1 - 48	IS

A unique node ID is used as the node's address for all cluster internal messages. For data nodes, this is an integer in the range 1 to 48 inclusive. Each node in the cluster must have a unique identifier.

`NodeId` is the preferred parameter name to use when identifying data nodes. Although the older `Id` is still supported for backward compatibility, it is now deprecated, and generates a warning when used. `Id` is also subject to removal in a future NDB Cluster release.

- `NodeId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	1 - 48	IS

A unique node ID is used as the node's address for all cluster internal messages. For data nodes, this is an integer in the range 1 to 48 inclusive. Each node in the cluster must have a unique identifier.

`NodeId` is the preferred parameter name to use when identifying data nodes. Although `Id` continues to be supported for backward compatibility, it is now deprecated, generates a warning when used, and is subject to removal in a future version of NDB Cluster.

- `ExecuteOnComputer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name	[none]	...	S

This refers to the `Id` set for one of the computers defined in a `[computer]` section.

- `HostName`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	localhost	...	N

Specifying this parameter defines the hostname of the computer on which the data node is to reside. To specify a hostname other than `localhost`, either this parameter or `ExecuteOnComputer` is required.

- `ServerPort`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	1 - 64K	S

Each node in the cluster uses a port to connect to other nodes. By default, this port is allocated dynamically in such a way as to ensure that no two nodes on the same host computer receive the same port number, so it should normally not be necessary to specify a value for this parameter.

However, if you need to be able to open specific ports in a firewall to permit communication between data nodes and API nodes (including SQL nodes), you can set this parameter to the number of the desired port in an `[ndbd]` section or (if you need to do this for multiple data nodes) the `[ndbd default]` section of the `config.ini` file, and then open the port having that number for incoming connections from SQL nodes, API nodes, or both.

Note

Connections from data nodes to management nodes is done using the `ndb_mgmd` management port (the management server's `PortNumber`; see Section 18.3.3.5, “Defining an NDB Cluster Management Server”) so outgoing connections to that port from any data nodes should always be permitted.

- `TcpBind_INADDR_ANY`

Setting this parameter to `TRUE` or `1` binds `IP_ADDR_ANY` so that connections can be made from anywhere (for autogenerated connections). The default is `FALSE` (`0`).

- `NodeGroup`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0		[none]	0 - 65536	IS

This parameter can be used to assign a data node to a specific node group. It is read only when the cluster is started for the first time, and cannot be used to reassign a data node to a different node group online. It is generally not desirable to use this parameter in the `[ndbd default]` section of the `config.ini` file, and care must be taken not to assign nodes to node groups in such a way that an invalid numbers of nodes are assigned to any node groups.

The `NodeGroup` parameter is chiefly intended for use in adding a new node group to a running NDB Cluster without having to perform a rolling restart. For this purpose, you should set it to 65536 (the maximum value). You are not required to set a `NodeGroup` value for all cluster data nodes, only for those nodes which are to be started and added to the cluster as a new node group at a later time. For more information, see Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”.

- `NoOfReplicas`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	2	1 - 4	IS

This global parameter can be set only in the `[ndbd default]` section, and defines the number of replicas for each table stored in the cluster. This parameter also specifies the size of node groups. A node group is a set of nodes all storing the same information.

Node groups are formed implicitly. The first node group is formed by the set of data nodes with the lowest node IDs, the next node group by the set of the next lowest node identities, and so on. By way of example, assume that we have 4 data nodes and that `NoOfReplicas` is set to 2. The four data nodes have node IDs 2, 3, 4 and 5. Then the first node group is formed from nodes 2 and 3, and the second node group by nodes 4 and 5. It is important to configure the cluster in such a manner that nodes in the same node groups are not placed on the same computer because a single hardware failure would cause the entire cluster to fail.

If no node IDs are provided, the order of the data nodes will be the determining factor for the node group. Whether or not explicit assignments are made, they can be viewed in the output of the management client's `SHOW` command.

The default value for `NoOfReplicas` is 2. *This is the recommended value for most production environments*.

Important

While the maximum *possible* value for this parameter is 4, **setting `NoOfReplicas` to a value greater than 2 is not supported in production**.

Warning

Setting `NoOfReplicas` to 1 means that there is only a single copy of all Cluster data; in this case, the loss of a single data node causes the cluster to fail because there are no additional copies of the data stored by that node.

The value for this parameter must divide evenly into the number of data nodes in the cluster. For example, if there are two data nodes, then `NoOfReplicas` must be equal to either 1 or 2, since 2/3 and 2/4 both yield fractional values; if there are four data nodes, then `NoOfReplicas` must be equal to 1, 2, or 4.

- `DataDir`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	path	.	...	IN

This parameter specifies the directory where trace files, log files, pid files and error logs are placed.

The default is the data node process working directory.

- `FileSystemPath`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	path	DataDir	...	IN

This parameter specifies the directory where all files created for metadata, REDO logs, UNDO logs (for Disk Data tables), and data files are placed. The default is the directory specified by `DataDir`.

Note

This directory must exist before the `ndbd` process is initiated.

The recommended directory hierarchy for NDB Cluster includes `/var/lib/mysql-cluster`, under which a directory for the node's file system is created. The name of this subdirectory contains the node ID. For example, if the node ID is 2, this subdirectory is named `ndb_2_fs`.

- `BackupDataDir`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	path	[see text]	...	IN

This parameter specifies the directory in which backups are placed.

Important

The string '`/BACKUP`' is always appended to this value. For example, if you set the value of `BackupDataDir` to `/var/lib/cluster-data`, then all backups are stored under `/var/lib/cluster-data/BACKUP`. This also means that the *effective* default backup location is the directory named `BACKUP` under the location specified by the `FileSystemPath` parameter.

Data Memory, Index Memory, and String Memory

`DataMemory` and `IndexMemory` are `[ndbd]` parameters specifying the size of memory segments used to store the actual records and their indexes. In setting values for these, it is important to understand how `DataMemory` and `IndexMemory` are used, as they usually need to be updated to reflect actual usage by the cluster:

- `DataMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	80M	1M - 1024G	N

This parameter defines the amount of space (in bytes) available for storing database records. The entire amount specified by this value is allocated in memory, so it is extremely important that the machine has sufficient physical memory to accommodate it.

The memory allocated by `DataMemory` is used to store both the actual records and indexes. There is a 16-byte overhead on each record; an additional amount for each record is incurred because it is stored in a 32KB page with 128 byte page overhead (see below). There is also a small amount wasted per page due to the fact that each record is stored in only one page.

For variable-size table attributes, the data is stored on separate data pages, allocated from `DataMemory`. Variable-length records use a fixed-size part with an extra overhead of 4 bytes to reference the variable-size part. The variable-size part has 2 bytes overhead plus 2 bytes per attribute.

The maximum record size is 14000 bytes.

The memory space defined by `DataMemory` is also used to store ordered indexes, which use about 10 bytes per record. Each table row is represented in the ordered index. A common error among users is to assume that all indexes are stored in the memory allocated by `IndexMemory`, but this is not the case: Only primary key and unique hash indexes use this memory; ordered indexes use the memory allocated by `DataMemory`. However, creating a primary key or unique hash index also creates an ordered index on the same keys, unless you specify `USING HASH` in the index creation statement. This can be verified by running `ndb_desc -d db_name table_name` in the management client.

NDB Cluster can use a maximum of 512 MB for hash indexes per partition, which means in some cases it is possible to get `Table is full` errors in MySQL client applications even when `ndb_mgm`

`-e "ALL REPORT MEMORYUSAGE"` shows significant free `DataMemory`. This can also pose a problem with data node restarts on nodes that are heavily loaded with data.

You can force `NDB` to create extra partitions for NDB Cluster tables and thus have more memory available for hash indexes by using the `MAX_ROWS` option for `CREATE TABLE`. In general, setting `MAX_ROWS` to twice the number of rows that you expect to store in the table should be sufficient.

You can also use the `MinFreePct` configuration parameter to help avoid problems with node restarts. (NDB 7.2.3 and later; Bug #13436216.)

The memory space allocated by `DataMemory` consists of 32KB pages, which are allocated to table fragments. Each table is normally partitioned into the same number of fragments as there are data nodes in the cluster. Thus, for each node, there are the same number of fragments as are set in `NoOfReplicas`.

Once a page has been allocated, it is currently not possible to return it to the pool of free pages, except by deleting the table. (This also means that `DataMemory` pages, once allocated to a given table, cannot be used by other tables.) Performing a data node recovery also compresses the partition because all records are inserted into empty partitions from other live nodes.

The `DataMemory` memory space also contains UNDO information: For each update, a copy of the unaltered record is allocated in the `DataMemory`. There is also a reference to each copy in the ordered table indexes. Unique hash indexes are updated only when the unique index columns are updated, in which case a new entry in the index table is inserted and the old entry is deleted upon commit. For this reason, it is also necessary to allocate enough memory to handle the largest transactions performed by applications using the cluster. In any case, performing a few large transactions holds no advantage over using many smaller ones, for the following reasons:

- Large transactions are not any faster than smaller ones
- Large transactions increase the number of operations that are lost and must be repeated in event of transaction failure
- Large transactions use more memory

The default value for `DataMemory` is 80MB; the minimum is 1MB. There is no maximum size, but in reality the maximum size has to be adapted so that the process does not start swapping when the limit is reached. This limit is determined by the amount of physical RAM available on the machine and by the amount of memory that the operating system may commit to any one process. 32-bit operating systems are generally limited to 2−4GB per process; 64-bit operating systems can use more. For large databases, it may be preferable to use a 64-bit operating system for this reason.

- `IndexMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	18M	1M - 1T	N

This parameter controls the amount of storage used for hash indexes in NDB Cluster. Hash indexes are always used for primary key indexes, unique indexes, and unique constraints. When defining a primary key or a unique index, two indexes are created, one of which is a hash index used for all tuple accesses as well as lock handling. This index is also used to enforce unique constraints.

You can estimate the size of a hash index using this formula:

```
size  = ( (fragments * 32K) + (rows * 18) )
        * replicas
```

fragments is the number of fragments, *replicas* is the number of replicas (normally 2), and *rows* is the number of rows. If a table has one million rows, 8 fragments, and 2 replicas, the expected index memory usage is calculated as shown here:

```
((8 * 32K) + (1000000 * 18)) * 2 = ((8 * 32768) + (1000000 * 18)) * 2
= (262144 + 18000000) * 2
= 18262144 * 2 = 36524288 bytes = ~35MB
```

In NDB Cluster 7.2 and later, index statistics (when enabled) for ordered indexes are stored in the `mysql.ndb_index_stat_sample` table. Since this table has a hash index, this adds to index memory usage. An upper bound to the number of rows for a given ordered index can be calculated as follows:

```
sample_size= key_size + ((key_attributes + 1) * 4)

sample_rows = IndexStatSaveSize
              * ((0.01 * IndexStatSaveScale * log2(rows * sample_size)) + 1)
              / sample_size
```

In the preceding formula, *key_size* is the size of the ordered index key in bytes, *key_attributes* is the number ot attributes in the ordered index key, and *rows* is the number of rows in the base table.

Assume that table `t1` has 1 million rows and an ordered index named `ix1` on two four-byte integers. Assume in addition that `IndexStatSaveSize` and `IndexStatSaveScale` are set to their default values (32K and 100, respectively). Using the previous 2 formulas, we can calculate as follows:

```
sample_size = 8  + ((1 + 2) * 4) = 20 bytes

sample_rows = 32K
              * ((0.01 * 100 * log2(1000000*20)) + 1)
              / 20
              = 32768 * ( (1 * ~16.811) +1) / 20
              = 32768 * ~17.811 / 20
              = ~29182 rows
```

The expected index memory usage is thus 2 * 18 * 29182 = ~1050550 bytes.

The default value for `IndexMemory` is 18MB. The minimum is 1MB.

- `StringMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	% or bytes	25	0 - 4294967039 (0xFFFFFEFF)	S
NDB 7.2.1	% or bytes	25	0 - 4294967039 (0xFFFFFEFF)	S

This parameter determines how much memory is allocated for strings such as table names, and is specified in an `[ndbd]` or `[ndbd default]` section of the `config.ini` file. A value between `0` and `100` inclusive is interpreted as a percent of the maximum default value, which is calculated based on a number of factors including the number of tables, maximum table name size, maximum size of `.FRM` files, `MaxNoOfTriggers`, maximum column name size, and maximum default column value.

A value greater than `100` is interpreted as a number of bytes.

The default value is 25—that is, 25 percent of the default maximum.

Under most circumstances, the default value should be sufficient, but when you have a great many Cluster tables (1000 or more), it is possible to get Error 773 `Out of string memory, please modify StringMemory config parameter: Permanent error: Schema error`, in which case you should increase this value. `25` (25 percent) is not excessive, and should prevent this error from recurring in all but the most extreme conditions.

The following example illustrates how memory is used for a table. Consider this table definition:

```
CREATE TABLE example (
  a INT NOT NULL,
  b INT NOT NULL,
  c INT NOT NULL,
  PRIMARY KEY(a),
  UNIQUE(b)
) ENGINE=NDBCLUSTER;
```

For each record, there are 12 bytes of data plus 12 bytes overhead. Having no nullable columns saves 4 bytes of overhead. In addition, we have two ordered indexes on columns `a` and `b` consuming roughly 10 bytes each per record. There is a primary key hash index on the base table using roughly 29 bytes per record. The unique constraint is implemented by a separate table with `b` as primary key and `a` as a column. This other table consumes an additional 29 bytes of index memory per record in the `example` table as well 8 bytes of record data plus 12 bytes of overhead.

Thus, for one million records, we need 58MB for index memory to handle the hash indexes for the primary key and the unique constraint. We also need 64MB for the records of the base table and the unique index table, plus the two ordered index tables.

You can see that hash indexes takes up a fair amount of memory space; however, they provide very fast access to the data in return. They are also used in NDB Cluster to handle uniqueness constraints.

The only partitioning algorithm is hashing and ordered indexes are local to each node. Thus, ordered indexes cannot be used to handle uniqueness constraints in the general case.

An important point for both `IndexMemory` and `DataMemory` is that the total database size is the sum of all data memory and all index memory for each node group. Each node group is used to store replicated information, so if there are four nodes with two replicas, there will be two node groups. Thus, the total data memory available is 2 × `DataMemory` for each data node.

It is highly recommended that `DataMemory` and `IndexMemory` be set to the same values for all nodes. Data distribution is even over all nodes in the cluster, so the maximum amount of space available for any node can be no greater than that of the smallest node in the cluster.

`DataMemory` and `IndexMemory` can be changed, but decreasing either of these can be risky; doing so can easily lead to a node or even an entire NDB Cluster that is unable to restart due to there being insufficient memory space. Increasing these values should be acceptable, but it is recommended that such upgrades are performed in the same manner as a software upgrade, beginning with an update of the configuration file, and then restarting the management server followed by restarting each data node in turn.

MinFreePct. Beginning with NDB 7.2.3, a proportion (5% by default) of data node resources including `DataMemory` and `IndexMemory` is kept in reserve to insure that the data node does not exhaust its memory when performing a restart. This can be adjusted using the `MinFreePct` data node configuration parameter (default 5) introduced in the same version of NDB Cluster.

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.3	unsigned	5	0 - 100	N

Updates do not increase the amount of index memory used. Inserts take effect immediately; however, rows are not actually deleted until the transaction is committed.

Transaction parameters. The next few `[ndbd]` parameters that we discuss are important because they affect the number of parallel transactions and the sizes of transactions that can be handled by the system. `MaxNoOfConcurrentTransactions` sets the number of parallel transactions possible in a node. `MaxNoOfConcurrentOperations` sets the number of records that can be in update phase or locked simultaneously.

Both of these parameters (especially `MaxNoOfConcurrentOperations`) are likely targets for users setting specific values and not using the default value. The default value is set for systems using small transactions, to ensure that these do not use excessive memory.

`MaxDMLOperationsPerTransaction` sets the maximum number of DML operations that can be performed in a given transaction.

- `MaxNoOfConcurrentTransactions`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	4096	32 - 4294967039 (0xFFFFFEFF)	N

Each cluster data node requires a transaction record for each active transaction in the cluster. The task of coordinating transactions is distributed among all of the data nodes. The total number of transaction records in the cluster is the number of transactions in any given node times the number of nodes in the cluster.

Transaction records are allocated to individual MySQL servers. Each connection to a MySQL server requires at least one transaction record, plus an additional transaction object per table accessed by that connection. This means that a reasonable minimum for the total number of transactions in the cluster can be expressed as

```
TotalNoOfConcurrentTransactions =
    (maximum number of tables accessed in any single transaction + 1)
    * number of SQL nodes
```

Suppose that there are 10 SQL nodes using the cluster. A single join involving 10 tables requires 11 transaction records; if there are 10 such joins in a transaction, then 10 * 11 = 110 transaction records are required for this transaction, per MySQL server, or 110 * 10 = 1100 transaction records total. Each data node can be expected to handle TotalNoOfConcurrentTransactions / number of data nodes. For an NDB Cluster having 4 data nodes, this would mean setting `MaxNoOfConcurrentTransactions` on each data node to 1100 / 4 = 275. In addition, you should provide for failure recovery by ensuring that a single node group can accommodate all concurrent transactions; in other words, that each data node's MaxNoOfConcurrentTransactions is sufficient to cover a number of transactions equal to TotalNoOfConcurrentTransactions / number of node groups. If this cluster has a single node group, then `MaxNoOfConcurrentTransactions` should be set to 1100 (the same as the total number of concurrent transactions for the entire cluster).

In addition, each transaction involves at least one operation; for this reason, the value set for `MaxNoOfConcurrentTransactions` should always be no more than the value of `MaxNoOfConcurrentOperations`.

This parameter must be set to the same value for all cluster data nodes. This is due to the fact that, when a data node fails, the oldest surviving node re-creates the transaction state of all transactions that were ongoing in the failed node.

It is possible to change this value using a rolling restart, but the amount of traffic on the cluster must be such that no more transactions occur than the lower of the old and new levels while this is taking place.

The default value is 4096.

- `MaxNoOfConcurrentOperations`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	32K	32 - 4294967039 (0xFFFFFEFF)	N

It is a good idea to adjust the value of this parameter according to the size and number of transactions. When performing transactions which involve only a few operations and records, the default value for this parameter is usually sufficient. Performing large transactions involving many records usually requires that you increase its value.

Records are kept for each transaction updating cluster data, both in the transaction coordinator and in the nodes where the actual updates are performed. These records contain state information needed to find UNDO records for rollback, lock queues, and other purposes.

This parameter should be set at a minimum to the number of records to be updated simultaneously in transactions, divided by the number of cluster data nodes. For example, in a cluster which has four data nodes and which is expected to handle one million concurrent updates using transactions, you should set this value to 1000000 / 4 = 250000. To help provide resiliency against failures, it is suggested that you set this parameter to a value that is high enough to permit an individual data node to handle the load for its node group. In other words, you should set the value equal to `total number of concurrent operations / number of node groups`. (In the case where there is a single node group, this is the same as the total number of concurrent operations for the entire cluster.)

Because each transaction always involves at least one operation, the value of `MaxNoOfConcurrentOperations` should always be greater than or equal to the value of `MaxNoOfConcurrentTransactions`.

Read queries which set locks also cause operation records to be created. Some extra space is allocated within individual nodes to accommodate cases where the distribution is not perfect over the nodes.

When queries make use of the unique hash index, there are actually two operation records used per record in the transaction. The first record represents the read in the index table and the second handles the operation on the base table.

The default value is 32768.

This parameter actually handles two values that can be configured separately. The first of these specifies how many operation records are to be placed with the transaction coordinator. The second part specifies how many operation records are to be local to the database.

A very large transaction performed on an eight-node cluster requires as many operation records in the transaction coordinator as there are reads, updates, and deletes involved in the transaction. However, the operation records of the are spread over all eight nodes. Thus, if it is necessary to configure the system for one very large transaction, it is a good idea to configure the two parts separately. `MaxNoOfConcurrentOperations` will always be used to calculate the number of operation records in the transaction coordinator portion of the node.

It is also important to have an idea of the memory requirements for operation records. These consume about 1KB per record.

- `MaxNoOfLocalOperations`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	UNDEFINED	32 - 4294967039 (0xFFFFFEFF)	N

By default, this parameter is calculated as 1.1 × `MaxNoOfConcurrentOperations`. This fits systems with many simultaneous transactions, none of them being very large. If there is a need to handle one very large transaction at a time and there are many nodes, it is a good idea to override the default value by explicitly specifying this parameter.

- `MaxDMLOperationsPerTransaction`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	operations (DML)	4294967295	32 - 4294967295	N

This parameter limits the size of a transaction. The transaction is aborted if it requires more than this many DML operations. The minimum number of operations per transaction is 32; however, you can set `MaxDMLOperationsPerTransaction` to 0 to disable any limitation on the number of DML operations per transaction. The maximum (and default) is 4294967295.

Transaction temporary storage. The next set of `[ndbd]` parameters is used to determine temporary storage when executing a statement that is part of a Cluster transaction. All records are released when the statement is completed and the cluster is waiting for the commit or rollback.

The default values for these parameters are adequate for most situations. However, users with a need to support transactions involving large numbers of rows or operations may need to increase these values to enable better parallelism in the system, whereas users whose applications require relatively small transactions can decrease the values to save memory.

- `MaxNoOfConcurrentIndexOperations`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	8K	0 - 4294967039 (0xFFFFFEFF)	N

For queries using a unique hash index, another temporary set of operation records is used during a query's execution phase. This parameter sets the size of that pool of records. Thus, this record is allocated only while executing a part of a query. As soon as this part has been executed, the record is released. The state needed to handle aborts and commits is handled by the normal operation records, where the pool size is set by the parameter `MaxNoOfConcurrentOperations`.

The default value of this parameter is 8192. Only in rare cases of extremely high parallelism using unique hash indexes should it be necessary to increase this value. Using a smaller value is possible and can save memory if the DBA is certain that a high degree of parallelism is not required for the cluster.

- `MaxNoOfFiredTriggers`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	4000	0 - 4294967039 (0xFFFFFEFF)	N

The default value of `MaxNoOfFiredTriggers` is 4000, which is sufficient for most situations. In some cases it can even be decreased if the DBA feels certain the need for parallelism in the cluster is not high.

A record is created when an operation is performed that affects a unique hash index. Inserting or deleting a record in a table with unique hash indexes or updating a column that is part of a unique hash index fires an insert or a delete in the index table. The resulting record is used to represent this index table operation while waiting for the original operation that fired it to complete. This operation is short-lived but can still require a large number of records in its pool for situations with many parallel write operations on a base table containing a set of unique hash indexes.

- `TransactionBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	1M	1K - 4294967039 (0xFFFFFEFF)	N

The memory affected by this parameter is used for tracking operations fired when updating index tables and reading unique indexes. This memory is used to store the key and column information for these operations. It is only very rarely that the value for this parameter needs to be altered from the default.

The default value for `TransactionBufferMemory` is 1MB.

Normal read and write operations use a similar buffer, whose usage is even more short-lived. The compile-time parameter `ZATTRBUF_FILESIZE` (found in `ndb/src/kernel/blocks/Dbtc/Dbtc.hpp`) set to 4000 × 128 bytes (500KB). A similar buffer for key information, `ZDATABUF_FILESIZE` (also in `Dbtc.hpp`) contains 4000 × 16 = 62.5KB of buffer space. `Dbtc` is the module that handles transaction coordination.

Scans and buffering. There are additional `[ndbd]` parameters in the `Dblqh` module (in `ndb/src/kernel/blocks/Dblqh/Dblqh.hpp`) that affect reads and updates. These include `ZATTRINBUF_FILESIZE`, set by default to 10000 × 128 bytes (1250KB) and `ZDATABUF_FILE_SIZE`, set by default to 10000*16 bytes (roughly 156KB) of buffer space. To date, there have been neither any reports from users nor any results from our own extensive tests suggesting that either of these compile-time limits should be increased.

- `MaxNoOfConcurrentScans`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	256	2 - 500	N

This parameter is used to control the number of parallel scans that can be performed in the cluster. Each transaction coordinator can handle the number of parallel scans defined for this parameter. Each scan query is performed by scanning all partitions in parallel. Each partition scan uses a scan record in the node where the partition is located, the number of records being the value of this parameter times the number of nodes. The cluster should be able to sustain `MaxNoOfConcurrentScans` scans concurrently from all nodes in the cluster.

Scans are actually performed in two cases. The first of these cases occurs when no hash or ordered indexes exists to handle the query, in which case the query is executed by performing a full table scan. The second case is encountered when there is no hash index to support the query but there is an ordered index. Using the ordered index means executing a parallel range scan. The order is kept on the local partitions only, so it is necessary to perform the index scan on all partitions.

The default value of `MaxNoOfConcurrentScans` is 256. The maximum value is 500.

- `MaxNoOfLocalScans`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	[see text]	32 - 4294967039 (0xFFFFFEFF)	N

Specifies the number of local scan records if many scans are not fully parallelized. In NDB 7.2.0 and later, when the number of local scan records is not provided, it is calculated as shown here:

```
4 * MaxNoOfConcurrentScans * [# data nodes] + 2
```

The minimum value is 32.

- `BatchSizePerLocalScan`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	64	1 - 992	N
NDB 7.2.1	integer	256	1 - 992	N

This parameter is used to calculate the number of lock records used to handle concurrent scan operations.

`BatchSizePerLocalScan` has a strong connection to the `BatchSize` defined in the SQL nodes.

- `LongMessageBuffer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	4M	512K - 4294967039 (0xFFFFFEFF)	N
NDB 7.2.16	bytes	64M	512K - 4294967039 (0xFFFFFEFF)	N

This is an internal buffer used for passing messages within individual nodes and between nodes. The default is 64MB. (Prior to NDB 7.2.16, this was 4MB.)

This parameter seldom needs to be changed from the default.

- `MaxParallelScansPerFragment`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	256	1 - 4294967039 (0xFFFFFEFF)	N

It is possible to configure the maximum number of parallel scans (`TUP` scans and `TUX` scans) allowed before they begin queuing for serial handling. You can increase this to take advantage of any unused CPU when performing large number of scans in parallel and improve their performance.

Beginning with NDB 7.2.0, the default value for this parameter was increased from 32 to 256.

Memory Allocation

`MaxAllocate`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	32M	1M - 1G	N

This is the maximum size of the memory unit to use when allocating memory for tables. In cases where `NDB` gives `Out of memory` errors, but it is evident by examining the cluster logs or the output of `DUMP 1000` that all available memory has not yet been used, you can increase the value of this parameter (or `MaxNoOfTables`, or both) to cause `NDB` to make sufficient memory available.

Hash Map Size

`DefaultHashMapSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.11	LDM threads	3840	0 - 3840	N

NDB 7.2.7 and later use a larger default table hash map size (3840) than in previous releases (240). Beginning with NDB 7.2.11, the size of the table hash maps used by NDB is configurable using this parameter; previously this value was hard-coded. DefaultHashMapSize can take any of three possible values (0, 240, 3840). These values and their effects are described in the following table:

Value	Description / Effect
0	Use the lowest value set, if any, for this parameter among all data nodes and API nodes in the cluster; if it is not set on any data or API node, use the default value.
240	Original hash map size, used by default in all NDB Cluster releases prior to NDB 7.2.7.
3840	Larger hash map size as used by default in NDB 7.2.7 and later

The primary intended use for this parameter is to facilitate upgrades and especially downgrades between NDB 7.2.7 and later NDB Cluster versions, in which the larger hash map size (3840) is the default, and earlier releases (in which the default was 240), due to the fact that this change is not otherwise backward compatible (Bug #14800539). By setting this parameter to 240 prior to performing an upgrade from an older version where this value is in use, you can cause the cluster to continue using the smaller size for table hash maps, in which case the tables remain compatible with earlier versions following the upgrade. DefaultHashMapSize can be set for individual data nodes, API nodes, or both, but setting it once only, in the [ndbd default] section of the config.ini file, is the recommended practice.

After increasing this parameter, to have existing tables to take advantage of the new size, you can run ALTER TABLE ... REORGANIZE PARTITION on them, after which they can use the larger hash map size. This is in addition to performing a rolling restart, which makes the larger hash maps available to new tables, but does not enable existing tables to use them.

Decreasing this parameter online after any tables have been created or modified with DefaultHashMapSize equal to 3840 is not currently supported.

Logging and checkpointing. The following [ndbd] parameters control log and checkpoint behavior.

- NoOfFragmentLogFiles

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	16	3 - 4294967039 (0xFFFFFEFF)	IN

This parameter sets the number of REDO log files for the node, and thus the amount of space allocated to REDO logging. Because the REDO log files are organized in a ring, it is extremely important that the first and last log files in the set (sometimes referred to as the “head” and “tail” log files, respectively) do not meet. When these approach one another too closely, the node begins aborting all transactions encompassing updates due to a lack of room for new log records.

A REDO log record is not removed until the required number of local checkpoints has been completed since that log record was inserted. (In NDB Cluster 7.2, only 2 local checkpoints are necessary). Checkpointing frequency is determined by its own set of configuration parameters discussed elsewhere in this chapter.

The default parameter value is 16, which by default means 16 sets of 4 16MB files for a total of 1024MB. The size of the individual log files is configurable using the FragmentLogFileSize parameter. In scenarios requiring a great many updates, the value for NoOfFragmentLogFiles may need to be set as high as 300 or even higher to provide sufficient space for REDO logs.

If the checkpointing is slow and there are so many writes to the database that the log files are full and the log tail cannot be cut without jeopardizing recovery, all updating transactions are aborted

with internal error code 410 (`Out of log file space temporarily`). This condition prevails until a checkpoint has completed and the log tail can be moved forward.

Important

This parameter cannot be changed “on the fly”; you must restart the node using `--initial`. If you wish to change this value for all data nodes in a running cluster, you can do so using a rolling node restart (using `--initial` when starting each data node).

- `FragmentLogFileSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	16M	4M - 1G	IN

Setting this parameter enables you to control directly the size of redo log files. This can be useful in situations when NDB Cluster is operating under a high load and it is unable to close fragment log files quickly enough before attempting to open new ones (only 2 fragment log files can be open at one time); increasing the size of the fragment log files gives the cluster more time before having to open each new fragment log file. The default value for this parameter is 16M.

For more information about fragment log files, see the description for `NoOfFragmentLogFiles`.

- `InitFragmentLogFiles`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	[see values]	SPARSE	SPARSE, FULL	IN

By default, fragment log files are created sparsely when performing an initial start of a data node—that is, depending on the operating system and file system in use, not all bytes are necessarily written to disk. However, it is possible to override this behavior and force all bytes to be written, regardless of the platform and file system type being used, by means of this parameter. `InitFragmentLogFiles` takes either of two values:

- `SPARSE`. Fragment log files are created sparsely. This is the default value.
- `FULL`. Force all bytes of the fragment log file to be written to disk.

Depending on your operating system and file system, setting `InitFragmentLogFiles=FULL` may help eliminate I/O errors on writes to the REDO log.

- `MaxNoOfOpenFiles`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	0	20 - 4294967039 (0xFFFFFEFF)	N

This parameter sets a ceiling on how many internal threads to allocate for open files. *Any situation requiring a change in this parameter should be reported as a bug*.

The default value is 0. However, the minimum value to which this parameter can be set is 20.

- `InitialNoOfOpenFiles`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	files	27	20 - 4294967039 (0xFFFFFEFF)	N

This parameter sets the initial number of internal threads to allocate for open files.

The default value is 27.

- `MaxNoOfSavedMessages`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	25	0 - 4294967039 (0xFFFFFEFF)	N

This parameter sets the maximum number of errors written in the error log as well as the maximum number of trace files that are kept before overwriting the existing ones. Trace files are generated when, for whatever reason, the node crashes.

The default is 25, which sets these maximums to 25 error messages and 25 trace files.

- `MaxLCPStartDelay`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	seconds	0	0 - 600	N

In parallel data node recovery, only table data is actually copied and synchronized in parallel; synchronization of metadata such as dictionary and checkpoint information is done in a serial fashion. In addition, recovery of dictionary and checkpoint information cannot be executed in parallel with performing of local checkpoints. This means that, when starting or restarting many data nodes concurrently, data nodes may be forced to wait while a local checkpoint is performed, which can result in longer node recovery times.

It is possible to force a delay in the local checkpoint to permit more (and possibly all) data nodes to complete metadata synchronization; once each data node's metadata synchronization is complete, all of the data nodes can recover table data in parallel, even while the local checkpoint is being executed. To force such a delay, set `MaxLCPStartDelay`, which determines the number of seconds the cluster can wait to begin a local checkpoint while data nodes continue to synchronize metadata. This parameter should be set in the `[ndbd default]` section of the `config.ini` file, so that it is the same for all data nodes. The maximum value is 600; the default is 0.

- `LcpScanProgressTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.14	second	60	0 - 4294967039 (0xFFFFFEFF)	N

A local checkpoint fragment scan watchdog checks periodically for no progress in each fragment scan performed as part of a local checkpoint, and shuts down the node if there is no progress after a given amount of time has elapsed. Prior to NDB 7.2.14, this interval is always 60 seconds (Bug #16630410). In NDB 7.2.14 and later, this interval can be set using the `LcpScanProgressTimeout` data node configuration parameter, which sets the maximum time for which the local checkpoint can be stalled before the LCP fragment scan watchdog shuts down the node.

The default value is 60 seconds (providing compatibility with previous releases). Setting this parameter to 0 disables the LCP fragment scan watchdog altogether.

Metadata objects. The next set of `[ndbd]` parameters defines pool sizes for metadata objects, used to define the maximum number of attributes, tables, indexes, and trigger objects used by indexes, events, and replication between clusters. Note that these act merely as “suggestions” to the cluster, and any that are not specified revert to the default values shown.

- `MaxNoOfAttributes`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	1000	32 - 4294967039 (0xFFFFFEFF)	N

This parameter sets a suggested maximum number of attributes that can be defined in the cluster; like `MaxNoOfTables`, it is not intended to function as a hard upper limit.

(In older NDB Cluster releases, this parameter was sometimes treated as a hard limit for certain operations. This caused problems with NDB Cluster Replication, when it was possible to create more tables than could be replicated, and sometimes led to confusion when it was possible [or not possible, depending on the circumstances] to create more than `MaxNoOfAttributes` attributes.)

The default value is 1000, with the minimum possible value being 32. The maximum is 4294967039. Each attribute consumes around 200 bytes of storage per node due to the fact that all metadata is fully replicated on the servers.

When setting `MaxNoOfAttributes`, it is important to prepare in advance for any `ALTER TABLE` statements that you might want to perform in the future. This is due to the fact, during the execution of `ALTER TABLE` on a Cluster table, 3 times the number of attributes as in the original table are used, and a good practice is to permit double this amount. For example, if the NDB Cluster table having the greatest number of attributes (*`greatest_number_of_attributes`*) has 100 attributes, a good starting point for the value of `MaxNoOfAttributes` would be `6 * greatest_number_of_attributes = 600`.

You should also estimate the average number of attributes per table and multiply this by `MaxNoOfTables`. If this value is larger than the value obtained in the previous paragraph, you should use the larger value instead.

Assuming that you can create all desired tables without any problems, you should also verify that this number is sufficient by trying an actual `ALTER TABLE` after configuring the parameter. If this is not successful, increase `MaxNoOfAttributes` by another multiple of `MaxNoOfTables` and test it again.

- `MaxNoOfTables`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	128	8 - 20320	N

A table object is allocated for each table and for each unique hash index in the cluster. This parameter sets a suggested maximum number of table objects for the cluster as a whole; like `MaxNoOfAttributes`, it is not intended to function as a hard upper limit.

(In older NDB Cluster releases, this parameter was sometimes treated as a hard limit for certain operations. This caused problems with NDB Cluster Replication, when it was possible to create more tables than could be replicated, and sometimes led to confusion when it was possible [or not possible, depending on the circumstances] to create more than `MaxNoOfTables` tables.)

For each attribute that has a `BLOB` data type an extra table is used to store most of the `BLOB` data. These tables also must be taken into account when defining the total number of tables.

The default value of this parameter is 128. The minimum is 8 and the maximum is 20320. Each table object consumes approximately 20KB per node.

Note

The sum of `MaxNoOfTables`, `MaxNoOfOrderedIndexes`, and `MaxNoOfUniqueHashIndexes` must not exceed $2^{32} - 2$ (4294967294).

- `MaxNoOfOrderedIndexes`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	128	0 - 4294967039 (0xFFFFFEFF)	N

For each ordered index in the cluster, an object is allocated describing what is being indexed and its storage segments. By default, each index so defined also defines an ordered index. Each unique index and primary key has both an ordered index and a hash index. `MaxNoOfOrderedIndexes` sets the total number of ordered indexes that can be in use in the system at any one time.

The default value of this parameter is 128. Each index object consumes approximately 10KB of data per node.

Note

The sum of `MaxNoOfTables`, `MaxNoOfOrderedIndexes`, and `MaxNoOfUniqueHashIndexes` must not exceed $2^{32} - 2$ (4294967294).

- `MaxNoOfUniqueHashIndexes`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	64	0 - 4294967039 (0xFFFFFEFF)	N

For each unique index that is not a primary key, a special table is allocated that maps the unique key to the primary key of the indexed table. By default, an ordered index is also defined for each unique index. To prevent this, you must specify the `USING HASH` option when defining the unique index.

The default value is 64. Each index consumes approximately 15KB per node.

Note

The sum of `MaxNoOfTables`, `MaxNoOfOrderedIndexes`, and `MaxNoOfUniqueHashIndexes` must not exceed $2^{32} - 2$ (4294967294).

- `MaxNoOfTriggers`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	768	0 - 4294967039 (0xFFFFFEFF)	N

Internal update, insert, and delete triggers are allocated for each unique hash index. (This means that three triggers are created for each unique hash index.) However, an *ordered* index requires only a single trigger object. Backups also use three trigger objects for each normal table in the cluster.

Replication between clusters also makes use of internal triggers.

This parameter sets the maximum number of trigger objects in the cluster.

The default value is 768.

- `MaxNoOfIndexes`

This parameter is deprecated and subject to removal in a future version of NDB Cluster. You should use `MaxNoOfOrderedIndexes` and `MaxNoOfUniqueHashIndexes` instead.

This parameter is used only by unique hash indexes. There needs to be one record in this pool for each unique hash index defined in the cluster.

The default value of this parameter is 128.

- `MaxNoOfSubscriptions`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

Each `NDB` table in an NDB Cluster requires a subscription in the NDB kernel. For some NDB API applications, it may be necessary or desirable to change this parameter. However, for normal usage with MySQL servers acting as SQL nodes, there is not any need to do so.

The default value for `MaxNoOfSubscriptions` is 0, which is treated as equal to `MaxNoOfTables`. Each subscription consumes 108 bytes.

- `MaxNoOfSubscribers`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter is of interest only when using NDB Cluster Replication. The default value is 0, which is treated as `2 * MaxNoOfTables`; that is, there is one subscription per `NDB` table for each of two MySQL servers (one acting as the replication master and the other as the slave). Each subscriber uses 16 bytes of memory.

When using circular replication, multi-master replication, and other replication setups involving more than 2 MySQL servers, you should increase this parameter to the number of `mysqld` processes included in replication (this is often, but not always, the same as the number of clusters). For example, if you have a circular replication setup using three NDB Clusters, with one `mysqld` attached to each cluster, and each of these `mysqld` processes acts as a master and as a slave, you should set `MaxNoOfSubscribers` equal to `3 * MaxNoOfTables`.

For more information, see Section 18.6, “NDB Cluster Replication”.

- `MaxNoOfConcurrentSubOperations`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	256	0 - 4294967039 (0xFFFFFEFF)	N

This parameter sets a ceiling on the number of operations that can be performed by all API nodes in the cluster at one time. The default value (256) is sufficient for normal operations, and might need to be adjusted only in scenarios where there are a great many API nodes each performing a high volume of operations concurrently.

Boolean parameters. The behavior of data nodes is also affected by a set of `[ndbd]` parameters taking on boolean values. These parameters can each be specified as `TRUE` by setting them equal to `1` or `Y`, and as `FALSE` by setting them equal to `0` or `N`.

- `LateAlloc`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	1	0 - 1	N

Allocate memory for this data node after a connection to the management server has been established. Enabled by default.

- `LockPagesInMainMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	0	0 - 2	N

For a number of operating systems, including Solaris and Linux, it is possible to lock a process into memory and so avoid any swapping to disk. This can be used to help guarantee the cluster's real-time characteristics.

This parameter takes one of the integer values `0`, `1`, or `2`, which act as shown in the following list:

- `0`: Disables locking. This is the default value.
- `1`: Performs the lock after allocating memory for the process.
- `2`: Performs the lock before memory for the process is allocated.

If the operating system is not configured to permit unprivileged users to lock pages, then the data node process making use of this parameter may have to be run as system root. (`LockPagesInMainMemory` uses the `mlockall` function. From Linux kernel 2.6.9, unprivileged users can lock memory as limited by `max locked memory`. For more information, see `ulimit -l` and http://linux.die.net/man/2/mlock).

Note

In older NDB Cluster releases, this parameter was a Boolean. `0` or `false` was the default setting, and disabled locking. `1` or `true` enabled locking of the process after its memory was allocated. In NDB Cluster 7.2, using `true` or `false` as the value of this parameter causes an error.

Important

Beginning with `glibc` 2.10, `glibc` uses per-thread arenas to reduce lock contention on a shared pool, which consumes real memory. In general, a data node process does not need per-thread arenas, since it does not perform any memory allocation after startup. (This difference in allocators does not appear to affect performance significantly.)

The `glibc` behavior is intended to be configurable via the `MALLOC_ARENA_MAX` environment variable, but a bug in this mechanism prior to `glibc` 2.16 meant that this variable could not be set to less than 8, so that the wasted memory could not be reclaimed. (Bug #15907219; see also http://sourceware.org/bugzilla/show_bug.cgi?id=13137 for more information concerning this issue.)

One possible workaround for this problem is to use the `LD_PRELOAD` environment variable to preload a `jemalloc` memory allocation library to take the place of that supplied with `glibc`.

- `StopOnError`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	1	0, 1	N

This parameter specifies whether a data node process should exit or perform an automatic restart when an error condition is encountered.

This parameter's default value is 1; this means that, by default, an error causes the data node process to halt.

When an error is encountered and `StopOnError` is 0, the data node process is restarted.

Important

If the data node process exits in an uncontrolled fashion (due, for example, to performing `kill -9` on the data node process while performing a query, or to a segmentation fault), and `StopOnError` is set to 0, the angel process attempts to restart it in exactly the same way as it was started previously—that is, using the same startup options that were employed the last time the node was started. Thus, if the data node process was originally started using the `--initial` option, it is also restarted with `--initial`. This means that, in such cases, if the failure occurs on a sufficient number of data nodes in a very short interval, the effect is the same as if you had performed an initial restart of the entire cluster, leading to loss of all data. (Bug #24945638)

Users of MySQL Cluster Manager should note that, when `StopOnError` equals 1, this prevents the MySQL Cluster Manager agent from restarting any data nodes after it has performed its own restart and recovery. See Starting and Stopping the Agent on Linux, for more information.

- `CrashOnCorruptedTuple`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.1	boolean	true	true, false	S

When this parameter is enabled, it forces a data node to shut down whenever it encounters a corrupted tuple. In NDB 7.2.1 and later, it is enabled by default. This is a change from NDB Cluster 7.0 and NDB Cluster 7.1, where it was disabled by default.

- `Diskless`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	true|false (1|0)	false	true, false	IS

It is possible to specify NDB Cluster tables as *diskless*, meaning that tables are not checkpointed to disk and that no logging occurs. Such tables exist only in main memory. A consequence of using diskless tables is that neither the tables nor the records in those tables survive a crash. However, when operating in diskless mode, it is possible to run `ndbd` on a diskless computer.

Important

This feature causes the *entire* cluster to operate in diskless mode.

When this feature is enabled, Cluster online backup is disabled. In addition, a partial start of the cluster is not possible.

`Diskless` is disabled by default.

- `ODirect`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

Enabling this parameter causes `NDB` to attempt using `O_DIRECT` writes for LCP, backups, and redo logs, often lowering `kswapd` and CPU usage. When using NDB Cluster on Linux, enable `ODirect` if you are using a 2.6 or later kernel.

`ODirect` is disabled by default.

- `RestartOnErrorInsert`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	error code	2	0 - 4	N

This feature is accessible only when building the debug version where it is possible to insert errors in the execution of individual blocks of code as part of testing.

This feature is disabled by default.

- `CompressedBackup`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

Enabling this parameter causes backup files to be compressed. The compression used is equivalent to `gzip --fast`, and can save 50% or more of the space required on the data node to store uncompressed backup files. Compressed backups can be enabled for individual data nodes, or for all data nodes (by setting this parameter in the `[ndbd default]` section of the `config.ini` file).

Important

You cannot restore a compressed backup to a cluster running a MySQL version that does not support this feature.

The default value is `0` (disabled).

- `CompressedLCP`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

Setting this parameter to `1` causes local checkpoint files to be compressed. The compression used is equivalent to `gzip --fast`, and can save 50% or more of the space required on the data node to store uncompressed checkpoint files. Compressed LCPs can be enabled for individual data nodes, or for all data nodes (by setting this parameter in the `[ndbd default]` section of the `config.ini` file).

Important

You cannot restore a compressed local checkpoint to a cluster running a MySQL version that does not support this feature.

The default value is `0` (disabled).

Controlling Timeouts, Intervals, and Disk Paging

There are a number of `[ndbd]` parameters specifying timeouts and intervals between various actions in Cluster data nodes. Most of the timeout values are specified in milliseconds. Any exceptions to this are mentioned where applicable.

- `TimeBetweenWatchDogCheck`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	6000	70 - 4294967039	N
		2142	(0xFFFFFEFF)	

To prevent the main thread from getting stuck in an endless loop at some point, a “watchdog” thread checks the main thread. This parameter specifies the number of milliseconds between checks. If the process remains in the same state after three checks, the watchdog thread terminates it.

This parameter can easily be changed for purposes of experimentation or to adapt to local conditions. It can be specified on a per-node basis although there seems to be little reason for doing so.

The default timeout is 6000 milliseconds (6 seconds).

- `TimeBetweenWatchDogCheckInitial`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	6000	70 - 4294967039 (0xFFFFFEFF)	N

This is similar to the `TimeBetweenWatchDogCheck` parameter, except that `TimeBetweenWatchDogCheckInitial` controls the amount of time that passes between execution checks inside a database node in the early start phases during which memory is allocated.

The default timeout is 6000 milliseconds (6 seconds).

- `StartPartialTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	30000	0 - 4294967039 (0xFFFFFEFF)	N

This parameter specifies how long the Cluster waits for all data nodes to come up before the cluster initialization routine is invoked. This timeout is used to avoid a partial Cluster startup whenever possible.

This parameter is overridden when performing an initial start or initial restart of the cluster.

The default value is 30000 milliseconds (30 seconds). 0 disables the timeout, in which case the cluster may start only if all nodes are available.

- `StartPartitionedTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	60000	0 - 4294967039 (0xFFFFFEFF)	N

If the cluster is ready to start after waiting for `StartPartialTimeout` milliseconds but is still possibly in a partitioned state, the cluster waits until this timeout has also passed. If `StartPartitionedTimeout` is set to 0, the cluster waits indefinitely.

This parameter is overridden when performing an initial start or initial restart of the cluster.

The default timeout is 60000 milliseconds (60 seconds).

- `StartFailureTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	0	0 - 4294967039 (0xFFFFFEFF)	N
		2143		

If a data node has not completed its startup sequence within the time specified by this parameter, the node startup fails. Setting this parameter to 0 (the default value) means that no data node timeout is applied.

For nonzero values, this parameter is measured in milliseconds. For data nodes containing extremely large amounts of data, this parameter should be increased. For example, in the case of a data node containing several gigabytes of data, a period as long as 10−15 minutes (that is, 600000 to 1000000 milliseconds) might be required to perform a node restart.

- `StartNoNodeGroupTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	15000	0 - 4294967039 (0xFFFFFEFF)	N

When a data node is configured with `Nodegroup = 65536`, is regarded as not being assigned to any node group. When that is done, the cluster waits `StartNoNodegroupTimeout` milliseconds, then treats such nodes as though they had been added to the list passed to the `--nowait-nodes` option, and starts. The default value is `15000` (that is, the management server waits 15 seconds). Setting this parameter equal to `0` means that the cluster waits indefinitely.

`StartNoNodegroupTimeout` must be the same for all data nodes in the cluster; for this reason, you should always set it in the `[ndbd default]` section of the `config.ini` file, rather than for individual data nodes.

See Section 18.5.13, “Adding NDB Cluster Data Nodes Online”, for more information.

- `HeartbeatIntervalDbDb`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	5000	10 - 4294967039 (0xFFFFFEFF)	N

One of the primary methods of discovering failed nodes is by the use of heartbeats. This parameter states how often heartbeat signals are sent and how often to expect to receive them. Heartbeats cannot be disabled.

After missing four heartbeat intervals in a row, the node is declared dead. Thus, the maximum time for discovering a failure through the heartbeat mechanism is five times the heartbeat interval.

In NDB 7.2.0 and later, the default heartbeat interval is 5000 milliseconds (5 seconds). (Previously, the default was 1500 milliseconds [1.5 seconds]). This parameter must not be changed drastically and should not vary widely between nodes. If one node uses 5000 milliseconds and the node watching it uses 1000 milliseconds, obviously the node will be declared dead very quickly. This parameter can be changed during an online software upgrade, but only in small increments.

See also Network communication and latency, as well as the description of the `ConnectCheckIntervalDelay` configuration parameter.

- `HeartbeatIntervalDbApi`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	1500	100 - 4294967039 (0xFFFFFEFF)	N

Each data node sends heartbeat signals to each MySQL server (SQL node) to ensure that it remains in contact. If a MySQL server fails to send a heartbeat in time it is declared “dead,” in which case all ongoing transactions are completed and all resources released. The SQL node cannot reconnect

until all activities initiated by the previous MySQL instance have been completed. The three-heartbeat criteria for this determination are the same as described for `HeartbeatIntervalDbDb`.

The default interval is 1500 milliseconds (1.5 seconds). This interval can vary between individual data nodes because each data node watches the MySQL servers connected to it, independently of all other data nodes.

For more information, see Network communication and latency.

- `HeartbeatOrder`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	0	0 - 65535	S

Data nodes send heartbeats to one another in a circular fashion whereby each data node monitors the previous one. If a heartbeat is not detected by a given data node, this node declares the previous data node in the circle “dead” (that is, no longer accessible by the cluster). The determination that a data node is dead is done globally; in other words; once a data node is declared dead, it is regarded as such by all nodes in the cluster.

It is possible for heartbeats between data nodes residing on different hosts to be too slow compared to heartbeats between other pairs of nodes (for example, due to a very low heartbeat interval or temporary connection problem), such that a data node is declared dead, even though the node can still function as part of the cluster. .

In this type of situation, it may be that the order in which heartbeats are transmitted between data nodes makes a difference as to whether or not a particular data node is declared dead. If this declaration occurs unnecessarily, this can in turn lead to the unnecessary loss of a node group and as thus to a failure of the cluster.

Consider a setup where there are 4 data nodes A, B, C, and D running on 2 host computers `host1` and `host2`, and that these data nodes make up 2 node groups, as shown in the following table:

Node Group	Nodes Running on `host1`	Nodes Running on `host2`
Node Group 0:	Node A	Node B
Node Group 1:	Node C	Node D

Suppose the heartbeats are transmitted in the order A->B->C->D->A. In this case, the loss of the heartbeat between the hosts causes node B to declare node A dead and node C to declare node B dead. This results in loss of Node Group 0, and so the cluster fails. On the other hand, if the order of transmission is A->B->D->C->A (and all other conditions remain as previously stated), the loss of the heartbeat causes nodes A and D to be declared dead; in this case, each node group has one surviving node, and the cluster survives.

The `HeartbeatOrder` configuration parameter makes the order of heartbeat transmission user-configurable. The default value for `HeartbeatOrder` is zero; allowing the default value to be used on all data nodes causes the order of heartbeat transmission to be determined by `NDB`. If this parameter is used, it must be set to a nonzero value (maximum 65535) for every data node in the cluster, and this value must be unique for each data node; this causes the heartbeat transmission to proceed from data node to data node in the order of their `HeartbeatOrder` values from lowest to highest (and then directly from the data node having the highest `HeartbeatOrder` to the data node having the lowest value, to complete the circle). The values need not be consecutive; for example, to force the heartbeat transmission order A->B->D->C->A in the scenario outlined previously, you could set the `HeartbeatOrder` values as shown here:

Node	`HeartbeatOrder`
A 2145	10

Node	HeartbeatOrder
B	20
C	30
D	25

To use this parameter to change the heartbeat transmission order in a running NDB Cluster, you must first set HeartbeatOrder for each data node in the cluster in the global configuration (config.ini) file (or files). To cause the change to take effect, you must perform either of the following:

- A complete shutdown and restart of the entire cluster.
- 2 rolling restarts of the cluster in succession. *All nodes must be restarted in the same order in both rolling restarts*.

You can use DUMP 908 to observe the effect of this parameter in the data node logs.

- ConnectCheckIntervalDelay

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	1500	0 - 4294967039 (0xFFFFFEFF)	N
NDB 7.2.1	milliseconds	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter enables connection checking between data nodes after one of them has failed heartbeat checks for 5 intervals of up to HeartbeatIntervalDbDb milliseconds.

Such a data node that further fails to respond within an interval of ConnectCheckIntervalDelay milliseconds is considered suspect, and is considered dead after two such intervals. This can be useful in setups with known latency issues.

The default value for this parameter is 0 (disabled); this represents a change from NDB Cluster 7.1.

- TimeBetweenLocalCheckpoints

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	number of 4-byte words, as a base-2 logarithm	20	0 - 31	N

This parameter is an exception in that it does not specify a time to wait before starting a new local checkpoint; rather, it is used to ensure that local checkpoints are not performed in a cluster where relatively few updates are taking place. In most clusters with high update rates, it is likely that a new local checkpoint is started immediately after the previous one has been completed.

The size of all write operations executed since the start of the previous local checkpoints is added. This parameter is also exceptional in that it is specified as the base-2 logarithm of the number of 4-byte words, so that the default value 20 means 4MB (4×2^{20}) of write operations, 21 would mean 8MB, and so on up to a maximum value of 31, which equates to 8GB of write operations.

All the write operations in the cluster are added together. Setting TimeBetweenLocalCheckpoints to 6 or less means that local checkpoints will be executed continuously without pause, independent of the cluster's workload.

- TimeBetweenGlobalCheckpoints

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	2000	20 - 32000	N

When a transaction is committed, it is committed in main memory in all nodes on which the data is mirrored. However, transaction log records are not flushed to disk as part of the commit. The reasoning behind this behavior is that having the transaction safely committed on at least two autonomous host machines should meet reasonable standards for durability.

It is also important to ensure that even the worst of cases—a complete crash of the cluster—is handled properly. To guarantee that this happens, all transactions taking place within a given interval are put into a global checkpoint, which can be thought of as a set of committed transactions that has been flushed to disk. In other words, as part of the commit process, a transaction is placed in a global checkpoint group. Later, this group's log records are flushed to disk, and then the entire group of transactions is safely committed to disk on all computers in the cluster.

This parameter defines the interval between global checkpoints. The default is 2000 milliseconds.

- `TimeBetweenGlobalCheckpointsTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.20	milliseconds	120000	10 - 4294967039 (0xFFFFFEFF)	N

This parameter defines the minimum timeout between global checkpoints. The default is 120000 milliseconds.

This parameter was added in NDB 7.2.20. (Bug #20069617)

- `TimeBetweenEpochs`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	100	0 - 32000	N

This parameter defines the interval between synchronization epochs for NDB Cluster Replication. The default value is 100 milliseconds.

`TimeBetweenEpochs` is part of the implementation of “micro-GCPs”, which can be used to improve the performance of NDB Cluster Replication.

- `TimeBetweenEpochsTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	0	0 - 256000	N

This parameter defines a timeout for synchronization epochs for NDB Cluster Replication. If a node fails to participate in a global checkpoint within the time determined by this parameter, the node is shut down. In NDB 7.2.0 and later, the default value is 0; in other words, the timeout is disabled. This represents a change from previous versions of NDB Cluster, in which the default value was 4000 milliseconds (4 seconds).

`TimeBetweenEpochsTimeout` is part of the implementation of “micro-GCPs”, which can be used to improve the performance of NDB Cluster Replication.

The current value of this parameter and a warning are written to the cluster log whenever a GCP save takes longer than 1 minute or a GCP commit takes longer than 10 seconds.

Setting this parameter to zero has the effect of disabling GCP stops caused by save timeouts, commit timeouts, or both. The maximum possible value for this parameter is 256000 milliseconds.

- `MaxBufferedEpochs`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	epochs	100	0 - 100000	N

The number of unprocessed epochs by which a subscribing node can lag behind. Exceeding this number causes a lagging subscriber to be disconnected.

The default value of 100 is sufficient for most normal operations. If a subscribing node does lag enough to cause disconnections, it is usually due to network or scheduling issues with regard to processes or threads. (In rare circumstances, the problem may be due to a bug in the `NDB` client.) It may be desirable to set the value lower than the default when epochs are longer.

Disconnection prevents client issues from affecting the data node service, running out of memory to buffer data, and eventually shutting down. Instead, only the client is affected as a result of the disconnect (by, for example gap events in the binary log), forcing the client to reconnect or restart the process.

- `MaxBufferedEpochBytes`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.13	bytes	26214400	26214400 (0x01900000) - 4294967039 (0xFFFFFEFF)	N

The total number of bytes allocated for buffering epochs by this node.

This parameter was introduced in NDB 7.2.13. (Bug #16203623)

- `TimeBetweenInactiveTransactionAbortCheck`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	1000	1000 - 4294967039 (0xFFFFFEFF)	N

Timeout handling is performed by checking a timer on each transaction once for every interval specified by this parameter. Thus, if this parameter is set to 1000 milliseconds, every transaction will be checked for timing out once per second.

The default value is 1000 milliseconds (1 second).

- `TransactionInactiveTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	[see text]	0 - 4294967039 (0xFFFFFEFF)	N

This parameter states the maximum time that is permitted to lapse between operations in the same transaction before the transaction is aborted.

The default for this parameter is `4G` (also the maximum). For a real-time database that needs to ensure that no transaction keeps locks for too long, this parameter should be set to a relatively small value. Setting it to 0 means that the application never times out. The unit is milliseconds.

- `TransactionDeadlockDetectionTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	1200	50 - 4294967039 (0xFFFFFEFF)	N

When a node executes a query involving a transaction, the node waits for the other nodes in the cluster to respond before continuing. This parameter sets the amount of time that the transaction can spend executing within a data node, that is, the time that the transaction coordinator waits for each data node participating in the transaction to execute a request.

A failure to respond can occur for any of the following reasons:

- The node is “dead”
- The operation has entered a lock queue
- The node requested to perform the action could be heavily overloaded.

This timeout parameter states how long the transaction coordinator waits for query execution by another node before aborting the transaction, and is important for both node failure handling and deadlock detection.

The default timeout value is 1200 milliseconds (1.2 seconds).

The minimum for this parameter is 50 milliseconds.

- `DiskSyncSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	4M	32K - 4294967039 (0xFFFFFEFF)	N

This is the maximum number of bytes to store before flushing data to a local checkpoint file. This is done to prevent write buffering, which can impede performance significantly. This parameter is *not* intended to take the place of `TimeBetweenLocalCheckpoints`.

Note

When `ODirect` is enabled, it is not necessary to set `DiskSyncSize`; in fact, in such cases its value is simply ignored.

The default value is 4M (4 megabytes).

- `DiskCheckpointSpeed`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	10M	1M - 4294967039 (0xFFFFFEFF)	N

The amount of data,in bytes per second, that is sent to disk during a local checkpoint. This allocation is shared by DML operations and backups (but not backup logging), which means that backups started during times of intensive DML may be impaired by flooding of the redo log buffer and may fail altogether if the contention is sufficiently severe.

The default value is 10M (10 megabytes per second).

- `DiskCheckpointSpeedInRestart`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	100M	1M - 4294967039 (0xFFFFFEFF)	N

The amount of data,in bytes per second, that is sent to disk during a local checkpoint as part of a restart operation.

The default value is 100M (100 megabytes per second).

- `NoOfDiskPagesToDiskAfterRestartTUP`

This parameter is deprecated and subject to removal in a future version of NDB Cluster. Use `DiskCheckpointSpeedInRestart` and `DiskSyncSize` instead.

- `NoOfDiskPagesToDiskAfterRestartACC`

This parameter is deprecated and subject to removal in a future version of NDB Cluster. Use `DiskCheckpointSpeedInRestart` and `DiskSyncSize` instead.

- `NoOfDiskPagesToDiskDuringRestartTUP` (DEPRECATED)

This parameter is deprecated and subject to removal in a future version of NDB Cluster. Use `DiskCheckpointSpeedInRestart` and `DiskSyncSize` instead.

- `NoOfDiskPagesToDiskDuringRestartACC` (DEPRECATED)

This parameter is deprecated and subject to removal in a future version of NDB Cluster. Use `DiskCheckpointSpeedInRestart` and `DiskSyncSize` instead.

- `ArbitrationTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	7500	10 - 4294967039 (0xFFFFFEFF)	N

This parameter specifies how long data nodes wait for a response from the arbitrator to an arbitration message. If this is exceeded, the network is assumed to have split.

In NDB 7.2.0 and later, the default value is 7500 milliseconds (7.5 seconds). Previously, this was 3000 milliseconds (3 seconds).

- `Arbitration`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	enumeration	Default	Default, Disabled, WaitExternal	N

The `Arbitration` parameter enables a choice of arbitration schemes, corresponding to one of 3 possible values for this parameter:

- **Default.** This enables arbitration to proceed normally, as determined by the `ArbitrationRank` settings for the management and API nodes. This is the default value.
- **Disabled.** Setting `Arbitration = Disabled` in the `[ndbd default]` section of the `config.ini` file to accomplishes the same task as setting `ArbitrationRank` to 0 on all

management and API nodes. When `Arbitration` is set in this way, any `ArbitrationRank` settings are ignored.

- **WaitExternal.** The `Arbitration` parameter also makes it possible to configure arbitration in such a way that the cluster waits until after the time determined by `ArbitrationTimeout` has passed for an external cluster manager application to perform arbitration instead of handling arbitration internally. This can be done by setting `Arbitration = WaitExternal` in the `[ndbd default]` section of the `config.ini` file. For best results with the `WaitExternal` setting, it is recommended that `ArbitrationTimeout` be 2 times as long as the interval required by the external cluster manager to perform arbitration.

Important

This parameter should be used only in the `[ndbd default]` section of the cluster configuration file. The behavior of the cluster is unspecified when `Arbitration` is set to different values for individual data nodes.

- `RestartSubscriberConnectTimeout`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.17	ms	12000	0 - 4294967039 (0xFFFFFEFF)	S

This parameter determines the time that a data node waits for subscribing API nodes to connect. Once this timeout expires, any “missing” API nodes are disconnected from the cluster. To disable this timeout, set `RestartSubscriberConnectTimeout` to 0.

While this parameter is specified in milliseconds, the timeout itself is resolved to the next-greatest whole second.

`RestartSubscriberConnectTimeout` was added in NDB 7.2.17.

Buffering and logging. Several `[ndbd]` configuration parameters enable the advanced user to have more control over the resources used by node processes and to adjust various buffer sizes at need.

These buffers are used as front ends to the file system when writing log records to disk. If the node is running in diskless mode, these parameters can be set to their minimum values without penalty due to the fact that disk writes are “faked” by the `NDB` storage engine's file system abstraction layer.

- `UndoIndexBuffer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	2M	1M - 4294967039 (0xFFFFFEFF)	N

The UNDO index buffer, whose size is set by this parameter, is used during local checkpoints. The `NDB` storage engine uses a recovery scheme based on checkpoint consistency in conjunction with an operational REDO log. To produce a consistent checkpoint without blocking the entire system for writes, UNDO logging is done while performing the local checkpoint. UNDO logging is activated on a single table fragment at a time. This optimization is possible because tables are stored entirely in main memory.

The UNDO index buffer is used for the updates on the primary key hash index. Inserts and deletes rearrange the hash index; the NDB storage engine writes UNDO log records that map all physical changes to an index page so that they can be undone at system restart. It also logs all active insert operations for each fragment at the start of a local checkpoint.

Reads and updates set lock bits and update a header in the hash index entry. These changes are handled by the page-writing algorithm to ensure that these operations need no UNDO logging.

This buffer is 2MB by default. The minimum value is 1MB, which is sufficient for most applications. For applications doing extremely large or numerous inserts and deletes together with large transactions and large primary keys, it may be necessary to increase the size of this buffer. If this buffer is too small, the NDB storage engine issues internal error code 677 (`Index UNDO buffers overloaded`).

Important

It is not safe to decrease the value of this parameter during a rolling restart.

- `UndoDataBuffer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	16M	1M - 4294967039 (0xFFFFFEFF)	N

This parameter sets the size of the UNDO data buffer, which performs a function similar to that of the UNDO index buffer, except the UNDO data buffer is used with regard to data memory rather than index memory. This buffer is used during the local checkpoint phase of a fragment for inserts, deletes, and updates.

Because UNDO log entries tend to grow larger as more operations are logged, this buffer is also larger than its index memory counterpart, with a default value of 16MB.

This amount of memory may be unnecessarily large for some applications. In such cases, it is possible to decrease this size to a minimum of 1MB.

It is rarely necessary to increase the size of this buffer. If there is such a need, it is a good idea to check whether the disks can actually handle the load caused by database update activity. A lack of sufficient disk space cannot be overcome by increasing the size of this buffer.

If this buffer is too small and gets congested, the NDB storage engine issues internal error code 891 (`Data UNDO buffers overloaded`).

Important

It is not safe to decrease the value of this parameter during a rolling restart.

- `RedoBuffer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	32M	1M - 4294967039 (0xFFFFFEFF)	N

All update activities also need to be logged. The REDO log makes it possible to replay these updates whenever the system is restarted. The NDB recovery algorithm uses a “fuzzy” checkpoint of the data together with the UNDO log, and then applies the REDO log to play back all changes up to the restoration point.

`RedoBuffer` sets the size of the buffer in which the REDO log is written. The default value is 32MB; the minimum value is 1MB.

If this buffer is too small, the NDB storage engine issues error code 1221 (REDO log buffers overloaded). For this reason, you should exercise care if you attempt to decrease the value of RedoBuffer as part of an online change in the cluster's configuration.

ndbmtd allocates a separate buffer for each LDM thread (see ThreadConfig). For example, with 4 LDM threads, an ndbmtd data node actually has 4 buffers and allocates RedoBuffer bytes to each one, for a total of 4 * RedoBuffer bytes.

- EventLogBufferSize

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	8192	0 - 64K	S

Controls the size of the circular buffer used for NDB log events within data nodes.

Controlling log messages. In managing the cluster, it is very important to be able to control the number of log messages sent for various event types to stdout. For each event category, there are 16 possible event levels (numbered 0 through 15). Setting event reporting for a given event category to level 15 means all event reports in that category are sent to stdout; setting it to 0 means that there will be no event reports made in that category.

By default, only the startup message is sent to stdout, with the remaining event reporting level defaults being set to 0. The reason for this is that these messages are also sent to the management server's cluster log.

An analogous set of levels can be set for the management client to determine which event levels to record in the cluster log.

- LogLevelStartup

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	1	0 - 15	N

The reporting level for events generated during startup of the process.

The default level is 1.

- LogLevelShutdown

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	0	0 - 15	N

The reporting level for events generated as part of graceful shutdown of a node.

The default level is 0.

- LogLevelStatistic

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	0	0 - 15	N

The reporting level for statistical events such as number of primary key reads, number of updates, number of inserts, information relating to buffer usage, and so on.

The default level is 0.

- LogLevelCheckpoint

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	log level	0	0 - 15	N

The reporting level for events generated by local and global checkpoints.

The default level is 0.

- `LogLevelNodeRestart`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	0	0 - 15	N

The reporting level for events generated during node restart.

The default level is 0.

- `LogLevelConnection`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	0	0 - 15	N

The reporting level for events generated by connections between cluster nodes.

The default level is 0.

- `LogLevelError`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	0	0 - 15	N

The reporting level for events generated by errors and warnings by the cluster as a whole. These errors do not cause any node failure but are still considered worth reporting.

The default level is 0.

- `LogLevelCongestion`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	levelr	0	0 - 15	N

The reporting level for events generated by congestion. These errors do not cause node failure but are still considered worth reporting.

The default level is 0.

- `LogLevelInfo`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	0	0 - 15	N

The reporting level for events generated for information about the general state of the cluster.

The default level is 0.

- `MemReportFrequency`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter controls how often data node memory usage reports are recorded in the cluster log; it is an integer value representing the number of seconds between reports.

Each data node's data memory and index memory usage is logged as both a percentage and a number of 32 KB pages of the `DataMemory` and `IndexMemory`, respectively, set in the `config.ini` file. For example, if `DataMemory` is equal to 100 MB, and a given data node is using 50 MB for data memory storage, the corresponding line in the cluster log might look like this:

```
2006-12-24 01:18:16 [MgmSrvr] INFO -- Node 2: Data usage is 50%(1280 32K pages of total 2560)
```

`MemReportFrequency` is not a required parameter. If used, it can be set for all cluster data nodes in the `[ndbd default]` section of `config.ini`, and can also be set or overridden for individual data nodes in the corresponding `[ndbd]` sections of the configuration file. The minimum value—which is also the default value—is 0, in which case memory reports are logged only when memory usage reaches certain percentages (80%, 90%, and 100%), as mentioned in the discussion of statistics events in Section 18.5.6.2, “NDB Cluster Log Events”.

- `StartupStatusReportFrequency`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	seconds	0	0 - 4294967039 (0xFFFFFEFF)	N

When a data node is started with the `--initial`, it initializes the redo log file during Start Phase 4 (see Section 18.5.1, “Summary of NDB Cluster Start Phases”). When very large values are set for `NoOfFragmentLogFiles`, `FragmentLogFileSize`, or both, this initialization can take a long time.You can force reports on the progress of this process to be logged periodically, by means of the `StartupStatusReportFrequency` configuration parameter. In this case, progress is reported in the cluster log, in terms of both the number of files and the amount of space that have been initialized, as shown here:

```
2009-06-20 16:39:23 [MgmSrvr] INFO -- Node 1: Local redo log file initialization status:
#Total files: 80, Completed: 60
#Total MBytes: 20480, Completed: 15557
2009-06-20 16:39:23 [MgmSrvr] INFO -- Node 2: Local redo log file initialization status:
#Total files: 80, Completed: 60
#Total MBytes: 20480, Completed: 15570
```

These reports are logged each `StartupStatusReportFrequency` seconds during Start Phase 4. If `StartupStatusReportFrequency` is 0 (the default), then reports are written to the cluster log only when at the beginning and at the completion of the redo log file initialization process.

Debugging Parameters. In NDB Cluster 7.2, it is possible to cause logging of traces for events generated by creating and dropping tables using `DictTrace`. This parameter is useful only in debugging NDB kernel code. `DictTrace` takes an integer value; currently, 0 (default - no logging) and 1 (logging enabled) are the only supported values.

Backup parameters. The `[ndbd]` parameters discussed in this section define memory buffers set aside for execution of online backups.

- `BackupDataBufferSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	16M	0 - 4294967039 (0xFFFFFEFF)	N

In creating a backup, there are two buffers used for sending data to the disk. The backup data buffer is used to fill in data recorded by scanning a node's tables. Once this buffer has been filled to the level specified as `BackupWriteSize`, the pages are sent to disk. While flushing data to disk, the backup process can continue filling this buffer until it runs out of space. When this happens, the backup process pauses the scan and waits until some disk writes have completed freeing up memory so that scanning may continue.

The default value for this parameter is 16MB.

- `BackupLogBufferSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	16M	0 - 4294967039 (0xFFFFFEFF)	N

The backup log buffer fulfills a role similar to that played by the backup data buffer, except that it is used for generating a log of all table writes made during execution of the backup. The same principles apply for writing these pages as with the backup data buffer, except that when there is no more space in the backup log buffer, the backup fails. For that reason, the size of the backup log buffer must be large enough to handle the load caused by write activities while the backup is being made. See Section 18.5.3.3, “Configuration for NDB Cluster Backups”.

The default value for this parameter should be sufficient for most applications. In fact, it is more likely for a backup failure to be caused by insufficient disk write speed than it is for the backup log buffer to become full. If the disk subsystem is not configured for the write load caused by applications, the cluster is unlikely to be able to perform the desired operations.

It is preferable to configure cluster nodes in such a manner that the processor becomes the bottleneck rather than the disks or the network connections.

The default value for this parameter is 16MB.

- `BackupMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	32M	0 - 4294967039 (0xFFFFFEFF)	N

This parameter is simply the sum of `BackupDataBufferSize` and `BackupLogBufferSize`.

The default value of this parameter in NDB Cluster 7.2 is 16MB + 16MB = 32MB.

Important

If `BackupDataBufferSize` and `BackupLogBufferSize` taken together exceed the default value for `BackupMemory`, then this parameter must be set explicitly in the `config.ini` file to their sum.

- `BackupReportFrequency`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	seconds	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter controls how often backup status reports are issued in the management client during a backup, as well as how often such reports are written to the cluster log (provided cluster event logging is configured to permit it—see Logging and checkpointing). `BackupReportFrequency` represents the time in seconds between backup status reports.

The default value is 0.

- `BackupWriteSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	256K	2K - 4294967039 (0xFFFFFEFF)	N

This parameter specifies the default size of messages written to disk by the backup log and backup data buffers.

The default value for this parameter is 256KB.

- `BackupMaxWriteSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	1M	2K - 4294967039 (0xFFFFFEFF)	N
NDB 7.2.1	bytes	1M	2K - 4294967039 (0xFFFFFEFF)	N

This parameter specifies the maximum size of messages written to disk by the backup log and backup data buffers.

The default value for this parameter is 1MB.

Note

The location of the backup files is determined by the `BackupDataDir` data node configuration parameter.

Additional requirements. When specifying these parameters, the following relationships must hold true. Otherwise, the data node will be unable to start.

- `BackupDataBufferSize >= BackupWriteSize + 188KB`
- `BackupLogBufferSize >= BackupWriteSize + 16KB`
- `BackupMaxWriteSize >= BackupWriteSize`

NDB Cluster Realtime Performance Parameters

The `[ndbd]` parameters discussed in this section are used in scheduling and locking of threads to specific CPUs on multiprocessor data node hosts.

Note

To make use of these parameters, the data node process must be run as system root.

- `LockExecuteThreadToCPU`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	set of CPU IDs	0	...	N

When used with ndbd, this parameter (now a string) specifies the ID of the CPU assigned to handle the NDBCLUSTER execution thread. When used with ndbmtd, the value of this parameter is a comma-separated list of CPU IDs assigned to handle execution threads. Each CPU ID in the list should be an integer in the range 0 to 65535 (inclusive).

The number of IDs specified should match the number of execution threads determined by MaxNoOfExecutionThreads. However, there is no guarantee that threads are assigned to CPUs in any given order when using this parameter; beginning with in NDB 7.2.5, you can obtain more finely-grained control of this type using ThreadConfig.

LockExecuteThreadToCPU has no default value.

- LockMaintThreadsToCPU

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	CPU ID	0	0 - 64K	N

This parameter specifies the ID of the CPU assigned to handle NDBCLUSTER maintenance threads.

The value of this parameter is an integer in the range 0 to 65535 (inclusive). In NDB Cluster 7.2, there is no default value.

- RealtimeScheduler

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

Setting this parameter to 1 enables real-time scheduling of data node threads.

Prior to NDB 7.2.14, this parameter did not work correctly with data nodes running ndbmtd. (Bug #16961971)

The default is 0 (scheduling disabled).

- SchedulerExecutionTimer

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	µs	50	0 - 11000	N

This parameter specifies the time in microseconds for threads to be executed in the scheduler before being sent. Setting it to 0 minimizes the response time; to achieve higher throughput, you can increase the value at the expense of longer response times.

The default is 50 µsec, which our testing shows to increase throughput slightly in high-load cases without materially delaying requests.

- SchedulerSpinTimer

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	µs	0	0 - 500	N

This parameter specifies the time in microseconds for threads to be executed in the scheduler before sleeping.

The default value is 0.

- BuildIndexThreads

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	0	0 - 128	S

This parameter determines the number of threads to create when rebuilding ordered indexes during a system or node start, as well as when running `ndb_restore --rebuild-indexes`. It is supported only when there is more than one fragment for the table per data node (for example, when the `MAX_ROWS` option has been used with `CREATE TABLE`).

Setting this parameter to 0 (the default) disables multi-threaded building of ordered indexes.

This parameter is supported when using `ndbd` or `ndbmtd`.

You can enable multi-threaded builds during data node initial restarts by setting the `TwoPassInitialNodeRestartCopy` data node configuration parameter to `TRUE`.

- `TwoPassInitialNodeRestartCopy`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

Multi-threaded building of ordered indexes can be enabled for initial restarts of data nodes by setting this configuration parameter to `TRUE`, which enables two-pass copying of data during initial node restarts.

You must also set `BuildIndexThreads` to a nonzero value.

- `Numa`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	1	0 - 1	N

This parameter determines whether Non-Uniform Memory Access (NUMA) is controlled by the operating or by the data node process, whether the data node uses `ndbd` or `ndbmtd`. By default, `NDB` attempts to use an interleaved NUMA memory allocation policy on any data node where the host operating system provides NUMA support.

Setting `Numa = 0` means that the datanode process does not itself attempt to set a policy for memory allocation, and permits this behavior to be determined by the operating system, which may be further guided by the separate `numactl` tool. That is, `Numa = 0` yields the system default behavior, which can be customised by `numactl`. For many Linux systems, the system default behavior is to allocate socket-local memory to any given process at allocation time. This can be problematic when using `ndbmtd`; this is because `nbdmtd` allocates all memory at startup, leading to an imbalance, giving different access speeds for different sockets, especially when locking pages in main memory.

Setting `Numa = 1` means that the data node process uses `libnuma` to request interleaved memory allocation. (This can also be accomplished manually, on the operating system level, using `numactl`.) Using interleaved allocation in effect tells the data node process to ignore non-uniform memory access but does not attempt to take any advantage of fast local memory; instead, the data node process tries to avoid imbalances due to slow remote memory. If interleaved allocation is not desired, set `Numa` to 0 so that the desired behavior can be determined on the operating system level.

The `Numa` configuration parameter is supported only on Linux systems where `libnuma.so` is available.

Multi-Threading Configuration Parameters (ndbmtd). `ndbmtd` runs by default as a single-threaded process and must be configured to use multiple threads, using either of two methods, both of which require setting configuration parameters in the `config.ini` file. The first method is simply to

set an appropriate value for the `MaxNoOfExecutionThreads` configuration parameter. In NDB 7.2.3 and later, a second method is also supported, whereby it is possible to set up more complex rules for `ndbmtd` multi-threading using `ThreadConfig`. The next few paragraphs provide information about these parameters and their use with multi-threaded data nodes.

- `MaxNoOfExecutionThreads`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	integer	2	2 - 8	IS
NDB 7.2.5	integer	2	2 - 36	IS

Starting with NDB 7.2.5, this parameter directly controls the number of execution threads used by `ndbmtd`, up to a maximum of 36. Although this parameter is set in `[ndbd]` or `[ndbd default]` sections of the `config.ini` file, it is exclusive to `ndbmtd` and does not apply to `ndbd`.

Setting `MaxNoOfExecutionThreads` sets the number of threads by type as determined in the following table:

`MaxNoOfExecutionThreads` Value	LDM Threads	TC Threads	Send Threads	Receive Threads
0 .. 3	1	0	0	1
4 .. 6	2	0	0	1
7 .. 8	4	0	0	1
9	4	2	0	1
10	4	2	1	1
11	4	3	1	1
12	4	3	1	2
13	4	3	2	2
14	4	4	2	2
15	4	5	2	2
16	8	3	1	2
17	8	4	1	2
18	8	4	2	2
19	8	5	2	2
20	8	5	2	3
21	8	5	3	3
22	8	6	3	3
23	8	7	3	3
24	12	5	2	3
25	12	6	2	3
26	12	6	3	3
27	12	7	3	3
28	12	7	3	4
29	12	8	3	4
30	12	8	4	4
31	12	9	4	4
32	16	8	3	3

MaxNoOfExecutionThreads Value	LDM Threads	TC Threads	Send Threads	Receive Threads
33	16	8	3	4
34	16	8	4	4
35	16	9	4	4
36	16	10	4	4

NoOfFragmentLogParts should be set equal to the number of LDM threads used by ndbmtd as determined by the setting for MaxNoOfExecutionThreads; see the description of this parameter for more information.

There is always one SUMA (replication) thread. There was no separate send thread in NDB 7.2.4 and earlier, as well as no means of changing the number of TC threads.

The number of LDM threads also determines the number of partitions used by an NDB table that is not explicitly partitioned; this is the number of LDM threads times the number of data nodes in the cluster. (If ndbd is used on the data nodes rather than ndbmtd, then there is always a single LDM thread; in this case, the number of partitions created automatically is simply equal to the number of data nodes. See Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”, for more information.

The thread types are described later in this section (see ThreadConfig).

Setting this parameter outside the permitted range of values causes the management server to abort on startup with the error `Error line number: Illegal value value for parameter MaxNoOfExecutionThreads`.

For MaxNoOfExecutionThreads, a value of 0 or 1 is rounded up internally by NDB to 2, so that 2 is considered this parameter's default and minimum value.

MaxNoOfExecutionThreads is generally intended to be set equal to the number of CPU threads available, and to allocate a number of threads of each type suitable to typical workloads. It does not assign particular threads to specified CPUs. For cases where it is desirable to vary from the settings provided, or to bind threads to CPUs, you should use ThreadConfig instead, which allows you to allocate each thread directly to a desired type, CPU, or both.

In NDB 7.2.5 and later, the multi-threaded data node process always spawns, at a minimum, the threads listed here:

- 1 local query handler (LDM) thread
- 1 receive thread
- 1 subscription manager (SUMA or replication) thread

For a MaxNoOfExecutionThreads value of 8 or less, no TC threads are created, and TC handling is instead performed by the main thread.

Changing the number of LDM threads always requires a system restart, whether it is changed using this parameter or ThreadConfig. If the cluster's IndexMemory usage is greater than 50%, changing this requires an initial restart of the cluster. (A maximum of 30-35% IndexMemory usage is recommended in such cases.) Otherwise, resource usage and LDM thread allocation cannot be balanced between nodes, which can result in underutilized and overutilized LDM threads, and ultimately data node failures.

In NDB 7.2.4 and earlier, there were only 4 thread types, with LDM threads being responsible for their own sends. In addition, it was not possible to cause ndbmtd to use more than 1 TC thread.

- `NoOfFragmentLogParts`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.5	numeric	4	4, 8, 12, 16	IN

Set the number of log file groups for redo logs belonging to this `ndbmtd`. The value must be an even multiple of 4 between 4 and 16, inclusive.

`NoOfFragmentLogParts` should be set equal to the number of LDM threads used by `ndbmtd` as determined by the setting for `MaxNoOfExecutionThreads`; see the description of this parameter for more information.

- `ThreadConfig`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.3	string	''	...	IS

This parameter is used with `ndbmtd` to assign threads of different types to different CPUs. Its value is a string whose format has the following syntax:

```
ThreadConfig := entry[,entry[,...]]

entry := type={param[,param[,...]]}

type := ldm | main | recv | send | rep | io | tc | watchdog

param := count=number
  | cpubind=cpu_list
  | cpuset=cpu_list
  | spintime=number
  | realtime={0|1}
```

The curly braces (`{...}`) surrounding the list of parameters are required, even if there is only one parameter in the list.

A *`param`* (parameter) specifies any or all of the following information:

- The number of threads of the given type (`count`).
- The set of CPUs to which the threads of the given type are to be nonexclusively bound. This is determined by either one of `cpubind` or `cpuset`). `cpubind` causes each thread to be bound (nonexclusively) to a CPU in the set; `cpuset` means that each thread is bound (nonexclusively) to the set of CPUs specified.

  Only one of `cpubind` or `cpuset` can be provided in a single configuration.
- `spintime` determines the wait time in microseconds the thread spins before going to sleep.

  The default value for `spintime` is the value of the `SchedulerSpinTimer` data node configuration parameter.

  `spintime` does not apply to I/O threads or watchdog threads and so cannot be set for these thread types.
- `realtime` can be set to 0 or 1. If it is set to 1, the threads run with real-time priority. This also means that `thread_prio` cannot be set.

  The `realtime` parameter is set by default to the value of the `RealtimeScheduler` data node configuration parameter.

The *`type`* attribute represents an NDB thread type. The thread types supported in NDB Cluster 7.2 and the range of permitted `count` values for each are provided in the following list:

- `ldm`: Local query handler (`DBLQH` kernel block) that handles data. The more LDM threads that are used, the more highly partitioned the data becomes. Each LDM thread maintains its own sets of data and index partitions, as well as its own redo log. The value set for `ldm` must be one of one of the values 1, 2, 4, 6, 8, 12, or 16.

  Important

  Changing the number of LDM threads requires a system restart to be effective and safe for cluster operations. (This is also true when this is done using `MaxNoOfExecutionThreads`.) If `IndexMemory` usage is in excess of 50%, an initial restart of the cluster is required; a maximum of 30-35% `IndexMemory` usage is recommended in such cases. Otherwise, `IndexMemory` and `DataMemory` usage as well as the allocation of LDM threads cannot be balanced between nodes, which can ultimately lead to data node failures.

- `tc`: Transaction coordinator thread (`DBTC` kernel block) containing the state of an ongoing transaction. In NDB 7.2.5 and later, the number of TC threads is configurable, with a total of 16 possible.

  Optimally, every new transaction can be assigned to a new TC thread. In most cases 1 TC thread per 2 LDM threads is sufficient to guarantee that this can happen. In cases where the number of writes is relatively small when compared to the number of reads, it is possible that only 1 TC thread per 4 LQH threads is required to maintain transaction states. Conversely, in applications that perform a great many updates, it may be necessary for the ratio of TC threads to LDM threads to approach 1 (for example, 3 TC threads to 4 LDM threads).

  Range: (*NDB 7.2.5 and later*:) 0 - 16; (*prior to NDB 7.2.5*:) 1 (not settable).

- `main`: Data dictionary and transaction coordinator (`DBDIH` and `DBTC` kernel blocks), providing schema management. This is always handled by a single dedicated thread.

  Range: 1 only.

- `recv`: Receive thread (`CMVMI` kernel block). Each receive thread handles one or more sockets for communicating with other nodes in an NDB Cluster, with one socket per node. Previously, this was limited to a single thread, but NDB Cluster 7.2 implements multiple receive threads (up to 8).

  Range: 1 - 8.

- `send`: Send thread (`CMVMI` kernel block). Added in NDB 7.2.5. To increase throughput, it is possible in NDB 7.2.5 and later to perform sends from one or more separate, dedicated threads (maximum 8).

  Previously, all threads handled their own sending directly; this can still be made to happen by setting the number of send threads to 0 (this also happens when `MaxNoOfExecutionThreads` is set less than 10). While doing so can have an adeverse impact on throughput, it can also in some cases provide decreased latency.

  Range: 0 - 8.

- `rep`: Replication thread (`SUMA` kernel block). Asynchronous replication operations are always handled by a single, dedicated thread.

  Range: 1 only.

- `io`: File system and other miscellaneous operations. These are not demanding tasks, and are always handled as a group by a single, dedicated I/O thread.

  Range: 1 only.

- `watchdog`: Settings to this parameter are actually applied to several threads of this type having specific uses. These threads include the `SocketServer` thread which receives connection setups from other nodes, the `SocketClient` thread which attempts to set up connections to other nodes, and the thread watchdog thread that checks that threads are progressing.

  Range: 1 only.

Simple examples:

```
# Example 1.

ThreadConfig=ldm={count=2,cpubind=1,2},main={cpubind=12},rep={cpubind=11}

# Example 2.

Threadconfig=main={cpubind=0},ldm={count=4,cpubind=1,2,5,6},io={cpubind=3}
```

It is usually desirable when configuring thread usage for a data node host to reserve one or more number of CPUs for operating system and other tasks. Thus, for a host machine with 24 CPUs, you might want to use 20 CPU threads (leaving 4 for other uses), with 8 LDM threads, 4 TC threads (half the number of LDM threads), 3 send threads, 3 receive threads, and 1 thread each for schema management, asynchronous replication, and I/O operations. (This is almost the same distribution of threads used when `MaxNoOfExecutionThreads` is set equal to 20.) The following `ThreadConfig` setting performs these assignments, additionally binding all of these threads to specific CPUs:

```
ThreadConfig=ldm{count=8,cpubind=1,2,3,4,5,6,7,8},main={cpubind=9},io={cpubind=9}, \
rep={cpubind=10},tc{count=4,cpubind=11,12,13,14},recv={count=3,cpubind=15,16,17}, \
send{count=3,cpubind=18,19,20}
```

It should be possible in most cases to bind the main (schema management) thread and the I/O thread to the same CPU, as we have done in the example just shown.

In order to take advantage of the enhanced stability that the use of `ThreadConfig` offers, it is necessary to insure that CPUs are isolated, and that they not subject to interrupts, or to being scheduled for other tasks by the operating system. On many Linux systems, you can do this by setting `IRQBALANCE_BANNED_CPUS` in `/etc/sysconfig/irqbalance` to `0xFFFFF0`, and by using the `isolcpus` boot option in `grub.conf`. For specific information, see your operating system or platform documentation.

Disk Data Configuration Parameters. Configuration parameters affecting Disk Data behavior include the following:

- `DiskPageBufferEntries`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.19	32K pages	10	1 - 1000	N

This is the number of page entries (page references) to allocate. It is specified as a number of 32K pages in `DiskPageBufferMemory`. The default is sufficient for most cases but you may need to increase the value of this parameter if you encounter problems with very large transactions on Disk Data tables. Each page entry requires approximately 100 bytes.

- `DiskPageBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	64M	4M - 1T	N

This determines the amount of space used for caching pages on disk, and is set in the `[ndbd]` or `[ndbd default]` section of the `config.ini` file. It is measured in bytes. Each page takes up 32 KB. This means that NDB Cluster Disk Data storage always uses *`N`* * 32 KB memory where *`N`* is some nonnegative integer.

The default value for this parameter is `64M` (2000 pages of 32 KB each).

You can query the `ndbinfo.diskpagebuffer` table to help determine whether the value for this parameter should be increased to minimize unnecessary disk seeks. See Section 18.5.10.8, "The ndbinfo diskpagebuffer Table", for more information.

- `SharedGlobalMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	128M	0 - 64T	N

This parameter determines the amount of memory that is used for log buffers, disk operations (such as page requests and wait queues), and metadata for tablespaces, log file groups, `UNDO` files, and data files. The shared global memory pool also provides memory used for satisfying the memory requirements of the `UNDO_BUFFER_SIZE` option used with `CREATE LOGFILE GROUP` and `ALTER LOGFILE GROUP` statements, including any default value implied for this options by the setting of the `InitialLogFileGroup` data node configuration parameter. `SharedGlobalMemory` can be set in the `[ndbd]` or `[ndbd default]` section of the `config.ini` configuration file, and is measured in bytes.

As of NDB 7.2.0, the default value is `128M`. (Previously, this was `20M`.)

- `DiskIOThreadPool`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	threads	2	0 - 4294967039 (0xFFFFFEFF)	N

This parameter determines the number of unbound threads used for Disk Data file access. Before `DiskIOThreadPool` was introduced, exactly one thread was spawned for each Disk Data file, which could lead to performance issues, particularly when using very large data files. With `DiskIOThreadPool`, you can—for example—access a single large data file using several threads working in parallel.

This parameter applies to Disk Data I/O threads only.

The optimum value for this parameter depends on your hardware and configuration, and includes these factors:

- **Physical distribution of Disk Data files.** You can obtain better performance by placing data files, undo log files, and the data node file system on separate physical disks. If you do this with some or all of these sets of files, then you can set `DiskIOThreadPool` higher to enable separate threads to handle the files on each disk.

- **Disk performance and types.** The number of threads that can be accommodated for Disk Data file handling is also dependent on the speed and throughput of the disks. Faster disks and higher throughput allow for more disk I/O threads. Our test results indicate that solid-state disk drives can handle many more disk I/O threads than conventional disks, and thus higher values for `DiskIOThreadPool`.

In NDB Cluster 7.2, the default value for this parameter is 2.

- **Disk Data file system parameters.** The parameters in the following list make it possible to place NDB Cluster Disk Data files in specific directories without the need for using symbolic links.

  - `FileSystemPathDD`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	filename	[see text]	...	IN

    If this parameter is specified, then NDB Cluster Disk Data data files and undo log files are placed in the indicated directory. This can be overridden for data files, undo log files, or both, by specifying values for `FileSystemPathDataFiles`, `FileSystemPathUndoFiles`, or both, as explained for these parameters. It can also be overridden for data files by specifying a path in the `ADD DATAFILE` clause of a `CREATE TABLESPACE` or `ALTER TABLESPACE` statement, and for undo log files by specifying a path in the `ADD UNDOFILE` clause of a `CREATE LOGFILE GROUP` or `ALTER LOGFILE GROUP` statement. If `FileSystemPathDD` is not specified, then `FileSystemPath` is used.

    If a `FileSystemPathDD` directory is specified for a given data node (including the case where the parameter is specified in the `[ndbd default]` section of the `config.ini` file), then starting that data node with `--initial` causes all files in the directory to be deleted.

  - `FileSystemPathDataFiles`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	filename	[see text]	...	IN

    If this parameter is specified, then NDB Cluster Disk Data data files are placed in the indicated directory. This overrides any value set for `FileSystemPathDD`. This parameter can be overridden for a given data file by specifying a path in the `ADD DATAFILE` clause of a `CREATE TABLESPACE` or `ALTER TABLESPACE` statement used to create that data file. If `FileSystemPathDataFiles` is not specified, then `FileSystemPathDD` is used (or `FileSystemPath`, if `FileSystemPathDD` has also not been set).

    If a `FileSystemPathDataFiles` directory is specified for a given data node (including the case where the parameter is specified in the `[ndbd default]` section of the `config.ini` file), then starting that data node with `--initial` causes all files in the directory to be deleted.

  - `FileSystemPathUndoFiles`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	filename	[see text]	...	IN

    If this parameter is specified, then NDB Cluster Disk Data undo log files are placed in the indicated directory. This overrides any value set for `FileSystemPathDD`. This parameter can be overridden for a given data file by specifying a path in the `ADD UNDO` clause of a `CREATE LOGFILE GROUP` or `ALTER LOGFILE GROUP` statement used to create that data file. If `FileSystemPathUndoFiles` is not specified, then `FileSystemPathDD` is used (or `FileSystemPath`, if `FileSystemPathDD` has also not been set).

    If a `FileSystemPathUndoFiles` directory is specified for a given data node (including the case where the parameter is specified in the `[ndbd default]` section of the `config.ini` file), then starting that data node with `--initial` causes all files in the directory to be deleted.

  For more information, see Section 18.5.12.1, “NDB Cluster Disk Data Objects”.

- **Disk Data object creation parameters.** The next two parameters enable you—when starting the cluster for the first time—to cause a Disk Data log file group, tablespace, or both, to be created without the use of SQL statements.

  - `InitialLogFileGroup`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	string	[see text]	...	S

  This parameter can be used to specify a log file group that is created when performing an initial start of the cluster. `InitialLogFileGroup` is specified as shown here:

```
InitialLogFileGroup = [name=name;] [undo_buffer_size=size;] file-specification-list

file-specification-list:
    file-specification[; file-specification[; ...]]

file-specification:
    filename:size
```

  The `name` of the log file group is optional and defaults to `DEFAULT-LG`. The `undo_buffer_size` is also optional; if omitted, it defaults to `64M`. Each *`file-specification`* corresponds to an undo log file, and at least one must be specified in the *`file-specification-list`*. Undo log files are placed according to any values that have been set for `FileSystemPath`, `FileSystemPathDD`, and `FileSystemPathUndoFiles`, just as if they had been created as the result of a `CREATE LOGFILE GROUP` or `ALTER LOGFILE GROUP` statement.

  Consider the following:

```
InitialLogFileGroup = name=LG1; undo_buffer_size=128M; undo1.log:250M; undo2.log:150M
```

  This is equivalent to the following SQL statements:

```
CREATE LOGFILE GROUP LG1
    ADD UNDOFILE 'undo1.log'
    INITIAL_SIZE 250M
    UNDO_BUFFER_SIZE 128M
    ENGINE NDBCLUSTER;

ALTER LOGFILE GROUP LG1
    ADD UNDOFILE 'undo2.log'
    INITIAL_SIZE 150M
    ENGINE NDBCLUSTER;
```

  This logfile group is created when the data nodes are started with `--initial`.

  Resources for the initial log file group are taken from the global memory pool whose size is determined by the value of the `SharedGlobalMemory` data node configuration parameter; if this parameter is set too low and the values set in `InitialLogFileGroup` for the logfile group's initial size or undo buffer size are too high, the cluster may fail to create the default log file group when starting, or fail to start altogether.

  This parameter, if used, should always be set in the `[ndbd default]` section of the `config.ini` file. The behavior of an NDB Cluster when different values are set on different data nodes is not defined.

  - `InitialTablespace`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	string	[see text]	...	S

This parameter can be used to specify an NDB Cluster Disk Data tablespace that is created when performing an initial start of the cluster. `InitialTablespace` is specified as shown here:

```
InitialTablespace = [name=name;] [extent_size=size;] file-specification-list
```

The `name` of the tablespace is optional and defaults to `DEFAULT-TS`. The `extent_size` is also optional; it defaults to `1M`. The *`file-specification-list`* uses the same syntax as shown with the `InitialLogfileGroup` parameter, the only difference being that each *`file-specification`* used with `InitialTablespace` corresponds to a data file. At least one must be specified in the *`file-specification-list`*. Data files are placed according to any values that have been set for `FileSystemPath`, `FileSystemPathDD`, and `FileSystemPathDataFiles`, just as if they had been created as the result of a `CREATE TABLESPACE` or `ALTER TABLESPACE` statement.

For example, consider the following line specifying `InitialTablespace` in the `[ndbd default]` section of the `config.ini` file (as with `InitialLogfileGroup`, this parameter should always be set in the `[ndbd default]` section, as the behavior of an NDB Cluster when different values are set on different data nodes is not defined):

```
InitialTablespace = name=TS1; extent_size=8M; data1.dat:2G; data2.dat:4G
```

This is equivalent to the following SQL statements:

```
CREATE TABLESPACE TS1
    ADD DATAFILE 'data1.dat'
    EXTENT_SIZE 8M
    INITIAL_SIZE 2G
    ENGINE NDBCLUSTER;

ALTER TABLESPACE TS1
    ADD DATAFILE 'data2.dat'
    INITIAL_SIZE 4G
    ENGINE NDBCLUSTER;
```

This tablespace is created when the data nodes are started with `--initial`, and can be used whenever creating NDB Cluster Disk Data tables thereafter.

Disk Data and GCP Stop errors. Errors encountered when using Disk Data tables such as `Node nodeid killed this node because GCP stop was detected` (error 2303) are often referred to as “GCP stop errors”. Such errors occur when the redo log is not flushed to disk quickly enough; this is usually due to slow disks and insufficient disk throughput.

You can help prevent these errors from occurring by using faster disks, and by placing Disk Data files on a separate disk from the data node file system. Reducing the value of `TimeBetweenGlobalCheckpoints` tends to decrease the amount of data to be written for each global checkpoint, and so may provide some protection against redo log buffer overflows when trying to write a global checkpoint; however, reducing this value also permits less time in which to write the GCP, so this must be done with caution.

In addition to the considerations given for `DiskPageBufferMemory` as explained previously, it is also very important that the `DiskIOThreadPool` configuration parameter be set correctly; having `DiskIOThreadPool` set too high is very likely to cause GCP stop errors (Bug #37227).

GCP stops can be caused by save or commit timeouts; the `TimeBetweenEpochsTimeout` data node configuration parameter determines the timeout for commits. However, it is possible to disable both types of timeouts by setting this parameter to 0.

Parameters for configuring send buffer memory allocation. Send buffer memory is allocated dynamically from a memory pool shared between all transporters, which means that the size of the

send buffer can be adjusted as necessary. (Previously, the NDB kernel used a fixed-size send buffer for every node in the cluster, which was allocated when the node started and could not be changed while the node was running.) The `TotalSendBufferMemory` and `OverLoadLimit` data node configuration parameters permit the setting of limits on this memory allocation. For more information about the use of these parameters (as well as `SendBufferMemory`), see Section 18.3.3.13, "Configuring NDB Cluster Send Buffer Parameters".

- `ExtraSendBufferMemory`

  This parameter specifies the amount of transporter send buffer memory to allocate in addition to any set using `TotalSendBufferMemory`, `SendBufferMemory`, or both.

  This parameter was added in NDB 7.2.5. (Bug #11760629, Bug #53053)

- `TotalSendBufferMemory`

  This parameter is used to determine the total amount of memory to allocate on this node for shared send buffer memory among all configured transporters.

  Prior to NDB 7.2.5, this parameter did not work correctly with `ndbmtd`. (Bug #13633845)

  If this parameter is set, its minimum permitted value is 256KB; 0 indicates that the parameter has not been set. For more detailed information, see Section 18.3.3.13, "Configuring NDB Cluster Send Buffer Parameters".

- `ReservedSendBufferMemory`

  This parameter is present in `NDBCLUSTER` source code beginning with NDB 6.4.0. However, it is not currently enabled.

  As of NDB 7.2.5, this parameter is deprecated, and is subject to removal in a future release of NDB Cluster (Bug #11760629, Bug #53053).

For more detailed information about the behavior and use of `TotalSendBufferMemory` and `ReservedSendBufferMemory`, and about configuring send buffer memory parameters in NDB Cluster, see Section 18.3.3.13, "Configuring NDB Cluster Send Buffer Parameters".

See also Section 18.5.13, "Adding NDB Cluster Data Nodes Online".

Redo log over-commit handling. It is possible to control a data node's handling of operations when too much time is taken flushing redo logs to disk. This occurs when a given redo log flush takes longer than `RedoOverCommitLimit` seconds, more than `RedoOverCommitCounter` times, causing any pending transactions to be aborted. When this happens, the API node that sent the transaction can handle the operations that should have been committed either by queuing the operations and re-trying them, or by aborting them, as determined by `DefaultOperationRedoProblemAction`. The data node configuration parameters for setting the timeout and number of times it may be exceeded before the API node takes this action are described in the following list:

- `RedoOverCommitCounter`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	3	0 - 4294967039 (0xFFFFFEFF)	N

  When `RedoOverCommitLimit` is exceeded when trying to write a given redo log to disk this many times or more, any transactions that were not committed as a result are aborted, and an API node where any of these transactions originated handles the operations making up those transactions according to its value for `DefaultOperationRedoProblemAction` (by either queuing the operations to be re-tried, or aborting them).

  `RedoOverCommitCounter` defaults to 3. Set it to 0 to disable the limit.

- `RedoOverCommitLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	seconds	20	0 - 4294967039 (0xFFFFFEFF)	N

This parameter sets an upper limit in seconds for trying to write a given redo log to disk before timing out. The number of times the data node tries to flush this redo log, but takes longer than `RedoOverCommitLimit`, is kept and compared with `RedoOverCommitCounter`, and when flushing takes too long more times than the value of that parameter, any transactions that were not committed as a result of the flush timeout are aborted. When this occurs, the API node where any of these transactions originated handles the operations making up those transactions according to its `DefaultOperationRedoProblemAction` setting (it either queues the operations to be re-tried, or aborts them).

By default, `RedoOverCommitLimit` is 20 seconds. Set to 0 to disable checking for redo log flush timeouts. This parameter was added in NDB 7.1.10.

Controlling restart attempts. It is possible to exercise finely-grained control over restart attempts by data nodes when they fail to start using the `MaxStartFailRetries` and `StartFailRetryDelay` data node configuration parameters.

`MaxStartFailRetries` limits the total number of retries made before giving up on starting the data node, `StartFailRetryDelay` sets the number of seconds between retry attempts. These parameters are listed here:

- `StartFailRetryDelay`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

Use this parameter to set the number of seconds between restart attempts by the data node in the event on failure on startup. The default is 0 (no delay).

Both this parameter and `MaxStartFailRetries` are ignored unless `StopOnError` is equal to 0.

- `MaxStartFailRetries`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	3	0 - 4294967039 (0xFFFFFEFF)	N

Use this parameter to limit the number restart attempts made by the data node in the event that it fails on startup. The default is 3 attempts.

Both this parameter and `StartFailRetryDelay` are ignored unless `StopOnError` is equal to 0.

NDB index statistics parameters. The parameters in the following list relate to NDB index statistics generation, which was introduced in NDB 7.2.1.

- `IndexStatAutoCreate`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.1	boolean	false	false, true	S

Enable or disable automatic statistics collection when indexes are created. Disabled by default.

This parameter was added in NDB 7.2.1.

- `IndexStatAutoUpdate`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.1	boolean	false	false, true	S

Enable or disable monitoring of indexes for changes and trigger automatic statistics updates these are detected. The amount and degree of change needed to trigger the updates are determined by the settings for the `IndexStatTriggerPct` and `IndexStatTriggerScale` options.

This parameter was added in NDB 7.2.1.

- `IndexStatSaveSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.1	bytes	32768	0 - 4294967039 (0xFFFFFEFF)	IN

Maximum space in bytes allowed for the saved statistics of any given index in the `NDB` system tables and in the `mysqld` memory cache. This consumes `IndexMemory`.

At least one sample is always produced, regardless of any size limit. Note that this size is scaled by `IndexStatSaveScale`.

This parameter was added in NDB 7.2.1.

The size specified by `IndexStatSaveSize` is scaled by the value of `IndexStatTriggerPct` for a large index, times 0.01. Note that this is further multiplied by the logarithm to the base 2 of the index size. Setting `IndexStatTriggerPct` equal to 0 disables the scaling effect.

- `IndexStatSaveScale`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.1	percentage	100	0 - 4294967039 (0xFFFFFEFF)	IN

The size specified by `IndexStatSaveSize` is scaled by the value of `IndexStatTriggerPct` for a large index, times 0.01. Note that this is further multiplied by the logarithm to the base 2 of the index size. Setting `IndexStatTriggerPct` equal to 0 disables the scaling effect.

This parameter was added in NDB 7.2.1.

- `IndexStatTriggerPct`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.1	percentage	100	0 - 4294967039 (0xFFFFFEFF)	IN

Percentage change in updates that triggers an index statistics update. The value is scaled by `IndexStatTriggerScale`. You can disable this trigger altogether by setting `IndexStatTriggerPct` to 0.

This parameter was added in NDB 7.2.1.

- `IndexStatTriggerScale`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.1	percentage	100	0 - 4294967039 (0xFFFFFEFF)	IN

Scale `IndexStatTriggerPct` by this amount times 0.01 for a large index. A value of 0 disables scaling.

This parameter was added in NDB 7.2.1.

- `IndexStatUpdateDelay`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.1	seconds	60	0 - 4294967039 (0xFFFFFEFF)	IN

Minimum delay in seconds between automatic index statistics updates for a given index. Setting this variable to 0 disables any delay. The default is 60 seconds.

This parameter was added in NDB 7.2.1.

18.3.3.7 Defining SQL and Other API Nodes in an NDB Cluster

The `[mysqld]` and `[api]` sections in the `config.ini` file define the behavior of the MySQL servers (SQL nodes) and other applications (API nodes) used to access cluster data. None of the parameters shown is required. If no computer or host name is provided, any host can use this SQL or API node.

Generally speaking, a `[mysqld]` section is used to indicate a MySQL server providing an SQL interface to the cluster, and an `[api]` section is used for applications other than `mysqld` processes accessing cluster data, but the two designations are actually synonymous; you can, for instance, list parameters for a MySQL server acting as an SQL node in an `[api]` section.

Note

For a discussion of MySQL server options for NDB Cluster, see MySQL Server Options for NDB Cluster; for information about MySQL server system variables relating to NDB Cluster, see NDB Cluster System Variables.

- `Id`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	1 - 255	IS

The `Id` is an integer value used to identify the node in all cluster internal messages. The permitted range of values is 1 to 255 inclusive. This value must be unique for each node in the cluster, regardless of the type of node.

Note

Data node IDs must be less than 49, regardless of the NDB Cluster version used. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for API nodes (and management nodes) to values greater than 48.

`NodeId` is the preferred parameter name to use when identifying API nodes. (`Id` continues to be supported for backward compatibility, but is now deprecated and generates a warning when used. It is also subject to future removal.)

- `ConnectionMap`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	string	[none]	...	N

Specifies which data nodes to connect.

- `NodeId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	1 - 255	IS

The `NodeId` is an integer value used to identify the node in all cluster internal messages. The permitted range of values is 1 to 255 inclusive. This value must be unique for each node in the cluster, regardless of the type of node.

Note

Data node IDs must be less than 49, regardless of the NDB Cluster version used. If you plan to deploy a large number of data nodes, it is a good idea to limit the node IDs for API nodes (and management nodes) to values greater than 48.

`NodeId` is the preferred parameter name to use when identifying management nodes in NDB Cluster 7.2 and later. Previously, `Id` was used for this purpose and this continues to be supported for backward compatibility. `Id` is now deprecated and generates a warning when used; it is subject to removal in a future release of NDB Cluster.

- `ExecuteOnComputer`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name	[none]	...	S

This refers to the `Id` set for one of the computers (hosts) defined in a `[computer]` section of the configuration file.

- `HostName`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	[none]	...	N

Specifying this parameter defines the hostname of the computer on which the SQL node (API node) is to reside. To specify a hostname, either this parameter or `ExecuteOnComputer` is required.

If no `HostName` or `ExecuteOnComputer` is specified in a given `[mysql]` or `[api]` section of the `config.ini` file, then an SQL or API node may connect using the corresponding “slot” from any host which can establish a network connection to the management server host machine. *This differs from the default behavior for data nodes, where `localhost` is assumed for `HostName` unless otherwise specified*.

- `ArbitrationRank`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	0-2	0	0 - 2	N

This parameter defines which nodes can act as arbitrators. Both management nodes and SQL nodes can be arbitrators. A value of 0 means that the given node is never used as an arbitrator, a value of 1 gives the node high priority as an arbitrator, and a value of 2 gives it low priority. A normal configuration uses the management server as arbitrator, setting its `ArbitrationRank` to 1 (the default for management nodes) and those for all SQL nodes to 0 (the default for SQL nodes).

By setting `ArbitrationRank` to 0 on all management and SQL nodes, you can disable arbitration completely. You can also control arbitration by overriding this parameter; to do so, set the

`Arbitration` parameter in the `[ndbd default]` section of the `config.ini` global configuration file.

- `ArbitrationDelay`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	milliseconds	0	0 - 4294967039 (0xFFFFFEFF)	N

Setting this parameter to any other value than 0 (the default) means that responses by the arbitrator to arbitration requests will be delayed by the stated number of milliseconds. It is usually not necessary to change this value.

- `BatchByteSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	32K	1K - 1M	N
NDB 7.2.1	bytes	16K	1K - 1M	N

For queries that are translated into full table scans or range scans on indexes, it is important for best performance to fetch records in properly sized batches. It is possible to set the proper size both in terms of number of records (`BatchSize`) and in terms of bytes (`BatchByteSize`). The actual batch size is limited by both parameters.

The speed at which queries are performed can vary by more than 40% depending upon how this parameter is set.

This parameter is measured in bytes. The default value prior to NDB 7.2.1 was 32K; in NDB 7.2.1 and later, the default is 16K.

- `BatchSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	records	64	1 - 992	N
NDB 7.2.1	records	256	1 - 992	N

This parameter is measured in number of records and is by default set to 256 (NDB 7.2.1 and later; previously, the default was 64). The maximum size is 992.

- `ExtraSendBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.14	bytes	0	0 - 4294967039 (0xFFFFFEFF)	N

This parameter specifies the amount of transporter send buffer memory to allocate in addition to any that has been set using `TotalSendBufferMemory`, `SendBufferMemory`, or both.

This parameter was added in NDB 7.2.14. (Bug #14555359)

- `HeartbeatThreadPriority`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	string	[none]	...	S

Use this parameter to set the scheduling policy and priority of heartbeat threads for management and API nodes. The syntax for setting this parameter is shown here:

```
HeartbeatThreadPriority = policy[, priority]

policy:
  {FIFO | RR}
```

When setting this parameter, you must specify a policy. This is one of `FIFO` (first in, first in) or `RR` (round robin). This followed optionally by the priority (an integer).

- `MaxScanBatchSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	256K	32K - 16M	N

The batch size is the size of each batch sent from each data node. Most scans are performed in parallel to protect the MySQL Server from receiving too much data from many nodes in parallel; this parameter sets a limit to the total batch size over all nodes.

The default value of this parameter is set to 256KB. Its maximum size is 16MB.

- `TotalSendBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	0	256K - 4294967039 (0xFFFFFEFF)	N

This parameter is available beginning with NDB 6.4.0. It is used to determine the total amount of memory to allocate on this node for shared send buffer memory among all configured transporters.

If this parameter is set, its minimum permitted value is 256KB; 0 indicates that the parameter has not been set. For more detailed information, see Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

- `AutoReconnect`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

This parameter is `false` by default. This forces disconnected API nodes (including MySQL Servers acting as SQL nodes) to use a new connection to the cluster rather than attempting to re-use an existing one, as re-use of connections can cause problems when using dynamically-allocated node IDs. (Bug #45921)

Note

This parameter can be overridden using the NDB API. For more information, see Ndb_cluster_connection::set_auto_reconnect(), and Ndb_cluster_connection::get_auto_reconnect().

- `DefaultOperationRedoProblemAction`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	enumeration	ABORT	ABORT, QUEUE	S
NDB 7.2.1	enumeration	ABORT	ABORT, QUEUE	S
NDB 7.2.10	enumeration	QUEUE	ABORT, QUEUE	S

This parameter (along with `RedoOverCommitLimit` and `RedoOverCommitCounter`) controls the data node's handling of operations when too much time is taken flushing redo logs to disk. This occurs when a given redo log flush takes longer than `RedoOverCommitLimit` seconds, more than `RedoOverCommitCounter` times, causing any pending transactions to be aborted.

When this happens, the node can respond in either of two ways, according to the value of `DefaultOperationRedoProblemAction`, listed here:

- `ABORT`: Any pending operations from aborted transactions are also aborted.
- `QUEUE`: Pending operations from transactions that were aborted are queued up to be re-tried. This the default in NDB Cluster 7.2 and later. In NDB 7.2.21 and later, pending operations are still aborted when the redo log runs out of space—that is, when **`P_TAIL_PROBLEM`** errors occur. (Bug #20782580)

Prior to NDB 7.2.10, setting this parameter did not have any effect. (Bug #15855588)

- `DefaultHashMapSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.11	buckets	3840	0 - 3840	N

NDB 7.2.7 and later use a larger default table hash map size (3840) than in previous releases (240). Beginning with NDB 7.2.11, the size of the table hash maps used by `NDB` is configurable using this parameter; previously this value was hard-coded. `DefaultHashMapSize` can take any of three possible values (0, 240, 3840). These values and their effects are described in the following table.

Value	Description / Effect
`0`	Use the lowest value set, if any, for this parameter among all data nodes and API nodes in the cluster; if it is not set on any data or API node, use the default value.
`240`	Original hash map size, used by default in all NDB Cluster releases prior to NDB 7.2.7.
`3840`	Larger hash map size as used by default in NDB 7.2.7 and later

The primary intended use for this parameter is to facilitate upgrades and especially downgrades between NDB 7.2.7 and later NDB Cluster versions, in which the larger hash map size (3840) is the default, and earlier releases (in which the default was 240), due to the fact that this change is not otherwise backward compatible (Bug #14800539). By setting this parameter to 240 prior to performing an upgrade from an older version where this value is in use, you can cause the cluster to continue using the smaller size for table hash maps, in which case the tables remain compatible with earlier versions following the upgrade. `DefaultHashMapSize` can be set for individual data nodes, API nodes, or both, but setting it once only, in the `[ndbd default]` section of the `config.ini` file, is the recommended practice.

After increasing this parameter, to have existing tables to take advantage of the new size, you can run `ALTER TABLE ... REORGANIZE PARTITION` on them, after which they can use the larger hash map size. This is in addition to performing a rolling restart, which makes the larger hash maps available to new tables, but does not enable existing tables to use them.

Decreasing this parameter online after any tables have been created or modified with `DefaultHashMapSize` equal to 3840 is not currently supported.

- `Wan`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

Use WAN TCP setting as default.

- `ConnectBackoffMaxTime`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.18	integer	0	0 - 4294967039 (0xFFFFFEFF)	N

Starting with NDB 7.2.18, in an NDB Cluster with many unstarted data nodes, the value of this parameter can be raised to circumvent connection attempts to data nodes which have not yet begun to function in the cluster, as well as moderate high traffic to management nodes. As long as the API node is not connected to any new data nodes, the value of the `StartConnectBackoffMaxTime` parameter is applied; otherwise, `ConnectBackoffMaxTime` is used to determine the length of time in milliseconds to wait between connection attempts.

Time elapsed *during* node connection attempts is not taken into account when calculating elapsed time for this parameter. The timeout is applied with approximately 100 ms resolution, starting with a 100 ms delay; for each subsequent attempt, the length of this period is doubled until it reaches `ConnectBackoffMaxTime` milliseconds, up to a maximum of 100000 ms (100s).

Once the API node is connected to a data node and that node reports (in a heartbeat message) that it has connected to other data nodes, connection attempts to those data nodes are no longer affected by this parameter, and are made every 100 ms thereafter until connected. Note that, once a data node has started, it can take up `HeartbeatIntervalDbApi` for the API node to be notified that this has occurred.

- `StartConnectBackoffMaxTime`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.18	integer	1500	0 - 4294967039 (0xFFFFFEFF)	N

Starting with NDB 7.2.18, in an NDB Cluster with many unstarted data nodes, the value of this parameter can be raised to circumvent connection attempts to data nodes which have not yet begun to function in the cluster, as well as moderate high traffic to management nodes. As long as the API node is not connected to any new data nodes, the value of the `StartConnectBackoffMaxTime` parameter is applied; otherwise, `ConnectBackoffMaxTime` is used to determine the length of time in milliseconds to wait between connection attempts.

Time elapsed *during* node connection attempts is not taken into account when calculating elapsed time for this parameter. The timeout is applied with approximately 100 ms resolution, starting with a 100 ms delay; for each subsequent attempt, the length of this period is doubled until it reaches `StartConnectBackoffMaxTime` milliseconds, up to a maximum of 100000 ms (100s).

Once the API node is connected to a data node and that node reports (in a heartbeat message) that it has connected to other data nodes, connection attempts to those data nodes are no longer affected by this parameter, and are made every 100 ms thereafter until connected. Note that, once a data node has started, it can take up `HeartbeatIntervalDbApi` for the API node to be notified that this has occurred.

You can also obtain information from a MySQL server running as an NDB Cluster SQL node using `SHOW STATUS` in the `mysql` client, as shown here:

```
mysql> SHOW STATUS LIKE 'ndb%';
```

```
+-----------------------------+----------------+
| Variable_name               | Value          |
+-----------------------------+----------------+
| Ndb_cluster_node_id         | 5              |
| Ndb_config_from_host        | 198.51.100.112 |
| Ndb_config_from_port        | 1186           |
| Ndb_number_of_storage_nodes | 4              |
+-----------------------------+----------------+
4 rows in set (0.02 sec)
```

For information about the status variables appearing in the output from this statement, see NDB Cluster Status Variables.

Note

To add new SQL or API nodes to the configuration of a running NDB Cluster, it is necessary to perform a rolling restart of all cluster nodes after adding new `[mysqld]` or `[api]` sections to the `config.ini` file (or files, if you are using more than one management server). This must be done before the new SQL or API nodes can connect to the cluster.

It is *not* necessary to perform any restart of the cluster if new SQL or API nodes can employ previously unused API slots in the cluster configuration to connect to the cluster.

18.3.3.8 MySQL Server Options and Variables for NDB Cluster

This section provides information about MySQL server options, server and status variables that are specific to NDB Cluster. For general information on using these, and for other options and variables not specific to NDB Cluster, see Section 5.1, “The MySQL Server”.

For NDB Cluster configuration parameters used in the cluster configuration file (usually named `config.ini`), see Section 18.3, “Configuration of NDB Cluster”.

MySQL Server Options for NDB Cluster

This section provides descriptions of `mysqld` server options relating to NDB Cluster. For information about `mysqld` options not specific to NDB Cluster, and for general information about the use of options with `mysqld`, see Section 5.1.4, “Server Command Options”.

For information about command-line options used with other NDB Cluster processes (`ndbd`, `ndb_mgmd`, and `ndb_mgm`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”. For information about command-line options used with `NDB` utility programs (such as `ndb_desc`, `ndb_size.pl`, and `ndb_show_tables`), see Section 18.4, “NDB Cluster Programs”.

- `--ndbcluster`

Table 18.10 Type and value information for ndbcluster

Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndbcluster`		
Yes	No	No
Yes		No
NDB 7.2	boolean	FALSE

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
DESCRIPTION: Enable NDB Cluster (if this version of MySQL supports it). Disabled by `--skip-ndbcluster`		

The `NDBCLUSTER` storage engine is necessary for using NDB Cluster. If a `mysqld` binary includes support for the `NDBCLUSTER` storage engine, the engine is disabled by default. Use the `--ndbcluster` option to enable it. Use `--skip-ndbcluster` to explicitly disable the engine.

- `--ndb-batch-size=#`

Table 18.11 Type and value information for ndb-batch-size

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-batch-size`		
Yes	Yes	No
Yes	Global	No
NDB 7.2	integer	32768 / 0 - 31536000
DESCRIPTION: Size (in bytes) to use for NDB transaction batches.		

This sets the size in bytes that is used for NDB transaction batches.

- `--ndb-cluster-connection-pool=#`

Table 18.12 Type and value information for ndb-cluster-connection-pool

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-cluster-connection-pool`		
Yes	Yes	Yes
Yes	Global	No
NDB 7.2	integer	1 / 1 - 63
DESCRIPTION: Number of connections to the cluster used by MySQL.		

By setting this option to a value greater than 1 (the default), a `mysqld` process can use multiple connections to the cluster, effectively mimicking several SQL nodes. Each connection requires its own `[api]` or `[mysqld]` section in the cluster configuration (`config.ini`) file, and counts against the maximum number of API connections supported by the cluster.

Suppose that you have 2 cluster host computers, each running an SQL node whose `mysqld` process was started with `--ndb-cluster-connection-pool=4`; this means that the cluster must have 8 API slots available for these connections (instead of 2). All of these connections are set up when the SQL node connects to the cluster, and are allocated to threads in a round-robin fashion.

This option is useful only when running `mysqld` on host machines having multiple CPUs, multiple cores, or both. For best results, the value should be smaller than the total number of cores available on the host machine. Setting it to a value greater than this is likely to degrade performance severely.

Important

Because each SQL node using connection pooling occupies multiple API node slots—each slot having its own node ID in the cluster—you must *not* use a node ID as part of the cluster connection string when starting any `mysqld` process that employs connection pooling.

Setting a node ID in the connection string when using the `--ndb-cluster-connection-pool` option causes node ID allocation errors when the SQL node attempts to connect to the cluster.

Note

In some older releases of NDB Cluster prior to NDB Cluster 7.2, there was also a separate status variable corresponding to this option; however, the status variable was removed as redundant as of these versions. (Bug #60119)

- `--ndb-blob-read-batch-bytes=`*`bytes`*

Table 18.13 Type and value information for ndb-blob-read-batch-bytes

Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-blob-read-batch-bytes`		
Yes	Yes	No
Yes	Both	Yes
NDB 7.2	integer	65536 / 0 - 4294967295
DESCRIPTION: Specifies size in bytes that large BLOB reads should be batched into. 0 = no limit..		

This option can be used to set the size (in bytes) for batching of `BLOB` data reads in NDB Cluster applications. When this batch size is exceeded by the amount of `BLOB` data to be read within the current transaction, any pending `BLOB` read operations are immediately executed.

The maximum value for this option is 4294967295; the default is 65536. Setting it to 0 has the effect of disabling `BLOB` read batching.

Note

In NDB API applications, you can control `BLOB` write batching with the `setMaxPendingBlobReadBytes()` and `getMaxPendingBlobReadBytes()` methods.

- `--ndb-blob-write-batch-bytes=`*`bytes`*

Table 18.14 Type and value information for ndb-blob-write-batch-bytes

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb-blob-write-batch-bytes		
Yes	Yes	No
Yes	Both	Yes
NDB 7.2	integer	65536 / 0 - 4294967295
DESCRIPTION: Specifies size in bytes that large BLOB writes should be batched into. 0 = no limit..		

This option can be used to set the size (in bytes) for batching of `BLOB` data writes in NDB Cluster applications. When this batch size is exceeded by the amount of `BLOB` data to be written within the current transaction, any pending `BLOB` write operations are immediately executed.

The maximum value for this option is 4294967295; the default is 65536. Setting it to 0 has the effect of disabling `BLOB` write batching.

Note

In NDB API applications, you can control `BLOB` write batching with the `setMaxPendingBlobWriteBytes()` and `getMaxPendingBlobWriteBytes()` methods.

- `--ndb-connectstring=`*`connection_string`*

Table 18.15 Type and value information for ndb-connectstring

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb-connectstring		
Yes	No	No
Yes		No
NDB 7.2	string	
DESCRIPTION: Point to the management server that distributes the cluster configuration.		

When using the `NDBCLUSTER` storage engine, this option specifies the management server that distributes cluster configuration data. See Section 18.3.3.3, “NDB Cluster Connection Strings”, for syntax.

- `--ndb-deferred-constraints=[0|1]`

Table 18.16 Type and value information for ndb-deferred-constraints

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb-deferred-constraints		
Yes	Yes	No
Yes	Both	Yes
NDB 7.2	integer	0 / 0 - 1
DESCRIPTION: Specifies that constraint checks on unique indexes (where these are supported) should be deferred until commit time. Not normally needed or used; for testing purposes only..		

Controls whether or not constraint checks on unique indexes are deferred until commit time, where such checks are supported. `0` is the default.

This option is not normally needed for operation of NDB Cluster or NDB Cluster Replication, and is intended primarily for use in testing.

- `--ndb-distribution=[KEYHASH|LINHASH]`

Table 18.17 Type and value information for ndb-distribution

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb-distribution		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	enumeration	KEYHASH / LINHASH, KEYHASH
DESCRIPTION: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH).		

Controls the default distribution method for `NDB` tables. Can be set to either of `KEYHASH` (key hashing) or `LINHASH` (linear hashing). `KEYHASH` is the default.

- `--ndb-log-apply-status`

Table 18.18 Type and value information for ndb-log-apply-status

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb-log-apply-status		
Yes	Yes	No
Yes	Global	No

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
NDB 7.2	boolean	OFF
DESCRIPTION: Cause a MySQL server acting as a slave to log mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID. Effective only if the server is started with the --ndbcluster option..		

Causes a slave `mysqld` to log any updates received from its immediate master to the `mysql.ndb_apply_status` table in its own binary log using its own server ID rather than the server ID of the master. In a circular or chain replication setting, this allows such updates to propagate to the `mysql.ndb_apply_status` tables of any MySQL servers configured as slaves of the current `mysqld`.

In a chain replication setup, using this option allows downstream (slave) clusters to be aware of their positions relative to all of their upstream contributors (masters).

In a circular replication setup, this option causes changes to `ndb_apply_status` tables to complete the entire circuit, eventually propagating back to the originating NDB Cluster. This also allows a cluster acting as a master to see when its changes (epochs) have been applied to the other clusters in the circle.

This option has no effect unless the MySQL server is started with the `--ndbcluster` option.

- `--ndb-log-empty-epochs=[ON|OFF]`

Table 18.19 Type and value information for ndb-log-empty-epochs

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-log-empty-epochs`		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	boolean	OFF
DESCRIPTION: When enabled, causes epochs in which there were no changes to be written to the ndb_apply_status and ndb_binlog_index tables, even when --log-slave-updates is enabled..		

Causes epochs during which there were no changes to be written to the `ndb_apply_status` and `ndb_binlog_index` tables, even when `--log-slave-updates` is enabled.

By default this option is disabled. Disabling `--ndb-log-empty-epochs` causes epoch transactions with no changes not to be written to the binary log, although a row is still written even for an empty epoch in `ndb_binlog_index`.

Because `--ndb-log-empty-epochs=1` causes the size of the `ndb_binlog_index` table to increase independently of the size of the binary log, users should be prepared to manage the growth of this table, even if they expect the cluster to be idle a large part of the time.

- `--ndb-log-empty-update=[ON|OFF]`

Table 18.20 Type and value information for ndb-log-empty-update

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-log-empty-update`		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	boolean	OFF
DESCRIPTION: When enabled, causes updates that produced no changes to be written to the ndb_apply_status and ndb_binlog_index tables, even when --log-slave-updates is enabled..		

Causes updates that produced no changes to be written to the `ndb_apply_status` and `ndb_binlog_index` tables, even when `--log-slave-updates` is enabled.

By default this option is disabled (`OFF`). Disabling `--ndb-log-empty-update` causes updates with no changes not to be written to the binary log.

- `--ndb-log-orig`

Table 18.21 Type and value information for ndb-log-orig

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-log-orig`		
Yes	Yes	No
Yes	Global	No
NDB 7.2	boolean	OFF
DESCRIPTION: Log originating server id and epoch in mysql.ndb_binlog_index table.		

Log the originating server ID and epoch in the `ndb_binlog_index` table.

Note that this makes it possible for a given epoch to have multiple rows in `ndb_binlog_index`, one for each originating epoch.

For more information, see Section 18.6.4, “NDB Cluster Replication Schema and Tables”.

- `--ndb-log-transaction-id`

Table 18.22 Type and value information for ndb-log-transaction-id

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-log-transaction-id`		
Yes	Yes	No

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
Yes	Global	No
NDB 7.2	boolean	OFF
DESCRIPTION: Write NDB transaction IDs in the binary log. Requires --log-bin-v1-events=OFF..		

Causes a slave `mysqld` to write the NDB transaction ID in each row of the binary log. Such logging requires the use of the Version 2 event format for the binary log; thus, `--log-bin-use-v1-row-events` must be set to `FALSE` in order to use this option.

This option is available beginning with NDB 7.2.1 (and is not supported in mainline MySQL Server 5.5). It is required to enable NDB Cluster Replication conflict detection and resolution using the `NDB$EPOCH_TRANS()` function introduced in the same NDB Cluster release.

The default value is `FALSE`.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `--ndb-mgmd-host=host[:port]`

Table 18.23 Type and value information for ndb-mgmd-host

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-mgmd-host`		
Yes	No	No
Yes		No
NDB 7.2	string	localhost:1186
DESCRIPTION: Set the host (and port, if desired) for connecting to management server.		

Can be used to set the host and port number of a single management server for the program to connect to. If the program requires node IDs or references to multiple management servers (or both) in its connection information, use the `--ndb-connectstring` option instead.

- `--ndb-nodeid=#`

Table 18.24 Type and value information for ndb-nodeid

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-nodeid`		
Yes	No	Yes
Yes	Global	No
5.0.45	integer	/ 1 - 63

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
5.1.5	integer	/ 1 - 255
DESCRIPTION: NDB Cluster node ID for this MySQL server.		

Set this MySQL server's node ID in an NDB Cluster.

The `--ndb-nodeid` option overrides any node ID set with `--ndb-connectstring`, regardless of the order in which the two options are used.

In addition, if `--ndb-nodeid` is used, then either a matching node ID must be found in a `[mysqld]` or `[api]` section of `config.ini`, or there must be an "open" `[mysqld]` or `[api]` section in the file (that is, a section without a `NodeId` or `Id` parameter specified). This is also true if the node ID is specified as part of the connection string.

Regardless of how the node ID is determined, its is shown as the value of the global status variable `Ndb_cluster_node_id` in the output of `SHOW STATUS`, and as `cluster_node_id` in the `connection` row of the output of `SHOW ENGINE NDBCLUSTER STATUS`.

For more information about node IDs for NDB Cluster SQL nodes, see Section 18.3.3.7, "Defining SQL and Other API Nodes in an NDB Cluster".

- `--ndb_optimization_delay=`*`milliseconds`*

Table 18.25 Type and value information for ndb_optimization_delay

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_optimization_delay`		
No	Yes	No
No	Global	Yes
NDB 7.2	integer	10 / 0 - 100000
DESCRIPTION: Sets the number of milliseconds to wait between processing sets of rows by OPTIMIZE TABLE on NDB tables.		

Set the number of milliseconds to wait between sets of rows by `OPTIMIZE TABLE` statements on `NDB` tables. The default is 10.

- `ndb-transid-mysql-connection-map=`*`state`*

Table 18.26 Type and value information for ndb-transid-mysql-connection-map

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb-transid-mysql-connection-map`		
Yes	No	No

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
No		No
NDB 7.2	enumeration	ON / ON, OFF, FORCE
DESCRIPTION: Enable or disable the ndb_transid_mysql_connection_map plugin; that is, enable or disable the INFORMATION_SCHEMA table having that name.		

Enables or disables the plugin that handles the `ndb_transid_mysql_connection_map` table in the `INFORMATION_SCHEMA` database. Takes one of the values `ON`, `OFF`, or `FORCE`. `ON` (the default) enables the plugin. `OFF` disables the plugin, which makes `ndb_transid_mysql_connection_map` inaccessible. `FORCE` keeps the MySQL Server from starting if the plugin fails to load and start.

You can see whether the `ndb_transid_mysql_connection_map` table plugin is running by checking the output of `SHOW PLUGINS`.

This option was added in NDB 7.2.2.

- `--ndb-wait-connected=`*`seconds`*

Table 18.27 Type and value information for ndb-wait-connected

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-wait-connected`		
Yes	Yes	No
Yes	Global	No
NDB 7.2	integer	0 / 0 - 31536000
5.1.56-ndb-7.0.27	integer	30 / 0 - 31536000
NDB 7.2	integer	0 / 0 - 31536000
5.1.56-ndb-7.1.16	integer	30 / 0 - 31536000
DESCRIPTION: Time (in seconds) for the MySQL server to wait for connection to cluster management and data nodes before accepting MySQL client connections.		

This option sets the period of time that the MySQL server waits for connections to NDB Cluster management and data nodes to be established before accepting MySQL client connections. The time is specified in seconds. The default value is `30`.

- `--ndb-wait-setup=`*`seconds`*

Table 18.28 Type and value information for ndb-wait-setup

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb-wait-setup`		
Yes	Yes	No
Yes	Global	No
5.1.39-ndb-6.2.19	integer	15 / 0 - 31536000
5.1.39-ndb-6.3.28	integer	15 / 0 - 31536000
5.1.39-ndb-7.0.9	integer	15 / 0 - 31536000
5.1.56-ndb-7.0.27	integer	30 / 0 - 31536000
5.1.39-ndb-7.1.0	integer	15 / 0 - 31536000
5.1.56-ndb-7.1.16	integer	30 / 0 - 31536000
DESCRIPTION: Time (in seconds) for the MySQL server to wait for NDB engine setup to complete.		

This variable shows the period of time that the MySQL server waits for the `NDB` storage engine to complete setup before timing out and treating `NDB` as unavailable. The time is specified in seconds. The default value is `30`.

- `--server-id-bits=#`

Table 18.29 Type and value information for server-id-bits

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`server-id-bits`		
Yes	Yes	No
Yes	Global	No
NDB 7.2	integer	32 / 7 - 32
DESCRIPTION: Sets the number of least significant bits in the server_id actually used for identifying the server, permitting NDB API applications to store application data in the most significant bits. server_id must be less than 2 to the power of this value..		

This option indicates the number of least significant bits within the 32-bit `server_id` which actually identify the server. Indicating that the server is actually identified by fewer than 32 bits makes it possible for some of the remaining bits to be used for other purposes, such as storing user data generated by applications using the NDB API's Event API within the `AnyValue` of an `OperationOptions` structure (NDB Cluster uses the `AnyValue` to store the server ID).

When extracting the effective server ID from `server_id` for purposes such as detection of replication loops, the server ignores the remaining bits. The `--server-id-bits` option is used to mask out any irrelevant bits of `server_id` in the IO and SQL threads when deciding whether an event should be ignored based on the server ID.

This data can be read from the binary log by `mysqlbinlog`, provided that it is run with its own `--server-id-bits` option set to 32 (the default).

The value of `server_id` must be less than 2 ^ `server_id_bits`; otherwise, `mysqld` refuses to start.

This system variable is supported only by NDB Cluster. It is not supported in the standard MySQL 5.5 Server.

- `--skip-ndbcluster`

Table 18.30 Type and value information for skip-ndbcluster

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`skip-ndbcluster`		
Yes	No	No
Yes		No
DESCRIPTION: Disable the NDB Cluster storage engine.		

Disable the `NDBCLUSTER` storage engine. This is the default for binaries that were built with `NDBCLUSTER` storage engine support; the server allocates memory and other resources for this storage engine only if the `--ndbcluster` option is given explicitly. See Section 18.3.1, “Quick Test Setup of NDB Cluster”, for an example.

NDB Cluster System Variables

This section provides detailed information about MySQL server system variables that are specific to NDB Cluster and the `NDB` storage engine. For system variables not specific to NDB Cluster, see Section 5.1.5, “Server System Variables”. For general information on using system variables, see Section 5.1.6, “Using System Variables”.

- `have_ndbcluster`

Table 18.31 Type and value information for have_ndbcluster

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`have_ndbcluster`		
No	Yes	No
No	Global	No
NDB 7.2	boolean	
DESCRIPTION: Whether mysqld supports NDB Cluster tables (set by --ndbcluster option).		

`YES` if `mysqld` supports `NDBCLUSTER` tables. `DISABLED` if `--skip-ndbcluster` is used.

This variable is deprecated and is removed in MySQL 5.6. Use `SHOW ENGINES` instead.

- `ndb_autoincrement_prefetch_sz`

Table 18.32 Type and value information for ndb_autoincrement_prefetch_sz

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_autoincrement_prefetch_sz		
Yes	Yes	No
Yes	Both	Yes
NDB 7.2	integer	32 / 1 - 256
5.0.56	integer	1 / 1 - 256
5.1.1	integer	32 / 1 - 256
5.1.23	integer	1 / 1 - 256
5.1.16-ndb-6.2.0	integer	32 / 1 - 256
5.1.23-ndb-6.2.10	integer	1 / 1 - 256
5.1.19-ndb-6.3.0	integer	32 / 1 - 256
5.1.23-ndb-6.3.7	integer	1 / 1 - 256
5.1.41-ndb-6.3.31	integer	1 / 1 - 65536
5.1.30-ndb-6.4.0	integer	32 / 1 - 256
5.1.41-ndb-7.0.11	integer	1 / 1 - 65536
5.5.15-ndb-7.2.1	integer	1 / 1 - 65536
DESCRIPTION: NDB auto-increment prefetch size.		

Determines the probability of gaps in an autoincremented column. Set it to `1` to minimize this. Setting it to a high value for optimization makes inserts faster, but decreases the likelihood that consecutive autoincrement numbers will be used in a batch of inserts. The mininum and default value is 1. The maximum value for `ndb_autoincrement_prefetch_sz` is 65536.

This variable affects only the number of `AUTO_INCREMENT` IDs that are fetched between statements; within a given statement, at least 32 IDs are obtained at a time. The default value is 1.

Important

This variable does not affect inserts performed using `INSERT ... SELECT`.

- `ndb_cache_check_time`

Table 18.33 Type and value information for ndb_cache_check_time

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_cache_check_time		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	integer	0 / -

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
DESCRIPTION: Number of milliseconds between checks of cluster SQL nodes made by the MySQL query cache.		

The number of milliseconds that elapse between checks of NDB Cluster SQL nodes by the MySQL query cache. Setting this to 0 (the default and minimum value) means that the query cache checks for validation on every query.

The recommended maximum value for this variable is 1000, which means that the check is performed once per second. A larger value means that the check is performed and possibly invalidated due to updates on different SQL nodes less often. It is generally not desirable to set this to a value greater than 2000.

- `ndb_deferred_constraints`

Table 18.34 Type and value information for ndb_deferred_constraints

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_deferred_constraints`		
Yes	Yes	No
Yes	Both	Yes
NDB 7.2	integer	0 / 0 - 1
DESCRIPTION: Specifies that constraint checks should be deferred (where these are supported). Not normally needed or used; for testing purposes only..		

Controls whether or not constraint checks are deferred, where these are supported. `0` is the default.

This variable is not normally needed for operation of NDB Cluster or NDB Cluster Replication, and is intended primarily for use in testing.

- `ndb_distribution`

Table 18.35 Type and value information for ndb_distribution

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
`ndb_distribution`		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	enumeration	KEYHASH / LINHASH, KEYHASH
DESCRIPTION: Default distribution for new tables in NDBCLUSTER (KEYHASH or LINHASH, default is KEYHASH).		

Controls the default distribution method for NDB tables. Can be set to either of KEYHASH (key hashing) or LINHASH (linear hashing). KEYHASH is the default.

- ndb_eventbuffer_max_alloc

Table 18.36 Type and value information for ndb_eventbuffer_max_alloc

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_eventbuffer_max_alloc		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	integer	0 / 0 - 4294967295
DESCRIPTION: Maximum memory that can be allocated for buffering events by the NDB API. Defaults to 0 (no limit)..		

Sets the maximum amount memory (in bytes) that can be allocated for buffering events by the NDB API. 0 means that no limit is imposed, and is the default.

This variable was added in NDB 7.2.14.

- ndb_extra_logging

Table 18.37 Type and value information for ndb_extra_logging

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_extra_logging		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	integer	0 / -
5.1.19-ndb-6.3.0	integer	1 / -
DESCRIPTION: Controls logging of NDB Cluster schema, connection, and data distribution events in the MySQL error log.		

This variable enables recording in the MySQL error log of information specific to the NDB storage engine.

When this variable is set to 0, the only information specific to NDB that is written to the MySQL error log relates to transaction handling. If it set to a value greater than 0 but less than 10, NDB table schema and connection events are also logged, as well as whether or not conflict resolution is in use, and other NDB errors and information. If the value is set to 10 or more, information about NDB internals, such as the progress of data distribution among cluster nodes, is also written to the MySQL error log. The default is 1.

- ndb_force_send

Table 18.38 Type and value information for ndb_force_send

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_force_send		
Yes	Yes	No
Yes	Both	Yes
NDB 7.2	boolean	TRUE
DESCRIPTION: Forces sending of buffers to NDB immediately, without waiting for other threads.		

Forces sending of buffers to NDB immediately, without waiting for other threads. Defaults to ON.

- ndb_index_stat_cache_entries

Table 18.39 Type and value information for ndb_index_stat_cache_entries

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_index_stat_cache_entries		
Yes	Yes	No
Yes	Both	Yes
NDB 7.2	integer	32 / 0 - 4294967295
DESCRIPTION: Sets the granularity of the statistics by determining the number of starting and ending keys.		

Sets the granularity of the statistics by determining the number of starting and ending keys to store in the statistics memory cache. Zero means no caching takes place; in this case, the data nodes are always queried directly. Default value: 32.

Note

If ndb_index_stat_enable is OFF, then setting this variable has no effect.

This variable was deprecated in MySQL 5.1, and is removed from NDB 7.2.16 and later.

- ndb_index_stat_enable

Table 18.40 Type and value information for ndb_index_stat_enable

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_index_stat_enable		
Yes	Yes	No

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
Yes	Both	Yes
NDB 7.2	boolean	OFF
5.5.15-ndb-7.2.1	boolean	ON
DESCRIPTION: Use NDB index statistics in query optimization.		

Use `NDB` index statistics in query optimization. `ON` is the default in NDB Cluster 7.2 and later.

- `ndb_index_stat_option`

Table 18.41 Type and value information for ndb_index_stat_option

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_index_stat_option`		
Yes	Yes	No
Yes	Both	Yes
NDB 7.2	string	loop_enable=1000ms,loop_idle=1000ms,loop_ update_batch=1,read_batch=4,idle_batch=32, check_delay=10m,delete_batch=8, clean_delay=1m,error_batch=4, error_delay=1m,evict_batch=8,evict_delay=1m cache_lowpct=90,zero_total=0
5.1.56-ndb-7.1.17	string	loop_checkon=1000ms,loop_idle=1000ms,loo update_batch=1,read_batch=4,idle_batch=32, check_delay=1m,delete_batch=8,clean_delay= error_delay=1m,evict_batch=8,evict_delay=1m cache_lowpct=90
DESCRIPTION: Comma-separated list of tunable options for NDB index statistics; the list should contain no spaces.		

This variable is used for providing tuning options for NDB index statistics generation. The list consist of comma-separated name-value pairs of option names and values. Note that this list must not contain any space characters.

Options not used when setting `ndb_index_stat_option` are not changed from their default values. For example, you can set `ndb_index_stat_option = 'loop_idle=1000ms,cache_limit=32M'`.

Time values can be optionally suffixed with `h` (hours), `m` (minutes), or `s` (seconds). Millisecond values can optionally be specified using `ms`; millisecond values cannot be specified using `h`, `m`, or `s`.) Integer values can be suffixed with `K`, `M`, or `G`.

The names of the options that can be set using this variable are shown in the table that follows. The table also provides brief descriptions of the options, their default values, and (where applicable) their minimum and maximum values.

Name	Description	Default/Units	Minimum/Maximum
loop_enable		1000 ms	0/4G
loop_idle	Time to sleep when idle	1000 ms	0/4G
loop_busy	Time to sleep when more work is waiting	100 ms	0/4G
update_batch		1	0/4G
read_batch		4	1/4G
idle_batch		32	1/4G
check_batch		8	1/4G
check_delay	How often to check for new statistics	10 m	1/4G
delete_batch		8	0/4G
clean_delay		1 m	0/4G
error_batch		4	1/4G
error_delay		1 m	1/4G
evict_batch		8	1/4G
evict_delay	Clean LRU cache, from read time	1 m	0/4G
cache_limit	Maximum amount of memory in bytes used for cached index statistics by this mysqld; clean up the cache when this is exceeded.	32 M	0/4G
cache_lowpct		90	0/100
zero_total	Setting this to 1 causes all accumulating counters in ndb_index_stat_status to be reset to 0. Note that the option value is also reset to 0 when this is done.	0	0/1

ndb_index_stat_option was added in NDB 7.2.1.

- ndb_index_stat_update_freq

Table 18.42 Type and value information for ndb_index_stat_update_freq

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_index_stat_update_freq		
Yes	Yes	No
Yes	Both	Yes

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
NDB 7.2	integer	20 / 0 - 4294967295
DESCRIPTION: How often to query data nodes instead of the statistics cache.		

How often to query data nodes instead of the statistics cache. For example, a value of `20` (the default) means to direct every 20th query to the data nodes.

Note

If `ndb_index_stat_cache_entries` is `0`, then setting this variable has no effect; in this case, every query is sent directly to the data nodes.

This variable was deprecated in MySQL 5.1, and is removed from NDB 7.2.16 and later.

- `ndb_join_pushdown`

Table 18.43 Type and value information for ndb_join_pushdown

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_join_pushdown`		
No	Yes	No
No	Both	Yes
5.1.51-ndb-7.2.0	boolean	TRUE
DESCRIPTION: Enables pushing down of joins to data nodes.		

Added in NDB 7.2.0, this variable controls whether joins on `NDB` tables are pushed down to the NDB kernel (data nodes). Previously, a join was handled using multiple accesses of `NDB` by the SQL node; however, when `ndb_join_pushdown` is enabled, a pushable join is sent in its entirety to the data nodes, where it can be distributed among the data nodes and executed in parallel on multiple copies of the data, with a single, merged result being returned to `mysqld`. This can reduce greatly the number of round trips between an SQL node and the data nodes required to handle such a join.

By default, `ndb_join_pushdown` is enabled.

Conditions for NDB pushdown joins. In order for a join to be pushable, it must meet the following conditions:

1. Only columns can be compared, and all columns to be joined must use *exactly* the same data type.

   This means that expressions such as `t1.a = t2.a + constant` cannot be pushed down, and that (for example) a join on an `INT` column and a `BIGINT` column also cannot be pushed down.

2. Queries referencing `BLOB` or `TEXT` columns are not supported.

3. Explicit locking is not supported; however, the `NDB` storage engine's characteristic implicit row-based locking is enforced.

This means that a join using `FOR UPDATE` cannot be pushed down.

4. In order for a join to be pushed down, child tables in the join must be accessed using one of the `ref`, `eq_ref`, or `const` access methods, or some combination of these methods.

   Outer joined child tables can only be pushed using `eq_ref`.

   If the root of the pushed join is an `eq_ref` or `const`, only child tables joined by `eq_ref` can be appended. (A table joined by `ref` is likely to become the root of another pushed join.)

   If the query optimizer decides on `Using join cache` for a candidate child table, that table cannot be pushed as a child. However, it may be the root of another set of pushed tables.

5. Joins referencing tables explicitly partitioned by `[LINEAR] HASH`, `LIST`, or `RANGE` currently cannot be pushed down.

You can see whether a given join can be pushed down by checking it with `EXPLAIN`; when the join can be pushed down, you can see references to the `pushed join` in the `Extra` column of the output, as shown in this example:

```
mysql> EXPLAIN
    ->     SELECT e.first_name, e.last_name, t.title, d.dept_name
    ->         FROM employees e
    ->         JOIN dept_emp de ON e.emp_no=de.emp_no
    ->         JOIN departments d ON d.dept_no=de.dept_no
    ->         JOIN titles t ON e.emp_no=t.emp_no\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: d
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 9
        Extra: Parent of 4 pushed join@1
*************************** 2. row ***************************
           id: 1
  select_type: SIMPLE
        table: de
         type: ref
possible_keys: PRIMARY,emp_no,dept_no
          key: dept_no
      key_len: 4
          ref: employees.d.dept_no
         rows: 5305
        Extra: Child of 'd' in pushed join@1
*************************** 3. row ***************************
           id: 1
  select_type: SIMPLE
        table: e
         type: eq_ref
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 4
          ref: employees.de.emp_no
         rows: 1
        Extra: Child of 'de' in pushed join@1
*************************** 4. row ***************************
           id: 1
  select_type: SIMPLE
        table: t
         type: ref
possible_keys: PRIMARY,emp_no
          key: emp_no
      key_len: 4
```

```
          ref: employees.de.emp_no
         rows: 19
        Extra: Child of 'e' in pushed join@1
4 rows in set (0.00 sec)
```

Note

If inner joined child tables are joined by `ref`, *and* the result is ordered or grouped by a sorted index, this index cannot provide sorted rows, which forces writing to a sorted tempfile.

Two additional sources of information about pushed join performance are available:

1. The status variables `Ndb_pushed_queries_defined`, `Ndb_pushed_queries_dropped`, `Ndb_pushed_queries_executed`, and `Ndb_pushed_reads` (all introduced in NDB 7.2.0).

2. The counters in the `ndbinfo.counters` table that belong to the `DBSPJ` kernel block. (These counters and the `DBSPJ` block were also introduced in NDB 7.2.0). See Section 18.5.10.7, "The ndbinfo counters Table", for information about these counters. See also The DBSPJ Block, in the *NDB Cluster API Developer Guide*.

- `ndb_log_apply_status`

Table 18.44 Type and value information for ndb_log_apply_status

Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_log_apply_status`		
Yes	Yes	No
Yes	Global	No
NDB 7.2	boolean	OFF
DESCRIPTION: Whether or not a MySQL server acting as a slave logs mysql.ndb_apply_status updates received from its immediate master in its own binary log, using its own server ID.		

A read-only variable which shows whether the server was started with the `--ndb-log-apply-status` option.

- `ndb_log_bin`

Table 18.45 Type and value information for ndb_log_bin

Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_log_bin`		
Yes	Yes	No
No	Both	Yes
NDB 7.2	boolean	ON
DESCRIPTION: Write updates to NDB tables in the binary log. Effective only if binary logging is enabled with --log-bin..		

Causes updates to NDB tables to be written to the binary log. Setting this variable has no effect if binary logging is not already enabled for the server using log_bin. ndb_log_bin defaults to 1 (ON); normally, there is never any need to change this value in a production environment.

- ndb_log_binlog_index

Table 18.46 Type and value information for ndb_log_binlog_index

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_log_binlog_index		
Yes	Yes	No
No	Global	Yes
NDB 7.2	boolean	ON
DESCRIPTION: Insert mapping between epochs and binary log positions into the ndb_binlog_index table. Defaults to ON. Effective only if binary logging is enabled on the server..		

Causes a mapping of epochs to positions in the binary log to be inserted into the ndb_binlog_index table. Setting this variable has no effect if binary logging is not already enabled for the server using log_bin. (In addition, ndb_log_bin must not be disabled.) ndb_log_binlog_index defaults to 1 (ON); normally, there is never any need to change this value in a production environment.

- ndb_log_empty_epochs

Table 18.47 Type and value information for ndb_log_empty_epochs

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_log_empty_epochs		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	boolean	OFF
DESCRIPTION: When enabled, epochs in which there were no changes are written to the ndb_apply_status and ndb_binlog_index tables, even when log_slave_updates is enabled.		

When this variable is set to 0, epoch transactions with no changes are not written to the binary log, although a row is still written even for an empty epoch in ndb_binlog_index.

- ndb_log_empty_update

Table 18.48 Type and value information for ndb_log_empty_update

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_log_empty_update		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	boolean	OFF
DESCRIPTION: When enabled, updates which produce no changes are written to the ndb_apply_status and ndb_binlog_index tables, even when log_slave_updates is enabled.		

When this variable is set to `ON` (`1`), update transactions with no changes are written to the binary log, even when `--log-slave-updates` is enabled.

- `ndb_log_orig`

Table 18.49 Type and value information for ndb_log_orig

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_log_orig		
Yes	Yes	No
Yes	Global	No
NDB 7.2	boolean	OFF
DESCRIPTION: Whether the id and epoch of the originating server are recorded in the mysql.ndb_binlog_index table. Set using the --ndb-log-orig option when starting mysqld..		

Shows whether the originating server ID and epoch are logged in the `ndb_binlog_index` table. Set using the `--ndb-log-orig` server option.

- `ndb_log_transaction_id`

Table 18.50 Type and value information for ndb_log_transaction_id

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_log_transaction_id		
No	Yes	No
No	Global	No
NDB 7.2	boolean	OFF
DESCRIPTION: Whether NDB transaction IDs are written into the binary log (Read-only.).		

This read-only, Boolean system variable shows whether a slave `mysqld` writes NDB transaction IDs in the binary log (required to use “active-active” NDB Cluster Replication with `NDB$EPOCH_TRANS()` conflict detection). To change the setting, use the `--ndb-log-transaction-id` option.

`ndb_log_transaction_id` is available in NDB 7.2.1 and later. It is not supported in mainline MySQL Server 5.5.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `ndb_optimized_node_selection`

Table 18.51 Type and value information for ndb_optimized_node_selection

Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_optimized_node_selection`		
Yes	Yes	No
Yes	Global	No
NDB 7.2	boolean	ON
5.1.22-ndb-6.3.4	integer	3 / 0 - 3
DESCRIPTION: Determines how an SQL node chooses a cluster data node to use as transaction coordinator.		

There are two forms of optimized node selection, described here:

1. The SQL node uses *promixity* to determine the transaction coordinator; that is, the “closest” data node to the SQL node is chosen as the transaction coordinator. For this purpose, a data node having a shared memory connection with the SQL node is considered to be “closest” to the SQL node; the next closest (in order of decreasing proximity) are: TCP connection to `localhost`; SCI connection; TCP connection from a host other than `localhost`.

2. The SQL thread uses *distribution awareness* to select the data node. That is, the data node housing the cluster partition accessed by the first statement of a given transaction is used as the transaction coordinator for the entire transaction. (This is effective only if the first statement of the transaction accesses no more than one cluster partition.)

This option takes one of the integer values `0`, `1`, `2`, or `3`. `3` is the default. These values affect node selection as follows:

- `0`: Node selection is not optimized. Each data node is employed as the transaction coordinator 8 times before the SQL thread proceeds to the next data node.

- `1`: Proximity to the SQL node is used to determine the transaction coordinator.

- `2`: Distribution awareness is used to select the transaction coordinator. However, if the first statement of the transaction accesses more than one cluster partition, the SQL node reverts to the round-robin behavior seen when this option is set to `0`.

- `3`: If distribution awareness can be employed to determine the transaction coordinator, then it is used; otherwise proximity is used to select the transaction coordinator. (This is the default behavior.)

Proximity is determined as follows:

1. Start with the value set for the `Group` parameter (default 55).

2. For an API node sharing the same host with other API nodes, decrement the value by 1. Assuming the default value for `Group`, the effective value for data nodes on same host as the API node is 54, and for remote data nodes 55.

- `ndb_report_thresh_binlog_epoch_slip`

Table 18.52 Type and value information for ndb_report_thresh_binlog_epoch_slip

Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_report_thresh_binlog_epoch_slip`		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	integer	3 / 0 - 256
DESCRIPTION: NDB 7.5.4 and later: Threshold for number of epochs completely buffered, but not yet consumed by binlog injector thread which when exceeded generates BUFFERED_EPOCHS_OVER_THRESHOLD event buffer status message; prior to NDB 7.5.4: Threshold for number of epochs to lag behind before reporting binary log status.		

This is a threshold on the number of epochs to be behind before reporting binary log status. For example, a value of `3` (the default) means that if the difference between which epoch has been received from the storage nodes and which epoch has been applied to the binary log is 3 or more, a status message is sent to the cluster log.

- `ndb_report_thresh_binlog_mem_usage`

Table 18.53 Type and value information for ndb_report_thresh_binlog_mem_usage

Command Line	**System Variable**	**Status Variable**
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndb_report_thresh_binlog_mem_usage`		
Yes	Yes	No
Yes	Global	Yes
NDB 7.2	integer	10 / 0 - 10
DESCRIPTION: This is a threshold on the percentage of free memory remaining before reporting binary log status.		

This is a threshold on the percentage of free memory remaining before reporting binary log status. For example, a value of `10` (the default) means that if the amount of available memory for receiving binary log data from the data nodes falls below 10%, a status message is sent to the cluster log.

- `ndb_table_no_logging`

Table 18.54 Type and value information for ndb_table_no_logging

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_table_no_logging		
No	Yes	No
No	Session	Yes
NDB 7.2	boolean	FALSE
DESCRIPTION: NDB tables created when this setting is enabled are not checkpointed to disk (although table schema files are created). The setting in effect when the table is created with or altered to use NDBCLUSTER persists for the lifetime of the table..		

When this variable is set to `ON` or `1`, it causes `NDB` tables not to be checkpointed to disk. More specifically, this setting applies to tables which are created or altered using `ENGINE NDB` when `ndb_table_no_logging` is enabled, and continues to apply for the lifetime of the table, even if `ndb_table_no_logging` is later changed. Suppose that `A`, `B`, `C`, and `D` are tables that we create (and perhaps also alter), and that we also change the setting for `ndb_table_no_logging` as shown here:

```
SET @@ndb_table_no_logging = 1;

CREATE TABLE A ... ENGINE NDB;

CREATE TABLE B ... ENGINE MYISAM;
CREATE TABLE C ... ENGINE MYISAM;

ALTER TABLE B ENGINE NDB;

SET @@ndb_table_no_logging = 0;

CREATE TABLE D ... ENGINE NDB;
ALTER TABLE C ENGINE NDB;

SET @@ndb_table_no_logging = 1;
```

After the previous sequence of events, tables `A` and `B` are not checkpointed; `A` was created with `ENGINE NDB` and B was altered to use `NDB`, both while `ndb_table_no_logging` was enabled. However, tables `C` and `D` are logged; `C` was altered to use `NDB` and `D` was created using `ENGINE NDB`, both while `ndb_table_no_logging` was disabled. Setting `ndb_table_no_logging` back to `1` or `ON` does *not* cause table `C` or `D` to be checkpointed.

Note

`ndb_table_no_logging` has no effect on the creation of `NDB` table schema files; to suppress these, use `ndb_table_temporary` instead.

- `ndb_table_temporary`

Table 18.55 Type and value information for ndb_table_temporary

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_table_temporary		
No	Yes	No
No	Session	Yes
NDB 7.2	boolean	FALSE
DESCRIPTION: NDB tables are not persistent on disk: no schema files are created and the tables are not logged.		

When set to `ON` or `1`, this variable causes `NDB` tables not to be written to disk: This means that no table schema files are created, and that the tables are not logged.

Note

Setting this variable currently has no effect in NDB Cluster 7.0 and later. This is a known issue; see Bug #34036.

- ndb_use_copying_alter_table

Table 18.56 Type and value information for ndb_use_copying_alter_table

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_use_copying_alter_table		
No	Yes	No
No	Both	No
DESCRIPTION: Use copying ALTER TABLE operations in NDB Cluster.		

Forces `NDB` to use copying of tables in the event of problems with online `ALTER TABLE` operations. The default value is `OFF`.

- ndb_use_exact_count

Table 18.57 Type and value information for ndb_use_exact_count

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_use_exact_count		
No	Yes	No
No	Both	Yes
NDB 7.2	boolean	ON

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
5.1.47-ndb-7.1.8	boolean	OFF
DESCRIPTION: Use exact row count when planning queries.		

Forces NDB to use a count of records during SELECT COUNT(*) query planning to speed up this type of query. The default value is OFF, which allows for faster queries overall.

- ndb_use_transactions

Table 18.58 Type and value information for ndb_use_transactions

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_use_transactions		
Yes	Yes	No
Yes	Both	Yes
NDB 7.2	boolean	ON
DESCRIPTION: Forces NDB to use a count of records during SELECT COUNT(*) query planning to speed up this type of query.		

You can disable NDB transaction support by setting this variable's values to OFF (not recommended). The default is ON.

- ndb_version

Table 18.59 Type and value information for ndb_version

Command Line	System Variable	Status Variable
Option File	Scope	Dynamic
From Version	Type	Default, Range
Notes		
ndb_version		
No	Yes	No
No	Global	No
NDB 7.2	string	
DESCRIPTION: Shows build and NDB engine version as an integer.		

NDB engine version, as a composite integer.

- ndb_version_string

Table 18.60 Type and value information for ndb_version_string

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndb_version_string		
No	Yes	No
No	Global	No
NDB 7.2	string	
DESCRIPTION: Shows build information including NDB engine version in ndb-x.y.z format.		

NDB engine version in ndb-*x.y.z* format.

- server_id_bits

Table 18.61 Type and value information for server_id_bits

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
server_id_bits		
Yes	Yes	No
Yes	Global	No
NDB 7.2	integer	32 / 7 - 32
DESCRIPTION: The effective value of server_id if the server was started with the --server-id-bits option set to a nondefault value.		

The effective value of server_id if the server was started with the --server-id-bits option set to a nondefault value.

If the value of server_id greater than or equal to 2 to the power of server_id_bits, mysqld refuses to start.

This system variable is supported only by NDB Cluster. server_id_bits is not supported by the standard MySQL Server.

- slave_allow_batching

Table 18.62 Type and value information for slave_allow_batching

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
slave_allow_batching		
Yes	Yes	No
Yes	Global	Yes

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
NDB 7.2	boolean	off
DESCRIPTION: Turns update batching on and off for a replication slave.		

Whether or not batched updates are enabled on NDB Cluster replication slaves.

This variable is available for `mysqld` only as supplied with NDB Cluster or built from the NDB Cluster sources. For more information, see Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”.

Setting this variable had no effect in NDB Cluster 7.2 prior to NDB 7.2.10. (Bug #15953730)

- `transaction_allow_batching`

Table 18.63 Type and value information for transaction_allow_batching

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`transaction_allow_batching`		
No	Yes	No
No	Session	Yes
NDB 7.2	boolean	FALSE
DESCRIPTION: Allows batching of statements within a transaction. Disable AUTOCOMMIT to use..		

When set to `1` or `ON`, this variable enables batching of statements within the same transaction. To use this variable, `autocommit` must first be disabled by setting it to `0` or `OFF`; otherwise, setting `transaction_allow_batching` has no effect.

It is safe to use this variable with transactions that performs writes only, as having it enabled can lead to reads from the “before” image. You should ensure that any pending transactions are committed (using an explicit `COMMIT` if desired) before issuing a `SELECT`.

Important

`transaction_allow_batching` should not be used whenever there is the possibility that the effects of a given statement depend on the outcome of a previous statement within the same transaction.

This variable is currently supported for NDB Cluster only.

Important

Due an issue in the NDB Cluster 7.2 codebase (Bug #64697) prior to General Availability, this variable is not available prior to NDB 7.2.6.

The system variables in the following list all relate to the `ndbinfo` information database.

- `ndbinfo_database`

Table 18.64 Type and value information for ndbinfo_database

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndbinfo_database		
No	Yes	No
No	Global	No
NDB 7.2	string	ndbinfo
DESCRIPTION: The name used for the NDB information database; read only.		

Shows the name used for the NDB information database; the default is ndbinfo. This is a read-only variable whose value is determined at compile time; you can set it by starting the server using --ndbinfo-database=*name*, which sets the value shown for this variable but does not actually change the name used for the NDB information database.

- ndbinfo_max_bytes

Table 18.65 Type and value information for ndbinfo_max_bytes

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndbinfo_max_bytes		
Yes	Yes	No
No	Both	Yes
NDB 7.2	integer	0 / -
DESCRIPTION: Used for debugging only.		

Used in testing and debugging only.

- ndbinfo_max_rows

Table 18.66 Type and value information for ndbinfo_max_rows

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndbinfo_max_rows		
Yes	Yes	No
No	Both	Yes
NDB 7.2	integer	10 / -
DESCRIPTION: Used for debugging only.		

Used in testing and debugging only.

- ndbinfo_offline

Table 18.67 Type and value information for ndbinfo_offline

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndbinfo_offline		
No	Yes	No
No	Global	Yes
NDB 7.2	boolean	OFF
DESCRIPTION: Put the ndbinfo database into offline mode, in which no rows are returned from tables or views.		

Place the ndbinfo database into offline mode, in which tables and views can be opened even when they do not actually exist, or when they exist but have different definitions in NDB. No rows are returned from such tables (or views).

- ndbinfo_show_hidden

Table 18.68 Type and value information for ndbinfo_show_hidden

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndbinfo_show_hidden		
Yes	Yes	No
No	Both	Yes
NDB 7.2	boolean	OFF
DESCRIPTION: Whether to show ndbinfo internal base tables in the mysql client. The default is OFF..		

Whether or not the ndbinfo database's underlying internal tables are shown in the mysql client. The default is OFF.

- ndbinfo_table_prefix

Table 18.69 Type and value information for ndbinfo_table_prefix

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
ndbinfo_table_prefix		
Yes	Yes	No
No	Both	Yes
NDB 7.2	string	ndb$

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
DESCRIPTION: The prefix to use for naming ndbinfo internal base tables.		

The prefix used in naming the ndbinfo database's base tables (normally hidden, unless exposed by setting `ndbinfo_show_hidden`). This is a read-only variable whose default value is `ndb$`. You can start the server with the `--ndbinfo-table-prefix` option, but this merely sets the variable and does not change the actual prefix used to name the hidden base tables; the prefix itself is determined at compile time.

- `ndbinfo_version`

  Table 18.70 Type and value information for ndbinfo_version

Command Line	System Variable	Status Variable
Option File	**Scope**	**Dynamic**
From Version	**Type**	**Default, Range**
Notes		
`ndbinfo_version`		
No	Yes	No
No	Global	No
NDB 7.2	string	
DESCRIPTION: The version of the ndbinfo engine; read only.		

  Shows the version of the `ndbinfo` engine in use; read-only.

NDB Cluster Status Variables

This section provides detailed information about MySQL server status variables that relate to NDB Cluster and the `NDB` storage engine. For status variables not specific to NDB Cluster, and for general information on using status variables, see Section 5.1.7, “Server Status Variables”.

- `Handler_discover`

  The MySQL server can ask the `NDBCLUSTER` storage engine if it knows about a table with a given name. This is called discovery. `Handler_discover` indicates the number of times that tables have been discovered using this mechanism.

- `Ndb_api_bytes_sent_count_session`

  Amount of data (in bytes) sent to the data nodes in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_bytes_sent_count_slave`

  Amount of data (in bytes) sent to the data nodes by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_bytes_sent_count`

  Amount of data (in bytes) sent to the data nodes by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_bytes_received_count_session`

  Amount of data (in bytes) received from the data nodes in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_bytes_received_count_slave`

  Amount of data (in bytes) received from the data nodes by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_bytes_received_count`

  Amount of data (in bytes) received from the data nodes by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_event_data_count_injector`

  The number of row change events received by the NDB binlog injector thread.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_event_data_count`

  The number of row change events received by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_event_nondata_count_injector`

  The number of events received, other than row change events, by the NDB binary log injector thread.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_event_nondata_count`

  The number of events received, other than row change events, by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_event_bytes_count_injector`

  The number of bytes of events received by the NDB binlog injector thread.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_event_bytes_count`

  The number of bytes of events received by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_pk_op_count_session`

  The number of operations in this client session based on or using primary keys. This includes operations on blob tables, implicit unlock operations, and auto-increment operations, as well as user-visible primary key operations.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_pk_op_count_slave`

  The number of operations by this slave based on or using primary keys. This includes operations on blob tables, implicit unlock operations, and auto-increment operations, as well as user-visible primary key operations.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_pk_op_count`

  The number of operations by this MySQL Server (SQL node) based on or using primary keys. This includes operations on blob tables, implicit unlock operations, and auto-increment operations, as well as user-visible primary key operations.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_pruned_scan_count_session`

  The number of scans in this client session that have been pruned to a single partition.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_pruned_scan_count_slave`

  The number of scans by this slave that have been pruned to a single partition.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_pruned_scan_count`

  The number of scans by this MySQL Server (SQL node) that have been pruned to a single partition.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_range_scan_count_session`

  The number of range scans that have been started in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_range_scan_count_slave`

  The number of range scans that have been started by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_range_scan_count`

  The number of range scans that have been started by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_read_row_count_session`

The total number of rows that have been read in this client session. This includes all rows read by any primary key, unique key, or scan operation made in this client session.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_read_row_count_slave`

  The total number of rows that have been read by this slave. This includes all rows read by any primary key, unique key, or scan operation made by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_read_row_count`

  The total number of rows that have been read by this MySQL Server (SQL node). This includes all rows read by any primary key, unique key, or scan operation made by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_scan_batch_count_session`

  The number of batches of rows received in this client session. 1 batch is defined as 1 set of scan results from a single fragment.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_scan_batch_count_slave`

  The number of batches of rows received by this slave. 1 batch is defined as 1 set of scan results from a single fragment.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_scan_batch_count`

  The number of batches of rows received by this MySQL Server (SQL node). 1 batch is defined as 1 set of scan results from a single fragment.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_table_scan_count_session`

The number of table scans that have been started in this client session, including scans of internal tables,.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_table_scan_count_slave`

  The number of table scans that have been started by this slave, including scans of internal tables,.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_table_scan_count`

  The number of table scans that have been started by this MySQL Server (SQL node), including scans of internal tables,.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_abort_count_session`

  The number of transactions aborted in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_abort_count_slave`

  The number of transactions aborted by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_abort_count`

  The number of transactions aborted by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_close_count_session`

  The number of transactions closed in this client session. This value may be greater than the sum of `Ndb_api_trans_commit_count_session` and `Ndb_api_trans_abort_count_session`, since some transactions may have been rolled back.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_close_count_slave`

  The number of transactions closed by this slave. This value may be greater than the sum of `Ndb_api_trans_commit_count_slave` and `Ndb_api_trans_abort_count_slave`, since some transactions may have been rolled back.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_close_count`

  The number of transactions closed by this MySQL Server (SQL node). This value may be greater than the sum of `Ndb_api_trans_commit_count` and `Ndb_api_trans_abort_count`, since some transactions may have been rolled back.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_commit_count_session`

  The number of transactions committed in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_commit_count_slave`

  The number of transactions committed by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_commit_count`

  The number of transactions committed by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_local_read_row_count_session`

  The total number of rows that have been read in this client session. This includes all rows read by any primary key, unique key, or scan operation made in this client session.

Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_local_read_row_count_slave`

  The total number of rows that have been read by this slave. This includes all rows read by any primary key, unique key, or scan operation made by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_local_read_row_count`

  The total number of rows that have been read by this MySQL Server (SQL node). This includes all rows read by any primary key, unique key, or scan operation made by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_start_count_session`

  The number of transactions started in this client session.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_start_count_slave`

  The number of transactions started by this slave.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_trans_start_count`

  The number of transactions started by this MySQL Server (SQL node).

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_uk_op_count_session`

  The number of operations in this client session based on or using unique keys.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_uk_op_count_slave`

  The number of operations by this slave based on or using unique keys.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_uk_op_count`

  The number of operations by this MySQL Server (SQL node) based on or using unique keys.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_exec_complete_count_session`

  The number of times a thread has been blocked in this client session while waiting for execution of an operation to complete. This includes all `execute()` calls as well as implicit implicit executes for blob and auto-increment operations not visible to clients.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_exec_complete_count_slave`

  The number of times a thread has been blocked by this slave while waiting for execution of an operation to complete. This includes all `execute()` calls as well as implicit implicit executes for blob and auto-increment operations not visible to clients.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_exec_complete_count`

  The number of times a thread has been blocked by this MySQL Server (SQL node) while waiting for execution of an operation to complete. This includes all `execute()` calls as well as implicit implicit executes for blob and auto-increment operations not visible to clients.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_meta_request_count_session`

  The number of times a thread has been blocked in this client session waiting for a metadata-based signal, such as is expected for DDL requests, new epochs, and seizure of transaction records.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_meta_request_count_slave`

  The number of times a thread has been blocked by this slave waiting for a metadata-based signal, such as is expected for DDL requests, new epochs, and seizure of transaction records.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_meta_request_count`

  The number of times a thread has been blocked by this MySQL Server (SQL node) waiting for a metadata-based signal, such as is expected for DDL requests, new epochs, and seizure of transaction records.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_nanos_count_session`

  Total time (in nanoseconds) spent in this client session waiting for any type of signal from the data nodes.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_nanos_count_slave`

  Total time (in nanoseconds) spent by this slave waiting for any type of signal from the data nodes.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_nanos_count`

  Total time (in nanoseconds) spent by this MySQL Server (SQL node) waiting for any type of signal from the data nodes.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_scan_result_count_session`

  The number of times a thread has been blocked in this client session while waiting for a scan-based signal, such as when waiting for more results from a scan, or when waiting for a scan to close.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it relates to the current session only, and is not affected by any other clients of this `mysqld`.

For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_scan_result_count_slave`

  The number of times a thread has been blocked by this slave while waiting for a scan-based signal, such as when waiting for more results from a scan, or when waiting for a scan to close.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope. If this MySQL server does not act as a replication slave, or does not use NDB tables, this value is always 0.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_api_wait_scan_result_count`

  The number of times a thread has been blocked by this MySQL Server (SQL node) while waiting for a scan-based signal, such as when waiting for more results from a scan, or when waiting for a scan to close.

  Although this variable can be read using either `SHOW GLOBAL STATUS` or `SHOW SESSION STATUS`, it is effectively global in scope.

  For more information, see Section 18.5.15, “NDB API Statistics Counters and Variables”.

- `Ndb_cluster_node_id`

  If the server is acting as an NDB Cluster node, then the value of this variable its node ID in the cluster.

  If the server is not part of an NDB Cluster, then the value of this variable is 0.

- `Ndb_config_from_host`

  If the server is part of an NDB Cluster, the value of this variable is the host name or IP address of the Cluster management server from which it gets its configuration data.

  If the server is not part of an NDB Cluster, then the value of this variable is an empty string.

- `Ndb_config_from_port`

  If the server is part of an NDB Cluster, the value of this variable is the number of the port through which it is connected to the Cluster management server from which it gets its configuration data.

  If the server is not part of an NDB Cluster, then the value of this variable is 0.

- `Ndb_conflict_fn_max`

  Used in NDB Cluster Replication conflict resolution, this variable shows the number of times that a row was not applied on the current SQL node due to “greatest timestamp wins” conflict resolution since the last time that this `mysqld` was started.

  For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `Ndb_conflict_fn_old`

  Used in NDB Cluster Replication conflict resolution, this variable shows the number of times that a row was not applied as the result of “same timestamp wins” conflict resolution on a given `mysqld` since the last time it was restarted.

  For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `Ndb_conflict_fn_epoch`

Used in NDB Cluster Replication conflict resolution, this variable shows the number of rows found to be in conflict using `NDB$EPOCH()` conflict resolution on a given `mysqld` since the last time it was restarted.

For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `Ndb_conflict_fn_epoch_trans`

  Used in NDB Cluster Replication conflict resolution, this variable shows the number of rows found to be in conflict using `NDB$EPOCH_TRANS()` conflict resolution on a given `mysqld` since the last time it was restarted.

  For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `Ndb_conflict_trans_row_conflict_count`

  Used in NDB Cluster Replication conflict resolution, this status variable shows the number of rows found to be directly in-conflict by a transactional conflict function on a given `mysqld` since the last time it was restarted.

  Currently, the only transactional conflict detection function supported by NDB Cluster is NDB$EPOCH_TRANS(), so this status variable is effectively the same as `Ndb_conflict_fn_epoch_trans`.

  For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `Ndb_conflict_trans_row_reject_count`

  Used in NDB Cluster Replication conflict resolution, this status variable shows the total number of rows realigned due to being determined as conflicting by a transactional conflict detection function. This includes not only `Ndb_conflict_trans_row_conflict_count`, but any rows in or dependent on conflicting transactions.

  For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `Ndb_conflict_trans_reject_count`

  Used in NDB Cluster Replication conflict resolution, this status variable shows the number of transactions found to be in conflict by a transactional conflict detection function.

  For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `Ndb_conflict_trans_detect_iter_count`

  Used in NDB Cluster Replication conflict resolution, this shows the number of internal iterations required to commit an epoch transaction. Should be (slightly) greater than or equal to `Ndb_conflict_trans_conflict_commit_count`.

  For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `Ndb_conflict_trans_conflict_commit_count`

  Used in NDB Cluster Replication conflict resolution, this shows the number of epoch transactions committed after they required transactional conflict handling.

  For more information, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

- `Ndb_execute_count`

  Provides the number of round trips to the `NDB` kernel made by operations.

- `Ndb_number_of_data_nodes`

If the server is part of an NDB Cluster, the value of this variable is the number of data nodes in the cluster.

If the server is not part of an NDB Cluster, then the value of this variable is 0.

- `Ndb_pushed_queries_defined`

  The total number of joins pushed down to the NDB kernel for distributed handling on the data nodes. Note that joins tested using `EXPLAIN` that can be pushed down contribute to this number. Added in NDB 7.2.0.

- `Ndb_pushed_queries_dropped`

  The number of joins that were pushed down to the NDB kernel but that could not be handled there. Added in NDB 7.2.0.

- `Ndb_pushed_queries_executed`

  The number of joins successfully pushed down to `NDB` and executed there. Added in NDB 7.2.0.

- `Ndb_pushed_reads`

  The number of rows returned to `mysqld` from the NDB kernel by joins that were pushed down. Note that executing `EXPLAIN` on joins that can be pushed down to `NDB` does not add to this number. Added in NDB 7.2.0.

- `Ndb_pruned_scan_count`

  This variable holds a count of the number of scans executed by `NDBCLUSTER` since the NDB Cluster was last started where `NDBCLUSTER` was able to use partition pruning.

  Using this variable together with `Ndb_scan_count` can be helpful in schema design to maximize the ability of the server to prune scans to a single table partition, thereby involving only a single data node.

- `Ndb_scan_count`

  This variable holds a count of the total number of scans executed by `NDBCLUSTER` since the NDB Cluster was last started.

18.3.3.9 NDB Cluster TCP/IP Connections

TCP/IP is the default transport mechanism for all connections between nodes in an NDB Cluster. Normally it is not necessary to define TCP/IP connections; NDB Cluster automatically sets up such connections for all data nodes, management nodes, and SQL or API nodes.

Note

For an exception to this rule, see Section 18.3.3.10, “NDB Cluster TCP/IP Connections Using Direct Connections”.

To override the default connection parameters, it is necessary to define a connection using one or more `[tcp]` sections in the `config.ini` file. Each `[tcp]` section explicitly defines a TCP/IP connection between two NDB Cluster nodes, and must contain at a minimum the parameters `NodeId1` and `NodeId2`, as well as any connection parameters to override.

It is also possible to change the default values for these parameters by setting them in the `[tcp default]` section.

Important

Any `[tcp]` sections in the `config.ini` file should be listed *last*, following all other sections in the file. However, this is not required for a `[tcp default]` section. This requirement is a known issue with the way in which the `config.ini` file is read by the NDB Cluster management server.

Connection parameters which can be set in `[tcp]` and `[tcp default]` sections of the `config.ini` file are listed here:

- `NodeId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide their node IDs in the `[tcp]` section of the configuration file as the values of `NodeId1` and `NodeId2`. These are the same unique `Id` values for each of these nodes as described in Section 18.3.3.7, "Defining SQL and Other API Nodes in an NDB Cluster".

- `NodeId2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide their node IDs in the `[tcp]` section of the configuration file as the values of `NodeId1` and `NodeId2`. These are the same unique `Id` values for each of these nodes as described in Section 18.3.3.7, "Defining SQL and Other API Nodes in an NDB Cluster".

- `HostName1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given TCP connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `HostName2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given TCP connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `OverloadLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	0	0 - 4294967039 (0xFFFFFEFF)	N

When more than this many unsent bytes are in the send buffer, the connection is considered overloaded.

This parameter can be used to determine the amount of unsent data that must be present in the send buffer before the connection is considered overloaded. See Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”, and Section 18.5.10.19, “The ndbinfo transporters Table”, for more information.

In some older releases, the effective value of this parameter was limited by the size of `SendBufferMemory`; in NDB Cluster 7.2, the actual value for `OverloadLimit` (up to the stated maximum of 4G) is used instead.

- `SendBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	2M	256K - 4294967039 (0xFFFFFEFF)	N

TCP transporters use a buffer to store all messages before performing the send call to the operating system. When this buffer reaches 64KB its contents are sent; these are also sent when a round of messages have been executed. To handle temporary overload situations it is also possible to define a bigger send buffer.

If this parameter is set explicitly, then the memory is not dedicated to each transporter; instead, the value used denotes the hard limit for how much memory (out of the total available memory —that is, `TotalSendBufferMemory`) that may be used by a single transporter. For more information about configuring dynamic transporter send buffer memory allocation in NDB Cluster, see Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

The default size of the send buffer in NDB Cluster 7.2 is 2MB, which is the size recommended in most situations. The minimum size is 64 KB; the theoretical maximum is 4 GB.

- `SendSignalId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	[see text]	true, false	N

To be able to retrace a distributed message datagram, it is necessary to identify each message. When this parameter is set to `Y`, message IDs are transported over the network. This feature is disabled by default in production builds, and enabled in `-debug` builds.

- `Checksum`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

This parameter is a boolean parameter (enabled by setting it to `Y` or `1`, disabled by setting it to `N` or `0`). It is disabled by default. When it is enabled, checksums for all messages are calculated before they placed in the send buffer. This feature ensures that messages are not corrupted while waiting in the send buffer, or by the transport mechanism.

- `PortNumber` (*OBSOLETE*)

This formerly specified the port number to be used for listening for connections from other nodes. This parameter is deprecated and should no longer be used; use the `ServerPort` data node configuration parameter for this purpose instead.

- `ReceiveBufferMemory`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	2M	16K - 4294967039 (0xFFFFFEFF)	N

Specifies the size of the buffer used when receiving data from the TCP/IP socket.

The default value of this parameter is 2MB. The minimum possible value is 16KB; the theoretical maximum is 4GB.

- `TCP_RCV_BUF_SIZE`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	70080	1 - 2G	N

Determines the size of the receive buffer set during TCP transporter initialization. The default is recommended for most common usage cases.

- `TCP_SND_BUF_SIZE`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	71540	1 - 2G	N

Determines the size of the send buffer set during TCP transporter initialization. The default is recommended for most common usage cases.

- `TCP_MAXSEG_SIZE`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	0	0 - 2G	N

Determines the size of the memory set during TCP transporter initialization. The default is recommended for most common usage cases.

- `TcpBind_INADDR_ANY`

  Setting this parameter to `TRUE` or `1` binds `IP_ADDR_ANY` so that connections can be made from anywhere (for autogenerated connections). The default is `FALSE` (`0`).

- `Group`

  When `ndb_optimized_node_selection` is enabled, node proximity is used in some cases to select which node to connect to. This parameter can be used to influence proximity by setting it to a lower value, which is interpreted as “closer”. See the description of the system variable for more information.

18.3.3.10 NDB Cluster TCP/IP Connections Using Direct Connections

Setting up a cluster using direct connections between data nodes requires specifying explicitly the crossover IP addresses of the data nodes so connected in the `[tcp]` section of the cluster `config.ini` file.

In the following example, we envision a cluster with at least four hosts, one each for a management server, an SQL node, and two data nodes. The cluster as a whole resides on the `172.23.72.*` subnet of a LAN. In addition to the usual network connections, the two data nodes are connected directly using a standard crossover cable, and communicate with one another directly using IP addresses in the `1.1.0.*` address range as shown:

```
# Management Server
```

```
[ndb_mgmd]
Id=1
HostName=172.23.72.20

# SQL Node
[mysqld]
Id=2
HostName=172.23.72.21

# Data Nodes
[ndbd]
Id=3
HostName=172.23.72.22

[ndbd]
Id=4
HostName=172.23.72.23

# TCP/IP Connections
[tcp]
NodeId1=3
NodeId2=4
HostName1=1.1.0.1
HostName2=1.1.0.2
```

The `HostName1` and `HostName2` parameters are used only when specifying direct connections.

The use of direct TCP connections between data nodes can improve the cluster's overall efficiency by enabling the data nodes to bypass an Ethernet device such as a switch, hub, or router, thus cutting down on the cluster's latency. It is important to note that to take the best advantage of direct connections in this fashion with more than two data nodes, you must have a direct connection between each data node and every other data node in the same node group.

18.3.3.11 NDB Cluster Shared-Memory Connections

NDB Cluster attempts to use the shared memory transporter and configure it automatically where possible. `[shm]` sections in the `config.ini` file explicitly define shared-memory connections between nodes in the cluster. When explicitly defining shared memory as the connection method, it is necessary to define at least `NodeId1`, `NodeId2`, and `ShmKey`. All other parameters have default values that should work well in most cases.

Important

SHM functionality is considered experimental only. It is not officially supported in any current NDB Cluster release, and testing results indicate that SHM performance is not appreciably greater than when using TCP/IP for the transporter.

For these reasons, you must determine for yourself or by using our free resources (forums, mailing lists) whether SHM can be made to work correctly in your specific case.

- `NodeId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as `NodeId1` and `NodeId2`.

- `NodeId2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as `NodeId1` and `NodeId2`.

- `HostName1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given SHM connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `HostName2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given SHM connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `OverloadLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	0	0 - 4294967039 (0xFFFFFEFF)	N

When more than this many unsent bytes are in the send buffer, the connection is considered overloaded.

This parameter can be used to determine the amount of unsent data that must be present in the send buffer before the connection is considered overloaded. See Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”, for more information.

In some older releases, the effective value of this parameter was limited by the size of `SendBufferMemory`; in NDB Cluster 7.2, the actual value for `OverloadLimit` (up to the stated maximum of 4G) is used instead.

- `ShmKey`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	0 - 4294967039 (0xFFFFFEFF)	N

When setting up shared memory segments, a node ID, expressed as an integer, is used to identify uniquely the shared memory segment to use for the communication. There is no default value.

- `ShmSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	1M	64K - 4294967039 (0xFFFFFEFF)	N

Each SHM connection has a shared memory segment where messages between nodes are placed by the sender and read by the reader. The size of this segment is defined by `ShmSize`. The default value is 1MB.

- `SendSignalId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

To retrace the path of a distributed message, it is necessary to provide each message with a unique identifier. Setting this parameter to `Y` causes these message IDs to be transported over the network as well. This feature is disabled by default in production builds, and enabled in `-debug` builds.

- `Checksum`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	true	true, false	N

This parameter is a boolean (`Y`/`N`) parameter which is disabled by default. When it is enabled, checksums for all messages are calculated before being placed in the send buffer.

This feature prevents messages from being corrupted while waiting in the send buffer. It also serves as a check against data being corrupted during transport.

- `SigNum`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	0 - 4294967039 (0xFFFFFEFF)	N

When using the shared memory transporter, a process sends an operating system signal to the other process when there is new data available in the shared memory. Should that signal conflict with an existing signal, this parameter can be used to change it. This is a possibility when using SHM due to the fact that different operating systems use different signal numbers.

The default value of `SigNum` is 0; therefore, it must be set to avoid errors in the cluster log when using the shared memory transporter. Typically, this parameter is set to 10 in the `[shm default]` section of the `config.ini` file.

18.3.3.12 SCI Transport Connections in NDB Cluster

`[sci]` sections in the `config.ini` file explicitly define SCI (Scalable Coherent Interface) connections between cluster nodes. Using SCI transporters in NDB Cluster requires specialized hardware as well as specially-built MySQL binaries; compiling such binaries is not supported using an NDB 7.2 or later distribution.

The following parameters are present in `NDB` source code as well as the output of `ndb_config` and other `NDB` programs, but are nonfunctional in NDB 7.2 and later.

- `NodeId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as `NodeId1` and `NodeId2`.

- `NodeId2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	numeric	[none]	...	N

To identify a connection between two nodes it is necessary to provide node identifiers for each of them, as `NodeId1` and `NodeId2`.

- `Host1SciId0`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	0 - 4294967039 (0xFFFFFEFF)	N

This identifies the SCI node ID on the first Cluster node (identified by `NodeId1`).

- `Host1SciId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

It is possible to set up SCI Transporters for failover between two SCI cards which then should use separate networks between the nodes. This identifies the node ID and the second SCI card to be used on the first node.

- `Host2SciId0`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	[none]	0 - 4294967039 (0xFFFFFEFF)	N

This identifies the SCI node ID on the second Cluster node (identified by `NodeId2`).

- `Host2SciId1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	0	0 - 4294967039 (0xFFFFFEFF)	N

When using two SCI cards to provide failover, this parameter identifies the second SCI card to be used on the second node.

- `HostName1`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given SCI connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `HostName2`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	name or IP address	[none]	...	N

The `HostName1` and `HostName2` parameters can be used to specify specific network interfaces to be used for a given SCI connection between two nodes. The values used for these parameters can be host names or IP addresses.

- `SharedBufferSize`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	10M	64K - 4294967039 (0xFFFFFEFF)	N

Each SCI transporter has a shared memory segment used for communication between the two nodes. Setting the size of this segment to the default value of 1MB should be sufficient for most applications. Using a smaller value can lead to problems when performing many parallel inserts; if the shared buffer is too small, this can also result in a crash of the `ndbd` process.

- `SendLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	unsigned	8K	128 - 32K	N

A small buffer in front of the SCI media stores messages before transmitting them over the SCI network. By default, this is set to 8KB. Our benchmarks show that performance is best at 64KB but 16KB reaches within a few percent of this, and there was little if any advantage to increasing it beyond 8KB.

- `SendSignalId`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	true	true, false	N

To trace a distributed message it is necessary to identify each message uniquely. When this parameter is set to `Y`, message IDs are transported over the network. This feature is disabled by default in production builds, and enabled in `-debug` builds.

- `Checksum`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	boolean	false	true, false	N

This parameter is a boolean value, and is disabled by default. When `Checksum` is enabled, checksums are calculated for all messages before they are placed in the send buffer. This feature prevents messages from being corrupted while waiting in the send buffer. It also serves as a check against data being corrupted during transport.

- `OverloadLimit`

Effective Version	Type/Units	Default	Range/Values	Restart Type
NDB 7.2.0	bytes	0	0 - 4294967039 (0xFFFFFEFF)	N

When more than this many unsent bytes are in the send buffer, the connection is considered overloaded. See Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”, for more information.

18.3.3.13 Configuring NDB Cluster Send Buffer Parameters

Formerly, the NDB kernel employed a send buffer whose size was fixed at 2MB for each node in the cluster, this buffer being allocated when the node started. Because the size of this buffer could not be changed after the cluster was started, it was necessary to make it large enough in advance to accommodate the maximum possible load on any transporter socket. However, this was an inefficient use of memory, since much of it often went unused, and could result in large amounts of resources being wasted when scaling up to many API nodes.

This problem was eventually solved (in NDB Cluster 7.0) by employing a unified send buffer whose memory is allocated dynamically from a pool shared by all transporters. This means that the size of the send buffer can be adjusted as necessary. Configuration of the unified send buffer can accomplished by setting the following parameters:

- **TotalSendBufferMemory.** This parameter can be set for all types of NDB Cluster nodes—that is, it can be set in the `[ndbd]`, `[mgm]`, and `[api]` (or `[mysql]`) sections of the `config.ini` file. It represents the total amount of memory (in bytes) to be allocated by each node for which it is set for use among all configured transporters. If set, its minimum is 256KB; the maximum is 4294967039.

  To be backward-compatible with existing configurations, this parameter takes as its default value the sum of the maximum send buffer sizes of all configured transporters, plus an additional 32KB (one page) per transporter. The maximum depends on the type of transporter, as shown in the following table:

Transporter	Maximum Send Buffer Size (bytes)
TCP	`SendBufferMemory` (default = 2M)
SCI	`SendLimit` (default = 8K) plus 16K
SHM	20K

  This enables existing configurations to function in close to the same way as they did with NDB Cluster 6.3 and earlier, with the same amount of memory and send buffer space available to each transporter. However, memory that is unused by one transporter is not available to other transporters.

- **OverloadLimit.** This parameter is used in the `config.ini` file `[tcp]` section, and denotes the amount of unsent data (in bytes) that must be present in the send buffer before the connection is considered overloaded. When such an overload condition occurs, transactions that affect the overloaded connection fail with NDB API Error 1218 (`Send Buffers overloaded in NDB kernel`) until the overload status passes. The default value is 0, in which case the effective overload limit is calculated as `SendBufferMemory * 0.8` for a given connection. The maximum value for this parameter is 4G.

- **SendBufferMemory.** This value denotes a hard limit for the amount of memory that may be used by a single transporter out of the entire pool specified by `TotalSendBufferMemory`. However, the sum of `SendBufferMemory` for all configured transporters may be greater than the `TotalSendBufferMemory` that is set for a given node. This is a way to save memory when many nodes are in use, as long as the maximum amount of memory is never required by all transporters at the same time.

- **ReservedSendBufferMemory.** This optional data node parameter, if set, gives an amount of memory (in bytes) that is reserved for connections between data nodes; this memory is not allocated to send buffers used for communications with management servers or API nodes. This provides a way to protect the cluster against misbehaving API nodes that use excess send memory and thus cause failures in communications internally in the NDB kernel. If set, its the minimum permitted value for this parameters is 256KB; the maximum is 4294967039.

You can use the `ndbinfo.transporters` table to monitor send buffer memory usage, and to detect slowdown and overload conditions that can adversely affect performance.

18.3.4 Using High-Speed Interconnects with NDB Cluster

Even before design of NDBCLUSTER began in 1996, it was evident that one of the major problems to be encountered in building parallel databases would be communication between the nodes in the network. For this reason, NDBCLUSTER was designed from the very beginning to permit the use of a number of different data transport mechanisms. In this Manual, we use the term *transporter* for these.

The NDB Cluster codebase provides for four different transporters:

- *TCP/IP using 100 Mbps or gigabit Ethernet*, as discussed in Section 18.3.3.9, “NDB Cluster TCP/IP Connections”.
- *Direct (machine-to-machine) TCP/IP*; although this transporter uses the same TCP/IP protocol as mentioned in the previous item, it requires setting up the hardware differently and is configured differently as well. For this reason, it is considered a separate transport mechanism for NDB Cluster. See Section 18.3.3.10, “NDB Cluster TCP/IP Connections Using Direct Connections”, for details.
- *Shared memory (SHM)*. For more information about SHM, see Section 18.3.3.11, “NDB Cluster Shared-Memory Connections”.

Note

SHM is considered experimental only, and is not officially supported.

- *Scalable Coherent Interface (SCI)*. For more information about SHM, see Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”.

Note

Using SCI transporters in NDB Cluster requires specialized hardware, software, and MySQL binaries not available using an NDB 7.2 or later distribution.

Most users today employ TCP/IP over Ethernet because it is ubiquitous. TCP/IP is also by far the best-tested transporter for use with NDB Cluster.

We are working to make sure that communication with the ndbd process is made in “chunks” that are as large as possible because this benefits all types of data transmission.

18.4 NDB Cluster Programs

Using and managing an NDB Cluster requires several specialized programs, which we describe in this chapter. We discuss the purposes of these programs in an NDB Cluster, how to use the programs, and what startup options are available for each of them.

These programs include the NDB Cluster data, management, and SQL node processes (ndbd, ndbmtd, ndb_mgmd, and mysqld) and the management client (ndb_mgm).

For information about using mysqld as an NDB Cluster process, see Section 18.5.4, “MySQL Server Usage for NDB Cluster”.

Other NDB utility, diagnostic, and example programs are included with the NDB Cluster distribution. These include ndb_restore, ndb_show_tables, and ndb_config. These programs are also covered in this section.

The final portion of this section contains tables of options that are common to all the various NDB Cluster programs.

18.4.1 ndbd — The NDB Cluster Data Node Daemon

ndbd is the process that is used to handle all the data in tables using the NDB Cluster storage engine. This is the process that empowers a data node to accomplish distributed transaction handling, node recovery, checkpointing to disk, online backup, and related tasks.

In an NDB Cluster, a set of ndbd processes cooperate in handling data. These processes can execute on the same computer (host) or on different computers. The correspondences between data nodes and Cluster hosts is completely configurable.

The following table includes command options specific to the NDB Cluster data node program ndbd. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndbd), see Section 18.4.27, "Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs".

Table 18.71 This table describes command-line options for the ndbd program

Format	Description	Added or Removed
--initial	Perform initial start of ndbd, including cleaning the file system. Consult the documentation before using this option	All MySQL 5.5 based releases
--nostart, -n	Don't start ndbd immediately; ndbd waits for command to start from ndb_mgmd	All MySQL 5.5 based releases
--daemon, -d	Start ndbd as daemon (default); override with --nodaemon	All MySQL 5.5 based releases
--nodaemon	Do not start ndbd as daemon; provided for testing purposes	All MySQL 5.5 based releases
--foreground	Run ndbd in foreground, provided for debugging purposes (implies --nodaemon)	All MySQL 5.5 based releases
--nowait-nodes=list	Do not wait for these data nodes to start (takes comma-separated list of node IDs). Also requires --ndb-nodeid to be used.	All MySQL 5.5 based releases
--initial-start	Perform partial initial start (requires --nowait-nodes)	All MySQL 5.5 based releases
--bind-address=name	Local bind address	All MySQL 5.5 based releases
--install[=name]	Used to install the data node process as a Windows service. Does not apply on non-Windows platforms.	All MySQL 5.5 based releases
--remove[=name]	Used to remove a data node process that was previously installed as a Windows service. Does not apply on non-Windows platforms.	All MySQL 5.5 based releases
--connect-retries=#	Set the number of times to retry a connection before giving up; 0 means 1 attempt only (and no retries)	ADDED: NDB 7.2.9
--connect-delay=#	Time to wait between attempts to contact a management server,	ADDED: NDB 7.2.9

Format	Description	Added or Removed
	in seconds; 0 means do not wait between attempts	

Note

All of these options also apply to the multi-threaded version of this program (ndbmtd) and you may substitute “ndbmtd” for “ndbd” wherever the latter occurs in this section.

- --bind-address

Command-Line Format	--bind-address=name	
Permitted Values	Type	string
	Default	

Causes ndbd to bind to a specific network interface (host name or IP address). This option has no default value.

- --daemon, -d

Command-Line Format	--daemon	
Permitted Values	Type	boolean
	Default	TRUE

Instructs ndbd or ndbmtd to execute as a daemon process. This is the default behavior. --nodaemon can be used to prevent the process from running as a daemon.

This option has no effect when running ndbd or ndbmtd on Windows platforms.

- --nodaemon

Command-Line Format	--nodaemon	
Permitted Values	Type	boolean
	Default	FALSE

Prevents ndbd or ndbmtd from executing as a daemon process. This option overrides the --daemon option. This is useful for redirecting output to the screen when debugging the binary.

The default behavior for ndbd and ndbmtd on Windows is to run in the foreground, making this option unnecessary on Windows platforms, where it has no effect.

- --foreground

Command-Line Format	--foreground	
Permitted Values	Type	boolean
	Default	FALSE

Causes ndbd or ndbmtd to execute as a foreground process, primarily for debugging purposes. This option implies the --nodaemon option.

This option has no effect when running ndbd or ndbmtd on Windows platforms.

- --initial

Command-Line Format	--initial

Permitted Values	Type	boolean
	Default	FALSE

Instructs ndbd to perform an initial start. An initial start erases any files created for recovery purposes by earlier instances of ndbd. It also re-creates recovery log files. On some operating systems, this process can take a substantial amount of time.

An --initial start is to be used *only* when starting the ndbd process under very special circumstances; this is because this option causes all files to be removed from the NDB Cluster file system and all redo log files to be re-created. These circumstances are listed here:

- When performing a software upgrade which has changed the contents of any files.
- When restarting the node with a new version of ndbd.
- As a measure of last resort when for some reason the node restart or system restart repeatedly fails. In this case, be aware that this node can no longer be used to restore data due to the destruction of the data files.

Warning

To avoid the possibility of eventual data loss, it is recommended that you *not* use the --initial option together with StopOnError = 0. Instead, set StopOnError to 0 in config.ini only after the cluster has been started, then restart the data nodes normally—that is, without the --initial option. See the description of the StopOnError parameter for a detailed explanation of this issue. (Bug #24945638)

Use of this option prevents the StartPartialTimeout and StartPartitionedTimeout configuration parameters from having any effect.

Important

This option does *not* affect either of the following types of files:

- Backup files that have already been created by the affected node
- NDB Cluster Disk Data files (see Section 18.5.12, “NDB Cluster Disk Data Tables”).

This option also has no effect on recovery of data by a data node that is just starting (or restarting) from data nodes that are already running. This recovery of data occurs automatically, and requires no user intervention in an NDB Cluster that is running normally.

It is permissible to use this option when starting the cluster for the very first time (that is, before any data node files have been created); however, it is *not* necessary to do so.

- --initial-start

Command-Line Format	--initial-start	
Permitted Values	Type	boolean
	Default	FALSE

This option is used when performing a partial initial start of the cluster. Each node should be started with this option, as well as --nowait-nodes.

Suppose that you have a 4-node cluster whose data nodes have the IDs 2, 3, 4, and 5, and you wish to perform a partial initial start using only nodes 2, 4, and 5—that is, omitting node 3:

```
shell> ndbd --ndb-nodeid=2 --nowait-nodes=3 --initial-start
shell> ndbd --ndb-nodeid=4 --nowait-nodes=3 --initial-start
shell> ndbd --ndb-nodeid=5 --nowait-nodes=3 --initial-start
```

When using this option, you must also specify the node ID for the data node being started with the `--ndb-nodeid` option.

Important

Do not confuse this option with the `--nowait-nodes` option for `ndb_mgmd`, which can be used to enable a cluster configured with multiple management servers to be started without all management servers being online.

- `--nowait-nodes=node_id_1[, node_id_2[, ...]]`

Command-Line Format	`--nowait-nodes=list`	
Permitted Values	Type	string
	Default	

This option takes a list of data nodes which for which the cluster will not wait for before starting.

This can be used to start the cluster in a partitioned state. For example, to start the cluster with only half of the data nodes (nodes 2, 3, 4, and 5) running in a 4-node cluster, you can start each `ndbd` process with `--nowait-nodes=3,5`. In this case, the cluster starts as soon as nodes 2 and 4 connect, and does *not* wait `StartPartitionedTimeout` milliseconds for nodes 3 and 5 to connect as it would otherwise.

If you wanted to start up the same cluster as in the previous example without one `ndbd` (say, for example, that the host machine for node 3 has suffered a hardware failure) then start nodes 2, 4, and 5 with `--nowait-nodes=3`. Then the cluster will start as soon as nodes 2, 4, and 5 connect and will not wait for node 3 to start.

- `--nostart`, `-n`

Command-Line Format	`--nostart`	
Permitted Values	Type	boolean
	Default	FALSE

Instructs `ndbd` not to start automatically. When this option is used, `ndbd` connects to the management server, obtains configuration data from it, and initializes communication objects. However, it does not actually start the execution engine until specifically requested to do so by the management server. This can be accomplished by issuing the proper `START` command in the management client (see Section 18.5.2, “Commands in the NDB Cluster Management Client”).

- `--install[=name]`

Command-Line Format	`--install[=name]`	
Platform Specific	Windows	
Permitted Values	Type	string
	Default	`ndbd`

Causes `ndbd` to be installed as a Windows service. Optionally, you can specify a name for the service; if not set, the service name defaults to `ndbd`. Although it is preferable to specify other `ndbd` program options in a `my.ini` or `my.cnf` configuration file, it is possible to use together with `--install`. However, in such cases, the `--install` option must be specified first, before any other options are given, for the Windows service installation to succeed.

It is generally not advisable to use this option together with the `--initial` option, since this causes the data node file system to be wiped and rebuilt every time the service is stopped and started. Extreme care should also be taken if you intend to use any of the other `ndbd` options that affect the starting of data nodes—including `--initial-start`, `--nostart`, and `--nowait-nodes`—together with `--install`, and you should make absolutely certain you fully understand and allow for any possible consequences of doing so.

The `--install` option has no effect on non-Windows platforms.

- `--remove[=name]`

Command-Line Format	`--remove[=name]`	
Platform Specific	Windows	
Permitted Values	**Type**	string
	Default	`ndbd`

Causes an `ndbd` process that was previously installed as a Windows service to be removed. Optionally, you can specify a name for the service to be uninstalled; if not set, the service name defaults to `ndbd`.

The `--remove` option has no effect on non-Windows platforms.

- `--connect-retries=#`

Introduced	5.5.28-ndb-7.2.9	
Command-Line Format	`--connect-retries=#`	
Permitted Values	**Type**	numeric
	Default	`12`
	Minimum	`0`
	Maximum	`65535`

Determines the number of times that the data node attempts to contact a management server when starting. Setting this option to -1 causes the data node to keep trying to make contact indefinitely. The default is 12 attempts. The time to wait between attempts is controlled by the `--connect-delay` option.

This option was added in NDB 7.2.9.

- `--connect-delay=#`

Introduced	5.5.28-ndb-7.2.9	
Command-Line Format	`--connect-delay=#`	
Permitted Values	**Type**	numeric
	Default	`5`
	Minimum	`0`
	Maximum	`3600`

Determines the time to wait between attempts to contact a management server when starting (the time between attempts is controlled by the `--connect-retries` option). The default is 5 attempts.

This option was added in NDB 7.2.9.

ndbd generates a set of log files which are placed in the directory specified by DataDir in the config.ini configuration file.

These log files are listed below. *node_id* is the node's unique identifier. Note that *node_id* represents the node's unique identifier. For example, ndb_2_error.log is the error log generated by the data node whose node ID is 2.

- ndb_*node_id*_error.log is a file containing records of all crashes which the referenced ndbd process has encountered. Each record in this file contains a brief error string and a reference to a trace file for this crash. A typical entry in this file might appear as shown here:

```
Date/Time: Saturday 30 July 2004 - 00:20:01
Type of error: error
Message: Internal program error (failed ndbrequire)
Fault ID: 2341
Problem data: DbtupFixAlloc.cpp
Object of reference: DBTUP (Line: 173)
ProgramName: NDB Kernel
ProcessID: 14909
TraceFile: ndb_2_trace.log.2
***EOM***
```

  Listings of possible ndbd exit codes and messages generated when a data node process shuts down prematurely can be found in Data Node Error Messages.

Important

The last entry in the error log file is not necessarily the newest one (nor is it likely to be). Entries in the error log are *not* listed in chronological order; rather, they correspond to the order of the trace files as determined in the ndb_*node_id*_trace.log.next file (see below). Error log entries are thus overwritten in a cyclical and not sequential fashion.

- ndb_*node_id*_trace.log.*trace_id* is a trace file describing exactly what happened just before the error occurred. This information is useful for analysis by the NDB Cluster development team.

  It is possible to configure the number of these trace files that will be created before old files are overwritten. *trace_id* is a number which is incremented for each successive trace file.

- ndb_*node_id*_trace.log.next is the file that keeps track of the next trace file number to be assigned.

- ndb_*node_id*_out.log is a file containing any data output by the ndbd process. This file is created only if ndbd is started as a daemon, which is the default behavior.

- ndb_*node_id*.pid is a file containing the process ID of the ndbd process when started as a daemon. It also functions as a lock file to avoid the starting of nodes with the same identifier.

- ndb_*node_id*_signal.log is a file used only in debug versions of ndbd, where it is possible to trace all incoming, outgoing, and internal messages with their data in the ndbd process.

It is recommended not to use a directory mounted through NFS because in some environments this can cause problems whereby the lock on the .pid file remains in effect even after the process has terminated.

To start ndbd, it may also be necessary to specify the host name of the management server and the port on which it is listening. Optionally, one may also specify the node ID that the process is to use.

```
shell> ndbd --connect-string="nodeid=2;host=ndb_mgmd.mysql.com:1186"
```

See Section 18.3.3.3, “NDB Cluster Connection Strings”, for additional information about this issue. Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster

Programs", describes other command-line options which can be used with ndbd. For information about data node configuration parameters, see Section 18.3.3.6, "Defining NDB Cluster Data Nodes".

When ndbd starts, it actually initiates two processes. The first of these is called the "angel process"; its only job is to discover when the execution process has been completed, and then to restart the ndbd process if it is configured to do so. Thus, if you attempt to kill ndbd using the Unix kill command, it is necessary to kill both processes, beginning with the angel process. The preferred method of terminating an ndbd process is to use the management client and stop the process from there.

The execution process uses one thread for reading, writing, and scanning data, as well as all other activities. This thread is implemented asynchronously so that it can easily handle thousands of concurrent actions. In addition, a watch-dog thread supervises the execution thread to make sure that it does not hang in an endless loop. A pool of threads handles file I/O, with each thread able to handle one open file. Threads can also be used for transporter connections by the transporters in the ndbd process. In a multi-processor system performing a large number of operations (including updates), the ndbd process can consume up to 2 CPUs if permitted to do so.

For a machine with many CPUs it is possible to use several ndbd processes which belong to different node groups; however, such a configuration is still considered experimental and is not supported for MySQL 5.5 in a production setting. See Section 18.1.6, "Known Limitations of NDB Cluster".

18.4.2 ndbinfo_select_all — Select From ndbinfo Tables

ndbinfo_select_all is a client program that selects all rows and columns from one or more tables in the ndbinfo database. It is included with the NDB Cluster distribution beginning with NDB 7.2.2.

Not all ndbinfo tables available in the mysql client can be read by this program. In addition, ndbinfo_select_all can show information about some tables internal to ndbinfo which cannot be accessed using SQL, including the tables and columns metadata tables.

To select from one or more ndbinfo tables using ndbinfo_select_all, it is necessary to supply the names of the tables when invoking the program as shown here:

```
shell> ndbinfo_select_all table_name1  [table_name2] [...]
```

For example:

```
shell> ndbinfo_select_all logbuffers logspaces
== logbuffers ==
node_id log_type        log_id  log_part        total   used    high
5       0       0       0       33554432        262144  0
6       0       0       0       33554432        262144  0
7       0       0       0       33554432        262144  0
8       0       0       0       33554432        262144  0
== logspaces ==
node_id log_type        log_id  log_part        total   used    high
5       0       0       0       268435456       0       0
5       0       0       1       268435456       0       0
5       0       0       2       268435456       0       0
5       0       0       3       268435456       0       0
6       0       0       0       268435456       0       0
6       0       0       1       268435456       0       0
6       0       0       2       268435456       0       0
6       0       0       3       268435456       0       0
7       0       0       0       268435456       0       0
7       0       0       1       268435456       0       0
7       0       0       2       268435456       0       0
7       0       0       3       268435456       0       0
8       0       0       0       268435456       0       0
8       0       0       1       268435456       0       0
8       0       0       2       268435456       0       0
8       0       0       3       268435456       0       0
```

```
shell>
```

The following table includes options that are specific to ndbinfo_select_all. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndbinfo_select_all), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.72 This table describes command-line options for the ndbinfo_select_all program

Format	Description	Added or Removed
--delay=#	Set the delay in seconds between loops. Default is 5.	All MySQL 5.5 based releases
--loops=#, -l	Set the number of times to perform the select. Default is 1.	All MySQL 5.5 based releases
--database=db_name, -d	Name of the database where the table located.	All MySQL 5.5 based releases
--parallelism=#, -p	Set the degree of parallelism.	All MySQL 5.5 based releases

- --delay=seconds

Command-Line Format	--delay=#	
Permitted Values	Type	numeric
	Default	5
	Minimum	0
	Maximum	MAX_INT

This option sets the number of seconds to wait between executing loops. Has no effect if --loops is set to 0 or 1.

- --loops=number, -l *number*

Command-Line Format	--loops=#	
Permitted Values	Type	numeric
	Default	1
	Minimum	0
	Maximum	MAX_INT

This option sets the number of times to execute the select. Use --delay to set the time between loops.

18.4.3 ndbmtd — The NDB Cluster Data Node Daemon (Multi-Threaded)

ndbmtd is a multi-threaded version of ndbd, the process that is used to handle all the data in tables using the NDBCLUSTER storage engine. ndbmtd is intended for use on host computers having multiple CPU cores. Except where otherwise noted, ndbmtd functions in the same way as ndbd; therefore, in this section, we concentrate on the ways in which ndbmtd differs from ndbd, and you should consult Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”, for additional information about running NDB Cluster data nodes that apply to both the single-threaded and multi-threaded versions of the data node process.

Command-line options and configuration parameters used with ndbd also apply to ndbmtd. For more information about these options and parameters, see Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”, and Section 18.3.3.6, “Defining NDB Cluster Data Nodes”, respectively.

ndbmtd is also file system-compatible with ndbd. In other words, a data node running ndbd can be stopped, the binary replaced with ndbmtd, and then restarted without any loss of data. (However, when doing this, you must make sure that MaxNoOfExecutionThreads is set to an apppriate value before restarting the node if you wish for ndbmtd to run in multi-threaded fashion.) Similarly, an ndbmtd binary can be replaced with ndbd simply by stopping the node and then starting ndbd in place of the multi-threaded binary. It is not necessary when switching between the two to start the data node binary using --initial.

Using ndbmtd differs from using ndbd in two key respects:

1. Because ndbmtd runs by default in single-threaded mode (that is, it behaves like ndbd), you must configure it to use multiple threads. This can be done by setting an appropriate value in the config.ini file for the MaxNoOfExecutionThreads configuration parameter or (in NDB 7.2.3 and later) the ThreadConfig configuration parameter. Using MaxNoOfExecutionThreads is simpler, but ThreadConfig offers more flexibility. For more information about these configuration parameters and their use, see Multi-Threading Configuration Parameters (ndbmtd).

2. Trace files are generated by critical errors in ndbmtd processes in a somewhat different fashion from how these are generated by ndbd failures. These differences are discussed in more detail in the next few paragraphs.

Like ndbd, ndbmtd generates a set of log files which are placed in the directory specified by DataDir in the config.ini configuration file. Except for trace files, these are generated in the same way and have the same names as those generated by ndbd.

In the event of a critical error, ndbmtd generates trace files describing what happened just prior to the error' occurrence. These files, which can be found in the data node's DataDir, are useful for analysis of problems by the NDB Cluster Development and Support teams. One trace file is generated for each ndbmtd thread. The names of these files have the following pattern:

```
ndb_node_id_trace.log.trace_id_tthread_id,
```

In this pattern, *node_id* stands for the data node's unique node ID in the cluster, *trace_id* is a trace sequence number, and *thread_id* is the thread ID. For example, in the event of the failure of an ndbmtd process running as an NDB Cluster data node having the node ID 3 and with MaxNoOfExecutionThreads equal to 4, four trace files are generated in the data node's data directory. If the is the first time this node has failed, then these files are named ndb_3_trace.log.1_t1, ndb_3_trace.log.1_t2, ndb_3_trace.log.1_t3, and ndb_3_trace.log.1_t4. Internally, these trace files follow the same format as ndbd trace files.

The ndbd exit codes and messages that are generated when a data node process shuts down prematurely are also used by ndbmtd. See Data Node Error Messages, for a listing of these.

Note

It is possible to use ndbd and ndbmtd concurrently on different data nodes in the same NDB Cluster. However, such configurations have not been tested extensively; thus, we cannot recommend doing so in a production setting at this time.

18.4.4 ndb_mgmd — The NDB Cluster Management Server Daemon

The management server is the process that reads the cluster configuration file and distributes this information to all nodes in the cluster that request it. It also maintains a log of cluster activities. Management clients can connect to the management server and check the cluster's status.

The following table includes options that are specific to the NDB Cluster management server program ndb_mgmd. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_mgmd), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.73 This table describes command-line options for the ndb_mgmd program

Format	Description	Added or Removed
--config-file=file, -f	Specify the cluster configuration file; in NDB-6.4.0 and later, needs --reload or --initial to override configuration cache if present	All MySQL 5.5 based releases
--configdir=directory, --config-dir=directory	Specify the cluster management server's configuration cache directory	All MySQL 5.5 based releases
--bind-address=host	Local bind address	All MySQL 5.5 based releases
--print-full-config, -P	Print full configuration and exit	All MySQL 5.5 based releases
--daemon, -d	Run ndb_mgmd in daemon mode (default)	All MySQL 5.5 based releases
--nodaemon	Do not run ndb_mgmd as a daemon	All MySQL 5.5 based releases
--interactive	Run ndb_mgmd in interactive mode (not officially supported in production; for testing purposes only)	All MySQL 5.5 based releases
--log-name=name	A name to use when writing messages applying to this node in the cluster log.	All MySQL 5.5 based releases
--no-nodeid-checks	Do not provide any node id checks	All MySQL 5.5 based releases
--mycnf	Read cluster configuration data from the my.cnf file	All MySQL 5.5 based releases
--reload	Causes the management server to compare the configuration file with its configuration cache	All MySQL 5.5 based releases
--initial	Causes the management server reload its configuration data from the configuration file, bypassing the configuration cache	All MySQL 5.5 based releases
--nowait-nodes=list	Do not wait for these management nodes when starting this management server. Also requires --ndb-nodeid to be used.	All MySQL 5.5 based releases
--config-cache[=TRUE|FALSE]	Enable the management server configuration cache; TRUE by default.	All MySQL 5.5 based releases
--install[=name]	Used to install the management server process as a Windows	All MySQL 5.5 based releases

Format	Description	Added or Removed
	service. Does not apply on non-Windows platforms.	
--remove[=name]	Used to remove a management server process that was previously installed as a Windows service, optionally specifying the name of the service to be removed. Does not apply on non-Windows platforms.	All MySQL 5.5 based releases

- `--bind-address=host`

Command-Line Format	--bind-address=host	
Permitted Values	Type	string
	Default	[none]

Causes the management server to bind to a specific network interface (host name or IP address). This option has no default value.

- `--no-nodeid-checks`

Command-Line Format	--no-nodeid-checks	
Permitted Values	Type	boolean
	Default	FALSE

Do not perform any checks of node IDs.

- `--configdir=dir_name`

Command-Line Format	--configdir=directory	
	--config-dir=directory	
Permitted Values	Type	file name
	Default	$INSTALLDIR/mysql-cluster

Specifies the cluster management server's configuration cache directory. `--config-dir` is an alias for this option.

- `--config-cache`

Command-Line Format	--config-cache[=TRUE|FALSE]	
Permitted Values	Type	boolean
	Default	TRUE

This option, whose default value is `1` (or `TRUE`, or `ON`), can be used to disable the management server's configuration cache, so that it reads its configuration from `config.ini` every time it starts (see Section 18.3.3, “NDB Cluster Configuration Files”). You can do this by starting the `ndb_mgmd` process with any one of the following options:

- `--config-cache=0`
- `--config-cache=FALSE`
- `--config-cache=OFF`

- `--skip-config-cache`

Using one of the options just listed is effective only if the management server has no stored configuration at the time it is started. If the management server finds any configuration cache files, then the `--config-cache` option or the `--skip-config-cache` option is ignored. Therefore, to disable configuration caching, the option should be used the *first* time that the management server is started. Otherwise—that is, if you wish to disable configuration caching for a management server that has *already* created a configuration cache—you must stop the management server, delete any existing configuration cache files manually, then restart the management server with `--skip-config-cache` (or with `--config-cache` set equal to 0, `OFF`, or `FALSE`).

Configuration cache files are normally created in a directory named `mysql-cluster` under the installation directory (unless this location has been overridden using the `--configdir` option). Each time the management server updates its configuration data, it writes a new cache file. The files are named sequentially in order of creation using the following format:

```
ndb_node-id_config.bin.seq-number
```

`node-id` is the management server's node ID; *`seq-number`* is a sequence number, beginning with 1. For example, if the management server's node ID is 5, then the first three configuration cache files would, when they are created, be named `ndb_5_config.bin.1`, `ndb_5_config.bin.2`, and `ndb_5_config.bin.3`.

If your intent is to purge or reload the configuration cache without actually disabling caching, you should start `ndb_mgmd` with one of the options `--reload` or `--initial` instead of `--skip-config-cache`.

To re-enable the configuration cache, simply restart the management server, but without the `--config-cache` or `--skip-config-cache` option that was used previously to disable the configuration cache.

Beginning with NDB 7.2.5, `ndb_mgmd` no longer checks for the configuration directory (`--configdir`) or attempts to create one when `--skip-config-cache` is used. (Bug #13428853)

- `--config-file=filename`, `-f filename`

Command-Line Format	`--config-file=file`	
Permitted Values	Type	file name
	Default	`[none]`

Instructs the management server as to which file it should use for its configuration file. By default, the management server looks for a file named `config.ini` in the same directory as the `ndb_mgmd` executable; otherwise the file name and location must be specified explicitly.

This option has no default value, and is ignored unless the management server is forced to read the configuration file, either because `ndb_mgmd` was started with the `--reload` or `--initial` option, or because the management server could not find any configuration cache. This option is also read if `ndb_mgmd` was started with `--config-cache=OFF`. See Section 18.3.3, “NDB Cluster Configuration Files”, for more information.

Formerly, using this option together with `--initial` caused removal of the configuration cache even if the file was not found. This issue was resolved in NDB 7.2.13. (Bug #1299289)

- `--mycnf`

Command-Line Format	`--mycnf`	
Permitted Values	Type	boolean

	Default	FALSE

Read configuration data from the my.cnf file.

- --daemon, -d

Command-Line Format	--daemon	
Permitted Values	**Type**	boolean
	Default	TRUE

Instructs ndb_mgmd to start as a daemon process. This is the default behavior.

This option has no effect when running ndb_mgmd on Windows platforms.

- --interactive

Command-Line Format	--interactive	
Permitted Values	**Type**	boolean
	Default	FALSE

Starts ndb_mgmd in interactive mode; that is, an ndb_mgm client session is started as soon as the management server is running. This option does not start any other NDB Cluster nodes.

- --initial

Command-Line Format	--initial	
Permitted Values	**Type**	boolean
	Default	FALSE

Configuration data is cached internally, rather than being read from the cluster global configuration file each time the management server is started (see Section 18.3.3, “NDB Cluster Configuration Files”). Using the --initial option overrides this behavior, by forcing the management server to delete any existing cache files, and then to re-read the configuration data from the cluster configuration file and to build a new cache.

This differs in two ways from the --reload option. First, --reload forces the server to check the configuration file against the cache and reload its data only if the contents of the file are different from the cache. Second, --reload does not delete any existing cache files.

If ndb_mgmd is invoked with --initial but cannot find a global configuration file, the management server cannot start.

When a management server starts, it checks for another management server in the same NDB Cluster and tries to use the other management server's configuration data; ndb_mgmd ignores --initial unless it is the only management server running. This behavior also has implications when performing a rolling restart of an NDB Cluster with multiple management nodes. See Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”, for more information.

Formerly, using this option together with the --config-file option caused removal of the configuration cache even if the file was not found. Starting with NDB 7.2.13, the cache is cleared in such cases only if the configuration file is actually found. (Bug #1299289)

- --log-name=*name*

Command-Line Format	--log-name=name	
Permitted Values	**Type**	string

	Default	MgmtSrvr

Provides a name to be used for this node in the cluster log.

- --nodaemon

Command-Line Format	--nodaemon	
Permitted Values	**Type**	boolean
	Default	FALSE

Instructs ndb_mgmd not to start as a daemon process.

The default behavior for ndb_mgmd on Windows is to run in the foreground, making this option unnecessary on Windows platforms.

- --print-full-config, -P

Command-Line Format	--print-full-config	
Permitted Values	**Type**	boolean
	Default	FALSE

Shows extended information regarding the configuration of the cluster. With this option on the command line the ndb_mgmd process prints information about the cluster setup including an extensive list of the cluster configuration sections as well as parameters and their values. Normally used together with the --config-file (-f) option.

- --reload

Command-Line Format	--reload	
Permitted Values	**Type**	boolean
	Default	FALSE

In NDB Cluster 7.2, configuration data is stored internally rather than being read from the cluster global configuration file each time the management server is started (see Section 18.3.3, “NDB Cluster Configuration Files”). Using this option forces the management server to check its internal data store against the cluster configuration file and to reload the configuration if it finds that the configuration file does not match the cache. Existing configuration cache files are preserved, but not used.

This differs in two ways from the --initial option. First, --initial causes all cache files to be deleted. Second, --initial forces the management server to re-read the global configuration file and construct a new cache.

If the management server cannot find a global configuration file, then the --reload option is ignored.

When a management server starts, it checks for another management server in the same NDB Cluster and tries to use the other management server's configuration data; ndb_mgmd ignores --reload unless it is the only management server running. This behavior also has implications when performing a rolling restart of an NDB Cluster with multiple management nodes. See Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”, for more information.

- --nowait-nodes

Command-Line Format	--nowait-nodes=list	
Permitted Values	**Type**	numeric

	Default	
	Minimum	1
	Maximum	255

When starting an NDB Cluster is configured with two management nodes, each management server normally checks to see whether the other ndb_mgmd is also operational and whether the other management server's configuration is identical to its own. However, it is sometimes desirable to start the cluster with only one management node (and perhaps to allow the other ndb_mgmd to be started later). This option causes the management node to bypass any checks for any other management nodes whose node IDs are passed to this option, permitting the cluster to start as though configured to use only the management node that was started.

For purposes of illustration, consider the following portion of a config.ini file (where we have omitted most of the configuration parameters that are not relevant to this example):

```
[ndbd]
NodeId = 1
HostName = 198.51.100.101

[ndbd]
NodeId = 2
HostName = 198.51.100.102

[ndbd]
NodeId = 3
HostName = 198.51.100.103

[ndbd]
NodeId = 4
HostName = 198.51.100.104

[ndb_mgmd]
NodeId = 10
HostName = 198.51.100.150

[ndb_mgmd]
NodeId = 11
HostName = 198.51.100.151

[api]
NodeId = 20
HostName = 198.51.100.200

[api]
NodeId = 21
HostName = 198.51.100.201
```

Assume that you wish to start this cluster using only the management server having node ID 10 and running on the host having the IP address 198.51.100.150. (Suppose, for example, that the host computer on which you intend to the other management server is temporarily unavailable due to a hardware failure, and you are waiting for it to be repaired.) To start the cluster in this way, use a command line on the machine at 198.51.100.150 to enter the following command:

```
shell> ndb_mgmd --ndb-nodeid=10 --nowait-nodes=11
```

As shown in the preceding example, when using --nowait-nodes, you must also use the --ndb-nodeid option to specify the node ID of this ndb_mgmd process.

You can then start each of the cluster's data nodes in the usual way. If you wish to start and use the second management server in addition to the first management server at a later time without restarting the data nodes, you must start each data node with a connection string that references both management servers, like this:

```
shell> ndbd -c 198.51.100.150,198.51.100.151
```

The same is true with regard to the connection string used with any mysqld processes that you wish to start as NDB Cluster SQL nodes connected to this cluster. See Section 18.3.3.3, “NDB Cluster Connection Strings”, for more information.

When used with ndb_mgmd, this option affects the behavior of the management node with regard to other management nodes only. Do not confuse it with the --nowait-nodes option used with ndbd or ndbmtd to permit a cluster to start with fewer than its full complement of data nodes; when used with data nodes, this option affects their behavior only with regard to other data nodes.

Multiple management node IDs may be passed to this option as a comma-separated list. Each node ID must be no less than 1 and no greater than 255. In practice, it is quite rare to use more than two management servers for the same NDB Cluster (or to have any need for doing so); in most cases you need to pass to this option only the single node ID for the one management server that you do not wish to use when starting the cluster.

Note

When you later start the “missing” management server, its configuration must match that of the management server that is already in use by the cluster. Otherwise, it fails the configuration check performed by the existing management server, and does not start.

It is not strictly necessary to specify a connection string when starting the management server. However, if you are using more than one management server, a connection string should be provided and each node in the cluster should specify its node ID explicitly.

See Section 18.3.3.3, “NDB Cluster Connection Strings”, for information about using connection strings. Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”, describes other options for ndb_mgmd.

The following files are created or used by ndb_mgmd in its starting directory, and are placed in the DataDir as specified in the config.ini configuration file. In the list that follows, *node_id* is the unique node identifier.

- config.ini is the configuration file for the cluster as a whole. This file is created by the user and read by the management server. Section 18.3, “Configuration of NDB Cluster”, discusses how to set up this file.
- ndb_*node_id*_cluster.log is the cluster events log file. Examples of such events include checkpoint startup and completion, node startup events, node failures, and levels of memory usage. A complete listing of cluster events with descriptions may be found in Section 18.5, “Management of NDB Cluster”.

  By default, when the size of the cluster log reaches one million bytes, the file is renamed to ndb_*node_id*_cluster.log.*seq_id*, where *seq_id* is the sequence number of the cluster log file. (For example: If files with the sequence numbers 1, 2, and 3 already exist, the next log file is named using the number 4.) You can change the size and number of files, and other characteristics of the cluster log, using the LogDestination configuration parameter.
- ndb_*node_id*_out.log is the file used for stdout and stderr when running the management server as a daemon.
- ndb_*node_id*.pid is the process ID file used when running the management server as a daemon.
- --install[=*name*]

Command-Line Format	--install[=name]

Platform Specific	Windows	
Permitted Values	Type	string
	Default	ndb_mgmd

Causes ndb_mgmd to be installed as a Windows service. Optionally, you can specify a name for the service; if not set, the service name defaults to ndb_mgmd. Although it is preferable to specify other ndb_mgmd program options in a my.ini or my.cnf configuration file, it is possible to use them together with --install. However, in such cases, the --install option must be specified first, before any other options are given, for the Windows service installation to succeed.

It is generally not advisable to use this option together with the --initial option, since this causes the configuration cache to be wiped and rebuilt every time the service is stopped and started. Care should also be taken if you intend to use any other ndb_mgmd options that affect the starting of the management server, and you should make absolutely certain you fully understand and allow for any possible consequences of doing so.

The --install option has no effect on non-Windows platforms.

- --remove[=*name*]

Command-Line Format	--remove[=name]	
Platform Specific	Windows	
Permitted Values	Type	string
	Default	ndb_mgmd

Causes an ndb_mgmd process that was previously installed as a Windows service to be removed. Optionally, you can specify a name for the service to be uninstalled; if not set, the service name defaults to ndb_mgmd.

The --remove option has no effect on non-Windows platforms.

18.4.5 ndb_mgm — The NDB Cluster Management Client

The ndb_mgm management client process is actually not needed to run the cluster. Its value lies in providing a set of commands for checking the cluster's status, starting backups, and performing other administrative functions. The management client accesses the management server using a C API. Advanced users can also employ this API for programming dedicated management processes to perform tasks similar to those performed by ndb_mgm.

To start the management client, it is necessary to supply the host name and port number of the management server:

```
shell> ndb_mgm [host_name [port_num]]
```

For example:

```
shell> ndb_mgm ndb_mgmd.mysql.com 1186
```

The default host name and port number are localhost and 1186, respectively.

The following table includes options that are specific to the NDB Cluster management client program ndb_mgm. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_mgm), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.74 This table describes command-line options for the ndb_mgm program

Format	Description	Added or Removed
--try-reconnect=#, -t	Set the number of times to retry a connection before giving up; synonym for --connect-retries	All MySQL 5.5 based releases
--execute=name, -e	Execute command and exit	All MySQL 5.5 based releases

- --execute=command, -e command

Command-Line Format	--execute=name

This option can be used to send a command to the NDB Cluster management client from the system shell. For example, either of the following is equivalent to executing SHOW in the management client:

```
shell> ndb_mgm -e "SHOW"

shell> ndb_mgm --execute="SHOW"
```

This is analogous to how the --execute or -e option works with the mysql command-line client. See Section 4.2.4, “Using Options on the Command Line”.

Note

If the management client command to be passed using this option contains any space characters, then the command *must* be enclosed in quotation marks. Either single or double quotation marks may be used. If the management client command contains no space characters, the quotation marks are optional.

- --try-reconnect=*number*

Command-Line Format	--try-reconnect=#	
Permitted Values	Type	integer
	Default	3
	Minimum	0
	Maximum	4294967295

If the connection to the management server is broken, the node tries to reconnect to it every 5 seconds until it succeeds. By using this option, it is possible to limit the number of attempts to *number* before giving up and reporting an error instead.

Additional information about using ndb_mgm can be found in Section 18.5.2, “Commands in the NDB Cluster Management Client”.

18.4.6 ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables

This tool can be used to check for and remove orphaned BLOB column parts from NDB tables, as well as to generate a file listing any orphaned parts. It is sometimes useful in diagnosing and repairing corrupted or damaged NDB tables containing BLOB or TEXT columns.

The basic syntax for ndb_blob_tool is shown here:

```
ndb_blob_tool [options] table [column, ...]
```

Unless you use the `--help` option, you must specify an action to be performed by including one or more of the options `--check-orphans`, `--delete-orphans`, or `--dump-file`. These options cause `ndb_blob_tool` to check for orphaned BLOB parts, remove any orphaned BLOB parts, and generate a dump file listing orphaned BLOB parts, respectively, and are described in more detail later in this section.

You must also specify the name of a table when invoking `ndb_blob_tool`. In addition, you can optionally follow the table name with the (comma-separated) names of one or more `BLOB` or `TEXT` columns from that table. If no columns are listed, the tool works on all of the table's `BLOB` and `TEXT` columns. If you need to specify a database, use the `--database` (`-d`) option.

The `--verbose` option provides additional information in the output about the tool's progress.

The following table includes options that are specific to `ndb_blob_tool`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_blob_tool`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.75 This table describes command-line options for the ndb_blob_tool program

Format	Description	Added or Removed
`--check-orphans`	Check for orphan blob parts	All MySQL 5.5 based releases
`--database=db_name`, `-d`	Database to find the table in.	All MySQL 5.5 based releases
`--delete-orphans`	Delete orphan blob parts	All MySQL 5.5 based releases
`--dump-file=file`	Write orphan keys to specified file	All MySQL 5.5 based releases
`--verbose`, `-v`	Verbose output	All MySQL 5.5 based releases

- `--check-orphans`

Command-Line Format	`--check-orphans`	
Permitted Values	Type	boolean
	Default	`FALSE`

Check for orphaned BLOB parts in NDB Cluster tables.

- `--database=db_name`, `-d`

Command-Line Format	`--database=db_name`	
Permitted Values	Type	string
	Default	`[none]`

Specify the database to find the table in.

- `--delete-orphans`

Command-Line Format	`--delete-orphans`	
Permitted Values	Type	boolean
	Default	`FALSE`

Remove orphaned BLOB parts from NDB Cluster tables.

- `--dump-file=file`

Command-Line Format	--dump-file=file	
Permitted Values	Type	file name
	Default	[none]

Writes a list of orphaned BLOB column parts to *file*. The information written to the file includes the table key and BLOB part number for each orphaned BLOB part.

- --verbose

Command-Line Format	--verbose	
Permitted Values	Type	boolean
	Default	FALSE

Provide extra information in the tool's output regarding its progress.

Example

First we create an NDB table in the test database, using the CREATE TABLE statement shown here:

```
USE test;

CREATE TABLE btest (
    c0 BIGINT UNSIGNED NOT NULL AUTO_INCREMENT PRIMARY KEY,
    c1 TEXT,
    c2 BLOB
)   ENGINE=NDB;
```

Then we insert a few rows into this table, using a series of statements similar to this one:

```
INSERT INTO btest VALUES (NULL, 'x', REPEAT('x', 1000));
```

When run with --check-orphans against this table, ndb_blob_tool generates the following output:

```
shell> ndb_blob_tool --check-orphans --verbose -d test btest
connected
processing 2 blobs
processing blob #0 c1 NDB$BLOB_19_1
NDB$BLOB_19_1: nextResult: res=1
total parts: 0
orphan parts: 0
processing blob #1 c2 NDB$BLOB_19_2
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=0
NDB$BLOB_19_2: nextResult: res=1
total parts: 10
orphan parts: 0
disconnected

NDBT_ProgramExit: 0 - OK
```

The tool reports that there are no NDB BLOB column parts associated with column c1, even though c1 is a TEXT column. This is due to the fact that, in an NDB table, only the first 256 bytes of a BLOB or TEXT column value are stored inline, and only the excess, if any, is stored separately; thus, if there are no values using more than 256 bytes in a given column of one of these types, no BLOB column parts

are created by NDB for this column. See Section 11.7, “Data Type Storage Requirements”, for more information.

18.4.7 ndb_config — Extract NDB Cluster Configuration Information

This tool extracts current configuration information for data nodes, SQL nodes, and API nodes from one of a number of sources: an NDB Cluster management node, or its config.ini or my.cnf file. By default, the management node is the source for the configuration data; to override the default, execute ndb_config with the --config-file or --mycnf option. It is also possible to use a data node as the source by specifying its node ID with --config_from_node=*node_id*.

ndb_config can also provide an offline dump of all configuration parameters which can be used, along with their default, maximum, and minimum values and other information. The dump can be produced in either text or XML format; for more information, see the discussion of the --configinfo and --xml options later in this section).

You can filter the results by section (DB, SYSTEM, or CONNECTIONS) using one of the options --nodes, --system, or --connections.

The following table includes options that are specific to ndb_config. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_config), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.76 This table describes command-line options for the ndb_config program

Format	Description	Added or Removed
--config-file=file_name	Set the path to config.ini file	All MySQL 5.5 based releases
--config_from_node=#	Obtain configuration data from the node having this ID (must be a data node).	All MySQL 5.5 based releases
--configinfo	Dumps information about all NDB configuration parameters in text format with default, maximum, and minimum values. Use with --xml to obtain XML output.	All MySQL 5.5 based releases
--connections	Print connections information ([tcp], [tcp default], [sci], [sci default], [shm], or [shm default] sections of cluster configuration file) only. Cannot be used with --system or --nodes.	All MySQL 5.5 based releases
--fields=string, -f	Field separator	All MySQL 5.5 based releases
--host=name	Specify host	All MySQL 5.5 based releases
--mycnf	Read configuration data from my.cnf file	All MySQL 5.5 based releases
--nodeid, --id	Get configuration of node with this ID	All MySQL 5.5 based releases
--nodes	Print node information ([ndbd] or [ndbd default] section of cluster configuration file) only. Cannot be used with --system or --connections.	All MySQL 5.5 based releases

Format	Description	Added or Removed
-c	Short form for --ndb-connectstring	All MySQL 5.5 based releases
--query=string, -q	One or more query options (attributes)	All MySQL 5.5 based releases
--query-all, -a	Dumps all parameters and values to a single comma-delimited string.	All MySQL 5.5 based releases
--rows=string, -r	Row separator	All MySQL 5.5 based releases
--system	Print SYSTEM section information only (see ndb_config --configinfo output). Cannot be used with --nodes or --connections.	All MySQL 5.5 based releases
--type=name	Specify node type	All MySQL 5.5 based releases
--configinfo --xml	Use --xml with --configinfo to obtain a dump of all NDB configuration parameters in XML format with default, maximum, and minimum values.	All MySQL 5.5 based releases

- --configinfo

  The --configinfo option causes ndb_config to dump a list of each NDB Cluster configuration parameter supported by the NDB Cluster distribution of which ndb_config is a part, including the following information:

  - A brief description of each parameter's purpose, effects, and usage
  - The section of the config.ini file where the parameter may be used
  - The parameter's data type or unit of measurement
  - Where applicable, the parameter's default, minimum, and maximum values
  - NDB Cluster release version and build information

  By default, this output is in text format. Part of this output is shown here:

```
shell> ndb_config --configinfo

****** SYSTEM ******

Name (String)
Name of system (NDB Cluster)
MANDATORY

PrimaryMGMNode (Non-negative Integer)
Node id of Primary ndb_mgmd(MGM) node
Default: 0 (Min: 0, Max: 4294967039)

ConfigGenerationNumber (Non-negative Integer)
Configuration generation number
Default: 0 (Min: 0, Max: 4294967039)

****** DB ******
```

```
MaxNoOfSubscriptions (Non-negative Integer)
Max no of subscriptions (default 0 == MaxNoOfTables)
Default: 0 (Min: 0, Max: 4294967039)

MaxNoOfSubscribers (Non-negative Integer)
Max no of subscribers (default 0 == 2 * MaxNoOfTables)
Default: 0 (Min: 0, Max: 4294967039)

…
```

Use this option together with the `--xml` option to obtain output in XML format.

- `--config-file=path-to-file`

Command-Line Format	`--config-file=file_name`	
Permitted Values	Type	file name
	Default	

Gives the path to the management server's configuration file (`config.ini`). This may be a relative or absolute path. If the management node resides on a different host from the one on which `ndb_config` is invoked, then an absolute path must be used.

- `--config_from_node=#`

Command-Line Format	`--config-from-node=#`	
Permitted Values	Type	numeric
	Default	`none`
	Minimum	`1`
	Maximum	`48`

Obtain the cluster's configuration data from the data node that has this ID.

If the node having this ID is not a data node, `ndb_config` fails with an error. (To obtain configuration data from the management node instead, simply omit this option.)

- `--connections`

Command-Line Format	`--connections`	
Permitted Values	Type	boolean
	Default	`FALSE`

Tells `ndb_config` to print `CONNECTIONS` information only—that is, information about parameters found in the `[tcp]`, `[tcp default]`, `[sci]`, `[sci default]`, `[shm]`, or `[shm default]` sections of the cluster configuration file (see Section 18.3.3.9, “NDB Cluster TCP/IP Connections”, Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”, and Section 18.3.3.11, “NDB Cluster Shared-Memory Connections”, for more information).

This option is mutually exclusive with `--nodes` and `--system`; only one of these 3 options can be used.

- `--fields=delimiter`, `-f delimiter`

Command-Line Format	`--fields=string`	
Permitted Values	Type	string
	Default	

Specifies a *delimiter* string used to separate the fields in the result. The default is , (the comma character).

Note

If the *delimiter* contains spaces or escapes (such as \n for the linefeed character), then it must be quoted.

- --host=*hostname*

Command-Line Format	--host=name	
Permitted Values	Type	string
	Default	

Specifies the host name of the node for which configuration information is to be obtained.

Note

While the hostname localhost usually resolves to the IP address 127.0.0.1, this may not necessarily be true for all operating platforms and configurations. This means that it is possible, when localhost is used in config.ini, for ndb_config --host=localhost to fail if ndb_config is run on a different host where localhost resolves to a different address (for example, on some versions of SUSE Linux, this is 127.0.0.2). In general, for best results, you should use numeric IP addresses for all NDB Cluster configuration values relating to hosts, or verify that all NDB Cluster hosts handle localhost in the same fashion.

- --ndb-connectstring=*connection_string*, -c *connection_string*

Command-Line Format	--ndb-connectstring=connectstring	
	--connect-string=connectstring	
Permitted Values	Type	string
	Default	localhost:1186

Specifies the connection string to use in connecting to the management server. The format for the connection string is the same as described in Section 18.3.3.3, “NDB Cluster Connection Strings”, and defaults to localhost:1186.

- --mycnf

Command-Line Format	--mycnf	
Permitted Values	Type	boolean
	Default	FALSE

Read configuration data from the my.cnf file.

- --nodeid=*node_id*, --id=*node_id*

Command-Line Format	--ndb-nodeid=#	
Permitted Values	Type	numeric
	Default	0

Specify the node ID of the node for which configuration information is to be obtained. --nodeid is the preferred form.

- `--nodes`

Command-Line Format	`--nodes`	
Permitted Values	Type	boolean
	Default	`FALSE`

Tells `ndb_config` to print information relating only to parameters defined in an `[ndbd]` or `[ndbd default]` section of the cluster configuration file (see Section 18.3.3.6, "Defining NDB Cluster Data Nodes").

This option is mutually exclusive with `--connections` and `--system`; only one of these 3 options can be used.

- `--rows=`*`separator`*, `-r` *`separator`*

Command-Line Format	`--rows=string`	
Permitted Values	Type	string
	Default	

Specifies a *`separator`* string used to separate the rows in the result. The default is a space character.

Note

If the *`separator`* contains spaces or escapes (such as `\n` for the linefeed character), then it must be quoted.

- `--query=`*`query-options`*, `-q` *`query-options`*

Command-Line Format	`--query=string`	
Permitted Values	Type	string
	Default	

This is a comma-delimited list of *query options*—that is, a list of one or more node attributes to be returned. These include `id` (node ID), type (node type—that is, `ndbd`, `mysqld`, or `ndb_mgmd`), and any configuration parameters whose values are to be obtained.

For example, `--query=id,type,indexmemory,datamemory` returns the node ID, node type, `DataMemory`, and `IndexMemory` for each node.

Note

If a given parameter is not applicable to a certain type of node, than an empty string is returned for the corresponding value. See the examples later in this section for more information.

- `--system`

Command-Line Format	`--system`	
Permitted Values	Type	boolean
	Default	`FALSE`

Tells `ndb_config` to print `SYSTEM` information only. This consists of system variables that cannot be changed at run time; thus, there is no corresponding section of the cluster configuration file for them. They can be seen (prefixed with `****** SYSTEM ******`) in the output of `ndb_config --configinfo`.

This option is mutually exclusive with `--nodes` and `--connections`; only one of these 3 options can be used.

- `--type=node_type`

Command-Line Format	`--type=name`	
Permitted Values	Type	enumeration
	Default	`[none]`
	Valid Values	`ndbd`
		`mysqld`
		`ndb_mgmd`

Filters results so that only configuration values applying to nodes of the specified *`node_type`* (`ndbd`, `mysqld`, or `ndb_mgmd`) are returned.

- `--usage`, `--help`, or `-?`

Command-Line Format	`--help`
	`--usage`

Causes `ndb_config` to print a list of available options, and then exit.

- `--version`, `-V`

Command-Line Format	`--version`

Causes `ndb_config` to print a version information string, and then exit.

- `--configinfo --xml`

Command-Line Format	`--configinfo --xml`	
Permitted Values	Type	boolean
	Default	`false`

Cause `ndb_config --configinfo` to provide output as XML by adding this option. A portion of such output is shown in this example:

```
shell> ndb_config --configinfo --xml

<configvariables protocolversion="1" ndbversionstring="5.5.58-ndb-7.2.32"
                 ndbversion="458758" ndbversionmajor="7" ndbversionminor="0"
                 ndbversionbuild="6">
  <section name="SYSTEM">
    <param name="Name" comment="Name of system (NDB Cluster)" type="string"
           mandatory="true"/>
    <param name="PrimaryMGMNode" comment="Node id of Primary ndb_mgmd(MGM) node"
           type="unsigned" default="0" min="0" max="4294967039"/>
    <param name="ConfigGenerationNumber" comment="Configuration generation number"
           type="unsigned" default="0" min="0" max="4294967039"/>
  </section>
  <section name="NDBD">
    <param name="MaxNoOfSubscriptions"
           comment="Max no of subscriptions (default 0 == MaxNoOfTables)"
           type="unsigned" default="0" min="0" max="4294967039"/>
    <param name="MaxNoOfSubscribers"
           comment="Max no of subscribers (default 0 == 2 * MaxNoOfTables)"
           type="unsigned" default="0" min="0" max="4294967039"/>

    …
```

```
  </section>

  …

</configvariables>
```

Note

Normally, the XML output produced by `ndb_config --configinfo --xml` is formatted using one line per element; we have added extra whitespace in the previous example, as well as the next one, for reasons of legibility. This should not make any difference to applications using this output, since most XML processors either ignore nonessential whitespace as a matter of course, or can be instructed to do so.

The XML output also indicates when changing a given parameter requires that data nodes be restarted using the `--initial` option. This is shown by the presence of an `initial="true"` attribute in the corresponding `<param>` element. In addition, the restart type (`system` or `node`) is also shown; if a given parameter requires a system restart, this is indicated by the presence of a `restart="system"` attribute in the corresponding `<param>` element. For example, changing the value set for the `Diskless` parameter requires a system initial restart, as shown here (with the `restart` and `initial` attributes highlighted for visibility):

```
<param name="Diskless" comment="Run wo/ disk" type="bool" default="false"
         restart="system" initial="true"/>
```

Currently, no `initial` attribute is included in the XML output for `<param>` elements corresponding to parameters which do not require initial restarts; in other words, `initial="false"` is the default, and the value `false` should be assumed if the attribute is not present. Similarly, the default restart type is `node` (that is, an online or “rolling” restart of the cluster), but the `restart` attribute is included only if the restart type is `system` (meaning that all cluster nodes must be shut down at the same time, then restarted).

Important

The `--xml` option can be used only with the `--configinfo` option. Using `--xml` without `--configinfo` fails with an error.

Unlike the options used with this program to obtain current configuration data, `--configinfo` and `--xml` use information obtained from the NDB Cluster sources when `ndb_config` was compiled. For this reason, no connection to a running NDB Cluster or access to a `config.ini` or `my.cnf` file is required for these two options.

Combining other `ndb_config` options (such as `--query` or `--type`) with `--configinfo` (with or without the `--xml` option) is not supported. Currently, if you attempt to do so, the usual result is that all other options besides `--configinfo` or `--xml` are simply ignored. *However, this behavior is not guaranteed and is subject to change at any time*. In addition, since `ndb_config`, when used with the `--configinfo` option, does not access the NDB Cluster or read any files, trying to specify additional options such as `--ndb-connectstring` or `--config-file` with `--configinfo` serves no purpose.

Examples

1. To obtain the node ID and type of each node in the cluster:

```
shell> ./ndb_config --query=id,type --fields=':' --rows='\n'
1:ndbd
2:ndbd
3:ndbd
4:ndbd
```

```
5:ndb_mgmd
6:mysqld
7:mysqld
8:mysqld
9:mysqld
```

In this example, we used the `--fields` options to separate the ID and type of each node with a colon character (`:`), and the `--rows` options to place the values for each node on a new line in the output.

2. To produce a connection string that can be used by data, SQL, and API nodes to connect to the management server:

```
shell> ./ndb_config --config-file=usr/local/mysql/cluster-data/config.ini \
--query=hostname,portnumber --fields=: --rows=, --type=ndb_mgmd
198.51.100.179:1186
```

3. This invocation of `ndb_config` checks only data nodes (using the `--type` option), and shows the values for each node's ID and host name, as well as the values set for its `DataMemory`, `IndexMemory`, and `DataDir` parameters:

```
shell> ./ndb_config --type=ndbd --query=id,host,datamemory,indexmemory,datadir -f ' : ' -r '\n'
1 : 198.51.100.193 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
2 : 198.51.100.112 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
3 : 198.51.100.176 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
4 : 198.51.100.119 : 83886080 : 18874368 : /usr/local/mysql/cluster-data
```

In this example, we used the short options `-f` and `-r` for setting the field delimiter and row separator, respectively.

4. To exclude results from any host except one in particular, use the `--host` option:

```
shell> ./ndb_config --host=198.51.100.176 -f : -r '\n' -q id,type
3:ndbd
5:ndb_mgmd
```

In this example, we also used the short form `-q` to determine the attributes to be queried.

Similarly, you can limit results to a node with a specific ID using the `--nodeid` option.

18.4.8 ndb_cpcd — Automate Testing for NDB Development

A utility having this name was formerly part of an internal automated test framework used in testing and debugging NDB Cluster. It was deprecated in NDB Cluster 7.0, and removed from NDB Cluster distributions provided by Oracle beginning with NDB 7.2.1.

18.4.9 ndb_delete_all — Delete All Rows from an NDB Table

`ndb_delete_all` deletes all rows from the given `NDB` table. In some cases, this can be much faster than `DELETE` or even `TRUNCATE TABLE`.

Usage

```
ndb_delete_all -c connection_string tbl_name -d db_name
```

This deletes all rows from the table named *`tbl_name`* in the database named *`db_name`*. It is exactly equivalent to executing `TRUNCATE db_name.tbl_name` in MySQL.

The following table includes options that are specific to `ndb_delete_all`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_delete_all`),

see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.77 This table describes command-line options for the ndb_delete_all program

Format	Description	Added or Removed
`--database=dbname`, `-d`	Name of the database in which the table is found	All MySQL 5.5 based releases
`--transactional`, `-t`	Perform the delete in a single transaction (may run out of operations)	All MySQL 5.5 based releases
`--tupscan`	Run tup scan	All MySQL 5.5 based releases
`--diskscan`	Run disk scan	All MySQL 5.5 based releases

- `--transactional`, `-t`

  Use of this option causes the delete operation to be performed as a single transaction.

Warning

With very large tables, using this option may cause the number of operations available to the cluster to be exceeded.

18.4.10 ndb_desc — Describe NDB Tables

`ndb_desc` provides a detailed description of one or more `NDB` tables.

Usage

```
ndb_desc -c connection_string tbl_name -d db_name [options]
```

(*NDB 7.2.9 and later:*)

```
ndb_desc -c connection_string index_name -d db_name -t tbl_name
```

Additional options that can be used with `ndb_desc` are listed later in this section.

Sample Output

MySQL table creation and population statements:

```
USE test;

CREATE TABLE fish (
    id INT(11) NOT NULL AUTO_INCREMENT,
    name VARCHAR(20) NOT NULL,
    length_mm INT(11) NOT NULL,
    weight_gm INT(11) NOT NULL,

    PRIMARY KEY pk (id),
    UNIQUE KEY uk (name)
) ENGINE=NDB;

INSERT INTO fish VALUES
    ('','guppy', 35, 2), ('','tuna', 2500, 150000),
    ('','shark', 3000, 110000), ('','manta ray', 1500, 50000),
    ('','grouper', 900, 125000), ('','puffer', 250, 2500);
```

Output from ndb_desc:

```
shell> ./ndb_desc -c localhost fish -d test -p
-- fish --
Version: 2
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 4
Number of primary keys: 1
Length of frm data: 311
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 2
TableStatus: Retrieved
-- Attributes --
id Int PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
length_mm Int NOT NULL AT=FIXED ST=MEMORY
weight_gm Int NOT NULL AT=FIXED ST=MEMORY

-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex
uk$unique(name) - UniqueHashIndex
uk(name) - OrderedIndex

-- Per partition info --
Partition  Row count  Commit count  Frag fixed memory ...
0          2          2             32768             ...
1          4          4             32768             ...

... Frag varsized memory  Extent_space  Free extent_space
... 32768                 0             0
... 32768                 0             0

NDBT_ProgramExit: 0 - OK
```

Information about multiple tables can be obtained in a single invocation of ndb_desc by using their names, separated by spaces. All of the tables must be in the same database.

Beginning with NDB 7.2.9, it is possible to obtain additional information about a specific index using the --table (short form: -t) option introduced in this version and supplying the name of the index as the first argument to ndb_desc, as shown here:

```
shell> ./ndb_desc uk -d test -t fish
-- uk --
Version: 3
Base table: fish
Number of attributes: 1
Logging: 0
Index type: OrderedIndex
Index status: Retrieved
-- Attributes --
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
-- IndexTable 10/uk --
Version: 3
Fragment type: FragUndefined
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: yes
Number of attributes: 2
Number of primary keys: 1
Length of frm data: 0
```

```
Row Checksum: 1
Row GCI: 1
SingleUserMode: 2
ForceVarPart: 0
FragmentCount: 4
ExtraRowGciBits: 0
ExtraRowAuthorBits: 0
TableStatus: Retrieved
-- Attributes --
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
NDB$TNODE Unsigned [64] PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY
-- Indexes --
PRIMARY KEY(NDB$TNODE) - UniqueHashIndex

NDBT_ProgramExit: 0 - OK
```

When an index is specified in this way, the `--extra-partition-info` and `--extra-node-info` options have no effect.

The `Version` column in the output contains the table's schema object version. For information about interpreting this value, see NDB Schema Object Versions.

The `Extent_space` and `Free extent_space` columns are applicable only to `NDB` tables having columns on disk; for tables having only in-memory columns, these columns always contain the value `0`.

To illustrate their use, we modify the previous example. First, we must create the necessary Disk Data objects, as shown here:

```
CREATE LOGFILE GROUP lg_1
    ADD UNDOFILE 'undo_1.log'
    INITIAL_SIZE 16M
    UNDO_BUFFER_SIZE 2M
    ENGINE NDB;

ALTER LOGFILE GROUP lg_1
    ADD UNDOFILE 'undo_2.log'
    INITIAL_SIZE 12M
    ENGINE NDB;

CREATE TABLESPACE ts_1
    ADD DATAFILE 'data_1.dat'
    USE LOGFILE GROUP lg_1
    INITIAL_SIZE 32M
    ENGINE NDB;

ALTER TABLESPACE ts_1
    ADD DATAFILE 'data_2.dat'
    INITIAL_SIZE 48M
    ENGINE NDB;
```

(For more information on the statements just shown and the objects created by them, see Section 18.5.12.1, “NDB Cluster Disk Data Objects”, as well as Section 13.1.14, “CREATE LOGFILE GROUP Syntax”, and Section 13.1.18, “CREATE TABLESPACE Syntax”.)

Now we can create and populate a version of the `fish` table that stores 2 of its columns on disk (deleting the previous version of the table first, if it already exists):

```
CREATE TABLE fish (
    id INT(11) NOT NULL AUTO_INCREMENT,
    name VARCHAR(20) NOT NULL,
    length_mm INT(11) NOT NULL,
    weight_gm INT(11) NOT NULL,

    PRIMARY KEY pk (id),
    UNIQUE KEY uk (name)
) TABLESPACE ts_1 STORAGE DISK
ENGINE=NDB;
```

```
INSERT INTO fish VALUES
    ('','guppy', 35, 2), ('','tuna', 2500, 150000),
    ('','shark', 3000, 110000), ('','manta ray', 1500, 50000),
    ('','grouper', 900, 125000), ('','puffer', 250, 2500);
```

When run against this version of the table, ndb_desc displays the following output:

```
shell> ./ndb_desc -c localhost fish -d test -p
-- fish --
Version: 3
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 4
Number of primary keys: 1
Length of frm data: 321
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 2
TableStatus: Retrieved
-- Attributes --
id Int PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
name Varchar(20;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
length_mm Int NOT NULL AT=FIXED ST=DISK
weight_gm Int NOT NULL AT=FIXED ST=DISK

-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex
uk$unique(name) - UniqueHashIndex
uk(name) - OrderedIndex
-- Per partition info --
Partition  Row count  Commit count  Frag fixed memory ...
0          2          2             32768             ...
1          4          4             32768             ...

... Frag varsized memory  Extent_space  Free extent_space
... 32768                 0             0
... 32768                 0             0

NDBT_ProgramExit: 0 - OK
```

This means that 1048576 bytes are allocated from the tablespace for this table on each partition, of which 1044440 bytes remain free for additional storage. In other words, 1048576 - 1044440 = 4136 bytes per partition is currently being used to store the data from this table's disk-based columns. The number of bytes shown as `Free extent_space` is available for storing on-disk column data from the `fish` table only; for this reason, it is not visible when selecting from the `INFORMATION_SCHEMA.FILES` table.

The following table includes options that are specific to ndb_desc. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_desc), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.78 This table describes command-line options for the ndb_desc program

Format	Description	Added or Removed
`--blob-info`, `-b`	Include partition information for BLOB tables in output. Requires that the -p option also be used	All MySQL 5.5 based releases
`--database=dbname`,	Name of database containing table	All MySQL 5.5 based releases

Format	Description	Added or Removed
-d --extra-node-info, -n	Include partition-to-data-node mappings in output. Requires that the -p option also be used	All MySQL 5.5 based releases
--extra-partition-info, -p	Display information about partitions	All MySQL 5.5 based releases
--retries=#, -r	Number of times to retry the connection (once per second)	All MySQL 5.5 based releases
--table=tbl_name, -t	Specify the table in which to find an index. When this option is used, -p and -n have no effect and are ignored.	ADDED: NDB 7.2.9
--unqualified, -u	Use unqualified table names	All MySQL 5.5 based releases

- `--blob-info`, `-b`

  Include information about subordinate `BLOB` and `TEXT` columns.

  Use of this option also requires the use of the `--extra-partition-info` (`-p`) option.

- `--database=db_name`, `-d`

  Specify the database in which the table should be found.

- `--extra-node-info`, `-n`

  Include information about the mappings between table partitions and the data nodes upon which they reside. This information can be useful for verifying distribution awareness mechanisms and supporting more efficient application access to the data stored in NDB Cluster.

  Use of this option also requires the use of the `--extra-partition-info` (`-p`) option.

- `--extra-partition-info`, `-p`

  Print additional information about the table's partitions.

- `--retries=#`, `-r`

  Try to connect this many times before giving up. One connect attempt is made per second.

- `--table=tbl_name`, `-t`

  Specify the table in which to look for an index.

  This option was added in NDB 7.2.9.

- `--unqualified`, `-u`

  Use unqualified table names.

18.4.11 ndb_drop_index — Drop Index from an NDB Table

`ndb_drop_index` drops the specified index from an `NDB` table. *It is recommended that you use this utility only as an example for writing NDB API applications*—see the Warning later in this section for details.

Usage

```
ndb_drop_index -c connection_string table_name index -d db_name
```

The statement shown above drops the index named *`index`* from the *`table`* in the *`database`*.

The following table includes options that are specific to `ndb_drop_index`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_drop_index`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.79 This table describes command-line options for the ndb_drop_index program

Format	Description	Added or Removed
`--database=dbname`, `-d`	Name of the database in which the table is found	All MySQL 5.5 based releases

Warning

Operations performed on Cluster table indexes using the NDB API are not visible to MySQL and make the table unusable by a MySQL server. If you use this program to drop an index, then try to access the table from an SQL node, an error results, as shown here:

```
shell> ./ndb_drop_index -c localhost dogs ix -d ctest1
Dropping index dogs/idx...OK

NDBT_ProgramExit: 0 - OK

shell> ./mysql -u jon -p ctest1
Enter password: *******
Reading table information for completion of table and column names
You can turn off this feature to get a quicker startup with -A

Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 7 to server version: 5.5.58-ndb-7.2.32

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> SHOW TABLES;
+------------------+
| Tables_in_ctest1 |
+------------------+
| a                |
| bt1              |
| bt2              |
| dogs             |
| employees        |
| fish             |
+------------------+
6 rows in set (0.00 sec)

mysql> SELECT * FROM dogs;
ERROR 1296 (HY000): Got error 4243 'Index not found' from NDBCLUSTER
```

In such a case, your *only* option for making the table available to MySQL again is to drop the table and re-create it. You can use either the SQL statement`DROP TABLE` or the `ndb_drop_table` utility (see Section 18.4.12, “`ndb_drop_table` — Drop an NDB Table”) to drop the table.

18.4.12 `ndb_drop_table` — Drop an NDB Table

`ndb_drop_table` drops the specified `NDB` table. (If you try to use this on a table created with a storage engine other than `NDB`, the attempt fails with the error `723: No such table exists`.) This

operation is extremely fast; in some cases, it can be an order of magnitude faster than using a MySQL DROP TABLE statement on an NDB table.

Usage

```
ndb_drop_table -c connection_string tbl_name -d db_name
```

The following table includes options that are specific to ndb_drop_table. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_drop_table), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.80 This table describes command-line options for the ndb_drop_table program

Format	Description	Added or Removed
--database=dbname, -d	Name of the database in which the table is found	All MySQL 5.5 based releases

18.4.13 ndb_error_reporter — NDB Error-Reporting Utility

ndb_error_reporter creates an archive from data node and management node log files that can be used to help diagnose bugs or other problems with a cluster. *It is highly recommended that you make use of this utility when filing reports of bugs in NDB Cluster*.

The following table includes command options specific to the NDB Cluster program ndb_error_reporter. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_error_reporter), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

ndb_error_reporter did not support the --help option prior to NDB 7.2.14 (Bug #11756666, Bug #48606). The --connection-timeout --dry-scp, and --skip-nodegroup options were also added in this release (Bug #16602002).

Table 18.81 This table describes command-line options for the ndb_error_reporter program

Format	Description	Added or Removed
--connection-timeout=timeout	Number of seconds to wait when connecting to nodes before timing out.	ADDED: NDB 7.2.14
--dry-scp	Disable scp with remote hosts; used only for testing.	ADDED: NDB 7.2.14
--fs	Include file system data in error report; can use a large amount of disk space	All MySQL 5.5 based releases
--skip-nodegroup=nodegroup_id	Skip all nodes in the node group having this ID.	ADDED: NDB 7.2.14

Usage

```
ndb_error_reporter path/to/config-file [username] [options]
```

This utility is intended for use on a management node host, and requires the path to the management host configuration file (usually named config.ini). Optionally, you can supply the name of a user that is able to access the cluster's data nodes using SSH, to copy the data node log files. ndb_error_reporter then includes all of these files in archive that is created in the same directory

in which it is run. The archive is named ndb_error_report_*YYYYMMDDHHMMSS*.tar.bz2, where *YYYYMMDDHHMMSS* is a datetime string.

ndb_error_reporter also accepts the options listed here:

- --connection-timeout=*timeout*

Introduced	5.5.34-ndb-7.2.14	
Command-Line Format	--connection-timeout=timeout	
Permitted Values	Type	integer
	Default	0

Wait this many seconds when trying to connect to nodes before timing out.

- --dry-scp

Introduced	5.5.34-ndb-7.2.14	
Command-Line Format	--dry-scp	
Permitted Values	Type	boolean
	Default	TRUE

Run ndb_error_reporter without using scp from remote hosts. Used for testing only.

- --fs

Command-Line Format	--fs	
Permitted Values	Type	boolean
	Default	FALSE

Copy the data node file systems to the management host and include them in the archive.

Because data node file systems can be extremely large, even after being compressed, we ask that you please do *not* send archives created using this option to Oracle unless you are specifically requested to do so.

- --skip-nodegroup=*nodegroup_id*

Introduced	5.5.34-ndb-7.2.14	
Command-Line Format	--connection-timeout=timeout	
Permitted Values	Type	integer
	Default	0

Skip all nodes belong to the node group having the supplied node group ID.

18.4.14 ndb_index_stat — NDB Index Statistics Utility

ndb_index_stat provides per-fragment statistical information about indexes on NDB tables. This includes cache version and age, number of index entries per partition, and memory consumption by indexes.

Usage

To obtain basic index statistics about a given NDB table, invoke ndb_index_stat as shown here, with the name of the table as the first argument and the name of the database containing this table specified immediately following it, using the --database (-d) option:

```
ndb_index_stat table -d database
```

In this example, we use ndb_index_stat to obtain such information about an NDB table named mytable in the test database:

```
shell> ndb_index_stat -d test mytable
table:City index:PRIMARY fragCount:2
sampleVersion:3 loadTime:1399585986 sampleCount:1994 keyBytes:7976
query cache: valid:1 sampleCount:1994 totalBytes:27916
times in ms: save: 7.133 sort: 1.974 sort per sample: 0.000

NDBT_ProgramExit: 0 - OK
```

sampleVersion is the version number of the cache from which the statistics data is taken. Running ndb_index_stat with the --update option causes sampleVersion to be incremented.

loadTime shows when the cache was last updated. This is expressed as seconds since the Unix Epoch.

sampleCount is the number of index entries found per partition. You can estimate the total number of entries by multiplying this by the number of fragments (shown as fragCount).

sampleCount can be compared with the cardinality of SHOW INDEX or INFORMATION_SCHEMA.STATISTICS, although the latter two provide a view of the table as a whole, while ndb_index_stat provides a per-fragment average.

keyBytes is the number of bytes used by the index. In this example, the primary key is an integer, which requires four bytes for each index, so keyBytes can be calculated in this case as shown here:

```
    keyBytes = sampleCount * (4 bytes per index) = 1994 * 4 = 7976
```

This information can also be obtained using the corresponding column definitions from INFORMATION_SCHEMA.COLUMNS (this requires a MySQL Server and a MySQL client application).

totalBytes is the total memory consumed by all indexes on the table, in bytes.

Timings shown in the preceding examples are specific to each invocation of ndb_index_stat.

The --verbose option provides some additional output, as shown here:

```
shell> ndb_index_stat -d test mytable --verbose
random seed 1337010518
connected
loop 1 of 1
table:mytable index:PRIMARY fragCount:4
sampleVersion:2 loadTime:1336751773 sampleCount:0 keyBytes:0
read stats
query cache created
query cache: valid:1 sampleCount:0 totalBytes:0
times in ms: save: 20.766 sort: 0.001
disconnected

NDBT_ProgramExit: 0 - OK

shell>
```

Options

The following table includes options that are specific to the NDB Cluster ndb_index_stat utility. Additional descriptions are listed following the table. For options common to most NDB Cluster programs (including ndb_index_stat), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.82 This table describes command-line options for the ndb_index_stat program

Format	Description	Added or Removed
--database=name, -d	Name of the database containing the table.	All MySQL 5.5 based releases
--delete	Delete index statistics for the given table, stopping any auto-update previously configured.	All MySQL 5.5 based releases
--update	Update index statistics for the given table, restarting any auto-update previously configured.	All MySQL 5.5 based releases
--dump	Print the query cache.	All MySQL 5.5 based releases
--query=#	Perform a number of random range queries on first key attr (must be int unsigned).	All MySQL 5.5 based releases
--sys-drop	Drop any statistics tables and events in NDB kernel (all statistics are lost)	All MySQL 5.5 based releases
--sys-create	Create all statistics tables and events in NDB kernel, if none of them already exist	All MySQL 5.5 based releases
--sys-create-if-not-exist	Create any statistics tables and events in NDB kernel that do not already exist.	All MySQL 5.5 based releases
--sys-create-if-not-valid	Create any statistics tables or events that do not already exist in the NDB kernel. after dropping any that are invalid.	All MySQL 5.5 based releases
--sys-check	Verify that NDB system index statistics and event tables exist.	All MySQL 5.5 based releases
--sys-skip-tables	Do not apply sys-* options to tables.	All MySQL 5.5 based releases
--sys-skip-events	Do not apply sys-* options to events.	All MySQL 5.5 based releases
--verbose, -v	Turn on verbose output	All MySQL 5.5 based releases
--loops=#	Set the number of times to perform a given command. Default is 0.	All MySQL 5.5 based releases

ndb_index_stat statistics options. The following options are used to generate index statistics. They work with a given table and database. They cannot be mixed with system options (see ndb_index_stat system options).

- `--database=name`, `-d name`

Command-Line Format	--database=name	
Permitted Values	Type	string
	Default	[none]
	Minimum	
	Maximum	

The name of the database that contains the table being queried.

- `--delete`

Command-Line Format	`--delete`	
Permitted Values	Type	boolean
	Default	`false`
	Minimum	
	Maximum	

Delete the index statistics for the given table, stopping any auto-update that was previously configured.

- `--update`

Command-Line Format	`--update`	
Permitted Values	Type	boolean
	Default	`false`
	Minimum	
	Maximum	

Update the index statistics for the given table, and restart any auto-update that was previously configured.

- `--dump`

Command-Line Format	`--dump`	
Permitted Values	Type	boolean
	Default	`false`
	Minimum	
	Maximum	

Dump the contents of the query cache.

- `--query=#`

Command-Line Format	`--query=#`	
Permitted Values	Type	numeric
	Default	`0`
	Minimum	`0`
	Maximum	`MAX_INT`

Perform random range queries on first key attribute (must be int unsigned).

ndb_index_stat system options. The following options are used to generate and update the statistics tables in the NDB kernel. None of these options can be mixed with statistics options (see ndb_index_stat statistics options).

- `--sys-drop`

Command-Line Format	`--sys-drop`	
Permitted Values	Type	boolean

	Default	`false`
	Minimum	
	Maximum	

Drop all statistics tables and events in the NDB kernel. *This causes all statistics to be lost*.

- `--sys-create`

Command-Line Format	`--sys-create`	
Permitted Values	**Type**	boolean
	Default	`false`
	Minimum	
	Maximum	

Create all statistics tables and events in the NDB kernel. This works only if none of them exist previously.

- `sys-create-if-not-exist`

Command-Line Format	`--sys-create-if-not-exist`	
Permitted Values	**Type**	boolean
	Default	`false`
	Minimum	
	Maximum	

Create any NDB system statistics tables or events (or both) that do not already exist when the program is invoked.

- `--sys-create-if-not-valid`

Command-Line Format	`--sys-create-if-not-valid`	
Permitted Values	**Type**	boolean
	Default	`false`
	Minimum	
	Maximum	

Create any NDB system statistics tables or events that do not already exist, after dropping any that are invalid.

- `--sys-check`

Command-Line Format	`--sys-check`	
Permitted Values	**Type**	boolean
	Default	`false`
	Minimum	
	Maximum	

Verify that all required system statistics tables and events exist in the NDB kernel.

- `--sys-skip-tables`

Command-Line Format	`--sys-skip-tables`

Permitted Values	Type	boolean
	Default	false
	Minimum	
	Maximum	

Do not apply any --sys-* options to any statistics tables.

- --sys-skip-events

Command-Line Format	--sys-skip-events	
Permitted Values	Type	boolean
	Default	false
	Minimum	
	Maximum	

Do not apply any --sys-* options to any events.

- --verbose

Command-Line Format	--verbose	
Permitted Values	Type	boolean
	Default	false
	Minimum	
	Maximum	

Turn on verbose output.

- --loops=#

Command-Line Format	--loops=#	
Permitted Values	Type	numeric
	Default	0
	Minimum	0
	Maximum	MAX_INT

Repeat commands this number of times (for use in testing).

18.4.15 ndb_move_data — NDB Data Copy Utility

ndb_move_data copies data from one NDB table to another.

Usage

The program is invoked with the names of the source and target tables; either or both of these may be qualified optionally with the database name. Both tables must use the NDB storage engine.

```
ndb_move_data options source target
```

The following table includes options that are specific to ndb_move_data. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_move_data), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.83 This table describes command-line options for the ndb_move_data program

Format	Description	Added or Removed
--abort-on-error	Dump core on permanent error (debug option)	All MySQL 5.5 based releases
--character-sets-dir=name	Directory where character sets are	All MySQL 5.5 based releases
--database=dbname, -d	Name of the database in which the table is found	All MySQL 5.5 based releases
--drop-source	Drop source table after all rows have been moved	All MySQL 5.5 based releases
--error-insert	Insert random temporary errors (testing option)	All MySQL 5.5 based releases
--exclude-missing-columns	Ignore extra columns in source or target table	All MySQL 5.5 based releases
--lossy-conversions, -l	Allow attribute data to be truncated when converted to a smaller type	All MySQL 5.5 based releases
--promote-attributes, -A	Allow attribute data to be converted to a larger type	All MySQL 5.5 based releases
--staging-tries=x[,y[,z]]	Specify tries on temporary errors. Format is x[,y[,z]] where x=max tries (0=no limit), y=min delay (ms), z=max delay (ms)	All MySQL 5.5 based releases
--verbose	Enable verbose messages	All MySQL 5.5 based releases

- `--abort-on-error`

Command-Line Format	--abort-on-error	
Permitted Values	Type	boolean
	Default	FALSE

Dump core on permanent error (debug option).

- `--character-sets-dir=`*`name`*

Command-Line Format	--character-sets-dir=name	
Permitted Values	Type	string
	Default	[none]

Directory where character sets are.

- `--database=`*`dbname`*, `-d`

Command-Line Format	--database=dbname	
Permitted Values	Type	string
	Default	TEST_DB

Name of the database in which the table is found.

- `--drop-source`

Command-Line Format	--drop-source	
Permitted Values	Type	boolean
	Default	FALSE

Drop source table after all rows have been moved.

- --error-insert

Command-Line Format	--error-insert	
Permitted Values	Type	boolean
	Default	FALSE

Insert random temporary errors (testing option).

- --exclude-missing-columns

Command-Line Format	--exclude-missing-columns	
Permitted Values	Type	boolean
	Default	FALSE

Ignore extra columns in source or target table.

- --lossy-conversions, -l

Command-Line Format	--lossy-conversions	
Permitted Values	Type	boolean
	Default	FALSE

Allow attribute data to be truncated when converted to a smaller type.

- --promote-attributes, -A

Command-Line Format	--promote-attributes	
Permitted Values	Type	boolean
	Default	FALSE

Allow attribute data to be converted to a larger type.

- --staging-tries=*x[,y[,z]]*

Command-Line Format	--staging-tries=x[,y[,z]]	
Permitted Values	Type	string
	Default	0,1000,60000

Specify tries on temporary errors. Format is x[,y[,z]] where x=max tries (0=no limit), y=min delay (ms), z=max delay (ms).

- --verbose

Command-Line Format	--verbose	
Permitted Values	Type	boolean
	Default	FALSE

Enable verbose messages.

18.4.16 ndb_print_backup_file — Print NDB Backup File Contents

ndb_print_backup_file obtains diagnostic information from a cluster backup file.

Usage

```
ndb_print_backup_file file_name
```

file_name is the name of a cluster backup file. This can be any of the files (.Data, .ctl, or .log file) found in a cluster backup directory. These files are found in the data node's backup directory under the subdirectory BACKUP-#, where # is the sequence number for the backup. For more information about cluster backup files and their contents, see Section 18.5.3.1, "NDB Cluster Backup Concepts".

Like ndb_print_schema_file and ndb_print_sys_file (and unlike most of the other NDB utilities that are intended to be run on a management server host or to connect to a management server) ndb_print_backup_file must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

Additional Options

None.

18.4.17 ndb_print_file — Print NDB Disk Data File Contents

ndb_print_file obtains information from an NDB Cluster Disk Data file.

Usage

```
ndb_print_file [-v] [-q] file_name+
```

file_name is the name of an NDB Cluster Disk Data file. Multiple filenames are accepted, separated by spaces.

Like ndb_print_schema_file and ndb_print_sys_file (and unlike most of the other NDB utilities that are intended to be run on a management server host or to connect to a management server) ndb_print_file must be run on an NDB Cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

Additional Options

ndb_print_file supports the following options:

- -v: Make output verbose.
- -q: Suppress output (quiet mode).
- --help, -h, -?: Print help message.

  This option did not work correctly prior to NDB 7.2.18. (Bug #17069285)

For more information, see Section 18.5.12, "NDB Cluster Disk Data Tables".

18.4.18 ndb_print_schema_file — Print NDB Schema File Contents

ndb_print_schema_file obtains diagnostic information from a cluster schema file.

Usage

```
ndb_print_schema_file file_name
```

file_name is the name of a cluster schema file. For more information about cluster schema files, see NDB Cluster Data Node File System Directory Files.

Like ndb_print_backup_file and ndb_print_sys_file (and unlike most of the other NDB utilities that are intended to be run on a management server host or to connect to a management server) ndb_print_schema_file must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

Additional Options

None.

18.4.19 ndb_print_sys_file — Print NDB System File Contents

ndb_print_sys_file obtains diagnostic information from an NDB Cluster system file.

Usage

```
ndb_print_sys_file file_name
```

file_name is the name of a cluster system file (sysfile). Cluster system files are located in a data node's data directory (DataDir); the path under this directory to system files matches the pattern ndb_#_fs/D#/DBDIH/P#.sysfile. In each case, the # represents a number (not necessarily the same number). For more information, see NDB Cluster Data Node File System Directory Files.

Like ndb_print_backup_file and ndb_print_schema_file (and unlike most of the other NDB utilities that are intended to be run on a management server host or to connect to a management server) ndb_print_backup_file must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

Additional Options

None.

18.4.20 ndb_redo_log_reader — Check and Print Content of Cluster Redo Log

Reads a redo log file, checking it for errors, printing its contents in a human-readable format, or both. ndb_redo_log_reader is intended for use primarily by NDB Cluster developers and Support personnel in debugging and diagnosing problems.

This utility remains under development, and its syntax and behavior are subject to change in future NDB Cluster releases.

Note

Prior to NDB 7.2, this utility was named ndbd_redo_log_reader.

The C++ source files for ndb_redo_log_reader can be found in the directory /storage/ndb/src/kernel/blocks/dblqh/redoLogReader.

The following table includes options that are specific to the NDB Cluster program ndb_redo_log_reader. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_redo_log_reader), see Section 18.4.27, "Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs".

Table 18.84 This table describes command-line options for the ndb_redo_log_reader program

Format	Description	Added or Removed
-dump	Print dump info	All MySQL 5.5 based releases
-filedescriptors	Print file descriptors only	All MySQL 5.5 based releases
--help	Print usage information	ADDED: NDB 7.2.15
-lap	Provide lap info, with max GCI started and completed	All MySQL 5.5 based releases
-mbyte #	Starting megabyte	All MySQL 5.5 based releases
-mbyteheaders	Show only the first page header of every megabyte in the file	All MySQL 5.5 based releases
-nocheck	Do not check records for errors	All MySQL 5.5 based releases
-noprint	Do not print records	All MySQL 5.5 based releases
-page #	Start with this page	All MySQL 5.5 based releases
-pageheaders	Show page headers only	All MySQL 5.5 based releases
-pageindex #	Start with this page index	All MySQL 5.5 based releases
-twiddle	Bit-shifted dump	All MySQL 5.5 based releases

Usage

```
ndb_redo_log_reader file_name [options]
```

file_name is the name of a cluster redo log file. redo log files are located in the numbered directories under the data node's data directory (DataDir); the path under this directory to the redo log files matches the pattern ndb_*nodeid*_fs/D#/DBLQH/S#.FragLog. *nodeid* is the data node's node ID. The two instances of # each represent a number (not necessarily the same number); the number following D is in the range 8-39 inclusive; the range of the number following S varies according to the value of the NoOfFragmentLogFiles configuration parameter, whose default value is 16; thus, the default range of the number in the file name is 0-15 inclusive. For more information, see NDB Cluster Data Node File System Directory Files.

The name of the file to be read may be followed by one or more of the options listed here:

- -dump

Command-Line Format	-dump	
Permitted Values	Type	boolean
	Default	FALSE

Print dump info.

-

Command-Line Format	-filedescriptors

Permitted Values	Type	boolean
	Default	FALSE

`-filedescriptors`: Print file descriptors only.

Introduced	5.5.35-ndb-7.2.15
Command-Line Format	`--help`

`--help`: Print usage information.

Added in NDB 7.2.15. (Bug #11749591, Bug #36805)

- `-lap`

Command-Line Format	`-lap`	
Permitted Values	Type	boolean
	Default	FALSE

Provide lap info, with max GCI started and completed.

Command-Line Format	`-mbyte #`	
Permitted Values	Type	numeric
	Default	0
	Minimum	0
	Maximum	15

`-mbyte #`: Starting megabyte.

`#` is an integer in the range 0 to 15, inclusive.

Command-Line Format	`-mbyteheaders`	
Permitted Values	Type	boolean
	Default	FALSE

`-mbyteheaders`: Show only the first page header of every megabyte in the file.

Command-Line Format	`-noprint`	
Permitted Values	Type	boolean
	Default	FALSE

`-noprint`: Do not print the contents of the log file.

Command-Line Format	`-nocheck`	
Permitted Values	Type	boolean
	Default	FALSE

`-nocheck`: Do not check the log file for errors.

Command-Line Format	`-page #`	
Permitted Values	Type	integer
	Default	0
	Minimum	0

	Maximum	31

`-page #`: Start at this page.

`#` is an integer in the range 0 to 31, inclusive.

Command-Line Format	`-pageheaders`	
Permitted Values	**Type**	boolean
	Default	`FALSE`

`-pageheaders`: Show page headers only.

Command-Line Format	`-pageindex #`	
Permitted Values	**Type**	integer
	Default	12
	Minimum	12
	Maximum	8191

`-pageindex #`: Start at this page index.

`#` is an integer between 12 and 8191, inclusive.

- `-twiddle`

Command-Line Format	`-twiddle`	
Permitted Values	**Type**	boolean
	Default	`FALSE`

Bit-shifted dump.

Like `ndb_print_backup_file` and `ndb_print_schema_file` (and unlike most of the `NDB` utilities that are intended to be run on a management server host or to connect to a management server) `ndb_redo_log_reader` must be run on a cluster data node, since it accesses the data node file system directly. Because it does not make use of the management server, this utility can be used when the management server is not running, and even when the cluster has been completely shut down.

18.4.21 `ndb_restore` — Restore an NDB Cluster Backup

The cluster restoration program is implemented as a separate command-line utility `ndb_restore`, which can normally be found in the MySQL `bin` directory. This program reads the files created as a result of the backup and inserts the stored information into the database.

`ndb_restore` must be executed once for each of the backup files that were created by the `START BACKUP` command used to create the backup (see Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”). This is equal to the number of data nodes in the cluster at the time that the backup was created.

Note

Before using `ndb_restore`, it is recommended that the cluster be running in single user mode, unless you are restoring multiple data nodes in parallel. See Section 18.5.8, “NDB Cluster Single User Mode”, for more information.

The following table includes options that are specific to the NDB Cluster native backup restoration program `ndb_restore`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_restore`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.85 This table describes command-line options for the ndb_restore program

Format	Description	Added or Removed
--append	Append data to a tab-delimited file	All MySQL 5.5 based releases
--backup_path=dir_name	Path to backup files directory	All MySQL 5.5 based releases
--backupid=#, -b	Restore from the backup with the given ID	All MySQL 5.5 based releases
--connect, -c	Alias for --connectstring.	All MySQL 5.5 based releases
--disable-indexes	Causes indexes from a backup to be ignored; may decrease time needed to restore data.	All MySQL 5.5 based releases
--dont_ignore_systab_0, -f	Do not ignore system table during restore. Experimental only; not for production use	All MySQL 5.5 based releases
--exclude-databases=db-list	List of one or more databases to exclude (includes those not named)	All MySQL 5.5 based releases
--exclude-intermediate-sql-tables[=TRUE|FALSE]	If TRUE (the default), do not restore any intermediate tables (having names prefixed with '#sql-') that were left over from copying ALTER TABLE operations.	ADDED: NDB 7.2.17
--exclude-missing-columns	Causes columns from the backup version of a table that are missing from the version of the table in the database to be ignored.	All MySQL 5.5 based releases
--exclude-missing-tables	Causes tables from the backup that are missing from the database to be ignored.	ADDED: NDB 7.2.18
--exclude-tables=table-list	List of one or more tables to exclude (includes those in the same database that are not named); each table reference must include the database name	All MySQL 5.5 based releases
--fields-enclosed-by=char	Fields are enclosed with the indicated character	All MySQL 5.5 based releases
--fields-optionally-enclosed-by	Fields are optionally enclosed with the indicated character	All MySQL 5.5 based releases
--fields-terminated-by=char	Fields are terminated by the indicated character	All MySQL 5.5 based releases
--hex	Print binary types in hexadecimal format	All MySQL 5.5 based releases
--include-databases=db-list	List of one or more databases to restore (excludes those not named)	All MySQL 5.5 based releases
--include-tables=table-list	List of one or more tables to restore (excludes those in same	All MySQL 5.5 based releases

Format	Description	Added or Removed
	database that are not named); each table reference must include the database name	
--lines-terminated-by=char	Lines are terminated by the indicated character	All MySQL 5.5 based releases
--lossy-conversions, -L	Allow lossy conversions of column values (type demotions or changes in sign) when restoring data from backup	All MySQL 5.5 based releases
--no-binlog	If a mysqld is connected and using binary logging, do not log the restored data	All MySQL 5.5 based releases
--no-restore-disk-objects, -d	Do not restore objects relating to Disk Data	All MySQL 5.5 based releases
--no-upgrade, -u	Do not upgrade array type for varsize attributes which do not already resize VAR data, and do not change column attributes	All MySQL 5.5 based releases
--ndb-nodegroup-map=map, -z	Nodegroup map for NDBCLUSTER storage engine. Syntax: list of (source_nodegroup, destination_nodegroup)	All MySQL 5.5 based releases
--nodeid=#, -n	ID of node where backup was taken	All MySQL 5.5 based releases
--parallelism=#, -p	Number of parallel transactions to use while restoring data	All MySQL 5.5 based releases
--preserve-trailing-spaces, -P	Allow preservation of trailing spaces (including padding) when promoting fixed-width string types to variable-width types	All MySQL 5.5 based releases
--print	Print metadata, data and log to stdout (equivalent to --print_meta --print_data --print_log)	All MySQL 5.5 based releases
--print_data	Print data to stdout	All MySQL 5.5 based releases
--print_log	Print to stdout	All MySQL 5.5 based releases
--print_meta	Print metadata to stdout	All MySQL 5.5 based releases
--progress-frequency=#	Print status of restoration each given number of seconds	All MySQL 5.5 based releases
--promote-attributes, -A	Allow attributes to be promoted when restoring data from backup	All MySQL 5.5 based releases
--rebuild-indexes	Causes multi-threaded rebuilding of ordered indexes found in the backup. Number of threads used is determined	All MySQL 5.5 based releases

Format	Description	Added or Removed
	by setting BuildIndexThreads parameter.	
--restore_data, -r	Restore table data and logs into NDB Cluster using the NDB API	All MySQL 5.5 based releases
--restore_epoch, -e	Restore epoch info into the status table. Convenient on a MySQL Cluster replication slave for starting replication. The row in mysql.ndb_apply_status with id 0 will be updated/inserted.	All MySQL 5.5 based releases
--restore_meta, -m	Restore metadata to NDB Cluster using the NDB API	All MySQL 5.5 based releases
--restore-privilege-tables	Restore MySQL privilege tables that were previously moved to NDB.	All MySQL 5.5 based releases
--rewrite-database=olddb,newdb	Restores to a database with a different name than the original	All MySQL 5.5 based releases
--skip-broken-objects	Causes missing blob tables in the backup file to be ignored.	All MySQL 5.5 based releases
--skip-table-check, -s	Skip table structure check during restoring of data	All MySQL 5.5 based releases
--skip-unknown-objects	Causes schema objects not recognized by ndb_restore to be ignored when restoring a backup made from a newer MySQL Cluster version to an older version.	All MySQL 5.5 based releases
--tab=dir_name, -T dir_name	Creates a tab-separated .txt file for each table in the given path	All MySQL 5.5 based releases
--verbose=#	Level of verbosity in output	All MySQL 5.5 based releases

Typical options for this utility are shown here:

```
ndb_restore [-c connection_string] -n node_id -b backup_id \
      [-m] -r --backup_path=/path/to/backup/files
```

Normally, when restoring from an NDB Cluster backup, ndb_restore requires at a minimum the --nodeid (short form: -n), --backupid (short form: -b), and --backup_path options. In addition, when ndb_restore is used to restore any tables containing unique indexes, you must include --disable-indexes or --rebuild-indexes. (Bug #57782, Bug #11764893)

The -c option is used to specify a connection string which tells ndb_restore where to locate the cluster management server (see Section 18.3.3.3, “NDB Cluster Connection Strings”). If this option is not used, then ndb_restore attempts to connect to a management server on localhost:1186. This utility acts as a cluster API node, and so requires a free connection “slot” to connect to the cluster management server. This means that there must be at least one [api] or [mysqld] section that can be used by it in the cluster config.ini file. It is a good idea to keep at least one empty [api] or [mysqld] section in config.ini that is not being used for a MySQL server or other application for this reason (see Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”).

You can verify that ndb_restore is connected to the cluster by using the SHOW command in the ndb_mgm management client. You can also accomplish this from a system shell, as shown here:

```
shell> ndb_mgm -e "SHOW"
```

More detailed information about all options used by ndb_restore can be found in the following list:

- --append

Command-Line Format	--append

When used with the --tab and --print_data options, this causes the data to be appended to any existing files having the same names.

- --backup_path=*dir_name*

Command-Line Format	--backup-path=dir_name	
Permitted Values	Type	directory name
	Default	./

The path to the backup directory is required; this is supplied to ndb_restore using the --backup_path option, and must include the subdirectory corresponding to the ID backup of the backup to be restored. For example, if the data node's DataDir is /var/lib/mysql-cluster, then the backup directory is /var/lib/mysql-cluster/BACKUP, and the backup files for the backup with the ID 3 can be found in /var/lib/mysql-cluster/BACKUP/BACKUP-3. The path may be absolute or relative to the directory in which the ndb_restore executable is located, and may be optionally prefixed with backup_path=.

It is possible to restore a backup to a database with a different configuration than it was created from. For example, suppose that a backup with backup ID 12, created in a cluster with two database nodes having the node IDs 2 and 3, is to be restored to a cluster with four nodes. Then ndb_restore must be run twice—once for each database node in the cluster where the backup was taken. However, ndb_restore cannot always restore backups made from a cluster running one version of MySQL to a cluster running a different MySQL version. See Section 18.2.7, “Upgrading and Downgrading NDB Cluster”, for more information.

Important

It is not possible to restore a backup made from a newer version of NDB Cluster using an older version of ndb_restore. You can restore a backup made from a newer version of MySQL to an older cluster, but you must use a copy of ndb_restore from the newer NDB Cluster version to do so.

For example, to restore a cluster backup taken from a cluster running NDB 7.2.5 to a cluster running NDB 7.1.21, you must use the ndb_restore that comes with the NDB 7.2.5 distribution.

For more rapid restoration, the data may be restored in parallel, provided that there is a sufficient number of cluster connections available. That is, when restoring to multiple nodes in parallel, you must have an [api] or [mysqld] section in the cluster config.ini file available for each concurrent ndb_restore process. However, the data files must always be applied before the logs.

- --backupid=#, -b

Command-Line Format	--backupid=#	
Permitted Values	Type	numeric
	Default	none

This option is used to specify the ID or sequence number of the backup, and is the same number shown by the management client in the `Backup backup_id completed` message displayed upon completion of a backup. (See Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”.)

Important

When restoring cluster backups, you must be sure to restore all data nodes from backups having the same backup ID. Using files from different backups will at best result in restoring the cluster to an inconsistent state, and may fail altogether.

- `--connect`, `-c`

Command-Line Format	`--connect`	
Permitted Values	Type	string
	Default	`localhost:1186`

Alias for `--ndb-connectstring`.

- `--disable-indexes`

Command-Line Format	`--disable-indexes`

Disable restoration of indexes during restoration of the data from a native `NDB` backup. Afterwards, you can restore indexes for all tables at once with multi-threaded building of indexes using `--rebuild-indexes`, which should be faster than rebuilding indexes concurrently for very large tables.

- `--dont_ignore_systab_0`, `-f`

Command-Line Format	`--dont-ignore-systab-0`

Normally, when restoring table data and metadata, `ndb_restore` ignores the copy of the `NDB` system table that is present in the backup. `--dont_ignore_systab_0` causes the system table to be restored. *This option is intended for experimental and development use only, and is not recommended in a production environment*.

- `--exclude-databases=db-list`

Command-Line Format	`--exclude-databases=db-list`	
Permitted Values	Type	string
	Default	

Comma-delimited list of one or more databases which should not be restored.

This option is often used in combination with `--exclude-tables`; see that option's description for further information and examples.

- `--exclude-intermediate-sql-tables[=TRUE|FALSE]`

Introduced	5.5.37-ndb-7.2.17	
Command-Line Format	`--exclude-intermediate-sql-tables[=TRUE|FALSE]`	
Permitted Values	Type	boolean
	Default	`TRUE`

When performing copying ALTER TABLE operations, mysqld creates intermediate tables (whose names are prefixed with #sql-). When TRUE, the --exclude-intermediate-sql-tables option keeps ndb_restore from restoring such tables that may have been left over from these operations. This option is TRUE by default.

This option was introduced in NDB 7.2.17. (Bug #17882305)

- --exclude-missing-columns

Command-Line Format	--exclude-missing-columns

It is possible to restore only selected table columns using this option, which causes ndb_restore to ignore any columns missing from tables being restored as compared to the versions of those tables found in the backup. This option applies to all tables being restored. If you wish to apply this option only to selected tables or databases, you can use it in combination with one or more of the --include-* or --exclude-* options described elsewhere in this section to do so, then restore data to the remaining tables using a complementary set of these options.

- --exclude-missing-tables

Introduced	5.5.40-ndb-7.2.18
Command-Line Format	--exclude-missing-tables

It is possible to restore only selected tables using this option, which causes ndb_restore to ignore any tables from the backup that are not found in the target database.

This option was introduced in NDB 7.2.18.

- --exclude-tables=*table-list*

Command-Line Format	--exclude-tables=table-list	
Permitted Values	Type	string
	Default	

List of one or more tables to exclude; each table reference must include the database name. Often used together with --exclude-databases.

When --exclude-databases or --exclude-tables is used, only those databases or tables named by the option are excluded; all other databases and tables are restored by ndb_restore.

This table shows several invocations of ndb_restore usng --exclude-* options (other options possibly required have been omitted for clarity), and the effects these options have on restoring from an NDB Cluster backup:

Option Used	Result
--exclude-databases=db1	All tables in all databases except db1 are restored; no tables in db1 are restored
--exclude-databases=db1,db2 (or --exclude-databases=db1 --exclude-databases=db2)	All tables in all databases except db1 and db2 are restored; no tables in db1 or db2 are restored
--exclude-tables=db1.t1	All tables except t1 in database db1 are restored; all other tables in db1 are restored; all tables in all other databases are restored
--exclude-tables=db1.t2,db2.t1 (or --exclude-tables=db1.t2 --exclude-tables=db2.t1)	All tables in database db1 except for t2 and all tables in database db2 except for table t1 are restored; no other tables in db1 or db2 are

Option Used	Result
	restored; all tables in all other databases are restored

You can use these two options together. For example, the following causes all tables in all databases *except for* databases `db1` and `db2`, and tables `t1` and `t2` in database `db3`, to be restored:

```
shell> ndb_restore [...] --exclude-databases=db1,db2 --exclude-tables=db3.t1,db3.t2
```

(Again, we have omitted other possibly necessary options in the interest of clarity and brevity from the example just shown.)

You can use `--include-*` and `--exclude-*` options together, subject to the following rules:

- The actions of all `--include-*` and `--exclude-*` options are cumulative.
- All `--include-*` and `--exclude-*` options are evaluated in the order passed to ndb_restore, from right to left.
- In the event of conflicting options, the first (rightmost) option takes precedence. In other words, the first option (going from right to left) that matches against a given database or table “wins”.

For example, the following set of options causes `ndb_restore` to restore all tables from database `db1` except `db1.t1`, while restoring no other tables from any other databases:

```
--include-databases=db1 --exclude-tables=db1.t1
```

However, reversing the order of the options just given simply causes all tables from database `db1` to be restored (including `db1.t1`, but no tables from any other database), because the `--include-databases` option, being farthest to the right, is the first match against database `db1` and thus takes precedence over any other option that matches `db1` or any tables in `db1`:

```
--exclude-tables=db1.t1 --include-databases=db1
```

- `--fields-enclosed-by=`*`char`*

Command-Line Format	`--fields-enclosed-by=char`	
Permitted Values	Type	string
	Default	

Each column value is enclosed by the string passed to this option (regardless of data type; see the description of `--fields-optionally-enclosed-by`).

- `--fields-optionally-enclosed-by`

Command-Line Format	`--fields-optionally-enclosed-by`	
Permitted Values	Type	string
	Default	

The string passed to this option is used to enclose column values containing character data (such as `CHAR`, `VARCHAR`, `BINARY`, `TEXT`, or `ENUM`).

- `--fields-terminated-by=`*`char`*

Command-Line Format	`--fields-terminated-by=char`	
Permitted Values	Type	string

	Default	`\t (tab)`

The string passed to this option is used to separate column values. The default value is a tab character (`\t`).

- `--hex`

Command-Line Format	`--hex`

If this option is used, all binary values are output in hexadecimal format.

- `--include-databases=`*`db-list`*

Command-Line Format	`--include-databases=db-list`	
Permitted Values	**Type**	string
	Default	

Comma-delimited list of one or more databases to restore. Often used together with `--include-tables`; see the description of that option for further information and examples.

- `--include-tables=`*`table-list`*

Command-Line Format	`--include-tables=table-list`	
Permitted Values	**Type**	string
	Default	

Comma-delimited list of tables to restore; each table reference must include the database name.

When `--include-databases` or `--include-tables` is used, only those databases or tables named by the option are restored; all other databases and tables are excluded by `ndb_restore`, and are not restored.

The following table shows several invocations of `ndb_restore` using `--include-*` options (other options possibly required have been omitted for clarity), and the effects these have on restoring from an NDB Cluster backup:

Option Used	Result
`--include-databases=db1`	Only tables in database `db1` are restored; all tables in all other databases are ignored
`--include-databases=db1,db2` (or `--include-databases=db1 --include-databases=db2`)	Only tables in databases `db1` and `db2` are restored; all tables in all other databases are ignored
`--include-tables=db1.t1`	Only table `t1` in database `db1` is restored; no other tables in `db1` or in any other database are restored
`--include-tables=db1.t2,db2.t1` (or `--include-tables=db1.t2 --include-tables=db2.t1`)	Only the table `t2` in database `db1` and the table `t1` in database `db2` are restored; no other tables in `db1`, `db2`, or any other database are restored

You can also use these two options together. For example, the following causes all tables in databases `db1` and `db2`, together with the tables `t1` and `t2` in database `db3`, to be restored (and no other databases or tables):

```
shell> ndb_restore [...] --include-databases=db1,db2 --include-tables=db3.t1,db3.t2
```

(Again we have omitted other, possibly required, options in the example just shown.)

It also possible to restore only selected databases, or selected tables from a single database, without any `--include-*` (or `--exclude-*`) options, using the syntax shown here:

```
ndb_restore other_options db_name,[db_name[,...] | tbl_name[,tbl_name][,...]]
```

In other words, you can specify either of the following to be restored:

- All tables from one or more databases
- One or more tables from a single database

- `--lines-terminated-by=char`

Command-Line Format	--lines-terminated-by=char	
Permitted Values	Type	string
	Default	\n (linebreak)

Specifies the string used to end each line of output. The default is a linefeed character (`\n`).

- `--lossy-conversions`, `-L`

Command-Line Format	--lossy-conversions	
Permitted Values	Type	boolean
	Default	FALSE

This option is intended to complement the `--promote-attributes` option. Using `--lossy-conversions` allows lossy conversions of column values (type demotions or changes in sign) when restoring data from backup. With some exceptions, the rules governing demotion are the same as for MySQL replication; see Replication of Columns Having Different Data Types, for information about specific type conversions currently supported by attribute demotion.

`ndb_restore` reports any truncation of data that it performs during lossy conversions once per attribute and column.

- `--no-binlog`

Command-Line Format	--no-binlog

This option prevents any connected SQL nodes from writing data restored by `ndb_restore` to their binary logs.

- `--no-restore-disk-objects`, `-d`

Command-Line Format	--no-restore-disk-objects	
Permitted Values	Type	boolean
	Default	FALSE

This option stops `ndb_restore` from restoring any NDB Cluster Disk Data objects, such as tablespaces and log file groups; see Section 18.5.12, “NDB Cluster Disk Data Tables”, for more information about these.

- `--no-upgrade`, `-u`

Command-Line Format	--no-upgrade

When using ndb_restore to restore a backup, VARCHAR columns created using the old fixed format are resized and recreated using the variable-width format now employed. This behavior can be overridden by specifying --no-upgrade.

- --ndb-nodegroup-map=*map*, -z

Command-Line Format	--ndb-nodegroup-map=map

This option can be used to restore a backup taken from one node group to a different node group. Its argument is a list of the form *source_node_group, target_node_group*.

- --nodeid=#, -n

Command-Line Format	--nodeid=#	
Permitted Values	Type	numeric
	Default	none

Specify the node ID of the data node on which the backup was taken.

When restoring to a cluster with different number of data nodes from that where the backup was taken, this information helps identify the correct set or sets of files to be restored to a given node. (In such cases, multiple files usually need to be restored to a single data node.) See Section 18.4.21.1, "Restoring to a different number of data nodes", for additional information and examples.

- --parallelism=#, -p

Command-Line Format	--parallelism=#	
Permitted Values	Type	numeric
	Default	128
	Minimum	1
	Maximum	1024

ndb_restore uses single-row transactions to apply many rows concurrently. This parameter determines the number of parallel transactions (concurrent rows) that an instance of ndb_restore tries to use. By default, this is 128; the minimum is 1, and the maximum is 1024.

The work of performing the inserts is parallelized across the threads in the data nodes involved. This mechanism is employed for restoring bulk data from the .Data file—that is, the fuzzy snapshot of the data; it is not used for building or rebuilding indexes. The change log is applied serially; index drops and builds are DDL operations and handled separately. There is no thread-level parallelism on the client side of the restore.

- --preserve-trailing-spaces, -P

Command-Line Format	--preserve-trailing-spaces

Cause trailing spaces to be preserved when promoting a fixed-width character data type to its variable-width equivalent—that is, when promoting a CHAR column value to VARCHAR, or a BINARY column value to VARBINARY. Otherwise, any trailing spaces are dropped from such column values when they are inserted into the new columns.

Note

Although you can promote CHAR columns to VARCHAR and BINARY columns to VARBINARY, you cannot promote VARCHAR columns to CHAR or VARBINARY columns to BINARY.

- `--print`

Command-Line Format	`--print`	
Permitted Values	Type	boolean
	Default	`FALSE`

Causes `ndb_restore` to print all data, metadata, and logs to `stdout`. Equivalent to using the `--print_data`, `--print_meta`, and `--print_log` options together.

Note

Use of `--print` or any of the `--print_*` options is in effect performing a dry run. Including one or more of these options causes any output to be redirected to `stdout`; in such cases, `ndb_restore` makes no attempt to restore data or metadata to an NDB Cluster.

- `--print_data`

Command-Line Format	`--print-data`	
Permitted Values	Type	boolean
	Default	`FALSE`

Cause `ndb_restore` to direct its output to `stdout`. Often used together with one or more of `--tab`, `--fields-enclosed-by`, `--fields-optionally-enclosed-by`, `--fields-terminated-by`, `--hex`, and `--append`.

`TEXT` and `BLOB` column values are always truncated. In NDB 7.2.18 and earlier, such values are truncated to the first 240 bytes in the output; in NDB 7.2.19 and later, they are truncated to 256 bytes. (Bug #14571512, Bug #65467) This cannot currently be overridden when using `--print_data`.

- `--print_log`

Command-Line Format	`--print-log`	
Permitted Values	Type	boolean
	Default	`FALSE`

Cause `ndb_restore` to output its log to `stdout`.

- `--print_meta`

Command-Line Format	`--print-meta`	
Permitted Values	Type	boolean
	Default	`FALSE`

Print all metadata to `stdout`.

- `--progress-frequency=N`

Command-Line Format	`--progress-frequency=#`	
Permitted Values	Type	numeric
	Default	`0`
	Minimum	`0`
	Maximum	`65535`

Print a status report each *N* seconds while the restore is in progress. 0 (the default) causes no status reports to be printed. The maximum is 65535.

- `--promote-attributes`, `-A`

Command-Line Format	`--promote-attributes`

`ndb_restore` supports limited *attribute promotion* in much the same way that it is supported by MySQL replication; that is, data backed up from a column of a given type can generally be restored to a column using a "larger, similar" type. For example, data from a `CHAR(20)` column can be restored to a column declared as `VARCHAR(20)`, `VARCHAR(30)`, or `CHAR(30)`; data from a `MEDIUMINT` column can be restored to a column of type `INT` or `BIGINT`. See Replication of Columns Having Different Data Types, for a table of type conversions currently supported by attribute promotion.

Attribute promotion by `ndb_restore` must be enabled explicitly, as follows:

1. Prepare the table to which the backup is to be restored. `ndb_restore` cannot be used to re-create the table with a different definition from the original; this means that you must either create the table manually, or alter the columns which you wish to promote using `ALTER TABLE` after restoring the table metadata but before restoring the data.

2. Invoke `ndb_restore` with the `--promote-attributes` option (short form `-A`) when restoring the table data. Attribute promotion does not occur if this option is not used; instead, the restore operation fails with an error.

Prior to NDB 7.2.14, conversions between character data types and `TEXT` or `BLOB` were not handled correctly.

Prior to NDB 7.2.18, demotion of `TEXT` to `TINYTEXT` was not handled correctly (Bug #18875137).

When converting between character data types and `TEXT` or `BLOB`, only conversions between character types (`CHAR` and `VARCHAR`) and binary types (`BINARY` and `VARBINARY`) can be performed at the same time. For example, you cannot promote an `INT` column to `BIGINT` while promoting a `VARCHAR` column to `TEXT` in the same invocation of `ndb_restore`.

Converting between `TEXT` columns using different character sets is not supported. Beginning with NDB 7.2.18, it is expressly disallowed (Bug #18875137).

When performing conversions of character or binary types to `TEXT` or `BLOB` with `ndb_restore`, you may notice that it creates and uses one or more staging tables named *`table_name`*`$ST`*`node_id`*. These tables are not needed afterwards, and are normally deleted by `ndb_restore` following a successful restoration.

- `--rebuild-indexes`

Command-Line Format	`--rebuild-indexes`

Enable multi-threaded rebuilding of the ordered indexes while restoring a native `NDB` backup. The number of threads used for building ordered indexes by `ndb_restore` with this option is controlled by the `BuildIndexThreads` data node configuration parameter and the number of LDMs.

It is necessary to use this option only for the first run of `ndb_restore`; this causes all ordered indexes to be rebuilt without using `--rebuild-indexes` again when restoring subsequent nodes. You should use this option prior to inserting new rows into the database; otherwise, it is possible for a row to be inserted that later causes a unique constraint violation when trying to rebuild the indexes.

Building of ordered indices is parallelized with the number of LDMs by default. Offline index builds performed during node and system restarts can be made faster using the `BuildIndexThreads`

data node configuration parameter; this parameter has no effect on dropping and rebuilding of indexes by ndb_restore, which is performed online.

Rebuilding of unique indexes uses disk write bandwidth for redo logging and local checkpointing. An insufficient amount of this bandwith can lead to redo buffer overload or log overload errors. In such cases you can run ndb_restore --rebuild-indexes again; the process resumes at the point where the error occurred. You can also do this when you have encountered temporary errors. You can repeat execution of ndb_restore --rebuild-indexes indefinitely; you may be able to stop such errors by reducing the value of --parallelism. If the problem is insufficient space, you can increase the size of the redo log (FragmentLogFileSize node configuration parameter), or you can increase the speed at which LCPs are performed (MaxDiskWriteSpeed and related parameters), in order to free space more quickly.

- --restore_data, -r

Command-Line Format	--restore-data	
Permitted Values	Type	boolean
	Default	FALSE

Output NDB table data and logs.

- --restore_epoch, -e

Command-Line Format	--restore-epoch

Add (or restore) epoch information to the cluster replication status table. This is useful for starting replication on an NDB Cluster replication slave. When this option is used, the row in the mysql.ndb_apply_status having 0 in the id column is updated if it already exists; such a row is inserted if it does not already exist. (See Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”.)

- --restore_meta, -m

Command-Line Format	--restore-meta	
Permitted Values	Type	boolean
	Default	FALSE

This option causes ndb_restore to print NDB table metadata.

The first time you run the ndb_restore restoration program, you also need to restore the metadata. In other words, you must re-create the database tables—this can be done by running it with the --restore_meta (-m) option. Restoring the metadata need be done only on a single data node; this is sufficient to restore it to the entire cluster.

Note

The cluster should have an empty database when starting to restore a backup. (In other words, you should start the data nodes with --initial prior to performing the restore.)

- --restore-privilege-tables

Command-Line Format	--restore-privilege-tables	
Permitted Values	Type	boolean
	Default	FALSE

ndb_restore does not by default restore distributed MySQL privilege tables. This option causes ndb_restore to restore the privilege tables.

This works only if the privilege tables were converted to NDB before the backup was taken. For more information, see Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”.

This option was added in NDB 7.2.0.

- --rewrite-database=*olddb,newdb*

Command-Line Format	--rewrite-database=olddb,newdb	
Permitted Values	Type	string
	Default	none

This option makes it possible to restore to a database having a different name from that used in the backup. For example, if a backup is made of a database named products, you can restore the data it contains to a database named inventory, use this option as shown here (omitting any other options that might be required):

```
shell> ndb_restore --rewrite-database=product,inventory
```

The option can be employed multiple times in a single invocation of ndb_restore. Thus it is possible to restore simultaneously from a database named db1 to a database named db2 and from a database named db3 to one named db4 using --rewrite-database=db1,db2 --rewrite-database=db3,db4. Other ndb_restore options may be used between multiple occurrences of --rewrite-database.

In the event of conflicts between multiple --rewrite-database options, the last --rewrite-database option used, reading from left to right, is the one that takes effect. For example, if --rewrite-database=db1,db2 --rewrite-database=db1,db3 is used, only --rewrite-database=db1,db3 is honored, and --rewrite-database=db1,db2 is ignored. It is also possible to restore from multiple databases to a single database, so that --rewrite-database=db1,db3 --rewrite-database=db2,db3 restores all tables and data from databases db1 and db2 into database db3.

Important

When restoring from multiple backup databases into a single target database using --rewrite-database, no check is made for collisions between table or other object names, and the order in which rows are restored is not guaranteed. This means that it is possible in such cases for rows to be overwritten and updates to be lost.

- --skip-broken-objects

Command-Line Format	--skip-broken-objects

This option causes ndb_restore to ignore corrupt tables while reading a native NDB backup, and to continue restoring any remaining tables (that are not also corrupted). Currently, the --skip-broken-objects option works only in the case of missing blob parts tables.

- --skip-table-check, -s

Command-Line Format	--skip-table-check

It is possible to restore data without restoring table metadata. By default when doing this, ndb_restore fails with an error if a mismatch is found between the table data and the table schema; this option overrides that behavior.

Some of the restrictions on mismatches in column definitions when restoring data using ndb_restore are relaxed; when one of these types of mismatches is encountered, ndb_restore does not stop with an error as it did previously, but rather accepts the data and inserts it into the target table while issuing a warning to the user that this is being done. This behavior occurs whether or not either of the options --skip-table-check or --promote-attributes is in use. These differences in column definitions are of the following types:

- Different COLUMN_FORMAT settings (FIXED, DYNAMIC, DEFAULT)
- Different STORAGE settings (MEMORY, DISK)
- Different default values
- Different distribution key settings

- --skip-unknown-objects

Command-Line Format	--skip-unknown-objects

This option causes ndb_restore to ignore any schema objects it does not recognize while reading a native NDB backup. This can be used for restoring a backup made from a cluster running NDB 7.5 to a cluster running NDB Cluster 7.4.

- --tab=*dir_name*, -T *dir_name*

Command-Line Format	--tab=dir_name	
Permitted Values	Type	directory name

Causes --print_data to create dump files, one per table, each named *tbl_name*.txt. It requires as its argument the path to the directory where the files should be saved; use . for the current directory.

- --verbose=#

Command-Line Format	--verbose=#	
Permitted Values	Type	numeric
	Default	1
	Minimum	0
	Maximum	255

Sets the level for the verbosity of the output. The minimum is 0; the maximum is 255. The default value is 1.

Error reporting.
ndb_restore reports both temporary and permanent errors. In the case of temporary errors, it may able to recover from them, and reports Restore successful, but encountered temporary error, please look at configuration in such cases.

Important

After using ndb_restore to initialize an NDB Cluster for use in circular replication, binary logs on the SQL node acting as the replication slave are not automatically created, and you must cause them to be created manually. To cause the binary logs to be created, issue a SHOW TABLES statement on that SQL node before running START SLAVE. This is a known issue in NDB Cluster.

18.4.21.1 Restoring to a different number of data nodes

It is possible to restore from an NDB backup to a cluster having a different number of data nodes than the original from which the backup was taken. The following two sections discuss, respectively, the cases where the target cluster has a lesser or greater number of data nodes than the source of the backup.

Restoring to Fewer Nodes Than the Original

You can restore to a cluster having fewer data nodes than the original provided that the larger number of nodes is an even multiple of the smaller number. In the following example, we use a backup taken on a cluster having four data nodes to a cluster having two data nodes.

1. The management server for the original cluster is on host `host10`. The original cluster has four data nodes, with the node IDs and host names shown in the following extract from the management server's `config.ini` file:

   ```
   [ndbd]
   NodeId=2
   HostName=host2

   [ndbd]
   NodeId=4
   HostName=host4

   [ndbd]
   NodeId=6
   HostName=host6

   [ndbd]
   NodeId=8
   HostName=host8
   ```

   We assume that each data node was originally started with `ndbmtd --ndb-connectstring=host10` or the equivalent.

2. Perform a backup in the normal manner. See Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”, for information about how to do this.

3. The files created by the backup on each data node are listed here, where *`N`* is the node ID and *`B`* is the backup ID.

   - `BACKUP-`*`B`*`-0.`*`N`*`.Data`
   - `BACKUP-`*`B`*`.`*`N`*`.ctl`
   - `BACKUP-`*`B`*`.`*`N`*`.log`

   These files are found under `BackupDataDir/BACKUP/BACKUP-`*`B`*, on each data node. For the rest of this example, we assume that the backup ID is 1.

   Have all of these files available for later copying to the new data nodes (where they can be accessed on the data node's local file system by `ndb_restore`). It is simplest to copy them all to a single location; we assume that this is what you have done.

4. The management server for the target cluster is on host `host20`, and the target has two data nodes, with the node IDs and host names shown, from the management server `config.ini` file on `host20`:

   ```
   [ndbd]
   NodeId=3
   hostname=host3

   [ndbd]
   ```

```
NodeId=5
hostname=host5
```

Each of the data node processes on host3 and host5 should be started with ndbmtd -c host20 --initial or the equivalent, so that the new (target) cluster starts with clean data node file systems.

5. Copy two different sets of two backup files to each of the target data nodes. For this example, copy the backup files from nodes 2 and 6 from the original cluster to node 3 in the target cluster. These files are listed here:

   - BACKUP-1-0.2.Data
   - BACKUP-1.2.ctl
   - BACKUP-1.2.log
   - BACKUP-1-0.6.Data
   - BACKUP-1.6.ctl
   - BACKUP-1.6.log

   Then copy the backup files from nodes 4 and 8 to node 5; these files are shown in the following list:

   - BACKUP-1-0.4.Data
   - BACKUP-1.4.ctl
   - BACKUP-1.4.log
   - BACKUP-1-0.8.Data
   - BACKUP-1.8.ctl
   - BACKUP-1.8.log

   For the remainder of this example, we assume that the respective backup files have been saved to the directory /BACKUP-1 on each of nodes 3 and 5.

6. On each of the two target data nodes, you must restore from both sets of backups. First, restore the backups from nodes 2 and 6 to node 3 by invoking ndb_restore on host3 as shown here:

```
shell> ndb_restore -c host20 --nodeid=2 --backupid=1 --restore_data --backup_path=/BACKUP-1

shell> ndb_restore -c host20 --nodeid=4 --backupid=1 --restore_data --backup_path=/BACKUP-1
```

   Then restore the backups from nodes 4 and 8 to node 5 by invoking ndb_restore on host5, like this:

```
shell> ndb_restore -c host20 --nodeid=6 --backupid=1 --restore_data --backup_path=/BACKUP-1

shell> ndb_restore -c host20 --nodeid=8 --backupid=1 --restore_data --backup_path=/BACKUP-1
```

Restoring to More Nodes Than the Original

The node ID specified for a given ndb_restore command is that of the node in the original backup and not that of the data node to restore it to. When performing a backup using the method described in this section, ndb_restore connects to the management server and obtains a list of data nodes in the cluster the backup is being restored to. The restored data is distributed accordingly, so that the number of nodes in the target cluster does not need to be to be known or calculated when performing the backup.

Note

When changing the total number of LCP threads or LQH threads per node group, you should recreate the schema from backup created using `mysqldump`.

1. *Create the backup of the data*. You can do this by invoking the `ndb_mgm` client `START BACKUP` command from the system shell, like this:

   ```
   shell> ndb_mgm -e "START BACKUP 1"
   ```

   This assumes that the desired backup ID is 1.

2. Create a backup of the schema (see also below):

   ```
   shell> mysqldump --no-data --routines --events --triggers --databases > myschema.sql
   ```

   Important

   You must not make any schema changes between the first and second steps.

3. Copy the backup directories from above to the new cluster. For example if the backup you want to restore is has ID 1 and `BackupDataDir` = `/backups/node_nodeid`, then the path to the backup on this node is `/backups/node_1/BACKUP/BACKUP-1`. Inside this directory there are three files, listed here:

   - `BACKUP-1-0.1.Data`
   - `BACKUP-1.1.ctl`
   - `BACKUP-1.1.log`

   You should copy the entire directory to the new node.

There is no requirement for the backup to be restored from a specific node or nodes.

To restore from the backup just created, perform the following steps:

1. *Restore the schema*. Import the schema file using the `mysql` client, as shown here:

   ```
   shell> mysql < myschema.sql
   ```

2. *Restore the data*. The following commands can be run in parallel:

   ```
   ndb_restore --nodeid=1 --backupid=1 --restore_data --backup_path=/backups/node_1/BACKUP/BACKUP-1 --disa
   ndb_restore --nodeid=2 --backupid=1 --restore_data --backup_path=/backups/node_2/BACKUP/BACKUP-1 --disa
   ndb_restore --nodeid=3 --backupid=1 --restore_data --backup_path=/backups/node_3/BACKUP/BACKUP-1 --disa
   ndb_restore --nodeid=4 --backupid=1 --restore_data --backup_path=/backups/node_4/BACKUP/BACKUP-1 --disa
   ndb_restore --nodeid=5 --backupid=1 --restore_data --backup_path=/backups/node_5/BACKUP/BACKUP-1 --disa
   ndb_restore --nodeid=6 --backupid=1 --restore_data --backup_path=/backups/node_6/BACKUP/BACKUP-1 --disa
   ndb_restore --nodeid=7 --backupid=1 --restore_data --backup_path=/backups/node_7/BACKUP/BACKUP-1 --disa
   ndb_restore --nodeid=8 --backupid=1 --restore_data --backup_path=/backups/node_8/BACKUP/BACKUP-1 --disa
   ```

   Add the `--ndb-connectstring` option as needed.

   If you in 3. for example copied the backups from the “old” nodes having node IDs 1 and 2 to a “new” node whose node ID is 1, you should perform the two invocations of `ndb_restore` with `--nodeid=1` and `--nodeid=2` on the new node that has 1 as its node ID.

3. *Rebuild the indexes*. These were disabled by the `--disable-indexes` option used in the commands just shown. Recreating the indexes avoids errors due to the restore not being consistent

at all points. Rebuilding the indexes can also improve performance in some cases. To rebuild the indexes, execute the following command once, on a single node:

```
shell> ndb_restore --nodeid=1 --backupid=1 --backup_path=/backups/node_1/BACKUP/BACKUP-1 --rebuild-i
```

Important

You should be aware that the supported number of partitions in each table depends on the number of data nodes, node groups, and LDM threads in the cluster. Other conditions (such as the values of `MaxNoOfExecutionThreads`, `ThreadConfig`, `NoOfReplicas`, and so on) being the same, a cluster with (for example) two data nodes supports fewer partitions than a cluster with eight data nodes supports. This means that using `ndb_restore --restore_meta` to restore the schema does not always work since this restores a given table with the same number of partitions as in the original; it is safer to restore the schema from a backup written by `mysqldump`—as in the example shown previously—when restoring to a cluster having fewer data nodes, LDM threads, or both, than were used in the original cluster.

The support for fewer partitions when restoring to a smaller cluster also means the maximum number of rows per table is lower. However, with the larger hash maps available in MySQL Cluster 7.2.9 and later (used by default for new tables), this is not likely to be an issue.

18.4.22 ndb_select_all — Print Rows from an NDB Table

`ndb_select_all` prints all rows from an `NDB` table to `stdout`.

Usage

```
ndb_select_all -c connection_string tbl_name -d db_name [> file_name]
```

The following table includes options that are specific to the NDB Cluster native backup restoration program `ndb_select_all`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_select_all`), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.86 This table describes command-line options for the ndb_select_all program

Format	Description	Added or Removed
`--database=dbname`, `-d`	Name of the database in which the table is found	All MySQL 5.5 based releases
`--parallelism=#`, `-p`	Degree of parallelism	All MySQL 5.5 based releases
`--lock=#`, `-l`	Lock type	All MySQL 5.5 based releases
`--order=index`, `-o`	Sort resultset according to index whose name is supplied	All MySQL 5.5 based releases
`--descending`, `-z`	Sort resultset in descending order (requires order flag)	All MySQL 5.5 based releases
`--header`, `-h`	Print header (set to 0|FALSE to disable headers in output)	All MySQL 5.5 based releases

Format	Description	Added or Removed
--useHexFormat, -x	Output numbers in hexadecimal format	All MySQL 5.5 based releases
--delimiter=char, -D	Set a column delimiter	All MySQL 5.5 based releases
--disk	Print disk references (useful only for Disk Data tables having nonindexed columns)	All MySQL 5.5 based releases
--rowid	Print rowid	All MySQL 5.5 based releases
--gci	Include GCI in output	All MySQL 5.5 based releases
--gci64	Include GCI and row epoch in output	All MySQL 5.5 based releases
--tupscan, -t	Scan in tup order	All MySQL 5.5 based releases
--nodata	Do not print table column data	All MySQL 5.5 based releases

- `--database=dbname`, `-d dbname`

  Name of the database in which the table is found. The default value is `TEST_DB`.

- `parallelism=#`, `-p #`

  Specifies the degree of parallelism.

- `--lock=lock_type`, `-l lock_type`

  Employs a lock when reading the table. Possible values for *`lock_type`* are:

  - `0`: Read lock
  - `1`: Read lock with hold
  - `2`: Exclusive read lock

  There is no default value for this option.

- `--order=index_name`, `-o index_name`

  Orders the output according to the index named *`index_name`*. Note that this is the name of an index, not of a column, and that the index must have been explicitly named when created.

- `--descending`, `-z`

  Sorts the output in descending order. This option can be used only in conjunction with the `-o` (`--order`) option.

- `--header=FALSE`

  Excludes column headers from the output.

- `--useHexFormat -x`

  Causes all numeric values to be displayed in hexadecimal format. This does not affect the output of numerals contained in strings or datetime values.

- `--delimiter=character`, `-D character`

Causes the *`character`* to be used as a column delimiter. Only table data columns are separated by this delimiter.

The default delimiter is the tab character.

- `--disk`

  Adds a disk reference column to the output. The column is nonempty only for Disk Data tables having nonindexed columns.

- `--rowid`

  Adds a `ROWID` column providing information about the fragments in which rows are stored.

- `--gci`

  Adds a `GCI` column to the output showing the global checkpoint at which each row was last updated. See Section 18.1, “NDB Cluster Overview”, and Section 18.5.6.2, “NDB Cluster Log Events”, for more information about checkpoints.

- `--gci64`

  Adds a `ROW$GCI64` column to the output showing the global checkpoint at which each row was last updated, as well as the number of the epoch in which this update occurred.

- `--tupscan`, `-t`

  Scan the table in the order of the tuples.

- `--nodata`

  Causes any table data to be omitted.

Sample Output

Output from a MySQL `SELECT` statement:

```
mysql> SELECT * FROM ctest1.fish;
+----+-----------+
| id | name      |
+----+-----------+
|  3 | shark     |
|  6 | puffer    |
|  2 | tuna      |
|  4 | manta ray |
|  5 | grouper   |
|  1 | guppy     |
+----+-----------+
6 rows in set (0.04 sec)
```

Output from the equivalent invocation of `ndb_select_all`:

```
shell> ./ndb_select_all -c localhost fish -d ctest1
id      name
3       [shark]
6       [puffer]
2       [tuna]
4       [manta ray]
5       [grouper]
1       [guppy]
6 rows returned

NDBT_ProgramExit: 0 - OK
```

All string values are enclosed by square brackets ([...]) in the output of ndb_select_all. Now consider the table created and populated as shown here:

```
CREATE TABLE dogs (
    id INT(11) NOT NULL AUTO_INCREMENT,
    name VARCHAR(25) NOT NULL,
    breed VARCHAR(50) NOT NULL,
    PRIMARY KEY pk (id),
    KEY ix (name)
)
TABLESPACE ts STORAGE DISK
ENGINE=NDBCLUSTER;

INSERT INTO dogs VALUES
    ('', 'Lassie', 'collie'),
    ('', 'Scooby-Doo', 'Great Dane'),
    ('', 'Rin-Tin-Tin', 'Alsatian'),
    ('', 'Rosscoe', 'Mutt');
```

This demonstrates the use of several additional ndb_select_all options:

```
shell> ./ndb_select_all -d ctest1 dogs -o ix -z --gci --disk
GCI     id name          breed        DISK_REF
834461  2  [Scooby-Doo]  [Great Dane] [ m_file_no: 0 m_page: 98 m_page_idx: 0 ]
834878  4  [Rosscoe]     [Mutt]       [ m_file_no: 0 m_page: 98 m_page_idx: 16 ]
834463  3  [Rin-Tin-Tin] [Alsatian]   [ m_file_no: 0 m_page: 34 m_page_idx: 0 ]
835657  1  [Lassie]      [Collie]     [ m_file_no: 0 m_page: 66 m_page_idx: 0 ]
4 rows returned

NDBT_ProgramExit: 0 - OK
```

18.4.23 ndb_select_count — Print Row Counts for NDB Tables

ndb_select_count prints the number of rows in one or more NDB tables. With a single table, the result is equivalent to that obtained by using the MySQL statement SELECT COUNT(*) FROM *tbl_name*.

Usage

```
ndb_select_count [-c connection_string] -ddb_name tbl_name[, tbl_name2[, ...]]
```

The following table includes options that are specific to the NDB Cluster native backup restoration program ndb_select_count. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_select_count), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.87 This table describes command-line options for the ndb_select_count program

Format	Description	Added or Removed
--database=dbname, -d	Name of the database in which the table is found	All MySQL 5.5 based releases
--parallelism=#, -p	Degree of parallelism	All MySQL 5.5 based releases
--lock=#, -l	Lock type	All MySQL 5.5 based releases

You can obtain row counts from multiple tables in the same database by listing the table names separated by spaces when invoking this command, as shown under **Sample Output**.

Sample Output

```
shell> ./ndb_select_count -c localhost -d ctest1 fish dogs
6 records in table fish
4 records in table dogs

NDBT_ProgramExit: 0 - OK
```

18.4.24 ndb_show_tables — Display List of NDB Tables

ndb_show_tables displays a list of all NDB database objects in the cluster. By default, this includes not only both user-created tables and NDB system tables, but NDB-specific indexes, internal triggers, and NDB Cluster Disk Data objects as well.

The following table includes options that are specific to the NDB Cluster native backup restoration program ndb_show_tables. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_show_tables), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.88 This table describes command-line options for the ndb_show_tables program

Format	Description	Added or Removed
--database=string, -d	Specifies the database in which the table is found	All MySQL 5.5 based releases
--loops=#, -l	Number of times to repeat output	All MySQL 5.5 based releases
--parsable, -p	Return output suitable for MySQL LOAD DATA INFILE statement	All MySQL 5.5 based releases
--show-temp-status	Show table temporary flag	All MySQL 5.5 based releases
--type=#, -t	Limit output to objects of this type	All MySQL 5.5 based releases
--unqualified, -u	Do not qualify table names	All MySQL 5.5 based releases

Usage

```
ndb_show_tables [-c connection_string]
```

- --database, -d

  Specifies the name of the database in which the tables are found.

- --loops, -l

  Specifies the number of times the utility should execute. This is 1 when this option is not specified, but if you do use the option, you must supply an integer argument for it.

- --parsable, -p

  Using this option causes the output to be in a format suitable for use with LOAD DATA INFILE.

- --show-temp-status

  If specified, this causes temporary tables to be displayed.

- `--type`, `-t`

  Can be used to restrict the output to one type of object, specified by an integer type code as shown here:

  - `1`: System table
  - `2`: User-created table
  - `3`: Unique hash index

  Any other value causes all `NDB` database objects to be listed (the default).

- `--unqualified`, `-u`

  If specified, this causes unqualified object names to be displayed.

Note

Only user-created NDB Cluster tables may be accessed from MySQL; system tables such as `SYSTAB_0` are not visible to `mysqld`. However, you can examine the contents of system tables using `NDB` API applications such as `ndb_select_all` (see Section 18.4.22, "`ndb_select_all` — Print Rows from an NDB Table").

18.4.25 `ndb_size.pl` — NDBCLUSTER Size Requirement Estimator

This is a Perl script that can be used to estimate the amount of space that would be required by a MySQL database if it were converted to use the `NDBCLUSTER` storage engine. Unlike the other utilities discussed in this section, it does not require access to an NDB Cluster (in fact, there is no reason for it to do so). However, it does need to access the MySQL server on which the database to be tested resides.

Requirements

- A running MySQL server. The server instance does not have to provide support for NDB Cluster.
- A working installation of Perl.
- The `DBI` module, which can be obtained from CPAN if it is not already part of your Perl installation. (Many Linux and other operating system distributions provide their own packages for this library.)
- A MySQL user account having the necessary privileges. If you do not wish to use an existing account, then creating one using `GRANT USAGE ON db_name.*`—where *`db_name`* is the name of the database to be examined—is sufficient for this purpose.

`ndb_size.pl` can also be found in the MySQL sources in `storage/ndb/tools`.

The following table includes options that are specific to the NDB Cluster program `ndb_size.pl`. Additional descriptions follow the table. For options common to most NDB Cluster programs (including `ndb_size.pl`), see Section 18.4.27, "Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs".

Table 18.89 This table describes command-line options for the ndb_size.pl program

Format	Description	Added or Removed
`--database=dbname`	The database or databases to examine; accepts a comma-delimited list; the default is ALL (use all databases found on the server)	All MySQL 5.5 based releases

Format	Description	Added or Removed
--hostname[:port]	Specify host and optional port as host[:port]	All MySQL 5.5 based releases
--socket=file_name	Specify a socket to connect to	All MySQL 5.5 based releases
--user=string	Specify a MySQL user name	All MySQL 5.5 based releases
--password=string	Specify a MySQL user password	All MySQL 5.5 based releases
--format=string	Set output format (text or HTML)	All MySQL 5.5 based releases
--excludetables=tbl_list	Skip any tables in a comma-separated list of tables	All MySQL 5.5 based releases
--excludedbs=db_list	Skip any databases in a comma-separated list of databases	All MySQL 5.5 based releases
--savequeries=file	Saves all queries to the database into the file specified	All MySQL 5.5 based releases
--loadqueries=file	Loads all queries from the file specified; does not connect to a database	All MySQL 5.5 based releases
--real_table_name=table	Designates a table to handle unique index size calculations	All MySQL 5.5 based releases

Usage

```
perl ndb_size.pl [--database={db_name|ALL}] [--hostname=host[:port]] [--socket=socket] \
      [--user=user] [--password=password]  \
      [--help|-h] [--format={html|text}] \
      [--loadqueries=file_name] [--savequeries=file_name]
```

By default, this utility attempts to analyze all databases on the server. You can specify a single database using the `--database` option; the default behavior can be made explicit by using `ALL` for the name of the database. You can also exclude one or more databases by using the `--excludedbs` option with a comma-separated list of the names of the databases to be skipped. Similarly, you can cause specific tables to be skipped by listing their names, separated by commas, following the optional `--excludetables` option. A host name can be specified using `--hostname`; the default is `localhost`. In NDB 7.2.6 and later, you can specify a port in addition to the host using *`host`*:*`port`* format for the value of `--hostname`. The default port number is 3306. If necessary, you can also specify a socket; the default is `/var/lib/mysql.sock`. A MySQL user name and password can be specified the corresponding options shown. It also possible to control the format of the output using the `--format` option; this can take either of the values `html` or `text`, with `text` being the default. An example of the text output is shown here:

```
shell> ndb_size.pl --database=test --socket=/tmp/mysql.sock
ndb_size.pl report for database: 'test' (1 tables)
----------------------------------------------------
Connected to: DBI:mysql:host=localhost;mysql_socket=/tmp/mysql.sock

Including information for versions: 4.1, 5.0, 5.1

test.t1
-------

DataMemory for Columns (* means varsized DataMemory):
         Column Name            Type  Varsized   Key  4.1  5.0   5.1
     HIDDEN_NDB_PKEY          bigint             PRI    8    8     8
                  c2     varchar(50)         Y         52   52    4*
                  c1         int(11)                    4    4     4
                                                       --   --    --
Fixed Size Columns DM/Row                              64   64    12
   Varsize Columns DM/Row                               0    0     4
```

```
DataMemory for Indexes:
   Index Name                Type        4.1        5.0        5.1
      PRIMARY               BTREE         16         16         16
                                          --         --         --
       Total Index DM/Row                 16         16         16

IndexMemory for Indexes:
               Index Name        4.1        5.0        5.1
                  PRIMARY         33         16         16
                                  --         --         --
           Indexes IM/Row         33         16         16

Summary (for THIS table):
                                 4.1        5.0        5.1
    Fixed Overhead DM/Row         12         12         16
           NULL Bytes/Row          4          4          4
           DataMemory/Row         96         96         48
                    (Includes overhead, bitmap and indexes)

  Varsize Overhead DM/Row          0          0          8
   Varsize NULL Bytes/Row          0          0          4
       Avg Varside DM/Row          0          0         16

                 No. Rows          0          0          0

        Rows/32kb DM Page        340        340        680
Fixedsize DataMemory (KB)          0          0          0

Rows/32kb Varsize DM Page          0          0       2040
  Varsize DataMemory (KB)          0          0          0

         Rows/8kb IM Page        248        512        512
         IndexMemory (KB)          0          0          0

Parameter Minimum Requirements
------------------------------
* indicates greater than default

                Parameter     Default        4.1        5.0        5.1
          DataMemory (KB)       81920          0          0          0
       NoOfOrderedIndexes         128          1          1          1
                NoOfTables         128          1          1          1
         IndexMemory (KB)       18432          0          0          0
    NoOfUniqueHashIndexes          64          0          0          0
            NoOfAttributes        1000          3          3          3
              NoOfTriggers         768          5          5          5
```

For debugging purposes, the Perl arrays containing the queries run by this script can be read from the file specified using can be saved to a file using `--savequeries`; a file containing such arrays to be read in during script execution can be specified using `--loadqueries`. Neither of these options has a default value.

To produce output in HTML format, use the `--format` option and redirect the output to a file, as shown here:

```
shell> ndb_size.pl --database=test --socket=/tmp/mysql.sock --format=html > ndb_size.html
```

(Without the redirection, the output is sent to `stdout`.)

The output from this script includes the following information:

- Minimum values for the `DataMemory`, `IndexMemory`, `MaxNoOfTables`, `MaxNoOfAttributes`, `MaxNoOfOrderedIndexes`, `MaxNoOfUniqueHashIndexes`, and `MaxNoOfTriggers` configuration parameters required to accommodate the tables analyzed.
- Memory requirements for all of the tables, attributes, ordered indexes, and unique hash indexes defined in the database.
- The `IndexMemory` and `DataMemory` required per table and table row.

18.4.26 ndb_waiter — Wait for NDB Cluster to Reach a Given Status

ndb_waiter repeatedly (each 100 milliseconds) prints out the status of all cluster data nodes until either the cluster reaches a given status or the --timeout limit is exceeded, then exits. By default, it waits for the cluster to achieve STARTED status, in which all nodes have started and connected to the cluster. This can be overridden using the --no-contact and --not-started options.

The node states reported by this utility are as follows:

- NO_CONTACT: The node cannot be contacted.
- UNKNOWN: The node can be contacted, but its status is not yet known. Usually, this means that the node has received a START or RESTART command from the management server, but has not yet acted on it.
- NOT_STARTED: The node has stopped, but remains in contact with the cluster. This is seen when restarting the node using the management client's RESTART command.
- STARTING: The node's ndbd process has started, but the node has not yet joined the cluster.
- STARTED: The node is operational, and has joined the cluster.
- SHUTTING_DOWN: The node is shutting down.
- SINGLE USER MODE: This is shown for all cluster data nodes when the cluster is in single user mode.

The following table includes options that are specific to the NDB Cluster native backup restoration program ndb_waiter. Additional descriptions follow the table. For options common to most NDB Cluster programs (including ndb_waiter), see Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”.

Table 18.90 This table describes command-line options for the ndb_waiter program

Format	Description	Added or Removed
--no-contact, -n	Wait for cluster to reach NO CONTACT state	All MySQL 5.5 based releases
--not-started	Wait for cluster to reach NOT STARTED state	All MySQL 5.5 based releases
--single-user	Wait for cluster to enter single user mode	All MySQL 5.5 based releases
--timeout=#, -t	Wait this many seconds, then exit whether or not cluster has reached desired state; default is 2 minutes (120 seconds)	All MySQL 5.5 based releases
--nowait-nodes=list	List of nodes not to be waited for.	All MySQL 5.5 based releases
--wait-nodes=list, -w	List of nodes to be waited for.	All MySQL 5.5 based releases

Usage

```
ndb_waiter [-c connection_string]
```

Additional Options

- --no-contact, -n

Instead of waiting for the STARTED state, ndb_waiter continues running until the cluster reaches NO_CONTACT status before exiting.

- --not-started

  Instead of waiting for the STARTED state, ndb_waiter continues running until the cluster reaches NOT_STARTED status before exiting.

- --timeout=*seconds*, -t *seconds*

  Time to wait. The program exits if the desired state is not achieved within this number of seconds. The default is 120 seconds (1200 reporting cycles).

- --single-user

  The program waits for the cluster to enter single user mode.

- --nowait-nodes=*list*

  When this option is used, ndb_waiter does not wait for the nodes whose IDs are listed. The list is comma-delimited; ranges can be indicated by dashes, as shown here:

```
shell> ndb_waiter --nowait-nodes=1,3,7-9
```

Important

Do *not* use this option together with the --wait-nodes option.

- --wait-nodes=*list*, -w *list*

  When this option is used, ndb_waiter waits only for the nodes whose IDs are listed. The list is comma-delimited; ranges can be indicated by dashes, as shown here:

```
shell> ndb_waiter --wait-nodes=2,4-6,10
```

Important

Do *not* use this option together with the --nowait-nodes option.

Sample Output. Shown here is the output from ndb_waiter when run against a 4-node cluster in which two nodes have been shut down and then started again manually. Duplicate reports (indicated by ...) are omitted.

```
shell> ./ndb_waiter -c localhost

Connecting to mgmsrv at (localhost)
State node 1 STARTED
State node 2 NO_CONTACT
State node 3 STARTED
State node 4 NO_CONTACT
Waiting for cluster enter state STARTED

...

State node 1 STARTED
State node 2 UNKNOWN
State node 3 STARTED
State node 4 NO_CONTACT
Waiting for cluster enter state STARTED

...
```

```
State node 1 STARTED
State node 2 STARTING
State node 3 STARTED
State node 4 NO_CONTACT
Waiting for cluster enter state STARTED

...

State node 1 STARTED
State node 2 STARTING
State node 3 STARTED
State node 4 UNKNOWN
Waiting for cluster enter state STARTED

...

State node 1 STARTED
State node 2 STARTING
State node 3 STARTED
State node 4 STARTING
Waiting for cluster enter state STARTED

...

State node 1 STARTED
State node 2 STARTED
State node 3 STARTED
State node 4 STARTING
Waiting for cluster enter state STARTED

...

State node 1 STARTED
State node 2 STARTED
State node 3 STARTED
State node 4 STARTED
Waiting for cluster enter state STARTED

NDBT_ProgramExit: 0 - OK
```

Note

If no connection string is specified, then `ndb_waiter` tries to connect to a management on `localhost`, and reports `Connecting to mgmsrv at (null)`.

18.4.27 Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs

All NDB Cluster programs accept the options described in this section, with the following exceptions:

- `mysqld`
- `ndb_print_backup_file`
- `ndb_print_schema_file`
- `ndb_print_sys_file`

Users of earlier NDB Cluster versions should note that some of these options have been changed to make them consistent with one another as well as with `mysqld`. You can use the `--help` option with any NDB Cluster program—with the exception of `ndb_print_backup_file`, `ndb_print_schema_file`, and `ndb_print_sys_file`—to view a list of the options which the program supports.

The options in the following table are common to all NDB Cluster executables (except those noted previously in this section).

Table 18.91 This table describes command-line options common to all MySQL NDB Cluster programs

Format	Description	Added or Removed
`--character-sets-dir=dir_name`	Directory where character sets are installed	All MySQL 5.5 based releases
`--core-file`	Write core on errors (defaults to TRUE in debug builds)	All MySQL 5.5 based releases
`--debug=options`	Enable output from debug calls. Can be used only for versions compiled with debugging enabled	All MySQL 5.5 based releases
`--defaults-extra-file=filename`	Read this file after global option files are read	All MySQL 5.5 based releases
`--defaults-file=filename`	Read default options from this file	All MySQL 5.5 based releases
`--help`, `--usage`, `-?`	Display help message and exit	All MySQL 5.5 based releases
`--ndb-connectstring=connectstring`, `--connect-string=connectstring`, `-c`	Set connection string for connecting to ndb_mgmd. Syntax: [nodeid=<id>;] [host=]<hostname>[:<port>]. Overrides entries specified in NDB_CONNECTSTRING or my.cnf.	All MySQL 5.5 based releases
`--ndb-mgmd-host=host[:port]`	Set the host (and port, if desired) for connecting to management server	All MySQL 5.5 based releases
`--ndb-nodeid=#`	Set node id for this node	All MySQL 5.5 based releases
`--ndb-optimized-node-selection`	Select nodes for transactions in a more optimal way	All MySQL 5.5 based releases
`--no-defaults`	Do not read default options from any option file other than login file	All MySQL 5.5 based releases
`--print-defaults`	Print the program argument list and exit	All MySQL 5.5 based releases
`--version`, `-V`	Output version information and exit	All MySQL 5.5 based releases

For options specific to individual NDB Cluster programs, see Section 18.4, “NDB Cluster Programs”.

See MySQL Server Options for NDB Cluster, for `mysqld` options relating to NDB Cluster.

- `--character-sets-dir=`*name*

Command-Line Format	`--character-sets-dir=dir_name`	
Permitted Values	Type	directory name
	Default	

Tells the program where to find character set information.

- `--core-file`

Command-Line Format	`--core-file`	
Permitted Values	Type	boolean
	Default	`FALSE`

Write a core file if the program dies. The name and location of the core file are system-dependent. (For NDB Cluster programs nodes running on Linux, the default location is the program's working directory—for a data node, this is the node's `DataDir`.) For some systems, there may be restrictions or limitations; for example, it might be necessary to execute `ulimit -c unlimited` before starting the server. Consult your system documentation for detailed information.

If NDB Cluster was built using the `--debug` option for `configure`, then `--core-file` is enabled by default. For regular builds, `--core-file` is disabled by default.

- `--debug[=options]`

Command-Line Format	`--debug=options`	
Permitted Values	Type	string
	Default	`d:t:O,/tmp/ndb_restore.trace`

This option can be used only for versions compiled with debugging enabled. It is used to enable output from debug calls in the same manner as for the `mysqld` process.

- `--defaults-extra-file=filename`

Command-Line Format	`--defaults-extra-file=filename`	
Permitted Values	Type	string
	Default	`[none]`

Read this file after global option files are read.

- `--defaults-file=filename`

Command-Line Format	`--defaults-file=filename`	
Permitted Values	Type	string
	Default	`[none]`

Read default options from this file.

- `--help`, `--usage`, `-?`

Command-Line Format	`--help`
	`--usage`

Prints a short list with descriptions of the available command options.

- `--ndb-connectstring=connection_string`, `--connect-string=connection_string`, `-c connection_string`

Command-Line Format	`--ndb-connectstring=connectstring`	
	`--connect-string=connectstring`	
Permitted Values	Type	string
	Default	`localhost:1186`

This option takes an NDB Cluster connection string that specifies the management server for the application to connect to, as shown here:

```
shell> ndbd --ndb-connectstring="nodeid=2;host=ndb_mgmd.mysql.com:1186"
```

For more information, see Section 18.3.3.3, “NDB Cluster Connection Strings”.

- `--ndb-mgmd-host=host[:port]`

Command-Line Format	`--ndb-mgmd-host=host[:port]`	
Permitted Values	Type	string
	Default	`localhost:1186`

Can be used to set the host and port number of a single management server for the program to connect to. If the program requires node IDs or references to multiple management servers (or both) in its connection information, use the `--ndb-connectstring` option instead.

- `--ndb-nodeid=#`

Command-Line Format	`--ndb-nodeid=#`	
Permitted Values	Type	numeric
	Default	`0`

Sets this node's NDB Cluster node ID. *The range of permitted values depends on the node's type (data, management, or API) and the NDB Cluster software version*. See Section 18.1.6.2, “Limits and Differences of NDB Cluster from Standard MySQL Limits”, for more information.

- `--no-defaults`

Command-Line Format	`--no-defaults`	
Permitted Values	Type	boolean
	Default	`TRUE`

Do not read default options from any option file other than login file.

- `--ndb-optimized-node-selection`

Command-Line Format	`--ndb-optimized-node-selection`	
Permitted Values	Type	boolean
	Default	`TRUE`

Optimize selection of nodes for transactions. Enabled by default.

- `--print-defaults`

Command-Line Format	`--print-defaults`	
Permitted Values	Type	boolean
	Default	`TRUE`

Print the program argument list and exit.

- `--version`, `-V`

Command-Line Format	`--version`

Prints the NDB Cluster version number of the executable. The version number is relevant because not all versions can be used together, and the NDB Cluster startup process verifies that the versions of the binaries being used can co-exist in the same cluster. This is also important when performing an online (rolling) software upgrade or downgrade of NDB Cluster.

See Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”), for more information.

18.5 Management of NDB Cluster

Managing an NDB Cluster involves a number of tasks, the first of which is to configure and start NDB Cluster. This is covered in Section 18.3, “Configuration of NDB Cluster”, and Section 18.4, “NDB Cluster Programs”.

The next few sections cover the management of a running NDB Cluster.

For information about security issues relating to management and deployment of an NDB Cluster, see Section 18.5.11, “NDB Cluster Security Issues”.

There are essentially two methods of actively managing a running NDB Cluster. The first of these is through the use of commands entered into the management client whereby cluster status can be checked, log levels changed, backups started and stopped, and nodes stopped and started. The second method involves studying the contents of the cluster log `ndb_node_id_cluster.log`; this is usually found in the management server's `DataDir` directory, but this location can be overridden using the `LogDestination` option. (Recall that *`node_id`* represents the unique identifier of the node whose activity is being logged.) The cluster log contains event reports generated by `ndbd`. It is also possible to send cluster log entries to a Unix system log.

Some aspects of the cluster's operation can be also be monitored from an SQL node using the `SHOW ENGINE NDB STATUS` statement.

More detailed information about NDB Cluster operations is available in real time through an SQL interface using the `ndbinfo` database. For more information, see Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”.

NDB statistics counters provide improved monitoring using the `mysql` client. These counters, implemented in the NDB kernel, relate to operations performed by or affecting `Ndb` objects, such as starting, closing, and aborting transactions; primary key and unique key operations; table, range, and pruned scans; blocked threads waiting for various operations to complete; and data and events sent and received by NDB Cluster. The counters are incremented by the NDB kernel whenever NDB API calls are made or data is sent to or received by the data nodes.

`mysqld` exposes the NDB API statistics counters as system status variables, which can be identified from the prefix common to all of their names (`Ndb_api_`). The values of these variables can be read in the `mysql` client from the output of a `SHOW STATUS` statement, or by querying either the `SESSION_STATUS` table or the `GLOBAL_STATUS` table (in the `INFORMATION_SCHEMA` database). By comparing the values of the status variables before and after the execution of an SQL statement that acts on `NDB` tables, you can observe the actions taken on the NDB API level that correspond to this statement, which can be beneficial for monitoring and performance tuning of NDB Cluster.

MySQL Cluster Manager provides an advanced command-line interface that simplifies many otherwise complex NDB Cluster management tasks, such as starting, stopping, or restarting an NDB Cluster with a large number of nodes. The MySQL Cluster Manager client also supports commands for getting and setting the values of most node configuration parameters as well as `mysqld` server options and variables relating to NDB Cluster. See MySQL™ Cluster Manager 1.3.6 User Manual, for more information.

18.5.1 Summary of NDB Cluster Start Phases

This section provides a simplified outline of the steps involved when NDB Cluster data nodes are started. More complete information can be found in NDB Cluster Start Phases, in the *NDB Internals Guide*.

These phases are the same as those reported in the output from the *`node_id`* `STATUS` command in the management client (see Section 18.5.2, "Commands in the NDB Cluster Management Client"). These start phases are also reported in the `start_phase` column of the `ndbinfo.nodes` table.

Start types. There are several different startup types and modes, as shown in the following list:

- **Initial start.** The cluster starts with a clean file system on all data nodes. This occurs either when the cluster started for the very first time, or when all data nodes are restarted using the `--initial` option.

  Note

  Disk Data files are not removed when restarting a node using `--initial`.

- **System restart.** The cluster starts and reads data stored in the data nodes. This occurs when the cluster has been shut down after having been in use, when it is desired for the cluster to resume operations from the point where it left off.

- **Node restart.** This is the online restart of a cluster node while the cluster itself is running.

- **Initial node restart.** This is the same as a node restart, except that the node is reinitialized and started with a clean file system.

Setup and initialization (phase -1). Prior to startup, each data node (`ndbd` process) must be initialized. Initialization consists of the following steps:

1. Obtain a node ID
2. Fetch configuration data
3. Allocate ports to be used for inter-node communications
4. Allocate memory according to settings obtained from the configuration file

When a data node or SQL node first connects to the management node, it reserves a cluster node ID. To make sure that no other node allocates the same node ID, this ID is retained until the node has managed to connect to the cluster and at least one `ndbd` reports that this node is connected. This retention of the node ID is guarded by the connection between the node in question and `ndb_mgmd`.

After each data node has been initialized, the cluster startup process can proceed. The stages which the cluster goes through during this process are listed here:

- **Phase 0.** The `NDBFS` and `NDBCNTR` blocks start (see NDB Kernel Blocks). Data node file systems are cleared on those data nodes that were started with `--initial` option.

- **Phase 1.** In this stage, all remaining `NDB` kernel blocks are started. NDB Cluster connections are set up, inter-block communications are established, and heartbeats are started. In the case of a node restart, API node connections are also checked.

  Note

  When one or more nodes hang in Phase 1 while the remaining node or nodes hang in Phase 2, this often indicates network problems. One possible cause of such issues is one or more cluster hosts having multiple network interfaces. Another common source of problems causing this condition is the blocking of TCP/IP ports needed for communications between cluster nodes. In the latter case, this is often due to a misconfigured firewall.

- **Phase 2.** The NDBCNTR kernel block checks the states of all existing nodes. The master node is chosen, and the cluster schema file is initialized.
- **Phase 3.** The DBLQH and DBTC kernel blocks set up communications between them. The startup type is determined; if this is a restart, the DBDIH block obtains permission to perform the restart.
- **Phase 4.** For an initial start or initial node restart, the redo log files are created. The number of these files is equal to NoOfFragmentLogFiles.

  For a system restart:

  - Read schema or schemas.
  - Read data from the local checkpoint.
  - Apply all redo information until the latest restorable global checkpoint has been reached.

  For a node restart, find the tail of the redo log.
- **Phase 5.** Most of the database-related portion of a data node start is performed during this phase. For an initial start or system restart, a local checkpoint is executed, followed by a global checkpoint. Periodic checks of memory usage begin during this phase, and any required node takeovers are performed.
- **Phase 6.** In this phase, node groups are defined and set up.
- **Phase 7.** The arbitrator node is selected and begins to function. The next backup ID is set, as is the backup disk write speed. Nodes reaching this start phase are marked as Started. It is now possible for API nodes (including SQL nodes) to connect to the cluster.
- **Phase 8.** If this is a system restart, all indexes are rebuilt (by DBDIH).
- **Phase 9.** The node internal startup variables are reset.
- **Phase 100 (OBSOLETE).** Formerly, it was at this point during a node restart or initial node restart that API nodes could connect to the node and begin to receive events. Currently, this phase is empty.
- **Phase 101.** At this point in a node restart or initial node restart, event delivery is handed over to the node joining the cluster. The newly-joined node takes over responsibility for delivering its primary data to subscribers. This phase is also referred to as *SUMA handover phase*.

After this process is completed for an initial start or system restart, transaction handling is enabled. For a node restart or initial node restart, completion of the startup process means that the node may now act as a transaction coordinator.

18.5.2 Commands in the NDB Cluster Management Client

In addition to the central configuration file, a cluster may also be controlled through a command-line interface available through the management client ndb_mgm. This is the primary administrative interface to a running cluster.

Commands for the event logs are given in Section 18.5.6, “Event Reports Generated in NDB Cluster”; commands for creating backups and restoring from them are provided in Section 18.5.3, “Online Backup of NDB Cluster”.

Using ndb_mgm with MySQL Cluster Manager. MySQL Cluster Manager handles starting and stopping processes and tracks their states internally, so it is not necessary to use ndb_mgm for these tasks for an NDB Cluster that is under MySQL Cluster Manager control. it is recommended *not* to use the ndb_mgm command-line client that comes with the NDB Cluster distribution to perform operations that involve starting or stopping nodes. These include but are not limited to the START, STOP, RESTART, and SHUTDOWN commands. For more information, see MySQL Cluster Manager Process Commands.

The management client has the following basic commands. In the listing that follows, *`node_id`* denotes either a database node ID or the keyword `ALL`, which indicates that the command should be applied to all of the cluster's data nodes.

- `HELP`

  Displays information on all available commands.

- `CONNECT` *`connection-string`*

  Connects to the management server indicated by the connection string. If the client is already connected to this server, the client reconnects.

- `SHOW`

  Displays information on the cluster's status. Possible node status values include `UNKNOWN`, `NO_CONTACT`, `NOT_STARTED`, `STARTING`, `STARTED`, `SHUTTING_DOWN`, and `RESTARTING`. The output from this command also indicates when the cluster is in single user mode (status `SINGLE USER MODE`).

- *`node_id`* `START`

  Brings online the data node identified by *`node_id`* (or all data nodes).

  `ALL START` works on all data nodes only, and does not affect management nodes.

  Important

  To use this command to bring a data node online, the data node must have been started using `--nostart` or `-n`.

- *`node_id`* `STOP [-a] [-f]`

  Stops the data or management node identified by *`node_id`*.

  Note

  `ALL STOP` works to stop all data nodes only, and does not affect management nodes.

  A node affected by this command disconnects from the cluster, and its associated `ndbd` or `ndb_mgmd` process terminates.

  The `-a` option causes the node to be stopped immediately, without waiting for the completion of any pending transactions.

  Normally, `STOP` fails if the result would cause an incomplete cluster. The `-f` option forces the node to shut down without checking for this. If this option is used and the result is an incomplete cluster, the cluster immediately shuts down.

  Warning

  Use of the `-a` option also disables the safety check otherwise performed when `STOP` is invoked to insure that stopping the node does not cause an incomplete cluster. In other words, you should exercise extreme care when using the `-a` option with the `STOP` command, due to the fact that this option makes it possible for the cluster to undergo a forced shutdown because it no longer has a complete copy of all data stored in `NDB`.

- *`node_id`* `RESTART [-n] [-i] [-a] [-f]`

  Restarts the data node identified by *`node_id`* (or all data nodes).

Using the `-i` option with `RESTART` causes the data node to perform an initial restart; that is, the node's file system is deleted and recreated. The effect is the same as that obtained from stopping the data node process and then starting it again using `ndbd --initial` from the system shell.

Note

Backup files and Disk Data files are not removed when this option is used.

Using the `-n` option causes the data node process to be restarted, but the data node is not actually brought online until the appropriate `START` command is issued. The effect of this option is the same as that obtained from stopping the data node and then starting it again using `ndbd --nostart` or `ndbd -n` from the system shell.

Using the `-a` causes all current transactions relying on this node to be aborted. No GCP check is done when the node rejoins the cluster.

Normally, `RESTART` fails if taking the node offline would result in an incomplete cluster. The `-f` option forces the node to restart without checking for this. If this option is used and the result is an incomplete cluster, the entire cluster is restarted.

- *`node_id`* `STATUS`

  Displays status information for the data node identified by *`node_id`* (or for all data nodes).

  The output from this command also indicates when the cluster is in single user mode.

- *`node_id`* `REPORT` *`report-type`*

  Displays a report of type *`report-type`* for the data node identified by *`node_id`*, or for all data nodes using `ALL`.

  Currently, there are three accepted values for *`report-type`*:

  - `BackupStatus` provides a status report on a cluster backup in progress
  - `MemoryUsage` displays how much data memory and index memory is being used by each data node as shown in this example:

    ```
    ndb_mgm> ALL REPORT MEMORY

    Node 1: Data usage is 5%(177 32K pages of total 3200)
    Node 1: Index usage is 0%(108 8K pages of total 12832)
    Node 2: Data usage is 5%(177 32K pages of total 3200)
    Node 2: Index usage is 0%(108 8K pages of total 12832)
    ```

    This information is also available from the `ndbinfo.memoryusage` table.

  - `EventLog` reports events from the event log buffers of one or more data nodes.

  `report-type` is case-insensitive and “fuzzy”; for `MemoryUsage`, you can use `MEMORY` (as shown in the prior example), `memory`, or even simply `MEM` (or `mem`). You can abbreviate `BackupStatus` in a similar fashion.

  Prior to NDB 7.2.10, `ALL REPORT BackupStatus` did not work correctly with multi-threaded data nodes. (Bug #15908907)

- `ENTER SINGLE USER MODE` *`node_id`*

  Enters single user mode, whereby only the MySQL server identified by the node ID *`node_id`* is permitted to access the database.

Currently, it is not possible for data nodes to join an NDB Cluster while it is running in single user mode. (Bug #20395)

- `EXIT SINGLE USER MODE`

  Exits single user mode, enabling all SQL nodes (that is, all running `mysqld` processes) to access the database.

  Note

  It is possible to use `EXIT SINGLE USER MODE` even when not in single user mode, although the command has no effect in this case.

- `QUIT`, `EXIT`

  Terminates the management client.

  This command does not affect any nodes connected to the cluster.

- `SHUTDOWN`

  Shuts down all cluster data nodes and management nodes. To exit the management client after this has been done, use `EXIT` or `QUIT`.

  This command does *not* shut down any SQL nodes or API nodes that are connected to the cluster.

- `CREATE NODEGROUP` *`nodeid`*`[, nodeid, ...]`

  Creates a new NDB Cluster node group and causes data nodes to join it.

  This command is used after adding new data nodes online to an NDB Cluster, and causes them to join a new node group and thus to begin participating fully in the cluster. The command takes as its sole parameter a comma-separated list of node IDs—these are the IDs of the nodes just added and started that are to join the new node group. The number of nodes must be the same as the number of nodes in each node group that is already part of the cluster (each NDB Cluster node group must have the same number of nodes). In other words, if the NDB Cluster has 2 node groups of 2 data nodes each, then the new node group must also have 2 data nodes.

  The node group ID of the new node group created by this command is determined automatically, and always the next highest unused node group ID in the cluster; it is not possible to set it manually.

  For more information, see Section 18.5.13, “Adding NDB Cluster Data Nodes Online”.

- `DROP NODEGROUP` *`nodegroup_id`*

  Drops the NDB Cluster node group with the given *`nodegroup_id`*.

  This command can be used to drop a node group from an NDB Cluster. `DROP NODEGROUP` takes as its sole argument the node group ID of the node group to be dropped.

  `DROP NODEGROUP` acts only to remove the data nodes in the effected node group from that node group. It does not stop data nodes, assign them to a different node group, or remove them from the cluster's configuration. A data node that does not belong to a node group is indicated in the output of the management client `SHOW` command with `no nodegroup` in place of the node group ID, like this (indicated using bold text):

  ```
  id=3    @10.100.2.67  (5.5.58-ndb-7.2.32, no nodegroup)
  ```

  Prior to NDB 7.0.4, the `SHOW` output was not updated correctly following `DROP NODEGROUP`. (Bug #43413)

`DROP NODEGROUP` works only when all data nodes in the node group to be dropped are completely empty of any table data and table definitions. Since there is currently no way using `ndb_mgm` or the `mysql` client to remove all data from a specific data node or node group, this means that the command succeeds only in the two following cases:

1. After issuing `CREATE NODEGROUP` in the `ndb_mgm` client, but before issuing any `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statements in the `mysql` client.
2. After dropping all `NDBCLUSTER` tables using `DROP TABLE`.

   `TRUNCATE TABLE` does not work for this purpose because this removes only the table data; the data nodes continue to store an `NDBCLUSTER` table's definition until a `DROP TABLE` statement is issued that causes the table metadata to be dropped.

For more information about `DROP NODEGROUP`, see Section 18.5.13, “Adding NDB Cluster Data Nodes Online”.

Additional commands. A number of other commands available in the `ndb_mgm` client are described elsewhere, as shown in the following list:

- `START BACKUP` is used to perform an online backup in the `ndb_mgm` client; the `ABORT BACKUP` command is used to cancel a backup already in progress. For more information, see Section 18.5.3, “Online Backup of NDB Cluster”.
- The `CLUSTERLOG` command is used to perform various logging functions. See Section 18.5.6, “Event Reports Generated in NDB Cluster”, for more information and examples.
- For testing and diagnostics work, the client also supports a `DUMP` command which can be used to execute internal commands on the cluster. It should never be used in a production setting unless directed to do so by MySQL Support. For more information, see MySQL NDB Cluster Internals Manual.

18.5.3 Online Backup of NDB Cluster

The next few sections describe how to prepare for and then to create an NDB Cluster backup using the functionality for this purpose found in the `ndb_mgm` management client. To distinguish this type of backup from a backup made using `mysqldump`, we sometimes refer to it as a “native” NDB Cluster backup. (For information about the creation of backups with `mysqldump`, see Section 4.5.4, “`mysqldump` — A Database Backup Program”.) Restoration of NDB Cluster backups is done using the `ndb_restore` utility provided with the NDB Cluster distribution; for information about `ndb_restore` and its use in restoring NDB Cluster backups, see Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”.

18.5.3.1 NDB Cluster Backup Concepts

A backup is a snapshot of the database at a given time. The backup consists of three main parts:

- **Metadata.** The names and definitions of all database tables
- **Table records.** The data actually stored in the database tables at the time that the backup was made
- **Transaction log.** A sequential record telling how and when data was stored in the database

Each of these parts is saved on all nodes participating in the backup. During backup, each node saves these three parts into three files on disk:

- `BACKUP-`*`backup_id`*`.`*`node_id`*`.ctl`

  A control file containing control information and metadata. Each node saves the same table definitions (for all tables in the cluster) to its own version of this file.

- `BACKUP-backup_id-0.node_id.data`

  A data file containing the table records, which are saved on a per-fragment basis. That is, different nodes save different fragments during the backup. The file saved by each node starts with a header that states the tables to which the records belong. Following the list of records there is a footer containing a checksum for all records.

- `BACKUP-backup_id.node_id.log`

  A log file containing records of committed transactions. Only transactions on tables stored in the backup are stored in the log. Nodes involved in the backup save different records because different nodes host different database fragments.

In the listing just shown, *`backup_id`* stands for the backup identifier and *`node_id`* is the unique identifier for the node creating the file.

The location of the backup files is determined by the `BackupDataDir` parameter.

18.5.3.2 Using The NDB Cluster Management Client to Create a Backup

Before starting a backup, make sure that the cluster is properly configured for performing one. (See Section 18.5.3.3, “Configuration for NDB Cluster Backups”.)

The `START BACKUP` command is used to create a backup:

```
START BACKUP [backup_id] [wait_option] [snapshot_option]

wait_option:
WAIT {STARTED | COMPLETED} | NOWAIT

snapshot_option:
SNAPSHOTSTART | SNAPSHOTEND
```

Successive backups are automatically identified sequentially, so the *`backup_id`*, an integer greater than or equal to 1, is optional; if it is omitted, the next available value is used. If an existing *`backup_id`* value is used, the backup fails with the error `Backup failed: file already exists`. If used, the *`backup_id`* must follow `START BACKUP` immediately, before any other options are used.

The *`wait_option`* can be used to determine when control is returned to the management client after a `START BACKUP` command is issued, as shown in the following list:

- If `NOWAIT` is specified, the management client displays a prompt immediately, as seen here:

  ```
  ndb_mgm> START BACKUP NOWAIT
  ndb_mgm>
  ```

  In this case, the management client can be used even while it prints progress information from the backup process.

- With `WAIT STARTED` the management client waits until the backup has started before returning control to the user, as shown here:

  ```
  ndb_mgm> START BACKUP WAIT STARTED
  Waiting for started, this may take several minutes
  Node 2: Backup 3 started from node 1
  ndb_mgm>
  ```

- **`WAIT COMPLETED`** causes the management client to wait until the backup process is complete before returning control to the user.

`WAIT COMPLETED` is the default.

A *snapshot_option* can be used to determine whether the backup matches the state of the cluster when START BACKUP was issued, or when it was completed. SNAPSHOTSTART causes the backup to match the state of the cluster when the backup began; SNAPSHOTEND causes the backup to reflect the state of the cluster when the backup was finished. SNAPSHOTEND is the default, and matches the behavior found in previous NDB Cluster releases.

Note

If you use the SNAPSHOTSTART option with START BACKUP, and the CompressedBackup parameter is enabled, only the data and control files are compressed—the log file is not compressed.

If both a *wait_option* and a *snapshot_option* are used, they may be specified in either order. For example, all of the following commands are valid, assuming that there is no existing backup having 4 as its ID:

```
START BACKUP WAIT STARTED SNAPSHOTSTART
START BACKUP SNAPSHOTSTART WAIT STARTED
START BACKUP 4 WAIT COMPLETED SNAPSHOTSTART
START BACKUP SNAPSHOTEND WAIT COMPLETED
START BACKUP 4 NOWAIT SNAPSHOTSTART
```

The procedure for creating a backup consists of the following steps:

1. Start the management client (ndb_mgm), if it not running already.
2. Execute the **START BACKUP** command. This produces several lines of output indicating the progress of the backup, as shown here:

   ```
   ndb_mgm> START BACKUP
   Waiting for completed, this may take several minutes
   Node 2: Backup 1 started from node 1
   Node 2: Backup 1 started from node 1 completed
    StartGCP: 177 StopGCP: 180
    #Records: 7362 #LogRecords: 0
    Data: 453648 bytes Log: 0 bytes
   ndb_mgm>
   ```

3. When the backup has started the management client displays this message:

   ```
   Backup backup_id started from node node_id
   ```

   backup_id is the unique identifier for this particular backup. This identifier is saved in the cluster log, if it has not been configured otherwise. *node_id* is the identifier of the management server that is coordinating the backup with the data nodes. At this point in the backup process the cluster has received and processed the backup request. It does not mean that the backup has finished. An example of this statement is shown here:

   ```
   Node 2: Backup 1 started from node 1
   ```

4. The management client indicates with a message like this one that the backup has started:

   ```
   Backup backup_id started from node node_id completed
   ```

   As is the case for the notification that the backup has started, *backup_id* is the unique identifier for this particular backup, and *node_id* is the node ID of the management server that is coordinating the backup with the data nodes. This output is accompanied by additional information including relevant global checkpoints, the number of records backed up, and the size of the data, as shown here:

   ```
   ```

```
Node 2: Backup 1 started from node 1 completed
 StartGCP: 177 StopGCP: 180
 #Records: 7362 #LogRecords: 0
 Data: 453648 bytes Log: 0 bytes
```

It is also possible to perform a backup from the system shell by invoking `ndb_mgm` with the `-e` or `--execute` option, as shown in this example:

```
shell> ndb_mgm -e "START BACKUP 6 WAIT COMPLETED SNAPSHOTSTART"
```

When using `START BACKUP` in this way, you must specify the backup ID.

Cluster backups are created by default in the `BACKUP` subdirectory of the `DataDir` on each data node. This can be overridden for one or more data nodes individually, or for all cluster data nodes in the `config.ini` file using the `BackupDataDir` configuration parameter. The backup files created for a backup with a given *`backup_id`* are stored in a subdirectory named `BACKUP-`*`backup_id`* in the backup directory.

Cancelling backups. To cancel or abort a backup that is already in progress, perform the following steps:

1. Start the management client.
2. Execute this command:

   ```
   ndb_mgm> ABORT BACKUP backup_id
   ```

   The number *`backup_id`* is the identifier of the backup that was included in the response of the management client when the backup was started (in the message `Backup` *`backup_id`* `started from node` *`management_node_id`*).
3. The management client will acknowledge the abort request with `Abort of backup` *`backup_id`* `ordered`.

   Note

   At this point, the management client has not yet received a response from the cluster data nodes to this request, and the backup has not yet actually been aborted.
4. After the backup has been aborted, the management client will report this fact in a manner similar to what is shown here:

   ```
   Node 1: Backup 3 started from 5 has been aborted.
     Error: 1321 - Backup aborted by user request: Permanent error: User defined error
   Node 3: Backup 3 started from 5 has been aborted.
     Error: 1323 - 1323: Permanent error: Internal error
   Node 2: Backup 3 started from 5 has been aborted.
     Error: 1323 - 1323: Permanent error: Internal error
   Node 4: Backup 3 started from 5 has been aborted.
     Error: 1323 - 1323: Permanent error: Internal error
   ```

   In this example, we have shown sample output for a cluster with 4 data nodes, where the sequence number of the backup to be aborted is 3, and the management node to which the cluster management client is connected has the node ID 5. The first node to complete its part in aborting the backup reports that the reason for the abort was due to a request by the user. (The remaining nodes report that the backup was aborted due to an unspecified internal error.)

   Note

   There is no guarantee that the cluster nodes respond to an `ABORT BACKUP` command in any particular order.

The `Backup backup_id started from node management_node_id has been aborted` messages mean that the backup has been terminated and that all files relating to this backup have been removed from the cluster file system.

It is also possible to abort a backup in progress from a system shell using this command:

```
shell> ndb_mgm -e "ABORT BACKUP backup_id"
```

Note

If there is no backup having the ID *`backup_id`* running when an `ABORT BACKUP` is issued, the management client makes no response, nor is it indicated in the cluster log that an invalid abort command was sent.

18.5.3.3 Configuration for NDB Cluster Backups

Five configuration parameters are essential for backup:

- `BackupDataBufferSize`

  The amount of memory used to buffer data before it is written to disk.

- `BackupLogBufferSize`

  The amount of memory used to buffer log records before these are written to disk.

- `BackupMemory`

  The total memory allocated in a data node for backups. This should be the sum of the memory allocated for the backup data buffer and the backup log buffer.

- `BackupWriteSize`

  The default size of blocks written to disk. This applies for both the backup data buffer and the backup log buffer.

- `BackupMaxWriteSize`

  The maximum size of blocks written to disk. This applies for both the backup data buffer and the backup log buffer.

More detailed information about these parameters can be found in Backup Parameters.

You can also set a location for the backup files using the `BackupDataDir` configuration parameter. The default is `FileSystemPath/BACKUP/BACKUP-backup_id`.

18.5.3.4 NDB Cluster Backup Troubleshooting

If an error code is returned when issuing a backup request, the most likely cause is insufficient memory or disk space. You should check that there is enough memory allocated for the backup.

Important

If you have set `BackupDataBufferSize` and `BackupLogBufferSize` and their sum is greater than 4MB, then you must also set `BackupMemory` as well.

You should also make sure that there is sufficient space on the hard drive partition of the backup target.

`NDB` does not support repeatable reads, which can cause problems with the restoration process. Although the backup process is “hot”, restoring an NDB Cluster from backup is not a 100% “hot”

process. This is due to the fact that, for the duration of the restore process, running transactions get nonrepeatable reads from the restored data. This means that the state of the data is inconsistent while the restore is in progress.

18.5.4 MySQL Server Usage for NDB Cluster

`mysqld` is the traditional MySQL server process. To be used with NDB Cluster, `mysqld` needs to be built with support for the `NDB` storage engine, as it is in the precompiled binaries available from http://dev.mysql.com/downloads/. If you build MySQL from source, you must invoke `CMake` with the `-DWITH_NDBCLUSTER=1` option to include support for `NDB`.

For more information about compiling NDB Cluster from source, see Section 18.2.1.4, "Building NDB Cluster from Source on Linux", and Section 18.2.2.2, "Compiling and Installing NDB Cluster from Source on Windows".

(For information about `mysqld` options and variables, in addition to those discussed in this section, which are relevant to NDB Cluster, see Section 18.3.3.8, "MySQL Server Options and Variables for NDB Cluster".)

If the `mysqld` binary has been built with Cluster support, the `NDBCLUSTER` storage engine is still disabled by default. You can use either of two possible options to enable this engine:

- Use `--ndbcluster` as a startup option on the command line when starting `mysqld`.
- Insert a line containing `ndbcluster` in the `[mysqld]` section of your `my.cnf` file.

An easy way to verify that your server is running with the `NDBCLUSTER` storage engine enabled is to issue the `SHOW ENGINES` statement in the MySQL Monitor (`mysql`). You should see the value `YES` as the `Support` value in the row for `NDBCLUSTER`. If you see `NO` in this row or if there is no such row displayed in the output, you are not running an `NDB`-enabled version of MySQL. If you see `DISABLED` in this row, you need to enable it in either one of the two ways just described.

To read cluster configuration data, the MySQL server requires at a minimum three pieces of information:

- The MySQL server's own cluster node ID
- The host name or IP address for the management server (MGM node)
- The number of the TCP/IP port on which it can connect to the management server

Node IDs can be allocated dynamically, so it is not strictly necessary to specify them explicitly.

The `mysqld` parameter `ndb-connectstring` is used to specify the connection string either on the command line when starting `mysqld` or in `my.cnf`. The connection string contains the host name or IP address where the management server can be found, as well as the TCP/IP port it uses.

In the following example, `ndb_mgmd.mysql.com` is the host where the management server resides, and the management server listens for cluster messages on port 1186:

```
shell> mysqld --ndbcluster --ndb-connectstring=ndb_mgmd.mysql.com:1186
```

See Section 18.3.3.3, "NDB Cluster Connection Strings", for more information on connection strings.

Given this information, the MySQL server will be a full participant in the cluster. (We often refer to a `mysqld` process running in this manner as an SQL node.) It will be fully aware of all cluster data nodes as well as their status, and will establish connections to all data nodes. In this case, it is able to use any data node as a transaction coordinator and to read and update node data.

You can see in the `mysql` client whether a MySQL server is connected to the cluster using `SHOW PROCESSLIST`. If the MySQL server is connected to the cluster, and you have the `PROCESS` privilege, then the first row of the output is as shown here:

```
mysql> SHOW PROCESSLIST \G
*************************** 1. row ***************************
     Id: 1
   User: system user
   Host:
     db:
Command: Daemon
   Time: 1
  State: Waiting for event from ndbcluster
   Info: NULL
```

Important

To participate in an NDB Cluster, the `mysqld` process must be started with *both* the options `--ndbcluster` and `--ndb-connectstring` (or their equivalents in `my.cnf`). If `mysqld` is started with only the `--ndbcluster` option, or if it is unable to contact the cluster, it is not possible to work with `NDB` tables, *nor is it possible to create any new tables regardless of storage engine*. The latter restriction is a safety measure intended to prevent the creation of tables having the same names as `NDB` tables while the SQL node is not connected to the cluster. If you wish to create tables using a different storage engine while the `mysqld` process is not participating in an NDB Cluster, you must restart the server *without* the `--ndbcluster` option.

18.5.5 Performing a Rolling Restart of an NDB Cluster

This section discusses how to perform a *rolling restart* of an NDB Cluster installation, so called because it involves stopping and starting (or restarting) each node in turn, so that the cluster itself remains operational. This is often done as part of a *rolling upgrade* or *rolling downgrade*, where high availability of the cluster is mandatory and no downtime of the cluster as a whole is permissible. Where we refer to upgrades, the information provided here also generally applies to downgrades as well.

There are a number of reasons why a rolling restart might be desirable. These are described in the next few paragraphs.

Configuration change.
To make a change in the cluster's configuration, such as adding an SQL node to the cluster, or setting a configuration parameter to a new value.

NDB Cluster software upgrade or downgrade. To upgrade the cluster to a newer version of the NDB Cluster software (or to downgrade it to an older version). This is usually referred to as a “rolling upgrade” (or “rolling downgrade”, when reverting to an older version of NDB Cluster).

Change on node host. To make changes in the hardware or operating system on which one or more NDB Cluster node processes are running.

System reset (cluster reset).
To reset the cluster because it has reached an undesirable state. In such cases it is often desirable to reload the data and metadata of one or more data nodes. This can be done in any of three ways:

- Start each data node process (`ndbd` or possibly `ndbmtd`) with the `--initial` option, which forces the data node to clear its file system and to reload all NDB Cluster data and metadata from the other data nodes.
- Create a backup using the `ndb_mgm` client `START BACKUP` command prior to performing the restart. Following the upgrade, restore the node or nodes using `ndb_restore`.

  See Section 18.5.3, “Online Backup of NDB Cluster”, and Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”, for more information.
- Use `mysqldump` to create a backup prior to the upgrade; afterward, restore the dump using `LOAD DATA INFILE`.

Resource Recovery.
To free memory previously allocated to a table by successive `INSERT` and `DELETE` operations, for re-use by other NDB Cluster tables.

The process for performing a rolling restart may be generalized as follows:

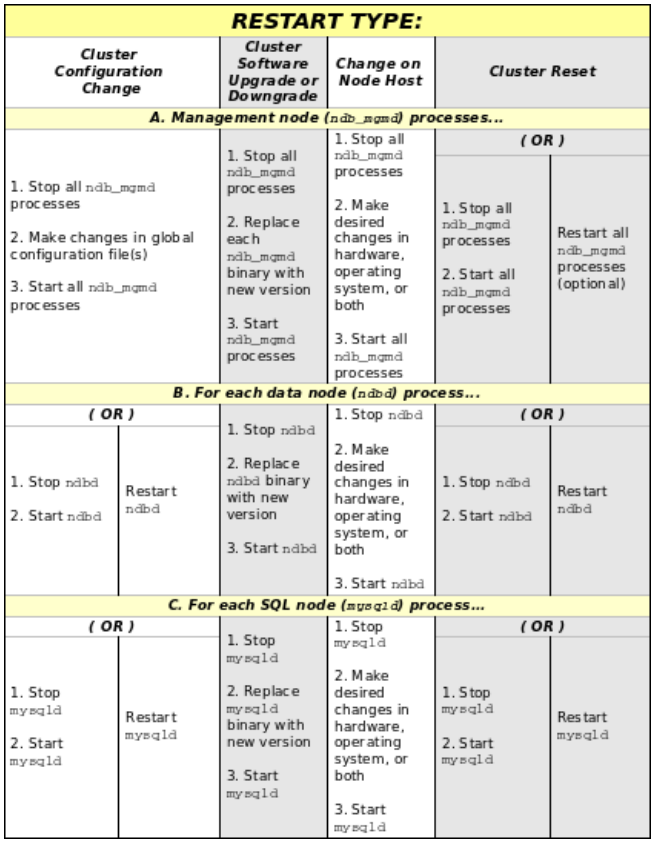
1. Stop all cluster management nodes (`ndb_mgmd` processes), reconfigure them, then restart them. (See Rolling restarts with multiple management servers.)

2. Stop, reconfigure, then restart each cluster data node (`ndbd` process) in turn.

3. Stop, reconfigure, then restart each cluster SQL node (`mysqld` process) in turn.

The specifics for implementing a given rolling upgrade depend upon the changes being made. A more detailed view of the process is presented here:

Figure 18.6 NDB Cluster Rolling Restarts By Type



In the previous diagram, the **Stop** and **Start** steps indicate that the process must be stopped completely using a shell command (such as `kill` on most Unix systems) or the management client `STOP` command, then started again from a system shell by invoking the `ndbd` or `ndb_mgmd` executable as appropriate. On Windows, you can also use the system `NET START` and `NET STOP` commands or the Windows Service Manager to start and stop nodes which have been installed as Windows services (see Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”).

Restart indicates that the process may be restarted using the `ndb_mgm` management client `RESTART` command.

NDB Cluster supports a flexible order for upgrading nodes. When upgrading an NDB Cluster, you may upgrade API nodes (including SQL nodes) before upgrading the management nodes, data nodes, or both. In other words, you are permitted to upgrade the API and SQL nodes in any order. This is subject to the following provisions:

- This functionality is intended for use as part of an online upgrade only. A mix of node binaries from different NDB Cluster releases is neither intended nor supported for continuous, long-term use in a production setting.
- All management nodes must be upgraded before any data nodes are upgraded. This remains true regardless of the order in which you upgrade the cluster's API and SQL nodes.
- Features specific to the “new” version must not be used until all management nodes and data nodes have been upgraded.

  This also applies to any MySQL Server version change that may apply, in addition to the NDB engine version change, so do not forget to take this into account when planning the upgrade. (This is true for online upgrades of NDB Cluster in general.)

See also Bug #48528 and Bug #49163.

Note

It is not possible for any API node to perform schema operations (such as data definition statements) during a node restart.

Rolling restarts with multiple management servers. When performing a rolling restart of an NDB Cluster with multiple management nodes, you should keep in mind that `ndb_mgmd` checks to see if any other management node is running, and, if so, tries to use that node's configuration data. To keep this from occurring, and to force `ndb_mgmd` to reread its configuration file, perform the following steps:

1. Stop all NDB Cluster `ndb_mgmd` processes.
2. Update all `config.ini` files.
3. Start a single `ndb_mgmd` with `--reload`, `--initial`, or both options as desired.
4. If you started the first `ndb_mgmd` with the `--initial` option, you must also start any remaining `ndb_mgmd` processes using `--initial`.

   Regardless of any other options used when starting the first `ndb_mgmd`, you should not start any remaining `ndb_mgmd` processes after the first one using `--reload`.
5. Complete the rolling restarts of the data nodes and API nodes as normal.

When performing a rolling restart to update the cluster's configuration, you can use the `config_generation` column of the `ndbinfo.nodes` table to keep track of which data nodes have been successfully restarted with the new configuration. See Section 18.5.10.13, “The ndbinfo nodes Table”.

18.5.6 Event Reports Generated in NDB Cluster

In this section, we discuss the types of event logs provided by NDB Cluster, and the types of events that are logged.

NDB Cluster provides two types of event log:

- The *cluster log*, which includes events generated by all cluster nodes. The cluster log is the log recommended for most uses because it provides logging information for an entire cluster in a single location.

  By default, the cluster log is saved to a file named `ndb_`*`node_id`*`_cluster.log`, (where *`node_id`* is the node ID of the management server) in the management server's `DataDir`.

  Cluster logging information can also be sent to `stdout` or a `syslog` facility in addition to or instead of being saved to a file, as determined by the values set for the `DataDir` and `LogDestination`

configuration parameters. See Section 18.3.3.5, “Defining an NDB Cluster Management Server”, for more information about these parameters.

- *Node logs* are local to each node.

  Output generated by node event logging is written to the file `ndb_node_id_out.log` (where `node_id` is the node's node ID) in the node's `DataDir`. Node event logs are generated for both management nodes and data nodes.

  Node logs are intended to be used only during application development, or for debugging application code.

Both types of event logs can be set to log different subsets of events.

Each reportable event can be distinguished according to three different criteria:

- *Category*: This can be any one of the following values: `STARTUP`, `SHUTDOWN`, `STATISTICS`, `CHECKPOINT`, `NODERESTART`, `CONNECTION`, `ERROR`, or `INFO`.
- *Priority*: This is represented by one of the numbers from 0 to 15 inclusive, where 0 indicates “most important” and 15 “least important.”
- *Severity Level*: This can be any one of the following values: `ALERT`, `CRITICAL`, `ERROR`, `WARNING`, `INFO`, or `DEBUG`.

Both the cluster log and the node log can be filtered on these properties.

The format used in the cluster log is as shown here:

```
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 1: Data usage is 2%(60 32K pages of total 2560)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 1: Index usage is 1%(24 8K pages of total 2336)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 1: Resource 0 min: 0 max: 639 curr: 0
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 2: Data usage is 2%(76 32K pages of total 2560)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 2: Index usage is 1%(24 8K pages of total 2336)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 2: Resource 0 min: 0 max: 639 curr: 0
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 3: Data usage is 2%(58 32K pages of total 2560)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 3: Index usage is 1%(25 8K pages of total 2336)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 3: Resource 0 min: 0 max: 639 curr: 0
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 4: Data usage is 2%(74 32K pages of total 2560)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 4: Index usage is 1%(25 8K pages of total 2336)
2007-01-26 19:35:55 [MgmSrvr] INFO     -- Node 4: Resource 0 min: 0 max: 639 curr: 0
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 4: Node 9 Connected
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 1: Node 9 Connected
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 1: Node 9: API 5.5.58-ndb-7.2.32
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 2: Node 9 Connected
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 2: Node 9: API 5.5.58-ndb-7.2.32
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 3: Node 9 Connected
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 3: Node 9: API 5.5.58-ndb-7.2.32
2007-01-26 19:39:42 [MgmSrvr] INFO     -- Node 4: Node 9: API 5.5.58-ndb-7.2.32
2007-01-26 19:59:22 [MgmSrvr] ALERT    -- Node 2: Node 7 Disconnected
2007-01-26 19:59:22 [MgmSrvr] ALERT    -- Node 2: Node 7 Disconnected
```

Each line in the cluster log contains the following information:

- A timestamp in *`YYYY-MM-DD HH:MM:SS`* format.
- The type of node which is performing the logging. In the cluster log, this is always `[MgmSrvr]`.
- The severity of the event.
- The ID of the node reporting the event.
- A description of the event. The most common types of events to appear in the log are connections and disconnections between different nodes in the cluster, and when checkpoints occur. In some cases, the description may contain status information.

18.5.6.1 NDB Cluster Logging Management Commands

`ndb_mgm` supports a number of management commands related to the cluster log. In the listing that follows, *`node_id`* denotes either a database node ID or the keyword `ALL`, which indicates that the command should be applied to all of the cluster's data nodes.

- `CLUSTERLOG ON`

  Turns the cluster log on.

- `CLUSTERLOG OFF`

  Turns the cluster log off.

- `CLUSTERLOG INFO`

  Provides information about cluster log settings.

- *`node_id`* `CLUSTERLOG` *`category=threshold`*

  Logs *`category`* events with priority less than or equal to *`threshold`* in the cluster log.

- `CLUSTERLOG FILTER` *`severity_level`*

  Toggles cluster logging of events of the specified *`severity_level`*.

The following table describes the default setting (for all data nodes) of the cluster log category threshold. If an event has a priority with a value lower than or equal to the priority threshold, it is reported in the cluster log.

Note

Events are reported per data node, and that the threshold can be set to different values on different nodes.

Category	Default threshold (All data nodes)
`STARTUP`	**7**
`SHUTDOWN`	**7**
`STATISTICS`	**7**
`CHECKPOINT`	**7**
`NODERESTART`	**7**
`CONNECTION`	**7**
`ERROR`	**15**
`INFO`	**7**

The `STATISTICS` category can provide a great deal of useful data. See Section 18.5.6.3, “Using CLUSTERLOG STATISTICS in the NDB Cluster Management Client”, for more information.

Thresholds are used to filter events within each category. For example, a `STARTUP` event with a priority of 3 is not logged unless the threshold for `STARTUP` is set to 3 or higher. Only events with priority 3 or lower are sent if the threshold is 3.

The following table shows the event severity levels.

Note

These correspond to Unix `syslog` levels, except for `LOG_EMERG` and `LOG_NOTICE`, which are not used or mapped.

Severity Level Value	Severity	Description
1	ALERT	A condition that should be corrected immediately, such as a corrupted system database
2	CRITICAL	Critical conditions, such as device errors or insufficient resources
3	ERROR	Conditions that should be corrected, such as configuration errors
4	WARNING	Conditions that are not errors, but that might require special handling
5	INFO	Informational messages
6	DEBUG	Debugging messages used for NDBCLUSTER development

Event severity levels can be turned on or off (using CLUSTERLOG FILTER—see above). If a severity level is turned on, then all events with a priority less than or equal to the category thresholds are logged. If the severity level is turned off then no events belonging to that severity level are logged.

Important

Cluster log levels are set on a per ndb_mgmd, per subscriber basis. This means that, in an NDB Cluster with multiple management servers, using a CLUSTERLOG command in an instance of ndb_mgm connected to one management server affects only logs generated by that management server but not by any of the others. This also means that, should one of the management servers be restarted, only logs generated by that management server are affected by the resetting of log levels caused by the restart.

18.5.6.2 NDB Cluster Log Events

An event report reported in the event logs has the following format:

```
datetime [string] severity -- message
```

For example:

```
09:19:30 2005-07-24 [NDB] INFO -- Node 4 Start phase 4 completed
```

This section discusses all reportable events, ordered by category and severity level within each category.

In the event descriptions, GCP and LCP mean “Global Checkpoint” and “Local Checkpoint”, respectively.

CONNECTION Events

These events are associated with connections between Cluster nodes.

Event	Priority	Severity Level	Description
Connected	8	INFO	Data nodes connected
Disconnected	8	ALERT	Data nodes disconnected
CommunicationClosed	8	INFO	SQL node or data node connection closed
CommunicationOpened	8	INFO	SQL node or data node connection open
ConnectedApiVersion	8	INFO	Connection using API version

CHECKPOINT Events

The logging messages shown here are associated with checkpoints.

Event	Priority	Severity Level	Description
GlobalCheckpointStarted	9	INFO	Start of GCP: REDO log is written to disk
GlobalCheckpointCompleted	10	INFO	GCP finished
LocalCheckpointStarted	7	INFO	Start of LCP: data written to disk
LocalCheckpointCompleted	7	INFO	LCP completed normally
LCPStoppedInCalcKeepGci	0	ALERT	LCP stopped
LCPFragmentCompleted	11	INFO	LCP on a fragment has been completed
UndoLogBlocked	7	INFO	UNDO logging blocked; buffer near overflow
RedoStatus	7	INFO	Redo status

STARTUP Events

The following events are generated in response to the startup of a node or of the cluster and of its success or failure. They also provide information relating to the progress of the startup process, including information concerning logging activities.

Event	Priority	Severity Level	Description
NDBStartStarted	1	INFO	Data node start phases initiated (all nodes starting)
NDBStartCompleted	1	INFO	Start phases completed, all data nodes
STTORRYRecieved	15	INFO	Blocks received after completion of restart
StartPhaseCompleted	4	INFO	Data node start phase *X* completed
CM_REGCONF	3	INFO	Node has been successfully included into the cluster; shows the node, managing node, and dynamic ID
CM_REGREF	8	INFO	Node has been refused for inclusion in the cluster; cannot be included in cluster due to misconfiguration, inability to establish communication, or other problem
FIND_NEIGHBOURS	8	INFO	Shows neighboring data nodes
NDBStopStarted	1	INFO	Data node shutdown initiated
NDBStopCompleted	1	INFO	Data node shutdown complete
NDBStopForced	1	ALERT	Forced shutdown of data node
NDBStopAborted	1	INFO	Unable to shut down data node normally
StartREDOLog	4	INFO	New redo log started; GCI keep *X*, newest restorable GCI *Y*
StartLog	10	INFO	New log started; log part *X*, start MB *Y*, stop MB *Z*
UNDORecordsExecuted	15	INFO	Undo records executed
StartReport	4	INFO	Report started
LogFileInitStatus	7	INFO	Log file initialization status
LogFileInitCompStatus	7	INFO	Log file completion status
StartReadLCP	10	INFO	Start read for local checkpoint

Event	Priority	Severity Level	Description
ReadLCPComplete	10	INFO	Read for local checkpoint completed
RunRedo	8	INFO	Running the redo log
RebuildIndex	10	INFO	Rebuilding indexes

NODERESTART Events

The following events are generated when restarting a node and relate to the success or failure of the node restart process.

Event	Priority	Severity Level	Description
NR_CopyDict	7	INFO	Completed copying of dictionary information
NR_CopyDistr	7	INFO	Completed copying distribution information
NR_CopyFragsStarted	7	INFO	Starting to copy fragments
NR_CopyFragDone	10	INFO	Completed copying a fragment
NR_CopyFragsCompleted	7	INFO	Completed copying all fragments
NodeFailCompleted	8	ALERT	Node failure phase completed
NODE_FAILREP	8	ALERT	Reports that a node has failed
ArbitState	6	INFO	Report whether an arbitrator is found or not; there are seven different possible outcomes when seeking an arbitrator, listed here: • Management server restarts arbitration thread [state=*X*] • Prepare arbitrator node *X* [ticket=*Y*] • Receive arbitrator node *X* [ticket=*Y*] • Started arbitrator node *X* [ticket=*Y*] • Lost arbitrator node *X* - process failure [state=*Y*] • Lost arbitrator node *X* - process exit [state=*Y*] • Lost arbitrator node *X* <error msg> [state=*Y*]
ArbitResult	2	ALERT	Report arbitrator results; there are eight different possible results for arbitration attempts, listed here: • Arbitration check failed: less than 1/2 nodes left • Arbitration check succeeded: node group majority • Arbitration check failed: missing node group • Network partitioning: arbitration required

Event	Priority	Severity Level	Description
			• Arbitration succeeded: affirmative response from node *X* • Arbitration failed: negative response from node *X* • Network partitioning: no arbitrator available • Network partitioning: no arbitrator configured
GCP_TakeoverStarted	7	INFO	GCP takeover started
GCP_TakeoverCompleted	7	INFO	GCP takeover complete
LCP_TakeoverStarted	7	INFO	LCP takeover started
LCP_TakeoverCompleted	7	INFO	LCP takeover complete (state = *X*)
ConnectCheckStarted	6	INFO	Connection check started
ConnectCheckCompleted	6	INFO	Connection check completed
NodeFailRejected	6	ALERT	Node failure phase failed

STATISTICS Events

The following events are of a statistical nature. They provide information such as numbers of transactions and other operations, amount of data sent or received by individual nodes, and memory usage.

Event	Priority	Severity Level	Description
TransReportCounters	8	INFO	Report transaction statistics, including numbers of transactions, commits, reads, simple reads, writes, concurrent operations, attribute information, and aborts
OperationReportCounters	8	INFO	Number of operations
TableCreated	7	INFO	Report number of tables created
JobStatistic	9	INFO	Mean internal job scheduling statistics
ThreadConfigLoop	9	INFO	Number of thread configuration loops
SendBytesStatistic	9	INFO	Mean number of bytes sent to node *X*
ReceiveBytesStatistic	9	INFO	Mean number of bytes received from node *X*
MemoryUsage	5	INFO	Data and index memory usage (80%, 90%, and 100%)
MTSignalStatistics	9	INFO	Multi-threaded signals

SCHEMA Events

These events relate to NDB Cluster schema operations.

Event	Priority	Severity	Description
CreateSchemaObject	8	INFO	Schema objected created
AlterSchemaObject	8	INFO	Schema object updated
DropSchemaObject	8	INFO	Schema object dropped

ERROR Events

These events relate to Cluster errors and warnings. The presence of one or more of these generally indicates that a major malfunction or failure has occurred.

Event	Priority	Severity	Description
TransporterError	2	ERROR	Transporter error
TransporterWarning	8	WARNING	Transporter warning
MissedHeartbeat	8	WARNING	Node *X* missed heartbeat number *Y*
DeadDueToHeartbeat	8	ALERT	Node *X* declared “dead” due to missed heartbeat
WarningEvent	2	WARNING	General warning event
SubscriptionStatus	4	WARNING	Change in subscription status

INFO Events

These events provide general information about the state of the cluster and activities associated with Cluster maintenance, such as logging and heartbeat transmission.

Event	Priority	Severity	Description
SentHeartbeat	12	INFO	Sent heartbeat
CreateLogBytes	11	INFO	Create log: Log part, log file, size in MB
InfoEvent	2	INFO	General informational event
EventBufferStatus	7	INFO	Event buffer status

Note

SentHeartbeat events are available only if NDB Cluster was compiled with VM_TRACE enabled.

SINGLEUSER Events

These events are associated with entering and exiting single user mode.

Event	Priority	Severity	Description
SingleUser	7	INFO	Entering or exiting single user mode

BACKUP Events

These events provide information about backups being created or restored.

Event	Priority	Severity	Description
BackupStarted	7	INFO	Backup started
BackupStatus	7	INFO	Backup status
BackupCompleted	7	INFO	Backup completed
BackupFailedToStart	7	ALERT	Backup failed to start
BackupAborted	7	ALERT	Backup aborted by user
RestoreStarted	7	INFO	Started restoring from backup
RestoreMetaData	7	INFO	Restoring metadata
RestoreData	7	INFO	Restoring data
RestoreLog	7	INFO	Restoring log files
RestoreCompleted	7	INFO	Completed restoring from backup
SavedEvent	7	INFO	Event saved

18.5.6.3 Using CLUSTERLOG STATISTICS in the NDB Cluster Management Client

The NDB management client's CLUSTERLOG STATISTICS command can provide a number of useful statistics in its output. Counters providing information about the state of the cluster are updated at 5-second reporting intervals by the transaction coordinator (TC) and the local query handler (LQH), and written to the cluster log.

Transaction coordinator statistics. Each transaction has one transaction coordinator, which is chosen by one of the following methods:

- In a round-robin fashion
- By communication proximity
- By supplying a data placement hint when the transaction is started

Note

You can determine which TC selection method is used for transactions started from a given SQL node using the ndb_optimized_node_selection system variable.

All operations within the same transaction use the same transaction coordinator, which reports the following statistics:

- **Trans count.** This is the number transactions started in the last interval using this TC as the transaction coordinator. Any of these transactions may have committed, have been aborted, or remain uncommitted at the end of the reporting interval.

  Note

  Transactions do not migrate between TCs.

- **Commit count.** This is the number of transactions using this TC as the transaction coordinator that were committed in the last reporting interval. Because some transactions committed in this reporting interval may have started in a previous reporting interval, it is possible for Commit count to be greater than Trans count.

- **Read count.** This is the number of primary key read operations using this TC as the transaction coordinator that were started in the last reporting interval, including simple reads. This count also includes reads performed as part of unique index operations. A unique index read operation generates 2 primary key read operations—1 for the hidden unique index table, and 1 for the table on which the read takes place.

- **Simple read count.** This is the number of simple read operations using this TC as the transaction coordinator that were started in the last reporting interval.

- **Write count.** This is the number of primary key write operations using this TC as the transaction coordinator that were started in the last reporting interval. This includes all inserts, updates, writes and deletes, as well as writes performed as part of unique index operations.

  Note

  A unique index update operation can generate multiple PK read and write operations on the index table and on the base table.

- **AttrInfoCount.** This is the number of 32-bit data words received in the last reporting interval for primary key operations using this TC as the transaction coordinator. For reads, this is proportional to the number of columns requested. For inserts and updates, this is proportional to the number of columns written, and the size of their data. For delete operations, this is usually zero.

  Unique index operations generate multiple PK operations and so increase this count. However, data words sent to describe the PK operation itself, and the key information sent, are *not* counted here.

Attribute information sent to describe columns to read for scans, or to describe ScanFilters, is also not counted in `AttrInfoCount`.

- **Concurrent Operations.** This is the number of primary key or scan operations using this TC as the transaction coordinator that were started during the last reporting interval but that were not completed. Operations increment this counter when they are started and decrement it when they are completed; this occurs after the transaction commits. Dirty reads and writes—as well as failed operations—decrement this counter.

  The maximum value that `Concurrent Operations` can have is the maximum number of operations that a TC block can support; currently, this is `(2 * MaxNoOfConcurrentOperations) + 16 + MaxNoOfConcurrentTransactions`. (For more information about these configuration parameters, see the *Transaction Parameters* section of Section 18.3.3.6, “Defining NDB Cluster Data Nodes”.)

- **Abort count.** This is the number of transactions using this TC as the transaction coordinator that were aborted during the last reporting interval. Because some transactions that were aborted in the last reporting interval may have started in a previous reporting interval, `Abort count` can sometimes be greater than `Trans count`.

- **Scans.** This is the number of table scans using this TC as the transaction coordinator that were started during the last reporting interval. This does not include range scans (that is, ordered index scans).

- **Range scans.** This is the number of ordered index scans using this TC as the transaction coordinator that were started in the last reporting interval.

- **Local reads.** This is the number of primary-key read operations performed using a transaction coordinator on a node that also holds the primary replica of the record. This count can also be obtained from the `LOCAL_READS` counter in the `ndbinfo.counters` table.

- **Local writes.** This contains the number of primary-key read operations that were performed using a transaction coordinator on a node that also holds the primary replica of the record. This count can also be obtained from the `LOCAL_WRITES` counter in the `ndbinfo.counters` table.

Local query handler statistics (Operations). There is 1 cluster event per local query handler block (that is, 1 per data node process). Operations are recorded in the LQH where the data they are operating on resides.

Note

A single transaction may operate on data stored in multiple LQH blocks.

The `Operations` statistic provides the number of local operations performed by this LQH block in the last reporting interval, and includes all types of read and write operations (insert, update, write, and delete operations). This also includes operations used to replicate writes. For example, in a 2-replica cluster, the write to the primary replica is recorded in the primary LQH, and the write to the backup will be recorded in the backup LQH. Unique key operations may result in multiple local operations; however, this does *not* include local operations generated as a result of a table scan or ordered index scan, which are not counted.

Process scheduler statistics. In addition to the statistics reported by the transaction coordinator and local query handler, each `ndbd` process has a scheduler which also provides useful metrics relating to the performance of an NDB Cluster. This scheduler runs in an infinite loop; during each loop the scheduler performs the following tasks:

1. Read any incoming messages from sockets into a job buffer.
2. Check whether there are any timed messages to be executed; if so, put these into the job buffer as well.
3. Execute (in a loop) any messages in the job buffer.

4. Send any distributed messages that were generated by executing the messages in the job buffer.
5. Wait for any new incoming messages.

Process scheduler statistics include the following:

- **Mean Loop Counter.** This is the number of loops executed in the third step from the preceding list. This statistic increases in size as the utilization of the TCP/IP buffer improves. You can use this to monitor changes in performance as you add new data node processes.
- **Mean send size and Mean receive size.** These statistics enable you to gauge the efficiency of, respectively writes and reads between nodes. The values are given in bytes. Higher values mean a lower cost per byte sent or received; the maximum value is 64K.

To cause all cluster log statistics to be logged, you can use the following command in the NDB management client:

```
ndb_mgm> ALL CLUSTERLOG STATISTICS=15
```

Note

Setting the threshold for STATISTICS to 15 causes the cluster log to become very verbose, and to grow quite rapidly in size, in direct proportion to the number of cluster nodes and the amount of activity in the NDB Cluster.

For more information about NDB Cluster management client commands relating to logging and reporting, see Section 18.5.6.1, “NDB Cluster Logging Management Commands”.

18.5.7 NDB Cluster Log Messages

This section contains information about the messages written to the cluster log in response to different cluster log events. It provides additional, more specific information on NDB transporter errors.

18.5.7.1 NDB Cluster: Messages in the Cluster Log

The following table lists the most common NDB cluster log messages. For information about the cluster log, log events, and event types, see Section 18.5.6, “Event Reports Generated in NDB Cluster”. These log messages also correspond to log event types in the MGM API; see The Ndb_logevent_type Type, for related information of interest to Cluster API developers.

Log Message	Description	Event Name	Event Type	Priority	Severity
Node *mgm_node_id*: Node *data_node_id* Connected	The data node having node ID *node_id* has connected to the management server (node *mgm_node_id*).	Connected	Connection	8	INFO
Node *mgm_node_id*: Node *data_node_id* Disconnected	The data node having node ID *data_node_id* has disconnected from the management server (node *mgm_node_id*).	Disconnected	Connection	8	ALERT
Node *data_node_id*: Communication to Node	The API node or SQL node having node ID *api_node_id*	CommunicationClosed	Connection	8	INFO

Log Message	Description	Event Name	Event Type	Priority	Severity
api_node_id closed	is no longer communicating with data node *data_node_id*.				
Node *data_node_id*: Communication to Node *api_node_id* opened	The API node or SQL node having node ID *api_node_id* is now communicating with data node *data_node_id*.	CommunicationOpened	Connection	8	INFO
Node *mgm_node_id*: Node *api_node_id*: API *version*	The API node having node ID *api_node_id* has connected to management node *mgm_node_id* using NDB API version *version* (generally the same as the MySQL version number).	ConnectedApiVersion	Connection	8	INFO
Node *node_id*: Global checkpoint *gci* started	A global checkpoint with the ID *gci* has been started; node *node_id* is the master responsible for this global checkpoint.	GlobalCheckpointStarted	Checkpoint	9	INFO
Node *node_id*: Global checkpoint *gci* completed	The global checkpoint having the ID *gci* has been completed; node *node_id* was the master responsible for this global checkpoint.	GlobalCheckpointCompleted	Checkpoint	10	INFO
Node *node_id*: Local checkpoint *lcp* started. Keep GCI = *current_gci* oldest restorable GCI = *old_gci*	The local checkpoint having sequence ID *lcp* has been started on node *node_id*. The most recent GCI that can be used has the index *current_gci*, and the oldest GCI from which the cluster can be restored has the index *old_gci*.	LocalCheckpointStarted	Checkpoint	7	INFO

Log Message	Description	Event Name	Event Type	Priority	Severity
Node *node_id*: Local checkpoint *lcp* completed	The local checkpoint having sequence ID *lcp* on node *node_id* has been completed.	LocalCheckpointCompleted	Checkpoint	8	INFO
Node *node_id*: Local Checkpoint stopped in CALCULATED_KEEP_GCI	The node was unable to determine the most recent usable GCI.	LCPStoppedInCalcKeepGci	Checkpoint	0	ALERT
Node *node_id*: Table ID = *table_id*, fragment *ID* = *fragment_id* has completed LCP on Node *node_id* maxGciStarted: *started_gci* maxGciCompleted *completed_gci*	A table fragment has been checkpointed to disk on node *node_id*. The GCI in progress has the index *started_gci*, and the most recent GCI to have been completed has the index *completed_gci*.	LCPFragmentCompleted	Checkpoint	11	INFO
Node *node_id*: ACC Blocked *num_1* and TUP Blocked *num_2* times last second	Undo logging is blocked because the log buffer is close to overflowing.	UndoLogBlocked	Checkpoint	7	INFO
Node *node_id*: Start initiated *version*	Data node *node_id*, running NDB version *version*, is beginning its startup process.	NDBStartStarted	StartUp	1	INFO
Node *node_id*: Started *version*	Data node *node_id*, running NDB version *version*, has started successfully.	NDBStartCompleted	StartUp	1	INFO
Node *node_id*: STTORRY received after restart finished	The node has received a signal indicating that a cluster restart has completed.	STTORRYRecieved	StartUp	15	INFO
Node *node_id*: Start phase *phase* completed (*type*)	The node has completed start phase *phase* of a *type* start. For a listing of start phases, see	StartPhaseCompleted	StartUp	4	INFO

Log Message	Description	Event Name	Event Type	Priority	Severity
	Section 18.5.1, “Summary of NDB Cluster Start Phases”. (*type* is one of `initial`, `system`, `node`, `initial node`, or `<Unknown>`.)				
`Node node_id: CM_REGCONF president = president_id, own Node = own_id, our dynamic id = dynamic_id`	Node *president_id* has been selected as “president”. *own_id* and *dynamic_id* should always be the same as the ID (*node_id*) of the reporting node.	`CM_REGCONF`	`StartUp`	3	`INFO`
`Node node_id: CM_REGREF from Node president_id to our Node node_id. Cause = cause`	The reporting node (ID *node_id*) was unable to accept node *president_id* as president. The *cause* of the problem is given as one of `Busy`, `Election with wait = false`, `Not president`, `Election without selecting new candidate`, or `No such cause`.	`CM_REGREF`	`StartUp`	8	`INFO`
`Node node_id: We are Node own_id with dynamic ID dynamic_id, our left neighbor is Node id_1, our right is Node id_2`	The node has discovered its neighboring nodes in the cluster (node *id_1* and node *id_2*). *node_id*, *own_id*, and *dynamic_id* should always be the same; if they are not, this indicates a serious misconfiguration of the cluster nodes.	`FIND_NEIGHBOURS`	`StartUp`	8	`INFO`
`Node node_id: type shutdown initiated`	The node has received a shutdown signal. The *type* of shutdown is either `Cluster` or `Node`.	`NDBStopStarted`	`StartUp`	1	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
Node *node_id*: Node shutdown completed [, *action*] [Initiated by signal *signal*.]	The node has been shut down. This report may include an *action*, which if present is one of restarting, no start, or initial. The report may also include a reference to an NDB Protocol *signal*; for possible signals, refer to Operations and Signals.	NDBStopCompleted	StartUp	1	INFO
Node *node_id*: Forced node shutdown completed [, action]. [Occured during startphase *start_phase*.] [Initiated by *signal*.] [Caused by error *error_code*: '*error_message*(*error_classification*).*error_status*'. [(extra info *extra_code*)]]	The node has been forcibly shut down. The *action* (one of restarting, no start, or initial) subsequently being taken, if any, is also reported. If the shutdown occurred while the node was starting, the report includes the *start_phase* during which the node failed. If this was a result of a *signal* sent to the node, this information is also provided (see Operations and Signals, for more information). If the error causing the failure is known, this is also included; for more information about NDB error messages and classifications, see NDB Cluster API Errors.	NDBStopForced	StartUp	1	ALERT
Node *node_id*: Node shutdown aborted	The node shutdown process was aborted by the user.	NDBStopAborted	StartUp	1	INFO
Node *node_id*: StartLog: [GCI	This reports global checkpoints	StartREDOLog	StartUp	4	INFO

Log Message	Description	Event Name	Event Type	Priority	Severity
Keep: *keep_pos* LastCompleted: *last_pos* NewestRestorable: *restore_pos*	referenced during a node start. The redo log prior to *keep_pos* is dropped. *last_pos* is the last global checkpoint in which data node the participated; *restore_pos* is the global checkpoint which is actually used to restore all data nodes.				
startup_message [*Listed separately; see below.*]	There are a number of possible startup messages that can be logged under different circumstances. These are listed separately; see Section 18.5.7.2, "NDB Cluster Log Startup Messages".	StartReport	StartUp	4	INFO
Node *node_id*: Node restart completed copy of dictionary information	Copying of data dictionary information to the restarted node has been completed.	NR_CopyDict	NodeRestart	8	INFO
Node *node_id*: Node restart completed copy of distribution information	Copying of data distribution information to the restarted node has been completed.	NR_CopyDistr	NodeRestart	8	INFO
Node *node_id*: Node restart starting to copy the fragments to Node *node_id*	Copy of fragments to starting data node *node_id* has begun	NR_CopyFragsStarted	NodeRestart	8	INFO
Node *node_id*: Table ID = *table_id*, fragment ID = *fragment_id* have been copied to Node *node_id*	Fragment *fragment_id* from table *table_id* has been copied to data node *node_id*	NR_CopyFragDone	NodeRestart	10	INFO
Node *node_id*: Node restart	Copying of all table fragments	NR_CopyFragsCompleted	NodeRestart	8	INFO

Log Message	Description	Event Name	Event Type	Priority	Severity
completed copying the fragments to Node *node_id*	to restarting data node *node_id* has been completed				
Node *node_id*: Node *node1_id* completed failure of Node *node2_id*	Data node *node1_id* has detected the failure of data node *node2_id*	NodeFailCompleted	NodeRestart	8	ALERT
All nodes completed failure of Node *node_id*	All (remaining) data nodes have detected the failure of data node *node_id*	NodeFailCompleted	NodeRestart	8	ALERT
Node failure of *node_id*block completed	The failure of data node *node_id* has been detected in the *block*NDB kernel block, where block is 1 of DBTC, DBDICT, DBDIH, or DBLQH; for more information, see NDB Kernel Blocks	NodeFailCompleted	NodeRestart	8	ALERT
Node *mgm_node_id*: Node *data_node_id* has failed. The Node state at failure was *state_code*	A data node has failed. Its state at the time of failure is described by an arbitration state code *state_code*: possible state code values can be found in the file include/kernel/signaldata/ArbitSignalData.hpp.	NODE_FAILREP	NodeRestart	8	ALERT
President restarts arbitration thread [state=*state_code*] or Prepare arbitrator node *node_id* [ticket=*ticket_id*] or Receive arbitrator node *node_id* [ticket=*ticket_id*] or Started arbitrator node *node_id*	This is a report on the current state and progress of arbitration in the cluster. *node_id* is the node ID of the management node or SQL node selected as the arbitrator. *state_code* is an arbitration state code, as found in include/kernel/signaldata/	ArbitState	NodeRestart	6	INFO

Log Message	Description	Event Name	Event Type	Priority	Severity
[ticket=*ticket_id*] or Lost arbitrator node *node_id* - process failure [state=*state_code*] or Lost arbitrator node *node_id* - process exit [state=*state_code*] or Lost arbitrator node *node_id* - *error_message* [state=*state_code*]	ArbitSignalData.hpp. When an error has occurred, an *error_message*, also defined in ArbitSignalData.hpp, is provided. *ticket_id* is a unique identifier handed out by the arbitrator when it is selected to all the nodes that participated in its selection; this is used to ensure that each node requesting arbitration was one of the nodes that took part in the selection process.				
Arbitration check lost - less than 1/2 nodes left or Arbitration check won - all node groups and more than 1/2 nodes left or Arbitration check won - node group majority or Arbitration check lost - missing node group or Network partitioning - arbitration required or Arbitration won - positive reply from node *node_id* or Arbitration lost - negative reply from node *node_id* or Network partitioning - no arbitrator available	This message reports on the result of arbitration. In the event of arbitration failure, an *error_message* and an arbitration *state_code* are provided; definitions for both of these are found in include/kernel/signaldata/ArbitSignalData.hpp.	ArbitResult	NodeRestart	2	ALERT

Log Message	Description	Event Name	Event Type	Priority	Severity
or `Network partitioning - no arbitrator configured` or `Arbitration failure - error_message [state=state_code]`					
`Node node_id: GCP Take over started`	This node is attempting to assume responsibility for the next global checkpoint (that is, it is becoming the master node)	`GCP_TakeoverStarted`	`NodeRestart`	7	`INFO`
`Node node_id: GCP Take over completed`	This node has become the master, and has assumed responsibility for the next global checkpoint	`GCP_TakeoverCompleted`	`NodeRestart`	7	`INFO`
`Node node_id: LCP Take over started`	This node is attempting to assume responsibility for the next set of local checkpoints (that is, it is becoming the master node)	`LCP_TakeoverStarted`	`NodeRestart`	7	`INFO`
`Node node_id: LCP Take over completed`	This node has become the master, and has assumed responsibility for the next set of local checkpoints	`LCP_TakeoverCompleted`	`NodeRestart`	7	`INFO`
`Node node_id: Trans. Count = transactions, Commit Count = commits, Read Count = reads, Simple Read Count = simple_reads, Write Count = writes, AttrInfo Count = AttrInfo_objects, Concurrent Operations =`	This report of transaction activity is given approximately once every 10 seconds	`TransReportCounters`	`Statistic`	8	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
concurrent_operations, Abort Count = *aborts*, Scans = *scans*, Range scans = *range_scans*					
Node *node_id*: Operations=*operations*	Number of operations performed by this node, provided approximately once every 10 seconds	OperationReportCounters	Statistic	8	INFO
Node *node_id*: Table with ID = *table_id* created	A table having the table ID shown has been created	TableCreated	Statistic	7	INFO
Node *node_id*: Mean loop Counter in doJob last 8192 times = *count*		JobStatistic	Statistic	9	INFO
Mean send size to Node = *node_id* last 4096 sends = *bytes* bytes	This node is sending an average of *bytes* bytes per send to node *node_id*	SendBytesStatistic	Statistic	9	INFO
Mean receive size to Node = *node_id* last 4096 sends = *bytes* bytes	This node is receiving an average of *bytes* of data each time it receives data from node *node_id*	ReceiveBytesStatistic	Statistic	9	INFO
Node *node_id*: Data usage is *data_memory_percentage*% (*data_pages_used* 32K pages of total *data_pages_total*) / Node *node_id*: Index usage is *index_memory_percentage*% (*index_pages_used* 8K pages of total *index_pages_total*)	This report is generated when a DUMP 1000 command is issued in the cluster management client; for more information, see DUMP 1000, in MySQL NDB Cluster Internals Manual	MemoryUsage	Statistic	5	INFO
Node *node1_id*: Transporter to node *node2_id* reported error *error_code*: *error_message*	A transporter error occurred while communicating with node *node2_id*; for a listing of transporter	TransporterError	Error	2	ERROR

Log Message	Description	Event Name	Event Type	Priority	Severity
	error codes and messages, see NDB Transporter Errors, in MySQL NDB Cluster Internals Manual				
`Node node1_id: Transporter to node node2_id reported error error_code: error_message`	A warning of a potential transporter problem while communicating with node *node2_id*; for a listing of transporter error codes and messages, see NDB Transporter Errors, for more information	`TransporterWarning`	`Error`	8	`WARNING`
`Node node1_id: Node node2_id missed heartbeat heartbeat_id`	This node missed a heartbeat from node *node2_id*	`MissedHeartbeat`	`Error`	8	`WARNING`
`Node node1_id: Node node2_id declared dead due to missed heartbeat`	This node has missed at least 3 heartbeats from node *node2_id*, and so has declared that node "dead"	`DeadDueToHeartbeat`	`Error`	8	`ALERT`
`Node node1_id: Node Sent Heartbeat to node = node2_id`	This node has sent a heartbeat to node *node2_id*	`SentHeartbeat`	`Info`	12	`INFO`
`Node node_id: Event buffer status: used=bytes_used (percent_used%) alloc=bytes_allocated (percent_available%) max=bytes_available apply_epoch=latest_consumable_epoch latest_epoch=latest_epoch`	This report is seen during heavy event buffer usage, for example, when many updates are being applied in a relatively short period of time; the report shows the number of bytes and the percentage of event buffer memory used, the bytes allocated and percentage still available, and the	`EventBufferStatus`	`Info`	7	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
	latest and latest restorable epochs				
`Node node_id: Entering single user mode`, `Node node_id: Entered single user mode Node API_node_id has exclusive access`, `Node node_id: Entering single user mode`	These reports are written to the cluster log when entering and exiting single user mode; *`API_node_id`* is the node ID of the API or SQL having exclusive access to the cluster (for more information, see Section 18.5.8, "NDB Cluster Single User Mode"); the message `Unknown single user report API_node_id` indicates an error has taken place and should never be seen in normal operation	`SingleUser`	`Info`	7	`INFO`
`Node node_id: Backup backup_id started from node mgm_node_id`	A backup has been started using the management node having *`mgm_node_id`*; this message is also displayed in the cluster management client when the `START BACKUP` command is issued; for more information, see Section 18.5.3.2, "Using The NDB Cluster Management Client to Create a Backup"	`BackupStarted`	`Backup`	7	`INFO`
`Node node_id: Backup backup_id started from node mgm_node_id completed. StartGCP: start_gcp`	The backup having the ID *`backup_id`* has been completed; for more information, see Section 18.5.3.2, "Using The NDB Cluster	`BackupCompleted`	`Backup`	7	`INFO`

Log Message	Description	Event Name	Event Type	Priority	Severity
StopGCP: *stop_gcp* #Records: *records* #LogRecords: *log_records* Data: *data_bytes* bytes Log: *log_bytes* bytes	Management Client to Create a Backup”				
Node *node_id*: Backup request from *mgm_node_id* failed to start. Error: *error_code*	The backup failed to start; for error codes, see MGM API Errors	BackupFailedToStart	Backup	7	ALERT
Node *node_id*: Backup *backup_id* started from *mgm_node_id* has been aborted. Error: *error_code*	The backup was terminated after starting, possibly due to user intervention	BackupAborted	Backup	7	ALERT

18.5.7.2 NDB Cluster Log Startup Messages

Possible startup messages with descriptions are provided in the following list:

- Initial start, waiting for %s to connect, nodes [all: %s connected: %s no-wait: %s]
- Waiting until nodes: %s connects, nodes [all: %s connected: %s no-wait: %s]
- Waiting %u sec for nodes %s to connect, nodes [all: %s connected: %s no-wait: %s]
- Waiting for non partitioned start, nodes [all: %s connected: %s missing: %s no-wait: %s]
- Waiting %u sec for non partitioned start, nodes [all: %s connected: %s missing: %s no-wait: %s]
- Initial start with nodes %s [missing: %s no-wait: %s]
- Start with all nodes %s
- Start with nodes %s [missing: %s no-wait: %s]
- Start potentially partitioned with nodes %s [missing: %s no-wait: %s]
- Unknown startreport: 0x%x [%s %s %s %s]

18.5.7.3 NDB Cluster: NDB Transporter Errors

This section lists error codes, names, and messages that are written to the cluster log in the event of transporter errors.

Error Code	Error Name	Error Text
0x00	**TE_NO_ERROR**	No error
0x01	**TE_ERROR_CLOSING_SOCKET**	Error found during closing of socket
0x02	**TE_ERROR_IN_SELECT_BEFORE_ACCEPT**	Error found before accept. The transporter will retry
0x03	**TE_INVALID_MESSAGE_LENGTH**	Error found in message (invalid message length)
0x04	**TE_INVALID_CHECKSUM**	Error found in message (checksum)
0x05	**TE_COULD_NOT_CREATE_SOCKET**	Error found while creating socket(can't create socket)
0x06	**TE_COULD_NOT_BIND_SOCKET**	Error found while binding server socket
0x07	**TE_LISTEN_FAILED**	Error found while listening to server socket
0x08	**TE_ACCEPT_RETURN_ERROR**	Error found during accept(accept return error)
0x0b	**TE_SHM_DISCONNECT**	The remote node has disconnected
0x0c	**TE_SHM_IPC_STAT**	Unable to check shm segment
0x0d	**TE_SHM_UNABLE_TO_CREATE_SEGMENT**	Unable to create shm segment
0x0e	**TE_SHM_UNABLE_TO_ATTACH_SEGMENT**	Unable to attach shm segment
0x0f	**TE_SHM_UNABLE_TO_REMOVE_SEGMENT**	Unable to remove shm segment
0x10	**TE_TOO_SMALL_SIGID**	Sig ID too small
0x11	**TE_TOO_LARGE_SIGID**	Sig ID too large
0x12	**TE_WAIT_STACK_FULL**	Wait stack was full
0x13	**TE_RECEIVE_BUFFER_FULL**	Receive buffer was full
0x14	**TE_SIGNAL_LOST_SEND_BUFFER_FULL**	Send buffer was full,and trying to force send fails
0x15	**TE_SIGNAL_LOST**	Send failed for unknown reason(signal lost)

Error Code	Error Name	Error Text
0x16	**TE_SEND_BUFFER_FULL**	The send buffer was full, but sleeping for a while solved
0x0017	**TE_SCI_LINK_ERROR**	There is no link from this node to the switch
0x18	**TE_SCI_UNABLE_TO_START_SEQUENCE**	Could not start a sequence, because system resources are exumed or no sequence has been created
0x19	**TE_SCI_UNABLE_TO_REMOVE_SEQUENCE**	Could not remove a sequence
0x1a	**TE_SCI_UNABLE_TO_CREATE_SEQUENCE**	Could not create a sequence, because system resources are exempted. Must reboot
0x1b	**TE_SCI_UNRECOVERABLE_DATA_TFX_ERROR**	Tried to send data on redundant link but failed
0x1c	**TE_SCI_CANNOT_INIT_LOCALSEGMENT**	Cannot initialize local segment
0x1d	**TE_SCI_CANNOT_MAP_REMOTESEGMENT**	Cannot map remote segment
0x1e	**TE_SCI_UNABLE_TO_UNMAP_SEGMENT**	Cannot free the resources used by this segment (step 1)
0x1f	**TE_SCI_UNABLE_TO_REMOVE_SEGMENT**	Cannot free the resources used by this segment (step 2)
0x20	**TE_SCI_UNABLE_TO_DISCONNECT_SEGMENT**	Cannot disconnect from a remote segment
0x21	**TE_SHM_IPC_PERMANENT**	Shm ipc Permanent error
0x22	**TE_SCI_UNABLE_TO_CLOSE_CHANNEL**	Unable to close the sci channel and the resources allocated

18.5.8 NDB Cluster Single User Mode

Single user mode enables the database administrator to restrict access to the database system to a single API node, such as a MySQL server (SQL node) or an instance of `ndb_restore`. When entering single user mode, connections to all other API nodes are closed gracefully and all running transactions are aborted. No new transactions are permitted to start.

Once the cluster has entered single user mode, only the designated API node is granted access to the database.

You can use the `ALL STATUS` command in the `ndb_mgm` client to see when the cluster has entered single user mode. You can also check the `status` column of the `ndbinfo.nodes` table (see Section 18.5.10.13, “The ndbinfo nodes Table”, for more information).

Example:

```
ndb_mgm> ENTER SINGLE USER MODE 5
```

After this command has executed and the cluster has entered single user mode, the API node whose node ID is 5 becomes the cluster's only permitted user.

The node specified in the preceding command must be an API node; attempting to specify any other type of node will be rejected.

Note

When the preceding command is invoked, all transactions running on the designated node are aborted, the connection is closed, and the server must be restarted.

The command `EXIT SINGLE USER MODE` changes the state of the cluster's data nodes from single user mode to normal mode. API nodes—such as MySQL Servers—waiting for a connection (that is, waiting for the cluster to become ready and available), are again permitted to connect. The API node denoted as the single-user node continues to run (if still connected) during and after the state change.

Example:

```
ndb_mgm> EXIT SINGLE USER MODE
```

There are two recommended ways to handle a node failure when running in single user mode:

- Method 1:

  1. Finish all single user mode transactions
  2. Issue the `EXIT SINGLE USER MODE` command
  3. Restart the cluster's data nodes

- Method 2:

  Restart database nodes prior to entering single user mode.

18.5.9 Quick Reference: NDB Cluster SQL Statements

This section discusses several SQL statements that can prove useful in managing and monitoring a MySQL server that is connected to an NDB Cluster, and in some cases provide information about the cluster itself.

- `SHOW ENGINE NDB STATUS`, `SHOW ENGINE NDBCLUSTER STATUS`

  The output of this statement contains information about the server's connection to the cluster, creation and usage of NDB Cluster objects, and binary logging for NDB Cluster replication.

  See Section 13.7.5.16, “SHOW ENGINE Syntax”, for a usage example and more detailed information.

- `SHOW ENGINES`

  This statement can be used to determine whether or not clustering support is enabled in the MySQL server, and if so, whether it is active.

  See Section 13.7.5.17, “SHOW ENGINES Syntax”, for more detailed information.

Note

In MySQL 5.1 and later, this statement does not support a `LIKE` clause. However, you can use `LIKE` to filter queries against the `INFORMATION_SCHEMA.ENGINES` table, as discussed in the next item.

- `SELECT * FROM INFORMATION_SCHEMA.ENGINES [WHERE ENGINE LIKE 'NDB%']`

  This is the equivalent of `SHOW ENGINES`, but uses the `ENGINES` table of the `INFORMATION_SCHEMA` database. Unlike the case with the `SHOW ENGINES` statement, it is possible to filter the results using a `LIKE` clause, and to select specific columns to obtain information that may be of use in scripts. For example, the following query shows whether the server was built with `NDB` support and, if so, whether it is enabled:

```
mysql> SELECT SUPPORT FROM INFORMATION_SCHEMA.ENGINES
    ->   WHERE ENGINE LIKE 'NDB%';
+---------+
| support |
+---------+
| ENABLED |
+---------+
```

  See Section 21.6, “The INFORMATION_SCHEMA ENGINES Table”, for more information.

- `SHOW VARIABLES LIKE 'NDB%'`

  This statement provides a list of most server system variables relating to the `NDB` storage engine, and their values, as shown here:

```
mysql> SHOW VARIABLES LIKE 'NDB%';
+-----------------------------------+-------+
| Variable_name                     | Value |
+-----------------------------------+-------+
| ndb_autoincrement_prefetch_sz     | 32    |
| ndb_cache_check_time              | 0     |
| ndb_extra_logging                 | 0     |
| ndb_force_send                    | ON    |
| ndb_index_stat_cache_entries      | 32    |
| ndb_index_stat_enable             | OFF   |
| ndb_index_stat_update_freq        | 20    |
| ndb_report_thresh_binlog_epoch_slip | 3     |
| ndb_report_thresh_binlog_mem_usage | 10    |
| ndb_use_copying_alter_table       | OFF   |
| ndb_use_exact_count               | ON    |
| ndb_use_transactions              | ON    |
+-----------------------------------+-------+
```

  See Section 5.1.5, “Server System Variables”, for more information.

- `SELECT * FROM INFORMATION_SCHEMA.GLOBAL_VARIABLES WHERE VARIABLE_NAME LIKE 'NDB%';`

  This statement is the equivalent of the `SHOW` command described in the previous item, and provides almost identical output, as shown here:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.GLOBAL_VARIABLES
    ->   WHERE VARIABLE_NAME LIKE 'NDB%';
+-----------------------------------+----------------+
| VARIABLE_NAME                     | VARIABLE_VALUE |
+-----------------------------------+----------------+
| NDB_AUTOINCREMENT_PREFETCH_SZ     | 32             |
| NDB_CACHE_CHECK_TIME              | 0              |
| NDB_EXTRA_LOGGING                 | 0              |
| NDB_FORCE_SEND                    | ON             |
```

```
| NDB_INDEX_STAT_CACHE_ENTRIES        | 32             |
| NDB_INDEX_STAT_ENABLE               | OFF            |
| NDB_INDEX_STAT_UPDATE_FREQ          | 20             |
| NDB_REPORT_THRESH_BINLOG_EPOCH_SLIP | 3              |
| NDB_REPORT_THRESH_BINLOG_MEM_USAGE  | 10             |
| NDB_USE_COPYING_ALTER_TABLE         | OFF            |
| NDB_USE_EXACT_COUNT                 | ON             |
| NDB_USE_TRANSACTIONS                | ON             |
+-------------------------------------+----------------+
```

Unlike the case with the `SHOW` command, it is possible to select individual columns. For example:

```
mysql> SELECT VARIABLE_VALUE
    ->   FROM INFORMATION_SCHEMA.GLOBAL_VARIABLES
    ->   WHERE VARIABLE_NAME = 'ndb_force_send';
+----------------+
| VARIABLE_VALUE |
+----------------+
| ON             |
+----------------+
```

See Section 21.9, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”, and Section 5.1.5, “Server System Variables”, for more information.

- `SHOW STATUS LIKE 'NDB%'`

  This statement shows at a glance whether or not the MySQL server is acting as a cluster SQL node, and if so, it provides the MySQL server's cluster node ID, the host name and port for the cluster management server to which it is connected, and the number of data nodes in the cluster, as shown here:

  ```
  mysql> SHOW STATUS LIKE 'NDB%';
  +--------------------------+----------------+
  | Variable_name            | Value          |
  +--------------------------+----------------+
  | Ndb_cluster_node_id      | 10             |
  | Ndb_config_from_host     | 198.51.100.103 |
  | Ndb_config_from_port     | 1186           |
  | Ndb_number_of_data_nodes | 4              |
  +--------------------------+----------------+
  ```

  If the MySQL server was built with clustering support, but it is not connected to a cluster, all rows in the output of this statement contain a zero or an empty string:

  ```
  mysql> SHOW STATUS LIKE 'NDB%';
  +--------------------------+-------+
  | Variable_name            | Value |
  +--------------------------+-------+
  | Ndb_cluster_node_id      | 0     |
  | Ndb_config_from_host     |       |
  | Ndb_config_from_port     | 0     |
  | Ndb_number_of_data_nodes | 0     |
  +--------------------------+-------+
  ```

  See also Section 13.7.5.36, “SHOW STATUS Syntax”.

- `SELECT * FROM INFORMATION_SCHEMA.GLOBAL_STATUS WHERE VARIABLE_NAME LIKE 'NDB%';`

  This statement provides similar output to the `SHOW` command discussed in the previous item. However, unlike the case with `SHOW STATUS`, it is possible using the `SELECT` to extract values in SQL for use in scripts for monitoring and automation purposes.

  See Section 21.8, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”, for more information.

You can also query the tables in the `ndbinfo` information database for real-time data about many NDB Cluster operations. See Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”.

18.5.10 ndbinfo: The NDB Cluster Information Database

`ndbinfo` is a database containing information specific to NDB Cluster.

This database contains a number of tables, each providing a different sort of data about NDB Cluster node status, resource usage, and operations. You can find more detailed information about each of these tables in the next several sections.

`ndbinfo` is included with NDB Cluster support in the MySQL Server; no special compilation or configuration steps are required; the tables are created by the MySQL Server when it connects to the cluster. You can verify that `ndbinfo` support is active in a given MySQL Server instance using `SHOW PLUGINS`; if `ndbinfo` support is enabled, you should see a row containing `ndbinfo` in the `Name` column and `ACTIVE` in the `Status` column, as shown here (emphasized text):

```
mysql> SHOW PLUGINS;
+----------------------------------+--------+--------------------+---------+---------+
| Name                             | Status | Type               | Library | License |
+----------------------------------+--------+--------------------+---------+---------+
| binlog                           | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| mysql_native_password            | ACTIVE | AUTHENTICATION     | NULL    | GPL     |
| mysql_old_password               | ACTIVE | AUTHENTICATION     | NULL    | GPL     |
| CSV                              | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MEMORY                           | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MRG_MYISAM                       | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MyISAM                           | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| PERFORMANCE_SCHEMA               | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| BLACKHOLE                        | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ARCHIVE                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndbcluster                       | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndbinfo                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndb_transid_mysql_connection_map | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| InnoDB                           | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| INNODB_TRX                       | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_LOCKS                     | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_LOCK_WAITS                | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMP                       | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMP_RESET                 | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMPMEM                    | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMPMEM_RESET              | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| partition                        | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
+----------------------------------+--------+--------------------+---------+---------+
22 rows in set (0.00 sec)
```

You can also do this by checking the output of `SHOW ENGINES` for a line including `ndbinfo` in the `Engine` column and `YES` in the `Support` column, as shown here (emphasized text):

```
mysql> SHOW ENGINES\G
*************************** 1. row ***************************
      Engine: ndbcluster
     Support: YES
     Comment: Clustered, fault-tolerant tables
Transactions: YES
          XA: NO
  Savepoints: NO
*************************** 2. row ***************************
      Engine: MRG_MYISAM
     Support: YES
     Comment: Collection of identical MyISAM tables
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 3. row ***************************
      Engine: ndbinfo
```

```
     Support: YES
     Comment: NDB Cluster system information storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 4. row ***************************
      Engine: CSV
     Support: YES
     Comment: CSV storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 5. row ***************************
      Engine: MEMORY
     Support: YES
     Comment: Hash based, stored in memory, useful for temporary tables
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 6. row ***************************
      Engine: FEDERATED
     Support: NO
     Comment: Federated MySQL storage engine
Transactions: NULL
          XA: NULL
  Savepoints: NULL
*************************** 7. row ***************************
      Engine: ARCHIVE
     Support: YES
     Comment: Archive storage engine
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 8. row ***************************
      Engine: InnoDB
     Support: YES
     Comment: Supports transactions, row-level locking, and foreign keys
Transactions: YES
          XA: YES
  Savepoints: YES
*************************** 9. row ***************************
      Engine: MyISAM
     Support: DEFAULT
     Comment: Default engine as of MySQL 3.23 with great performance
Transactions: NO
          XA: NO
  Savepoints: NO
*************************** 10. row ***************************
      Engine: BLACKHOLE
     Support: YES
     Comment: /dev/null storage engine (anything you write to it disappears)
Transactions: NO
          XA: NO
  Savepoints: NO
10 rows in set (0.00 sec)
```

If `ndbinfo` support is enabled, then you can access `ndbinfo` using SQL statements in `mysql` or another MySQL client. For example, you can see `ndbinfo` listed in the output of `SHOW DATABASES`, as shown here (emphasized text):

```
mysql> SHOW DATABASES;
+--------------------+
| Database           |
+--------------------+
| information_schema |
| mysql              |
| ndbinfo            |
| test               |
+--------------------+
4 rows in set (0.00 sec)
```

If the `mysqld` process was not started with the `--ndbcluster` option, `ndbinfo` is not available and is not displayed by `SHOW DATABASES`. If `mysqld` was formerly connected to an NDB Cluster but the cluster becomes unavailable (due to events such as cluster shutdown, loss of network connectivity, and so forth), `ndbinfo` and its tables remain visible, but an attempt to access any tables (other than `blocks` or `config_params`) fails with `Got error 157 'Connection to NDB failed' from NDBINFO`.

With the exception of the `blocks` and `config_params` tables, what we refer to as `ndbinfo` "tables" are actually views generated from internal `NDB` tables not normally visible to the MySQL Server.

All `ndbinfo` tables are read-only, and are generated on demand when queried. Because many of them are generated in parallel by the data nodes while other are specific to a given SQL node, they are not guaranteed to provide a consistent snapshot.

In addition, pushing down of joins is not supported on `ndbinfo` tables; so joining large `ndbinfo` tables can require transfer of a large amount of data to the requesting API node, even when the query makes use of a `WHERE` clause.

`ndbinfo` tables are not included in the query cache. (Bug #59831)

You can select the `ndbinfo` database with a `USE` statement, and then issue a `SHOW TABLES` statement to obtain a list of tables, just as for any other database, like this:

```
mysql> USE ndbinfo;
Database changed

mysql> SHOW TABLES;
+----------------------------+
| Tables_in_ndbinfo          |
+----------------------------+
| arbitrator_validity_detail |
| arbitrator_validity_summary |
| blocks                     |
| cluster_operations         |
| cluster_transactions       |
| config_params              |
| counters                   |
| diskpagebuffer             |
| logbuffers                 |
| logspaces                  |
| membership                 |
| memoryusage                |
| nodes                      |
| resources                  |
| server_operations          |
| server_transactions        |
| threadblocks               |
| threadstat                 |
| transporters               |
+----------------------------+
19 rows in set (0.03 sec)
```

The `cluster_operations`, `cluster_transactions`, `server_operations`, `server_transactions`, `threadblocks`, and `threadstat` tables were added in NDB 7.2.2. The `arbitrator_validity_detail`, `arbitrator_validity_summary`, and `membership` tables were added in NDB 7.2.10.

You can execute `SELECT` statements against these tables, just as you would normally expect:

```
mysql> SELECT * FROM memoryusage;
+---------+--------------------+--------+------------+------------+-------------+
| node_id | memory_type        | used   | used_pages | total      | total_pages |
+---------+--------------------+--------+------------+------------+-------------+
|       5 | Data memory        | 753664 |         23 | 1073741824 |       32768 |
|       5 | Index memory       | 163840 |         20 | 1074003968 |      131104 |
```

```
|       5 | Long message buffer |   2304 |          9 |   67108864 |      262144 |
|       6 | Data memory         | 753664 |         23 | 1073741824 |       32768 |
|       6 | Index memory        | 163840 |         20 | 1074003968 |      131104 |
|       6 | Long message buffer |   2304 |          9 |   67108864 |      262144 |
+---------+---------------------+--------+------------+------------+-------------+
6 rows in set (0.02 sec)
```

More complex queries, such as the two following `SELECT` statements using the `memoryusage` table, are possible:

```
mysql> SELECT SUM(used) as 'Data Memory Used, All Nodes'
     >     FROM memoryusage
     >     WHERE memory_type = 'Data memory';
+----------------------------+
| Data Memory Used, All Nodes |
+----------------------------+
|                       6460 |
+----------------------------+
1 row in set (0.37 sec)

mysql> SELECT SUM(max) as 'Total IndexMemory Available'
     >     FROM memoryusage
     >     WHERE memory_type = 'Index memory';
+----------------------------+
| Total IndexMemory Available |
+----------------------------+
|                      25664 |
+----------------------------+
1 row in set (0.33 sec)
```

`ndbinfo` table and column names are case sensitive (as is the name of the `ndbinfo` database itself). These identifiers are in lowercase. Trying to use the wrong lettercase results in an error, as shown in this example:

```
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+
| node_id | uptime | status  | start_phase |
+---------+--------+---------+-------------+
|       1 |  13602 | STARTED |           0 |
|       2 |     16 | STARTED |           0 |
+---------+--------+---------+-------------+
2 rows in set (0.04 sec)

mysql> SELECT * FROM Nodes;
ERROR 1146 (42S02): Table 'ndbinfo.Nodes' doesn't exist
```

`mysqldump` ignores the `ndbinfo` database entirely, and excludes it from any output. This is true even when using the `--databases` or `--all-databases` option.

NDB Cluster also maintains tables in the `INFORMATION_SCHEMA` information database, including the `FILES` table which contains information about files used for NDB Cluster Disk Data storage. For more information, see Section 21.29, “NDB Cluster INFORMATION_SCHEMA Tables”.

18.5.10.1 The ndbinfo arbitrator_validity_detail Table

The `arbitrator_validity_detail` table shows the view that each data node in the cluster has of the arbitrator. It is a subset of the `membership` table.

The following table provides information about the columns in the `arbitrator_validity_detail` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	This node's node ID

Column Name	Type	Description
arbitrator	integer	Node ID of arbitrator
arb_ticket	string	Internal identifier used to track arbitration
arb_connected	Yes or No	Whether this node is connected to the arbitrator
arb_state	Enumeration (see text)	Arbitration state

The node ID is the same as that reported by ndb_mgm -e "SHOW".

All nodes should show the same arbitrator and arb_ticket values as well as the same arb_state value. Possible arb_state values are ARBIT_NULL, ARBIT_INIT, ARBIT_FIND, ARBIT_PREP1, ARBIT_PREP2, ARBIT_START, ARBIT_RUN, ARBIT_CHOOSE, ARBIT_CRASH, and UNKNOWN.

arb_connected shows whether the current node is connected to the arbitrator.

Like the membership and arbitrator_validity_summary tables, this table was added in NDB 7.2.10.

18.5.10.2 The ndbinfo arbitrator_validity_summary Table

The arbitrator_validity_summary table provides a composite view of the arbitrator with regard to the cluster's data nodes.

The following table provides information about the columns in the arbitrator_validity_summary table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
arbitrator	integer	Node ID of arbitrator
arb_ticket	string	Internal identifier used to track arbitration
arb_connected	Yes or No	Whether this arbitrator is connected to the cluster
consensus_count	integer	Number of data nodes that see this node as arbitrator

In normal operations, this table should have only 1 row for any appreciable length of time. If it has more than 1 row for longer than a few moments, then either not all nodes are connected to the arbitrator, or all nodes are connected, but do not agree on the same arbitrator.

The arbitrator column shows the arbitrator's node ID.

arb_ticket is the internal identifier used by this arbitrator.

arb_connected shows whether this node is connected to the cluster as an arbitrator.

Like the membership and arbitrator_validity_detail tables, this table was added in NDB 7.2.10.

18.5.10.3 The ndbinfo blocks Table

The blocks table is a static table which simply contains the names and internal IDs of all NDB kernel blocks (see NDB Kernel Blocks). It is for use by the other ndbinfo tables (most of which are actually views) in mapping block numbers to block names for producing human-readable output.

The following table provides information about the columns in the blocks table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
block_number	integer	Block number
block_name	string	Block name

To obtain a list of all block names, simply execute SELECT block_name FROM ndbinfo.blocks. Although this is a static table, its content can vary between different NDB Cluster releases.

18.5.10.4 The ndbinfo cluster_operations Table

The cluster_operations table provides a per-operation (stateful primary key op) view of all activity in the NDB Cluster from the point of view of the local data management (LQH) blocks (see The DBLQH Block).

The following table provides information about the columns in the cluster_operations table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
node_id	integer	Node ID of reporting LQH block
block_instance	integer	LQH block instance
transid	integer	Transaction ID
operation_type	string	Operation type (see text for possible values)
state	string	Operation state (see text for possible values)
tableid	integer	Table ID
fragmentid	integer	Fragment ID
client_node_id	integer	Client node ID
client_block_ref	integer	Client block reference
tc_node_id	integer	Transaction coordinator node ID
tc_block_no	integer	Transaction coordinator block number
tc_block_instance	integer	Transaction coordinator block instance

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's getTransactionId() method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The operation_type column can take any one of the values READ, READ-SH, READ-EX, INSERT, UPDATE, DELETE, WRITE, UNLOCK, REFRESH, SCAN, SCAN-SH, SCAN-EX, or <unknown>.

The state column can have any one of the values ABORT_QUEUED, ABORT_STOPPED, COMMITTED, COMMIT_QUEUED, COMMIT_STOPPED, COPY_CLOSE_STOPPED, COPY_FIRST_STOPPED, COPY_STOPPED, COPY_TUPKEY, IDLE, LOG_ABORT_QUEUED, LOG_COMMIT_QUEUED, LOG_COMMIT_QUEUED_WAIT_SIGNAL, LOG_COMMIT_WRITTEN, LOG_COMMIT_WRITTEN_WAIT_SIGNAL, LOG_QUEUED, PREPARED, PREPARED_RECEIVED_COMMIT, SCAN_CHECK_STOPPED, SCAN_CLOSE_STOPPED, SCAN_FIRST_STOPPED, SCAN_RELEASE_STOPPED, SCAN_STATE_USED, SCAN_STOPPED, SCAN_TUPKEY, STOPPED, TC_NOT_CONNECTED, WAIT_ACC, WAIT_ACC_ABORT, WAIT_AI_AFTER_ABORT, WAIT_ATTR, WAIT_SCAN_AI, WAIT_TUP, WAIT_TUPKEYINFO, WAIT_TUP_COMMIT, or WAIT_TUP_TO_ABORT. (If the MySQL Server is running with ndbinfo_show_hidden enabled, you can view this list of states by selecting from the ndb$dblqh_tcconnect_state table, which is normally hidden.)

You can obtain the name of an NDB table from its table ID by checking the output of ndb_show_tables.

The fragid is the same as the partition number seen in the output of ndb_desc --extra-partition-info (short form -p).

In `client_node_id` and `client_block_ref`, `client` refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The `block_instance` and `tc_block_instance` column provide, respectively, the `DBLQH` and `DBTC` block instance numbers. You can use these along with the block names to obtain information about specific threads from the `threadblocks` table.

This table was added in NDB 7.2.2.

18.5.10.5 The ndbinfo cluster_transactions Table

The `cluster_transactions` table shows information about all ongoing transactions in an NDB Cluster.

The following table provides information about the columns in the `cluster_transactions` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	Node ID of transaction coordinator
`block_instance`	integer	TC block instance
`transid`	integer	Transaction ID
`state`	string	Operation state (see text for possible values)
`count_operations`	integer	Number of stateful primary key operations in transaction (includes reads with locks, as well as DML operations)
`outstanding_operations`	integer	Operations still being executed in local data management blocks
`inactive_seconds`	integer	Time spent waiting for API
`client_node_id`	integer	Client node ID
`client_block_ref`	integer	Client block reference

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's `getTransactionId()` method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

`block_instance` refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the `threadblocks` table.

The `state` column can have any one of the values `CS_ABORTING`, `CS_COMMITTING`, `CS_COMMIT_SENT`, `CS_COMPLETE_SENT`, `CS_COMPLETING`, `CS_CONNECTED`, `CS_DISCONNECTED`, `CS_FAIL_ABORTED`, `CS_FAIL_ABORTING`, `CS_FAIL_COMMITTED`, `CS_FAIL_COMMITTING`, `CS_FAIL_COMPLETED`, `CS_FAIL_PREPARED`, `CS_PREPARE_TO_COMMIT`, `CS_RECEIVING`, `CS_REC_COMMITTING`, `CS_RESTART`, `CS_SEND_FIRE_TRIG_REQ`, `CS_STARTED`, `CS_START_COMMITTING`, `CS_START_SCAN`, `CS_WAIT_ABORT_CONF`, `CS_WAIT_COMMIT_CONF`, `CS_WAIT_COMPLETE_CONF`, `CS_WAIT_FIRE_TRIG_REQ`. (If the MySQL Server is running with `ndbinfo_show_hidden` enabled, you can view this list of states by selecting from the `ndb$dbtc_apiconnect_state` table, which is normally hidden.)

In `client_node_id` and `client_block_ref`, `client` refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The `tc_block_instance` column provides the `DBTC` block instance number. You can use this along with the block name to obtain information about specific threads from the `threadblocks` table.

This table was added in NDB 7.2.2.

18.5.10.6 The ndbinfo config_params Table

The `config_params` table is a static table which provides the names and internal ID numbers of and other information about NDB Cluster configuration parameters.

The following table provides information about the columns in the `config_params` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`param_number`	integer	The parameter's internal ID number
`param_name`	string	The name of the parameter

Although this is a static table, its content can vary between NDB Cluster installations, since supported parameters can vary due to differences between software releases, cluster hardware configurations, and other factors.

18.5.10.7 The ndbinfo counters Table

The `counters` table provides running totals of events such as reads and writes for specific kernel blocks and data nodes. Counts are kept from the most recent node start or restart; a node start or restart resets all counters on that node. Not all kernel blocks have all types of counters.

The following table provides information about the columns in the `counters` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	The data node ID
`block_name`	string	Name of the associated NDB kernel block (see NDB Kernel Blocks).
`block_instance`	integer	Block instance
`counter_id`	integer	The counter's internal ID number; normally an integer between 1 and 10, inclusive.
`counter_name`	string	The name of the counter. See text for names of individual counters and the NDB kernel block with which each counter is associated.
`val`	integer	The counter's value

Each counter is associated with a particular `NDB` kernel block. Prior to NDB 7.2.0, this was limited to either the `DBLQH` kernel block or the `DBTC` kernel block. In NDB 7.2.0 and later, a number of counters relating to the `DBSPJ` kernel block are also available; these counters are described later in this section.

The `OPERATIONS` counter is associated with the `DBLQH` (local query handler) kernel block (see The DBLQH Block). A primary-key read counts as one operation, as does a primary-key update. For reads, there is one operation in `DBLQH` per operation in `DBTC`. For writes, there is one operation counted per replica.

The `ATTRINFO`, `TRANSACTIONS`, `COMMITS`, `READS`, `LOCAL_READS`, `SIMPLE_READS`, `WRITES`, `LOCAL_WRITES`, `ABORTS`, `TABLE_SCANS`, and `RANGE_SCANS` counters are associated with the DBTC (transaction co-ordinator) kernel block (see The DBTC Block).

`LOCAL_WRITES` and `LOCAL_READS` are primary-key operations using a transaction coordinator in a node that also holds the primary replica of the record.

The `READS` counter includes all reads. `LOCAL_READS` includes only those reads of the primary replica on the same node as this transaction coordinator. `SIMPLE_READS` includes only those reads in which

the read operation is the beginning and ending operation for a given transaction. Simple reads do not hold locks but are part of a transaction, in that they observe uncommitted changes made by the transaction containing them but not of any other uncommitted transactions. Such reads are “simple” from the point of view of the TC block; since they hold no locks they are not durable, and once `DBTC` has routed them to the relevant LQH block, it holds no state for them.

`ATTRINFO` keeps a count of the number of times an interpreted program is sent to the data node. See NDB Protocol Messages, for more information about `ATTRINFO` messages in the `NDB` kernel.

NDB 7.2.0, as part of its implementation of distributed pushed-down joins, adds the `LOCAL_TABLE_SCANS_SENT`, `READS_RECEIVED`, `PRUNED_RANGE_SCANS_RECEIVED`, `RANGE_SCANS_RECEIVED`, `LOCAL_READS_SENT`, `CONST_PRUNED_RANGE_SCANS_RECEIVED`, `LOCAL_RANGE_SCANS_SENT`, `REMOTE_READS_SENT`, `REMOTE_RANGE_SCANS_SENT`, `READS_NOT_FOUND`, `SCAN_BATCHES_RETURNED`, `TABLE_SCANS_RECEIVED`, and `SCAN_ROWS_RETURNED` counters. These counters are associated with the `DBSPJ` (select push-down join) kernel block (see The DBSPJ Block).

The `block_name` and `block_instance` columns provide, respectively, the applicable NDB kernel block name and instance number. You can use these to obtain information about specific threads from the `threadblocks` table.

A number of counters increasing the visibility of transporter overload and send buffer sizing when troubleshooting such issues were added in NDB 7.2.10. (Bug #15935206) For each LQH instance, there is one instance of each counter in the following list:

- `LQHKEY_OVERLOAD`: Number of primary key requests rejected at the LQH block instance due to transporter overload
- `LQHKEY_OVERLOAD_TC`: Count of instances of `LQHKEY_OVERLOAD` where the TC node transporter was overloaded
- `LQHKEY_OVERLOAD_READER`: Count of instances of `LQHKEY_OVERLOAD` where the API reader (reads only) node was overloaded.
- `LQHKEY_OVERLOAD_NODE_PEER`: Count of instances of `LQHKEY_OVERLOAD` where the next backup data node (writes only) was overloaded
- `LQHKEY_OVERLOAD_SUBSCRIBER`: Count of instances of `LQHKEY_OVERLOAD` where a event subscriber (writes only) was overloaded.
- `LQHSCAN_SLOWDOWNS`: Count of instances where a fragment scan batch size was reduced due to scanning API transporter overload.

18.5.10.8 The ndbinfo diskpagebuffer Table

The `diskpagebuffer` table provides statistics about disk page buffer usage by NDB Cluster Disk Data tables.

The following table provides information about the columns in the `diskpagebuffer` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	The data node ID
`block_instance`	integer	Block instance
`pages_written`	integer	Number of pages written to disk.
`pages_written_lcp`	integer	Number of pages written by local checkpoints.
`pages_read`	integer	Number of pages read from disk

Column Name	Type	Description
log_waits	integer	Number of page writes waiting for log to be written to disk
page_requests_direct_return	integer	Number of requests for pages that were available in buffer
page_requests_wait_queue	integer	Number of requests that had to wait for pages to become available in buffer
page_requests_wait_io	integer	Number of requests that had to be read from pages on disk (pages were unavailable in buffer)

You can use this table with NDB Cluster Disk Data tables to determine whether DiskPageBufferMemory is sufficiently large to allow data to be read from the buffer rather from disk; minimizing disk seeks can help improve performance of such tables.

You can determine the proportion of reads from DiskPageBufferMemory to the total number of reads using a query such as this one, which obtains this ratio as a percentage:

```
SELECT
  node_id,
  100 * page_requests_direct_return /
    (page_requests_direct_return + page_requests_wait_io)
      AS hit_ratio
FROM ndbinfo.diskpagebuffer;
```

The result from this query should be similar to what is shown here, with one row for each data node in the cluster (in this example, the cluster has 4 data nodes):

```
+---------+-----------+
| node_id | hit_ratio |
+---------+-----------+
|       5 |   97.6744 |
|       6 |   97.6879 |
|       7 |   98.1776 |
|       8 |   98.1343 |
+---------+-----------+
4 rows in set (0.00 sec)
```

hit_ratio values approaching 100% indicate that only a very small number of reads are being made from disk rather than from the buffer, which means that Disk Data read performance is approaching an optimum level. If any of these values are less than 95%, this is a strong indicator that the setting for DiskPageBufferMemory needs to be increased in the config.ini file.

Note

A change in DiskPageBufferMemory requires a rolling restart of all of the cluster's data nodes before it takes effect.

The block_instance column provides the NDB kernel block instance number. You can use this to obtain information about specific threads from the threadblocks table.

18.5.10.9 The ndbinfo logbuffers Table

The logbuffer table provides information on NDB Cluster log buffer usage.

The following table provides information about the columns in the logbuffers table. For each column, the table shows the name, data type, and a brief description.

Column Name	Type	Description
node_id	integer	The ID of this data node.

Column Name	Type	Description
log_type	string	Type of log; one of: REDO or DD-UNDO.
log_id	integer	The log ID.
log_part	integer	The log part number.
total	integer	Total space available for this log.
used	integer	Space used by this log.

18.5.10.10 The ndbinfo logspaces Table

This table provides information about NDB Cluster log space usage.

The following table provides information about the columns in the logspaces table. For each column, the table shows the name, data type, and a brief description.

Column Name	Type	Description
node_id	integer	The ID of this data node.
log_type	string	Type of log; one of: REDO or DD-UNDO.
log_id	integer	The log ID.
log_part	integer	The log part number.
total	integer	Total space available for this log.
used	integer	Space used by this log.

18.5.10.11 The ndbinfo membership Table

The membership table describes the view that each data node has of all the others in the cluster, including node group membership, president node, arbitrator, arbitrator successor, arbitrator connection states, and other information.

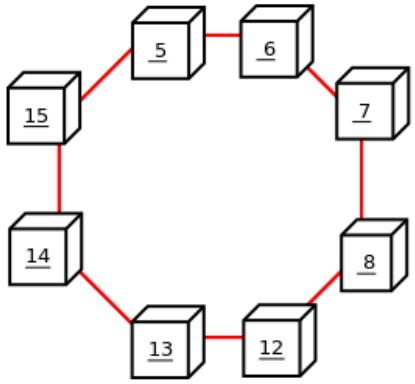
The following table provides information about the columns in the membership table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
node_id	integer	This node's node ID
group_id	integer	Node group to which this node belongs
left node	integer	Node ID of the previous node
right_node	integer	Node ID of the next node
president	integer	President's node ID
successor	integer	Node ID of successor to president
succession_order	integer	Order in which this node succeeds to presidency
Conf_HB_order	integer	-
arbitrator	integer	Node ID of arbitrator
arb_ticket	string	Internal identifier used to track arbitration
arb_state	Enumeration (see text)	Arbitration state
arb_connected	Yes or No	Whether this node is connected to the arbitrator
connected_rank1_arbs	List of node IDs	Connected arbitrators of rank 1
connected_rank2_arbs	List of node IDs	Connected arbitrators of rank 1

The node ID and node group ID are the same as reported by `ndb_mgm -e "SHOW"`.

`left_node` and `right_node` are defined in terms of a model that connects all data nodes in a circle, in order of their node IDs, similar to the ordering of the numbers on a clock dial, as shown here:

Figure 18.7 Circular Arrangement of NDB Cluster Nodes



In this example, we have 8 data nodes, numbered 5, 6, 7, 8, 12, 13, 14, and 15, ordered clockwise in a circle. We determine “left” and “right” from the interior of the circle. The node to the left of node 5 is node 15, and the node to the right of node 5 is node 6. You can see all these relationships by running the following query and observing the output:

```
mysql> SELECT node_id,left_node,right_node
    -> FROM ndbinfo.membership;
+---------+-----------+------------+
| node_id | left_node | right_node |
+---------+-----------+------------+
|       5 |        15 |          6 |
|       6 |         5 |          7 |
|       7 |         6 |          8 |
|       8 |         7 |         12 |
|      12 |         8 |         13 |
|      13 |        12 |         14 |
|      14 |        13 |         15 |
|      15 |        14 |          5 |
+---------+-----------+------------+
8 rows in set (0.00 sec)
```

The designations “left” and “right” are used in the event log in the same way.

The `president` node is the node viewed by the current node as responsible for setting an arbitrator (see NDB Cluster Start Phases). If the president fails or becomes disconnected, the current node expects the node whose ID is shown in the `successor` column to become the new president. The `succession_order` column shows the place in the succession queue that the current node views itself as having.

In a normal NDB Cluster, all data nodes should see the same node as `president`, and the same node (other than the president) as its `successor`. In addition, the current president should see itself as `1` in the order of succession, the `successor` node should see itself as `2`, and so on.

All nodes should show the same `arb_ticket` values as well as the same `arb_state` values. Possible `arb_state` values are `ARBIT_NULL`, `ARBIT_INIT`, `ARBIT_FIND`, `ARBIT_PREP1`, `ARBIT_PREP2`, `ARBIT_START`, `ARBIT_RUN`, `ARBIT_CHOOSE`, `ARBIT_CRASH`, and `UNKNOWN`.

`arb_connected` shows whether this node is connected to the node shown as this node's `arbitrator`.

The `connected_rank1_arbs` and `connected_rank2_arbs` columns each display a list of 0 or more arbitrators having an `ArbitrationRank` equal to 1, or to 2, respectively.

Note

Both management nodes and API nodes are eligible to become arbitrators.

Like the `arbitrator_validity_detail` and `arbitrator_validity_summary` tables, this table was added in NDB 7.2.10.

18.5.10.12 The ndbinfo memoryusage Table

Querying this table provides information similar to that provided by the `ALL REPORT MemoryUsage` command in the `ndb_mgm` client, or logged by `ALL DUMP 1000`.

The following table provides information about the columns in the `memoryusage` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	The node ID of this data node.
`memory_type`	string	One of `Data memory` or `Index memory`, or (*NDB 7.2.16 and later*) `Long message buffer`.
`used`	integer	Number of bytes currently used for data memory or index memory by this data node.
`used_pages`	integer	Number of pages currently used for data memory or index memory by this data node; see text.
`total`	integer	Total number of bytes of data memory or index memory available for this data node; see text.
`total_pages`	integer	Total number of memory pages available for data memory or index memory on this data node; see text.

The `total` column represents the total amount of memory in bytes available for the given resource (data memory or index memory) on a particular data node. This number should be approximately equal to the setting of the corresponding configuration parameter in the `config.ini` file.

Suppose that the cluster has 2 data nodes having node IDs `5` and `6`, and the `config.ini` file contains the following:

```
[ndbd default]
DataMemory = 1G
IndexMemory = 1G
```

Suppose also that the value of the `LongMessageBuffer` configuration parameter is allowed to assume its default (64 MB in NDB 7.2.16 and later).

The following query shows approximately the same values:

```
mysql> SELECT node_id, memory_type, total
     > FROM ndbinfo.memoryusage;
+---------+--------------------+------------+
| node_id | memory_type        | total      |
+---------+--------------------+------------+
|       5 | Data memory        | 1073741824 |
|       5 | Index memory       | 1074003968 |
|       5 | Long message buffer |   67108864 |
|       6 | Data memory        | 1073741824 |
```

```
|       6 | Index memory        | 1074003968 |
|       6 | Long message buffer |   67108864 |
+---------+---------------------+------------+
6 rows in set (0.00 sec)
```

In this case, the `total` column values for index memory are slightly higher than the value set of `IndexMemory` due to internal rounding.

For the `used_pages` and `total_pages` columns, resources are measured in pages, which are 32K in size for `DataMemory` and 8K for `IndexMemory`. For long message buffer memory, the page size is 256 bytes.

Long message buffer information can be found in this table beginning with NDB 7.2.16; in earlier versions of NDB Cluster 7.2, only data memory and index memory were included.

18.5.10.13 The ndbinfo nodes Table

This table contains information on the status of data nodes. For each data node that is running in the cluster, a corresponding row in this table provides the node's node ID, status, and uptime. For nodes that are starting, it also shows the current start phase.

The following table provides information about the columns in the `nodes` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	The data node's unique node ID in the cluster.
`uptime`	integer	Time since the node was last started, in seconds.
`status`	string	Current status of the data node; see text for possible values.
`start_phase`	integer	If the data node is starting, the current start phase.
`config_generation`	integer	The version of the cluster configuration file in use on this data node.

The `uptime` column shows the time in seconds that this node has been running since it was last started or restarted. This is a `BIGINT` value. This figure includes the time actually needed to start the node; in other words, this counter starts running the moment that `ndbd` or `ndbmtd` is first invoked; thus, even for a node that has not yet finished starting, `uptime` may show a non-zero value.

The `status` column shows the node's current status. This is one of: `NOTHING`, `CMVMI`, `STARTING`, `STARTED`, `SINGLEUSER`, `STOPPING_1`, `STOPPING_2`, `STOPPING_3`, or `STOPPING_4`. When the status is `STARTING`, you can see the current start phase in the `start_phase` column (see later in this section). `SINGLEUSER` is displayed in the `status` column for all data nodes when the cluster is in single user mode (see Section 18.5.8, “NDB Cluster Single User Mode”). Seeing one of the `STOPPING` states does not necessarily mean that the node is shutting down but can mean rather that it is entering a new state; for example, if you put the cluster in single user mode, you can sometimes see data nodes report their state briefly as `STOPPING_2` before the status changes to `SINGLEUSER`.

The `start_phase` column uses the same range of values as those used in the output of the `ndb_mgm` client *`node_id`* `STATUS` command (see Section 18.5.2, “Commands in the NDB Cluster Management Client”). If the node is not currently starting, then this column shows `0`. For a listing of NDB Cluster start phases with descriptions, see Section 18.5.1, “Summary of NDB Cluster Start Phases”.

The `config_generation` column shows which version of the cluster configuration is in effect on each data node. This can be useful when performing a rolling restart of the cluster in order to make

changes in configuration parameters. For example, from the output of the following `SELECT` statement, you can see that node 3 is not yet using the latest version of the cluster configuration (6) although nodes 1, 2, and 4 are doing so:

```
mysql> USE ndbinfo;
Database changed
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+-------------------+
| node_id | uptime | status  | start_phase | config_generation |
+---------+--------+---------+-------------+-------------------+
|       1 |  10462 | STARTED |           0 |                 6 |
|       2 |  10460 | STARTED |           0 |                 6 |
|       3 |  10457 | STARTED |           0 |                 5 |
|       4 |  10455 | STARTED |           0 |                 6 |
+---------+--------+---------+-------------+-------------------+
2 rows in set (0.04 sec)
```

Therefore, for the case just shown, you should restart node 3 to complete the rolling restart of the cluster.

Nodes that are stopped are not accounted for in this table. Suppose that you have an NDB Cluster with 4 data nodes (node IDs 1, 2, 3 and 4), and all nodes are running normally, then this table contains 4 rows, 1 for each data node:

```
mysql> USE ndbinfo;
Database changed
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+-------------------+
| node_id | uptime | status  | start_phase | config_generation |
+---------+--------+---------+-------------+-------------------+
|       1 |  11776 | STARTED |           0 |                 6 |
|       2 |  11774 | STARTED |           0 |                 6 |
|       3 |  11771 | STARTED |           0 |                 6 |
|       4 |  11769 | STARTED |           0 |                 6 |
+---------+--------+---------+-------------+-------------------+
4 rows in set (0.04 sec)
```

If you shut down one of the nodes, only the nodes that are still running are represented in the output of this `SELECT` statement, as shown here:

```
ndb_mgm> 2 STOP
Node 2: Node shutdown initiated
Node 2: Node shutdown completed.
Node 2 has shutdown.
```

```
mysql> SELECT * FROM nodes;
+---------+--------+---------+-------------+-------------------+
| node_id | uptime | status  | start_phase | config_generation |
+---------+--------+---------+-------------+-------------------+
|       1 |  11807 | STARTED |           0 |                 6 |
|       3 |  11802 | STARTED |           0 |                 6 |
|       4 |  11800 | STARTED |           0 |                 6 |
+---------+--------+---------+-------------+-------------------+
3 rows in set (0.02 sec)
```

18.5.10.14 The ndbinfo resources Table

This table provides information about data node resource availability and usage.

These resources are sometimes known as *super-pools*.

The following table provides information about the columns in the `resources` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
node_id	integer	The unique node ID of this data node.
resource_name	string	Name of the resource; see text.
reserved	integer	The amount reserved for this resource.
used	integer	The amount actually used by this resource.
max	integer	The maximum amount of this resource used, since the node was last started.

The resource_name can be one of the names shown in the following table:

Resource name	Description
RESERVED	Reserved by the system; cannot be overridden.
DISK_OPERATIONS	If a log file group is allocated, the size of the undo log buffer is used to set the size of this resource. This resource is used only to allocate the undo log buffer for an undo log file group; there can only be one such group. Overallocation occurs as needed by CREATE LOGFILE GROUP.
DISK_RECORDS	Records allocated for Disk Data operations.
DATA_MEMORY	Used for main memory tuples, indexes, and hash indexes. Sum of DataMemory and IndexMemory, plus 8 pages of 32 KB each if IndexMemory has been set. Cannot be overallocated.
JOBBUFFER	Used for allocating job buffers by the NDB scheduler; cannot be overallocated. This is approximately 2 MB per thread plus a 1 MB buffer in both directions for all threads that can communicate. For large configurations this consume several GB.
FILE_BUFFERS	Used by the redo log handler in the DBLQH kernel block; cannot be overallocated. Size is NoOfFragmentLogParts * RedoBuffer, plus 1 MB per log file part.
TRANSPORTER_BUFFERS	Used for send buffers by ndbmtd; the sum of TotalSendBufferMemory and ExtraSendBufferMemory. This resource that can be overallocated by up to 25 percent. TotalSendBufferMemory is calculated by summing the send buffer memory per node, the default value of which is 2 MB. Thus, in a system having four data nodes and eight API nodes, the data nodes have 12 * 2 MB send buffer memory. ExtraSendBufferMemory is used by ndbmtd and amounts to 2 MB extra memory per thread. Thus, with 4 LDM threads, 2 TC threads, 1 main thread, 1 replication thread, and 2 receive threads, ExtraSendBufferMemory is 10 * 2 MB. Overallocation of this resource can be performed by setting the SharedGlobalMemory data node configuration parameter.
DISK_PAGE_BUFFER	Used for the disk page buffer; determined by the DiskPageBufferMemory configuration parameter. Cannot be overallocated.
QUERY_MEMORY	Used by the DBSPJ kernel block.
SCHEMA_TRANS_MEMORY	Minimum is 2 MB; can be overallocated to use any remaining available memory.

18.5.10.15 The ndbinfo server_operations Table

The server_operations table contains entries for all ongoing NDB operations that the current SQL node (MySQL Server) is currently involved in. It effectively is a subset of the cluster_operations table, in which operations for other SQL and API nodes are not shown.

The following table provides information about the columns in the server_operations table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
mysql_connection_id	integer	MySQL Server connection ID
node_id	integer	Node ID
block_instance	integer	Block instance
transid	integer	Transaction ID
operation_type	string	Operation type (see text for possible values)
state	string	Operation state (see text for possible values)
tableid	integer	Table ID
fragmentid	integer	Fragment ID
client_node_id	integer	Client node ID
client_block_ref	integer	Client block reference
tc_node_id	integer	Transaction coordinator node ID
tc_block_no	integer	Transaction coordinator block number
tc_block_instance	integer	Transaction coordinator block instance

The mysql_connection_id is the same as the connection or session ID shown in the output of SHOW PROCESSLIST. It is obtained from the INFORMATION_SCHEMA table NDB_TRANSID_MYSQL_CONNECTION_MAP.

block_instance refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the threadblocks table.

The transaction ID (transid) is a unique 64-bit number which can be obtained using the NDB API's getTransactionId() method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The operation_type column can take any one of the values READ, READ-SH, READ-EX, INSERT, UPDATE, DELETE, WRITE, UNLOCK, REFRESH, SCAN, SCAN-SH, SCAN-EX, or <unknown>.

The state column can have any one of the values ABORT_QUEUED, ABORT_STOPPED, COMMITTED, COMMIT_QUEUED, COMMIT_STOPPED, COPY_CLOSE_STOPPED, COPY_FIRST_STOPPED, COPY_STOPPED, COPY_TUPKEY, IDLE, LOG_ABORT_QUEUED, LOG_COMMIT_QUEUED, LOG_COMMIT_QUEUED_WAIT_SIGNAL, LOG_COMMIT_WRITTEN, LOG_COMMIT_WRITTEN_WAIT_SIGNAL, LOG_QUEUED, PREPARED, PREPARED_RECEIVED_COMMIT, SCAN_CHECK_STOPPED, SCAN_CLOSE_STOPPED, SCAN_FIRST_STOPPED, SCAN_RELEASE_STOPPED, SCAN_STATE_USED, SCAN_STOPPED, SCAN_TUPKEY, STOPPED, TC_NOT_CONNECTED, WAIT_ACC, WAIT_ACC_ABORT, WAIT_AI_AFTER_ABORT, WAIT_ATTR, WAIT_SCAN_AI, WAIT_TUP, WAIT_TUPKEYINFO, WAIT_TUP_COMMIT, or WAIT_TUP_TO_ABORT. (If the MySQL Server is running with ndbinfo_show_hidden enabled, you can view this list of states by selecting from the ndb$dblqh_tcconnect_state table, which is normally hidden.)

You can obtain the name of an NDB table from its table ID by checking the output of ndb_show_tables.

The fragid is the same as the partition number seen in the output of ndb_desc --extra-partition-info (short form -p).

In client_node_id and client_block_ref, client refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The block_instance and tc_block_instance column provide NDB kernel block instance numbers. You can use these to obtain information about specific threads from the threadblocks table.

This table was added in NDB 7.2.2.

18.5.10.16 The ndbinfo server_transactions Table

The `server_transactions` table is subset of the `cluster_transactions` table, but includes only those transactions in which the current SQL node (MySQL Server) is a participant, while including the relevant connection IDs.

The following table provides information about the columns in the `server_transactions` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`mysql_connection_id`	integer	MySQL Server connection ID
`node_id`	integer	Transaction coordinator node ID
`block_instance`	integer	Transaction coordinator block instance
`transid`	integer	Transaction ID
`state`	string	Operation state (see text for possible values)
`count_operations`	integer	Number of stateful operations in the transaction
`outstanding_operations`	integer	Operations still being executed by local data management layer (LQH blocks)
`inactive_seconds`	integer	Time spent waiting for API
`client_node_id`	integer	Client node ID
`client_block_ref`	integer	Client block reference

The `mysql_connection_id` is the same as the connection or session ID shown in the output of `SHOW PROCESSLIST`. It is obtained from the `INFORMATION_SCHEMA` table `NDB_TRANSID_MYSQL_CONNECTION_MAP`.

`block_instance` refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the `threadblocks` table.

The transaction ID (`transid`) is a unique 64-bit number which can be obtained using the NDB API's `getTransactionId()` method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The `state` column can have any one of the values `CS_ABORTING`, `CS_COMMITTING`, `CS_COMMIT_SENT`, `CS_COMPLETE_SENT`, `CS_COMPLETING`, `CS_CONNECTED`, `CS_DISCONNECTED`, `CS_FAIL_ABORTED`, `CS_FAIL_ABORTING`, `CS_FAIL_COMMITTED`, `CS_FAIL_COMMITTING`, `CS_FAIL_COMPLETED`, `CS_FAIL_PREPARED`, `CS_PREPARE_TO_COMMIT`, `CS_RECEIVING`, `CS_REC_COMMITTING`, `CS_RESTART`, `CS_SEND_FIRE_TRIG_REQ`, `CS_STARTED`, `CS_START_COMMITTING`, `CS_START_SCAN`, `CS_WAIT_ABORT_CONF`, `CS_WAIT_COMMIT_CONF`, `CS_WAIT_COMPLETE_CONF`, `CS_WAIT_FIRE_TRIG_REQ`. (If the MySQL Server is running with `ndbinfo_show_hidden` enabled, you can view this list of states by selecting from the `ndb$dbtc_apiconnect_state` table, which is normally hidden.)

In `client_node_id` and `client_block_ref`, `client` refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The `block_instance` column provides the `DBTC` kernel block instance number. You can use this to obtain information about specific threads from the `threadblocks` table.

This table was added in NDB 7.2.2.

18.5.10.17 The ndbinfo threadblocks Table

The `threadblocks` table associates data nodes, threads, and instances of `NDB` kernel blocks.

The following table provides information about the columns in the `threadblocks` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	Node ID
`thr_no`	integer	Thread ID
`block_name`	string	Block name
`block_instance`	integer	Block instance number

The value of the `block_name` in this table is one of the values found in the `block_name` column when selecting from the `ndbinfo.blocks` table. Although the list of possible values is static for a given NDB Cluster release, the list may vary between releases.

The `block_instance` column provides the kernel block instance number.

This table was added in NDB 7.2.2.

18.5.10.18 The ndbinfo threadstat Table

The `threadstat` table provides a rough snapshot of statistics for threads running in the `NDB` kernel.

The following table provides information about the columns in the `threadstat` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	Node ID
`thr_no`	integer	Thread ID
`thr_nm`	string	Thread name
`c_loop`	string	Number of loops in main loop
`c_exec`	string	Number of signals executed
`c_wait`	string	Number of times waiting for additional input
`c_l_sent_prioa`	integer	Number of priority A signals sent to own node
`c_l_sent_priob`	integer	Number of priority B signals sent to own node
`c_r_sent_prioa`	integer	Number of priority A signals sent to remote node
`c_r_sent_priob`	integer	Number of priority B signals sent to remote node
`os_tid`	integer	OS thread ID
`os_now`	integer	OS time (ms)
`os_ru_utime`	integer	OS user CPU time (µs)
`os_ru_stime`	integer	OS system CPU time (µs)
`os_ru_minflt`	integer	OS page reclaims (soft page faults)
`os_ru_majflt`	integer	OS page faults (hard page faults)
`os_ru_nvcsw`	integer	OS voluntary context switches
`os_ru_nivcsw`	integer	OS involuntary context switches

`os_time` uses the system `gettimeofday()` call.

The values of the `os_ru_utime`, `os_ru_stime`, `os_ru_minflt`, `os_ru_majflt`, `os_ru_nvcsw`, and `os_ru_nivcsw` columns are obtained using the system `getrusage()` call, or the equivalent.

Since this table contains counts taken at a given point in time, for best results it is necessary to query this table periodically and store the results in an intermediate table or tables. The MySQL Server's Event Scheduler can be employed to automate such monitoring. For more information, see Section 20.4, “Using the Event Scheduler”.

This table was added in NDB 7.2.2.

18.5.10.19 The ndbinfo transporters Table

This table contains information about NDB transporters.

The following table provides information about the columns in the `transporters` table. For each column, the table shows the name, data type, and a brief description. Additional information can be found in the notes following the table.

Column Name	Type	Description
`node_id`	integer	This data node's unique node ID in the cluster
`remote_node_id`	integer	The remote data node's node ID
`status`	string	Status of the connection
`remote_address`	string	Name or IP address of the remote host
`bytes_sent`	integer	Number of bytes sent using this connection
`bytes_received`	integer	Number of bytes received using this connection
`connect_count`	integer	Number of times connection established on this transporter
`overloaded`	boolean (0 or 1)	1 if this transporter is currently overloaded, otherwise 0
`overload_count`	integer	Number of times this transporter has entered overload state since connecting
`slowdown`	boolean (0 or 1)	1 if this transporter is in slowdown state, otherwise 0
`slowdown_count`	integer	Number of times this transporter has entered slowdown state since connecting

For each running data node in the cluster, the `transporters` table displays a row showing the status of each of that node's connections with all nodes in the cluster, *including itself*. This information is shown in the table's *status* column, which can have any one of the following values: `CONNECTING`, `CONNECTED`, `DISCONNECTING`, or `DISCONNECTED`.

Connections to API and management nodes which are configured but not currently connected to the cluster are shown with status `DISCONNECTED`. Rows where the `node_id` is that of a data node which is not currently connected are not shown in this table. (This is similar omission of disconnected nodes in the `ndbinfo.nodes` table.

The `remote_address`, `bytes_sent`, and `bytes_received` columns were added in NDB 7.2.9. The `remote_address` is the host name or address for the node whose ID is shown in the `remote_node_id` column. The `bytes_sent` from this node and `bytes_received` by this node are the numbers, respectively, of bytes sent and received by the node using this connection since it

was established. For nodes whose status is `CONNECTING` or `DISCONNECTED`, these columns always display `0`.

Assume you have a 5-node cluster consisting of 2 data nodes, 2 SQL nodes, and 1 management node, as shown in the output of the `SHOW` command in the `ndb_mgm` client:

```
ndb_mgm> SHOW
Connected to Management Server at: localhost:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @10.100.10.1  (5.5.58-ndb-7.2.32, Nodegroup: 0, *)
id=2    @10.100.10.2  (5.5.58-ndb-7.2.32, Nodegroup: 0)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @10.100.10.10  (5.5.58-ndb-7.2.32)

[mysqld(API)]   2 node(s)
id=20   @10.100.10.20  (5.5.58-ndb-7.2.32)
id=21   @10.100.10.21  (5.5.58-ndb-7.2.32)
```

There are 10 rows in the `transporters` table—5 for the first data node, and 5 for the second—assuming that all data nodes are running, as shown here:

```
mysql> SELECT node_id, remote_node_id, status
    ->   FROM ndbinfo.transporters;
+---------+----------------+---------------+
| node_id | remote_node_id | status        |
+---------+----------------+---------------+
|       1 |              1 | DISCONNECTED  |
|       1 |              2 | CONNECTED     |
|       1 |             10 | CONNECTED     |
|       1 |             20 | CONNECTED     |
|       1 |             21 | CONNECTED     |
|       2 |              1 | CONNECTED     |
|       2 |              2 | DISCONNECTED  |
|       2 |             10 | CONNECTED     |
|       2 |             20 | CONNECTED     |
|       2 |             21 | CONNECTED     |
+---------+----------------+---------------+
10 rows in set (0.04 sec)
```

If you shut down one of the data nodes in this cluster using the command `2 STOP` in the `ndb_mgm` client, then repeat the previous query (again using the `mysql` client), this table now shows only 5 rows—1 row for each connection from the remaining management node to another node, including both itself and the data node that is currently offline—and displays `CONNECTING` for the status of each remaining connection to the data node that is currently offline, as shown here:

```
mysql> SELECT node_id, remote_node_id, status
    ->   FROM ndbinfo.transporters;
+---------+----------------+---------------+
| node_id | remote_node_id | status        |
+---------+----------------+---------------+
|       1 |              1 | DISCONNECTED  |
|       1 |              2 | CONNECTING    |
|       1 |             10 | CONNECTED     |
|       1 |             20 | CONNECTED     |
|       1 |             21 | CONNECTED     |
+---------+----------------+---------------+
5 rows in set (0.02 sec)
```

The `connect_count`, `overloaded`, `overload_count` ,`slowdown`, and `slowdown_count` columns were added in NDB 7.2.10. These counters are reset on connection, and retain their values after the remote node disconnects. Also beginning with NDB 7.2.10, the `bytes_send` and `bytes_received` counters are reset on connection as well, and so retain their values following disconnection. (Previously, the values in these columns were reset on disconnection.) (Bug #15935206)

The *overload* state referred to by the `overloaded` and `overload_count` columns occurs when this transporter's send buffer contains more than `OVerloadLimit` bytes (default is 80% of `SendBufferMemory`, that is, 0.8 * 2097152 = 1677721 bytes). When a given transporter is in a state of overload, any new transaction that tries to use this transporter fails with Error 1218 (`Send Buffers overloaded in NDB kernel`). This affects both scans and primary key operations.

The *slowdown* state referenced by the `slowdown` and `slowdown_count` columns of this table occurs when the transporter's send buffer contains more than 60% of the overload limit (equal to 0.6 * 2097152 = 1258291 bytes by default). In this state, any new scan using this transporter has its batch size reduced to minimize the load on the transporter.

Common causes of send buffer slowdown or overloading include the following:

- Data size, in particular the quantity of data stored in `TEXT` columns or `BLOB` columns (or both types of columns)
- Having a data node (ndbd or ndbmtd) on the same host as an SQL node that is engaged in binary logging
- Large number of rows per transaction or transaction batch
- Configuration issues such as insufficient `SendBufferMemory`
- Hardware issues such as insufficient RAM or poor network connectivity

See also Section 18.3.3.13, “Configuring NDB Cluster Send Buffer Parameters”.

18.5.11 NDB Cluster Security Issues

This section discusses security considerations to take into account when setting up and running NDB Cluster.

Topics covered in this section include the following:

- NDB Cluster and network security issues
- Configuration issues relating to running NDB Cluster securely
- NDB Cluster and the MySQL privilege system
- MySQL standard security procedures as applicable to NDB Cluster

18.5.11.1 NDB Cluster Security and Networking Issues

In this section, we discuss basic network security issues as they relate to NDB Cluster. It is extremely important to remember that NDB Cluster “out of the box” is not secure; you or your network administrator must take the proper steps to ensure that your cluster cannot be compromised over the network.

Cluster communication protocols are inherently insecure, and no encryption or similar security measures are used in communications between nodes in the cluster. Because network speed and latency have a direct impact on the cluster's efficiency, it is also not advisable to employ SSL or other encryption to network connections between nodes, as such schemes will effectively slow communications.

It is also true that no authentication is used for controlling API node access to an NDB Cluster. As with encryption, the overhead of imposing authentication requirements would have an adverse impact on Cluster performance.

In addition, there is no checking of the source IP address for either of the following when accessing the cluster:

- SQL or API nodes using “free slots” created by empty `[mysqld]` or `[api]` sections in the `config.ini` file

  This means that, if there are any empty `[mysqld]` or `[api]` sections in the `config.ini` file, then any API nodes (including SQL nodes) that know the management server's host name (or IP address) and port can connect to the cluster and access its data without restriction. (See Section 18.5.11.2, “NDB Cluster and MySQL Privileges”, for more information about this and related issues.)

  Note

  You can exercise some control over SQL and API node access to the cluster by specifying a `HostName` parameter for all `[mysqld]` and `[api]` sections in the `config.ini` file. However, this also means that, should you wish to connect an API node to the cluster from a previously unused host, you need to add an `[api]` section containing its host name to the `config.ini` file.

  More information is available elsewhere in this chapter about the `HostName` parameter. Also see Section 18.3.1, “Quick Test Setup of NDB Cluster”, for configuration examples using `HostName` with API nodes.

- Any `ndb_mgm` client

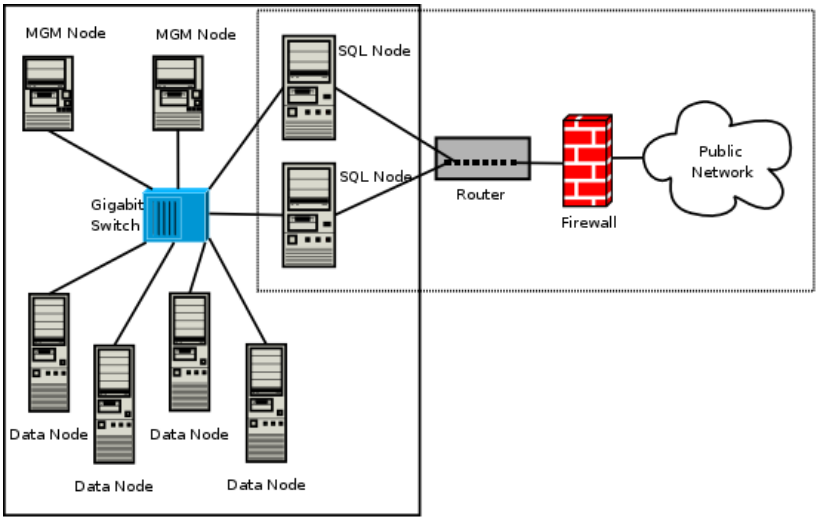
  This means that any cluster management client that is given the management server's host name (or IP address) and port (if not the standard port) can connect to the cluster and execute any management client command. This includes commands such as `ALL STOP` and `SHUTDOWN`.

For these reasons, it is necessary to protect the cluster on the network level. The safest network configuration for Cluster is one which isolates connections between Cluster nodes from any other network communications. This can be accomplished by any of the following methods:

1. Keeping Cluster nodes on a network that is physically separate from any public networks. This option is the most dependable; however, it is the most expensive to implement.

   We show an example of an NDB Cluster setup using such a physically segregated network here:

   Figure 18.8 NDB Cluster with Hardware Firewall

   This setup has two networks, one private (solid box) for the Cluster management servers and data nodes, and one public (dotted box) where the SQL nodes reside. (We show the management and data nodes connected using a gigabit switch since this provides the best performance.) Both networks are protected from the outside by a hardware firewall, sometimes also known as a *network-based firewall*.

This network setup is safest because no packets can reach the cluster's management or data nodes from outside the network—and none of the cluster's internal communications can reach the outside—without going through the SQL nodes, as long as the SQL nodes do not permit any packets to be forwarded. This means, of course, that all SQL nodes must be secured against hacking attempts.

Important

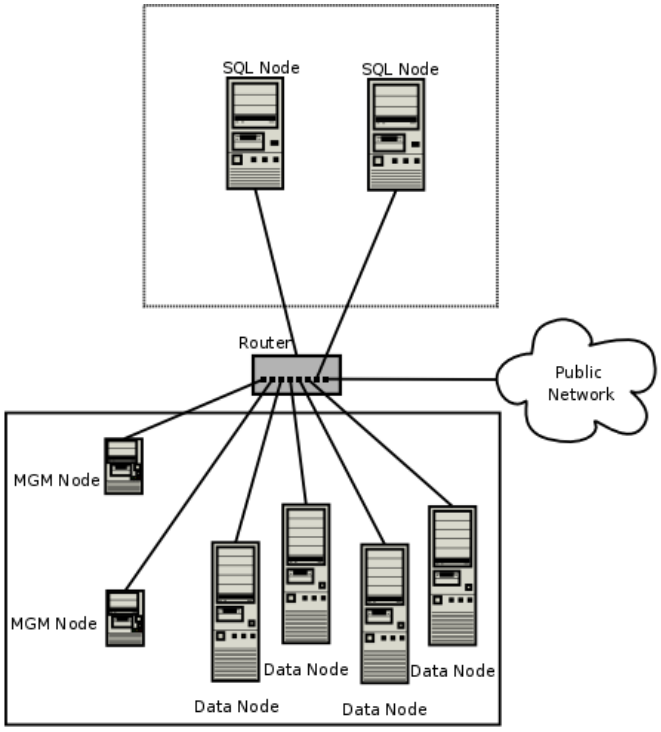
With regard to potential security vulnerabilities, an SQL node is no different from any other MySQL server. See Section 6.1.3, “Making MySQL Secure Against Attackers”, for a description of techniques you can use to secure MySQL servers.

2. Using one or more software firewalls (also known as *host-based firewalls*) to control which packets pass through to the cluster from portions of the network that do not require access to it. In this type of setup, a software firewall must be installed on every host in the cluster which might otherwise be accessible from outside the local network.

   The host-based option is the least expensive to implement, but relies purely on software to provide protection and so is the most difficult to keep secure.

   This type of network setup for NDB Cluster is illustrated here:

Figure 18.9 NDB Cluster with Software Firewalls



Using this type of network setup means that there are two zones of NDB Cluster hosts. Each cluster host must be able to communicate with all of the other machines in the cluster, but only those hosting SQL nodes (dotted box) can be permitted to have any contact with the outside, while those in the zone containing the data nodes and management nodes (solid box) must be isolated from any machines that are not part of the cluster. Applications using the cluster and user of those applications must *not* be permitted to have direct access to the management and data node hosts.

To accomplish this, you must set up software firewalls that limit the traffic to the type or types shown in the following table, according to the type of node that is running on each cluster host computer:

Type of Node to be Accessed	Traffic to Permit
SQL or API node	• It originates from the IP address of a management or data node (using any TCP or UDP port). • It originates from within the network in which the cluster resides and is on the port that your application is using.
Data node or Management node	• It originates from the IP address of a management or data node (using any TCP or UDP port). • It originates from the IP address of an SQL or API node.

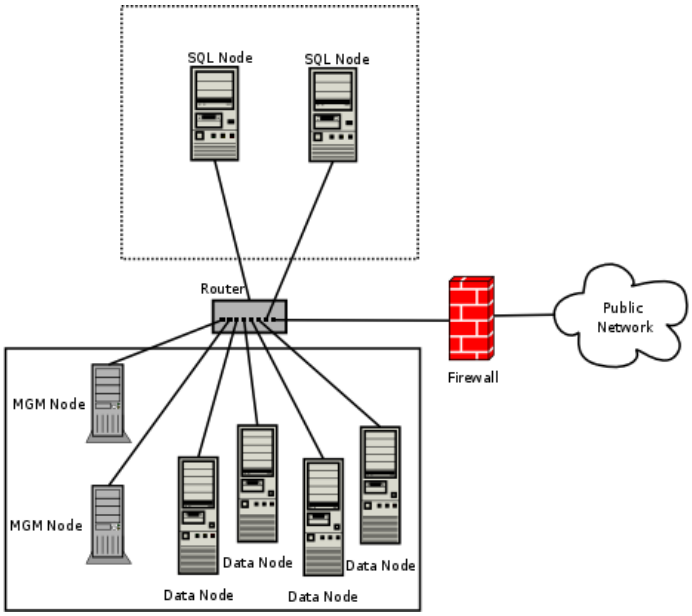
Any traffic other than that shown in the table for a given node type should be denied.

The specifics of configuring a firewall vary from firewall application to firewall application, and are beyond the scope of this Manual. `iptables` is a very common and reliable firewall application, which is often used with APF as a front end to make configuration easier. You can (and should) consult the documentation for the software firewall that you employ, should you choose to implement an NDB Cluster network setup of this type, or of a “mixed” type as discussed under the next item.

3. It is also possible to employ a combination of the first two methods, using both hardware and software to secure the cluster—that is, using both network-based and host-based firewalls. This is between the first two schemes in terms of both security level and cost. This type of network setup keeps the cluster behind the hardware firewall, but permits incoming packets to travel beyond the router connecting all cluster hosts to reach the SQL nodes.

   One possible network deployment of an NDB Cluster using hardware and software firewalls in combination is shown here:

   Figure 18.10 NDB Cluster with a Combination of Hardware and Software Firewalls



   In this case, you can set the rules in the hardware firewall to deny any external traffic except to SQL nodes and API nodes, and then permit traffic to them only on the ports required by your application.

Whatever network configuration you use, remember that your objective from the viewpoint of keeping the cluster secure remains the same—to prevent any unessential traffic from reaching the cluster while ensuring the most efficient communication between the nodes in the cluster.

Because NDB Cluster requires large numbers of ports to be open for communications between nodes, the recommended option is to use a segregated network. This represents the simplest way to prevent unwanted traffic from reaching the cluster.

Note

If you wish to administer an NDB Cluster remotely (that is, from outside the local network), the recommended way to do this is to use `ssh` or another secure login shell to access an SQL node host. From this host, you can then run the management client to access the management server safely, from within the Cluster's own local network.

Even though it is possible to do so in theory, it is *not* recommended to use `ndb_mgm` to manage a Cluster directly from outside the local network on which the Cluster is running. Since neither authentication nor encryption takes place between the management client and the management server, this represents an extremely insecure means of managing the cluster, and is almost certain to be compromised sooner or later.

18.5.11.2 NDB Cluster and MySQL Privileges

In this section, we discuss how the MySQL privilege system works in relation to NDB Cluster and the implications of this for keeping an NDB Cluster secure.

Standard MySQL privileges apply to NDB Cluster tables. This includes all MySQL privilege types (`SELECT` privilege, `UPDATE` privilege, `DELETE` privilege, and so on) granted on the database, table, and column level. As with any other MySQL Server, user and privilege information is stored in the `mysql` system database. The SQL statements used to grant and revoke privileges on `NDB` tables, databases containing such tables, and columns within such tables are identical in all respects with the `GRANT` and `REVOKE` statements used in connection with database objects involving any (other) MySQL storage engine. The same thing is true with respect to the `CREATE USER` and `DROP USER` statements.

It is important to keep in mind that, by default, the MySQL grant tables use the `MyISAM` storage engine. Because of this, those tables are not normally duplicated or shared among MySQL servers acting as SQL nodes in an NDB Cluster. In other words, changes in users and their privileges do not automatically propagate between SQL nodes by default. In NDB Cluster 7.2 (and later), you can enable automatic distribution of MySQL users and privileges across NDB Cluster SQL nodes; see Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”, for details.

Conversely, because there is no way in MySQL to deny privileges (privileges can either be revoked or not granted in the first place, but not denied as such), there is no special protection for `NDB` tables on one SQL node from users that have privileges on another SQL node; (This is true even if you are not using automatic distribution of user privileges. The definitive example of this is the MySQL `root` account, which can perform any action on any database object. In combination with empty `[mysqld]` or `[api]` sections of the `config.ini` file, this account can be especially dangerous. To understand why, consider the following scenario:

- The `config.ini` file contains at least one empty `[mysqld]` or `[api]` section. This means that the NDB Cluster management server performs no checking of the host from which a MySQL Server (or other API node) accesses the NDB Cluster.
- There is no firewall, or the firewall fails to protect against access to the NDB Cluster from hosts external to the network.
- The host name or IP address of the NDB Cluster management server is known or can be determined from outside the network.

If these conditions are true, then anyone, anywhere can start a MySQL Server with `--ndbcluster --ndb-connectstring=`*`management_host`* and access this NDB Cluster. Using the MySQL `root` account, this person can then perform the following actions:

- Execute metadata statements such as `SHOW DATABASES` statement (to obtain a list of all `NDB` databases on the server) or `SHOW TABLES FROM *some_ndb_database*` statement to obtain a list of all `NDB` tables in a given database

- Run any legal MySQL statements on any of the discovered tables, such as:

  - `SELECT * FROM *some_table*` to read all the data from any table

  - `DELETE FROM *some_table*` to delete all the data from a table

  - `DESCRIBE *some_table*` or `SHOW CREATE TABLE *some_table*` to determine the table schema

  - `UPDATE *some_table* SET *column1* = *some_value*` to fill a table column with “garbage” data; this could actually cause much greater damage than simply deleting all the data

    More insidious variations might include statements like these:

    ```
    UPDATE some_table SET an_int_column = an_int_column + 1
    ```

    or

    ```
    UPDATE some_table SET a_varchar_column = REVERSE(a_varchar_column)
    ```

    Such malicious statements are limited only by the imagination of the attacker.

  The only tables that would be safe from this sort of mayhem would be those tables that were created using storage engines other than `NDB`, and so not visible to a “rogue” SQL node.

  A user who can log in as `root` can also access the `INFORMATION_SCHEMA` database and its tables, and so obtain information about databases, tables, stored routines, scheduled events, and any other database objects for which metadata is stored in `INFORMATION_SCHEMA`.

  It is also a very good idea to use different passwords for the `root` accounts on different NDB Cluster SQL nodes unless you are using distributed privileges.

In sum, you cannot have a safe NDB Cluster if it is directly accessible from outside your local network.

Important

Never leave the MySQL root account password empty. This is just as true when running MySQL as an NDB Cluster SQL node as it is when running it as a standalone (non-Cluster) MySQL Server, and should be done as part of the MySQL installation process before configuring the MySQL Server as an SQL node in an NDB Cluster.

Prior to NDB Cluster 7.2, you should never convert the system tables in the `mysql` database to use the `NDB` storage engine. There are a number of reasons why you should not do this, but the most important reason is this: *Many of the SQL statements that affect `mysql` tables storing information about user privileges, stored routines, scheduled events, and other database objects cease to function if these tables are changed to use any storage engine other than `MyISAM`*. This is a consequence of various MySQL Server internals. Beginning with NDB Cluster 7.2, you can use a stored procedure provided for this purpose (see Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”), but you are strongly advised not to attempt convert the system tables manually.

Otherwise, if you need to synchronize `mysql` system tables between SQL nodes, you can use standard MySQL replication to do so, or employ a script to copy table entries between the MySQL servers.

Summary. The most important points to remember regarding the MySQL privilege system with regard to NDB Cluster are listed here:

1. Users and privileges established on one SQL node do not automatically exist or take effect on other SQL nodes in the cluster. Conversely, removing a user or privilege on one SQL node in the cluster does not remove the user or privilege from any other SQL nodes.

2. You can distribute MySQL users and privileges among SQL nodes using the SQL script, and the stored procedures it contains, that are supplied for this purpose in the NDB Cluster distribution.

3. Once a MySQL user is granted privileges on an `NDB` table from one SQL node in an NDB Cluster, that user can "see" any data in that table regardless of the SQL node from which the data originated, even if you are not using privilege distribution.

18.5.11.3 NDB Cluster and MySQL Security Procedures

In this section, we discuss MySQL standard security procedures as they apply to running NDB Cluster.

In general, any standard procedure for running MySQL securely also applies to running a MySQL Server as part of an NDB Cluster. First and foremost, you should always run a MySQL Server as the `mysql` system user; this is no different from running MySQL in a standard (non-Cluster) environment. The `mysql` system account should be uniquely and clearly defined. Fortunately, this is the default behavior for a new MySQL installation. You can verify that the `mysqld` process is running as the system user `mysql` by using the system command such as the one shown here:

```
shell> ps aux | grep mysql
root     10467  0.0  0.1   3616  1380 pts/3    S    11:53   0:00 \
  /bin/sh ./mysqld_safe --ndbcluster --ndb-connectstring=localhost:1186
mysql    10512  0.2  2.5  58528 26636 pts/3    Sl   11:53   0:00 \
  /usr/local/mysql/libexec/mysqld --basedir=/usr/local/mysql \
  --datadir=/usr/local/mysql/var --user=mysql --ndbcluster \
  --ndb-connectstring=localhost:1186 --pid-file=/usr/local/mysql/var/mothra.pid \
  --log-error=/usr/local/mysql/var/mothra.err
jon      10579  0.0  0.0   2736   688 pts/0    S+   11:54   0:00 grep mysql
```

If the `mysqld` process is running as any other user than `mysql`, you should immediately shut it down and restart it as the `mysql` user. If this user does not exist on the system, the `mysql` user account should be created, and this user should be part of the `mysql` user group; in this case, you should also make sure that the MySQL data directory on this system (as set using the `--datadir` option for `mysqld`) is owned by the `mysql` user, and that the SQL node's `my.cnf` file includes `user=mysql` in the `[mysqld]` section. Alternatively, you can start the MySQL server process with `--user=mysql` on the command line, but it is preferable to use the `my.cnf` option, since you might forget to use the command-line option and so have `mysqld` running as another user unintentionally. The `mysqld_safe` startup script forces MySQL to run as the `mysql` user.

Important

Never run `mysqld` as the system root user. Doing so means that potentially any file on the system can be read by MySQL, and thus—should MySQL be compromised—by an attacker.

As mentioned in the previous section (see Section 18.5.11.2, "NDB Cluster and MySQL Privileges"), you should always set a root password for the MySQL Server as soon as you have it running. You should also delete the anonymous user account that is installed by default. You can accomplish these tasks using the following statements:

```
shell> mysql -u root

mysql> UPDATE mysql.user
    ->     SET Password=PASSWORD('secure_password')
    ->     WHERE User='root';

mysql> DELETE FROM mysql.user
    ->     WHERE User='';

mysql> FLUSH PRIVILEGES;
```

Be very careful when executing the `DELETE` statement not to omit the `WHERE` clause, or you risk deleting *all* MySQL users. Be sure to run the `FLUSH PRIVILEGES` statement as soon as you have modified the `mysql.user` table, so that the changes take immediate effect. Without `FLUSH PRIVILEGES`, the changes do not take effect until the next time that the server is restarted.

Note

Many of the NDB Cluster utilities such as `ndb_show_tables`, `ndb_desc`, and `ndb_select_all` also work without authentication and can reveal table names, schemas, and data. By default these are installed on Unix-style systems with the permissions `wxr-xr-x` (755), which means they can be executed by any user that can access the `mysql/bin` directory.

See Section 18.4, “NDB Cluster Programs”, for more information about these utilities.

18.5.12 NDB Cluster Disk Data Tables

It is possible to store the nonindexed columns of `NDB` tables on disk, rather than in RAM.

As part of implementing NDB Cluster Disk Data work, a number of improvements were made in NDB Cluster for the efficient handling of very large amounts (terabytes) of data during node recovery and restart. These include a “no-steal” algorithm for synchronizing a starting node with very large data sets. For more information, see the paper *Recovery Principles of NDB Cluster 5.1*, by NDB Cluster developers Mikael Ronström and Jonas Oreland.

NDB Cluster Disk Data performance can be influenced by a number of configuration parameters. For information about these parameters and their effects, see *NDB Cluster Disk Data configuration parameters* and *NDB Cluster Disk Data storage and `GCP Stop` errors*

The performance of an NDB Cluster that uses Disk Data storage can also be greatly improved by separating data node file systems from undo log files and tablespace data files, which can be done using symbolic links. For more information, see Section 18.5.12.2, “Using Symbolic Links with Disk Data Objects”.

18.5.12.1 NDB Cluster Disk Data Objects

NDB Cluster Disk Data storage is implemented using a number of *Disk Data objects*. These include the following:

- *Tablespaces* act as containers for other Disk Data objects.
- *Undo log files* undo information required for rolling back transactions.
- One or more undo log files are assigned to a *log file group*, which is then assigned to a tablespace.
- *Data files* store Disk Data table data. A data file is assigned directly to a tablespace.

Undo log files and data files are actual files in the file system of each data node; by default they are placed in `ndb_node_id_fs` in the `DataDir` specified in the NDB Cluster `config.ini` file, and where `node_id` is the data node's node ID. It is possible to place these elsewhere by specifying either an absolute or relative path as part of the filename when creating the undo log or data file. Statements that create these files are shown later in this section.

NDB Cluster tablespaces and log file groups are not implemented as files.

Important

Although not all Disk Data objects are implemented as files, they all share the same namespace. This means that *each Disk Data object* must be uniquely named (and not merely each Disk Data object of a given type). For example, you cannot have a tablespace and a log file group both named `dd1`.

Assuming that you have already set up an NDB Cluster with all nodes (including management and SQL nodes), the basic steps for creating an NDB Cluster table on disk are as follows:

1. Create a log file group, and assign one or more undo log files to it (an undo log file is also sometimes referred to as an *undofile*).

   Note

   Undo log files are necessary only for Disk Data tables; they are not used for `NDBCLUSTER` tables that are stored only in memory.

2. Create a tablespace; assign the log file group, as well as one or more data files, to the tablespace.

3. Create a Disk Data table that uses this tablespace for data storage.

Each of these tasks can be accomplished using SQL statements in the `mysql` client or other MySQL client application, as shown in the example that follows.

1. We create a log file group named `lg_1` using `CREATE LOGFILE GROUP`. This log file group is to be made up of two undo log files, which we name `undo_1.log` and `undo_2.log`, whose initial sizes are 16 MB and 12 MB, respectively. (The default initial size for an undo log file is 128 MB.) Optionally, you can also specify a size for the log file group's undo buffer, or permit it to assume the default value of 8 MB. In this example, we set the UNDO buffer's size at 2 MB. A log file group must be created with an undo log file; so we add `undo_1.log` to `lg_1` in this `CREATE LOGFILE GROUP` statement:

   ```
   CREATE LOGFILE GROUP lg_1
       ADD UNDOFILE 'undo_1.log'
       INITIAL_SIZE 16M
       UNDO_BUFFER_SIZE 2M
       ENGINE NDBCLUSTER;
   ```

   To add `undo_2.log` to the log file group, use the following `ALTER LOGFILE GROUP` statement:

   ```
   ALTER LOGFILE GROUP lg_1
       ADD UNDOFILE 'undo_2.log'
       INITIAL_SIZE 12M
       ENGINE NDBCLUSTER;
   ```

   Some items of note:

   - The `.log` file extension used here is not required. We use it merely to make the log files easily recognisable.
   - Every `CREATE LOGFILE GROUP` and `ALTER LOGFILE GROUP` statement must include an `ENGINE` option. The only permitted values for this option are `NDBCLUSTER` and `NDB`.

     Important

     There can exist at most one log file group in the same NDB Cluster at any given time.

   - When you add an undo log file to a log file group using `ADD UNDOFILE 'filename'`, a file with the name *`filename`* is created in the `ndb_node_id_fs` directory within the `DataDir` of each data node in the cluster, where *`node_id`* is the node ID of the data node. Each undo log file is of the size specified in the SQL statement. For example, if an NDB Cluster has 4 data nodes, then the `ALTER LOGFILE GROUP` statement just shown creates 4 undo log files, 1 each on in the data directory of each of the 4 data nodes; each of these files is named `undo_2.log` and each file is 12 MB in size.
   - `UNDO_BUFFER_SIZE` is limited by the amount of system memory available.

- For more information about the `CREATE LOGFILE GROUP` statement, see Section 13.1.14, “CREATE LOGFILE GROUP Syntax”. For more information about `ALTER LOGFILE GROUP`, see Section 13.1.4, “ALTER LOGFILE GROUP Syntax”.

2. Now we can create a tablespace, which contains files to be used by NDB Cluster Disk Data tables for storing their data. A tablespace is also associated with a particular log file group. When creating a new tablespace, you must specify the log file group which it is to use for undo logging; you must also specify a data file. You can add more data files to the tablespace after the tablespace is created; it is also possible to drop data files from a tablespace (an example of dropping data files is provided later in this section).

   Assume that we wish to create a tablespace named `ts_1` which uses `lg_1` as its log file group. This tablespace is to contain two data files named `data_1.dat` and `data_2.dat`, whose initial sizes are 32 MB and 48 MB, respectively. (The default value for `INITIAL_SIZE` is 128 MB.) We can do this using two SQL statements, as shown here:

```
CREATE TABLESPACE ts_1
    ADD DATAFILE 'data_1.dat'
    USE LOGFILE GROUP lg_1
    INITIAL_SIZE 32M
    ENGINE NDBCLUSTER;

ALTER TABLESPACE ts_1
    ADD DATAFILE 'data_2.dat'
    INITIAL_SIZE 48M
    ENGINE NDBCLUSTER;
```

   The `CREATE TABLESPACE` statement creates a tablespace `ts_1` with the data file `data_1.dat`, and associates `ts_1` with log file group `lg_1`. The `ALTER TABLESPACE` adds the second data file (`data_2.dat`).

   Some items of note:

   - As is the case with the `.log` file extension used in this example for undo log files, there is no special significance for the `.dat` file extension; it is used merely for easy recognition of data files.
   - When you add a data file to a tablespace using `ADD DATAFILE 'filename'`, a file with the name *`filename`* is created in the `ndb_node_id_fs` directory within the `DataDir` of each data node in the cluster, where *`node_id`* is the node ID of the data node. Each data file is of the size specified in the SQL statement. For example, if an NDB Cluster has 4 data nodes, then the `ALTER TABLESPACE` statement just shown creates 4 data files, 1 each in the data directory of each of the 4 data nodes; each of these files is named `data_2.dat` and each file is 48 MB in size.
   - All `CREATE TABLESPACE` and `ALTER TABLESPACE` statements must contain an `ENGINE` clause; only tables using the same storage engine as the tablespace can be created in the tablespace. In MySQL NDB Cluster 7.2, the only permitted values for this clause are `NDBCLUSTER` and `NDB`.
   - For more information about the `CREATE TABLESPACE` and `ALTER TABLESPACE` statements, see Section 13.1.18, “CREATE TABLESPACE Syntax”, and Section 13.1.8, “ALTER TABLESPACE Syntax”.

3. Now it is possible to create a table whose nonindexed columns are stored on disk in the tablespace `ts_1`:

```
CREATE TABLE dt_1 (
    member_id INT UNSIGNED NOT NULL AUTO_INCREMENT PRIMARY KEY,
    last_name VARCHAR(50) NOT NULL,
    first_name VARCHAR(50) NOT NULL,
```

```
    dob DATE NOT NULL,
    joined DATE NOT NULL,
    INDEX(last_name, first_name)
    )
    TABLESPACE ts_1 STORAGE DISK
    ENGINE NDBCLUSTER;
```

The `TABLESPACE ... STORAGE DISK` option tells the `NDBCLUSTER` storage engine to use tablespace `ts_1` for disk data storage.

Once table `ts_1` has been created as shown, you can perform `INSERT`, `SELECT`, `UPDATE`, and `DELETE` statements on it just as you would with any other MySQL table.

It is also possible to specify whether an individual column is stored on disk or in memory by using a `STORAGE` clause as part of the column's definition in a `CREATE TABLE` or `ALTER TABLE` statement. `STORAGE DISK` causes the column to be stored on disk, and `STORAGE MEMORY` causes in-memory storage to be used. See Section 13.1.17, “CREATE TABLE Syntax”, for more information.

Indexing of columns implicitly stored on disk. For table `dt_1` as defined in the example just shown, only the `dob` and `joined` columns are stored on disk. This is because there are indexes on the `id`, `last_name`, and `first_name` columns, and so data belonging to these columns is stored in RAM. Only nonindexed columns can be held on disk; indexes and indexed column data continue to be stored in memory. This tradeoff between the use of indexes and conservation of RAM is something you must keep in mind as you design Disk Data tables.

You cannot add an index to a column that has been explicitly declared `STORAGE DISK`, without first changing its storage type to `MEMORY`; any attempt to do so fails with an error. A column which *implicitly* uses disk storage can be indexed; when this is done, the column's storage type is changed to `MEMORY` automatically. By “implicitly”, we mean a column whose storage type is not declared, but which is which inherited from the parent table. In the following CREATE TABLE statement (using the tablespace `ts_1` defined previously), columns `c2` and `c3` use disk storage implicitly:

```
mysql> CREATE TABLE ti (
    ->     c1 INT PRIMARY KEY,
    ->     c2 INT,
    ->     c3 INT,
    ->     c4 INT
    -> )
    ->     STORAGE DISK
    ->     TABLESPACE ts_1
    ->     ENGINE NDBCLUSTER;
Query OK, 0 rows affected (1.31 sec)
```

Because `c2`, `c3`, and `c4` are themselves not declared with `STORAGE DISK`, it is possible to index them. Here, we add indexes to `c2` and `c3`, using, respectively, `CREATE INDEX` and `ALTER TABLE`:

```
mysql> CREATE INDEX i1 ON ti(c2);
Query OK, 0 rows affected (2.72 sec)
Records: 0  Duplicates: 0  Warnings: 0

mysql> ALTER TABLE ti ADD INDEX i2(c3);
Query OK, 0 rows affected (0.92 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

`SHOW CREATE TABLE` confirms that the indexes were added.

```
mysql> SHOW CREATE TABLE ti\G
*************************** 1. row ***************************
       Table: ti
Create Table: CREATE TABLE `ti` (
  `c1` int(11) NOT NULL,
  `c2` int(11) DEFAULT NULL,
  `c3` int(11) DEFAULT NULL,
```

```
  `c4` int(11) DEFAULT NULL,
  PRIMARY KEY (`c1`),
  KEY `i1` (`c2`),
  KEY `i2` (`c3`)
) /*!50100 TABLESPACE `ts_1` STORAGE DISK */ ENGINE=ndbcluster DEFAULT CHARSET=latin1
1 row in set (0.00 sec)
```

You can see using `ndb_desc` that the indexed columns (emphasized text) now use in-memory rather than on-disk storage:

```
shell> ./ndb_desc -d test t1
-- t1 --
Version: 33554433
Fragment type: HashMapPartition
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 4
Number of primary keys: 1
Length of frm data: 317
Max Rows: 0
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
PartitionCount: 4
FragmentCount: 4
PartitionBalance: FOR_RP_BY_LDM
ExtraRowGciBits: 0
ExtraRowAuthorBits: 0
TableStatus: Retrieved
Table options:
HashMap: DEFAULT-HASHMAP-3840-4
-- Attributes --
c1 Int PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY
c2 Int NULL AT=FIXED ST=MEMORY
c3 Int NULL AT=FIXED ST=MEMORY
c4 Int NULL AT=FIXED ST=DISK
-- Indexes --
PRIMARY KEY(c1) - UniqueHashIndex
i2(c3) - OrderedIndex
PRIMARY(c1) - OrderedIndex
i1(c2) - OrderedIndex

NDBT_ProgramExit: 0 - OK
```

Performance note. The performance of a cluster using Disk Data storage is greatly improved if Disk Data files are kept on a separate physical disk from the data node file system. This must be done for each data node in the cluster to derive any noticeable benefit.

You may use absolute and relative file system paths with `ADD UNDOFILE` and `ADD DATAFILE`. Relative paths are calculated relative to the data node's data directory. You may also use symbolic links; see Section 18.5.12.2, “Using Symbolic Links with Disk Data Objects”, for more information and examples.

A log file group, a tablespace, and any Disk Data tables using these must be created in a particular order. The same is true for dropping any of these objects:

- A log file group cannot be dropped as long as any tablespaces are using it.
- A tablespace cannot be dropped as long as it contains any data files.
- You cannot drop any data files from a tablespace as long as there remain any tables which are using the tablespace.
- It is not possible to drop files created in association with a different tablespace than the one with which the files were created. (Bug #20053)

For example, to drop all the objects created so far in this section, you would use the following statements:

```
mysql> DROP TABLE dt_1;

mysql> ALTER TABLESPACE ts_1
    -> DROP DATAFILE 'data_2.dat'
    -> ENGINE NDBCLUSTER;

mysql> ALTER TABLESPACE ts_1
    -> DROP DATAFILE 'data_1.dat'
    -> ENGINE NDBCLUSTER;

mysql> DROP TABLESPACE ts_1
    -> ENGINE NDBCLUSTER;

mysql> DROP LOGFILE GROUP lg_1
    -> ENGINE NDBCLUSTER;
```

These statements must be performed in the order shown, except that the two `ALTER TABLESPACE ... DROP DATAFILE` statements may be executed in either order.

You can obtain information about data files used by Disk Data tables by querying the `FILES` table in the `INFORMATION_SCHEMA` database. An extra "`NULL` row" provides additional information about undo log files. For more information and examples, see Section 21.29.1, "The INFORMATION_SCHEMA FILES Table".

18.5.12.2 Using Symbolic Links with Disk Data Objects

The performance of an NDB Cluster that uses Disk Data storage can be greatly improved by separating data node file systems from undo log files and tablespace data files and placing these on different disks. In early versions of NDB Cluster, there was no direct support for this in NDB Cluster, but it was possible to achieve this separation using symbolic links as described in this section. NDB Cluster 7.2 supports the data node configuration parameters `FileSystemPathDD`, `FileSystemPathDataFiles`, and `FileSystemPathUndoFiles`, which make the use of symbolic links for this purpose unnecessary. For more information about these parameters, see Disk Data file system parameters.

Each data node in the cluster creates a file system in the directory named `ndb_node_id_fs` under the data node's `DataDir` as defined in the `config.ini` file. In this example, we assume that each data node host has 3 disks, aliased as `/data0`, `/data1`, and `/data2`, and that the cluster's `config.ini` includes the following:

```
[ndbd default]
DataDir= /data0
```

Our objective is to place all Disk Data log files in `/data1`, and all Disk Data data files in `/data2`, on each data node host.

Note

In this example, we assume that the cluster's data node hosts are all using Linux operating systems. For other platforms, you may need to substitute you operating system's commands for those shown here.

To accomplish this, perform the following steps:

- Under the data node file system create symbolic links pointing to the other drives:

```
shell> cd /data0/ndb_2_fs
shell> ls
D1  D10  D11  D2  D8  D9  LCP
```

```
shell> ln -s /data0 dnlogs
shell> ln -s /data1 dndata
```

You should now have two symbolic links:

```
shell> ls -l --hide=D*
lrwxrwxrwx 1 user group   30 2007-03-19 13:58 dndata -> /data1
lrwxrwxrwx 1 user group   30 2007-03-19 13:59 dnlogs -> /data2
```

We show this only for the data node with node ID 2; however, you must do this for *each* data node.

- Now, in the `mysql` client, create a log file group and tablespace using the symbolic links, as shown here:

```
mysql> CREATE LOGFILE GROUP lg1
    ->    ADD UNDOFILE 'dnlogs/undo1.log'
    ->    INITIAL_SIZE 150M
    ->    UNDO_BUFFER_SIZE = 1M
    ->    ENGINE=NDBCLUSTER;

mysql> CREATE TABLESPACE ts1
    ->    ADD DATAFILE 'dndata/data1.log'
    ->    USE LOGFILE GROUP lg1
    ->    INITIAL_SIZE 1G
    ->    ENGINE=NDBCLUSTER;
```

Verify that the files were created and placed correctly as shown here:

```
shell> cd /data1
shell> ls -l
total 2099304
-rw-rw-r--  1 user group 157286400 2007-03-19 14:02 undo1.dat

shell> cd /data2
shell> ls -l
total 2099304
-rw-rw-r--  1 user group 1073741824 2007-03-19 14:02 data1.dat
```

- If you are running multiple data nodes on one host, you must take care to avoid having them try to use the same space for Disk Data files. You can make this easier by creating a symbolic link in each data node file system. Suppose you are using `/data0` for both data node file systems, but you wish to have the Disk Data files for both nodes on `/data1`. In this case, you can do something similar to what is shown here:

```
shell> cd /data0
shell> ln -s /data1/dn2 ndb_2_fs/dd
shell> ln -s /data1/dn3 ndb_3_fs/dd
shell> ls -l --hide=D* ndb_2_fs
lrwxrwxrwx 1 user group   30 2007-03-19 14:22 dd -> /data1/dn2
shell> ls -l --hide=D* ndb_3_fs
lrwxrwxrwx 1 user group   30 2007-03-19 14:22 dd -> /data1/dn3
```

- Now you can create a logfile group and tablespace using the symbolic link, like this:

```
mysql> CREATE LOGFILE GROUP lg1
    ->    ADD UNDOFILE 'dd/undo1.log'
    ->    INITIAL_SIZE 150M
    ->    UNDO_BUFFER_SIZE = 1M
    ->    ENGINE=NDBCLUSTER;

mysql> CREATE TABLESPACE ts1
    ->    ADD DATAFILE 'dd/data1.log'
    ->    USE LOGFILE GROUP lg1
    ->    INITIAL_SIZE 1G
    ->    ENGINE=NDBCLUSTER;
```

Verify that the files were created and placed correctly as shown here:

```
shell> cd /data1
shell> ls
dn2        dn3
shell> ls dn2
undo1.log        data1.log
shell> ls dn3
undo1.log        data1.log
```

18.5.12.3 NDB Cluster Disk Data Storage Requirements

The following items apply to Disk Data storage requirements:

- Variable-length columns of Disk Data tables take up a fixed amount of space. For each row, this is equal to the space required to store the largest possible value for that column.

  For general information about calculating these values, see Section 11.7, “Data Type Storage Requirements”.

  You can obtain an estimate the amount of space available in data files and undo log files by querying the `INFORMATION_SCHEMA.FILES` table. For more information and examples, see Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”.

  Note

  The `OPTIMIZE TABLE` statement does not have any effect on Disk Data tables.

- In a Disk Data table, the first 256 bytes of a `TEXT` or `BLOB` column are stored in memory; only the remainder is stored on disk.

- Each row in a Disk Data table uses 8 bytes in memory to point to the data stored on disk. This means that, in some cases, converting an in-memory column to the disk-based format can actually result in greater memory usage. For example, converting a `CHAR(4)` column from memory-based to disk-based format increases the amount of `DataMemory` used per row from 4 to 8 bytes.

  Important

  Starting the cluster with the `--initial` option does *not* remove Disk Data files. You must remove these manually prior to performing an initial restart of the cluster.

Performance of Disk Data tables can be improved by minimizing the number of disk seeks by making sure that `DiskPageBufferMemory` is of sufficient size. You can query the `diskpagebuffer` table to help determine whether the value for this parameter needs to be increased.

18.5.13 Adding NDB Cluster Data Nodes Online

This section describes how to add NDB Cluster data nodes “online”—that is, without needing to shut down the cluster completely and restart it as part of the process.

Important

Currently, you must add new data nodes to an NDB Cluster as part of a new node group. In addition, it is not possible to change the number of replicas (or the number of nodes per node group) online.

18.5.13.1 Adding NDB Cluster Data Nodes Online: General Issues

This section provides general information about the behavior of and current limitations in adding NDB Cluster nodes online.

Redistribution of Data. The ability to add new nodes online includes a means to reorganize `NDBCLUSTER` table data and indexes so that they are distributed across all data nodes, including the new ones, by means of the `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement. Table reorganization of both in-memory and Disk Data tables is supported. This redistribution does not currently include unique indexes (only ordered indexes are redistributed). Prior to NDB 7.2.14, `BLOB` table data is also not redistributed using this method (Bug #13714148).

The redistribution for `NDBCLUSTER` tables already existing before the new data nodes were added is not automatic, but can be accomplished using simple SQL statements in `mysql` or another MySQL client application. However, all data and indexes added to tables created after a new node group has been added are distributed automatically among all cluster data nodes, including those added as part of the new node group.

Partial starts. It is possible to add a new node group without all of the new data nodes being started. It is also possible to add a new node group to a degraded cluster—that is, a cluster that is only partially started, or where one or more data nodes are not running. In the latter case, the cluster must have enough nodes running to be viable before the new node group can be added.

Effects on ongoing operations. Normal DML operations using NDB Cluster data are not prevented by the creation or addition of a new node group, or by table reorganization. However, it is not possible to perform DDL concurrently with table reorganization—that is, no other DDL statements can be issued while an `ALTER TABLE ... REORGANIZE PARTITION` statement is executing. In addition, during the execution of `ALTER TABLE ... REORGANIZE PARTITION` (or the execution of any other DDL statement), it is not possible to restart cluster data nodes.

Failure handling. Failures of data nodes during node group creation and table reorganization are handled as hown in the following table:

Failure occurs during:	**Failure occurs in:**		
	“Old” data nodes	**“New” data nodes**	**System**

Node group creation	• **If a node other than the master fails:** The creation of the node group is always rolled forward.
	• **If the master fails:**
	  • **If the internal commit point has been reached:** The creation of the node group is rolled forward.
	  • **If the internal commit point has not yet been reached.** The creation of the node group is rolled back
		• **If a node other than the master fails:** The creation of the node group is always rolled forward.
		• **If the master fails:**
		  • **If the internal commit point has been reached:** The creation of the node group is rolled forward.
		  • **If the internal commit point has not yet been reached.** The creation of the node group is rolled back
			• **If the execution of CREATE NODEGROUP has reached the internal commit point:** When restarted, the cluster includes the new node group. Otherwise it without.
			• **If the execution of CREATE NODEGROUP has not yet reached the internal commit point:** When restarted, the cluster does not include the new node group.

Table reorganization	• **If a node other than the master fails:** The table reorganization is always rolled forward. • **If the master fails:**	• **If a node other than the master fails:** The table reorganization is always rolled forward. • **If the master fails:**	• **If the execution of an ALTER ONLINE TABLE table REORGANIZE PARTITION statement has reached the internal**

Failure occurs during:	Failure occurs in:		
	“Old” data nodes	“New” data nodes	System
	• **If the internal commit point has been reached:** The table reorganization is rolled forward. • **If the internal commit point has not yet been reached.** The table reorganization is rolled back.	• **If the internal commit point has been reached:** The table reorganization is rolled forward. • **If the internal commit point has not yet been reached.** The table reorganization is rolled back.	**commit point:** When the cluster is restarted, the data and indexes belonging to *`table`* are distributed using the “new” data nodes. • **If the execution of an ALTER ONLINE TABLE table REORGANIZE PARTITION statement has not yet reached the internal commit point:** When the cluster is restarted, the data and indexes belonging to *`table`* are distributed using only the “old” data nodes.

Dropping node groups. The `ndb_mgm` client supports a `DROP NODEGROUP` command, but it is possible to drop a node group only when no data nodes in the node group contain any data. Since there is currently no way to “empty” a specific data node or node group, this command works only the following two cases:

1. After issuing `CREATE NODEGROUP` in the `ndb_mgm` client, but before issuing any `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statements in the `mysql` client.

2. After dropping all `NDBCLUSTER` tables using `DROP TABLE`.

   `TRUNCATE TABLE` does not work for this purpose because the data nodes continue to store the table definitions.

18.5.13.2 Adding NDB Cluster Data Nodes Online: Basic procedure

In this section, we list the basic steps required to add new data nodes to an NDB Cluster. This procedure applies whether you are using `ndbd` or `ndbmtd` binaries for the data node processes. For a more detailed example, see Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”.

Assuming that you already have a running NDB Cluster, adding data nodes online requires the following steps:

1. Edit the cluster configuration `config.ini` file, adding new `[ndbd]` sections corresponding to the nodes to be added. In the case where the cluster uses multiple management servers, these changes need to be made to all `config.ini` files used by the management servers.

   You must be careful that node IDs for any new data nodes added in the `config.ini` file do not overlap node IDs used by existing nodes. In the event that you have API nodes using dynamically allocated node IDs and these IDs match node IDs that you want to use for new data nodes, it is possible to force any such API nodes to “migrate”, as described later in this procedure.

2. Perform a rolling restart of all NDB Cluster management servers.

Important

All management servers must be restarted with the `--reload` or `--initial` option to force the reading of the new configuration.

3. Perform a rolling restart of all existing NDB Cluster data nodes. It is not necessary (or usually even desirable) to use `--initial` when restarting the existing data nodes.

   If you are using API nodes with dynamically allocated IDs matching any node IDs that you wish to assign to new data nodes, you must restart all API nodes (including SQL nodes) before restarting any of the data nodes processes in this step. This causes any API nodes with node IDs that were previously not explicitly assigned to relinquish those node IDs and acquire new ones.

4. Perform a rolling restart of any SQL or API nodes connected to the NDB Cluster.

5. Start the new data nodes.

   The new data nodes may be started in any order. They can also be started concurrently, as long as they are started after the rolling restarts of all existing data nodes have been completed, and before proceeding to the next step.

6. Execute one or more `CREATE NODEGROUP` commands in the NDB Cluster management client to create the new node group or node groups to which the new data nodes will belong.

7. Redistribute the cluster's data among all data nodes, including the new ones. Normally this is done by issuing an `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement in the `mysql` client for each `NDBCLUSTER` table.

   Exception: For tables created using the `MAX_ROWS` option, this statement does not work; instead, use `ALTER ONLINE TABLE ... MAX_ROWS=...` to reorganize such tables.

Note

This needs to be done only for tables already existing at the time the new node group is added. Data in tables created after the new node group is added is distributed automatically; however, data added to any given table `tbl` that existed before the new nodes were added is not distributed using the new nodes until that table has been reorganized.

8. `ALTER ONLINE TABLE ... REORGANIZE PARTITION` reorganizes partitions but does not reclaim the space freed on the “old” nodes. You can do this by issuing, for each `NDBCLUSTER` table, an `OPTIMIZE TABLE` statement in the `mysql` client.

   This works for space used by variable-width columns of in-memory `NDB` tables. `OPTIMIZE TABLE` is not supported for fixed-width columns of in-memory tables; it is also not supported for Disk Data tables.

You can add all the nodes desired, then issue several `CREATE NODEGROUP` commands in succession to add the new node groups to the cluster.

18.5.13.3 Adding NDB Cluster Data Nodes Online: Detailed Example

In this section we provide a detailed example illustrating how to add new NDB Cluster data nodes online, starting with an NDB Cluster having 2 data nodes in a single node group and concluding with a cluster having 4 data nodes in 2 node groups.

Starting configuration. For purposes of illustration, we assume a minimal configuration, and that the cluster uses a `config.ini` file containing only the following information:

```
[ndbd default]
DataMemory = 100M
IndexMemory = 100M
NoOfReplicas = 2
DataDir = /usr/local/mysql/var/mysql-cluster

[ndbd]
Id = 1
HostName = 198.51.100.1

[ndbd]
Id = 2
HostName = 198.51.100.2

[mgm]
HostName = 198.51.100.10
Id = 10

[api]
Id=20
HostName = 198.51.100.20

[api]
Id=21
HostName = 198.51.100.21
```

Note

We have left a gap in the sequence between data node IDs and other nodes. This make it easier later to assign node IDs that are not already in use to data nodes which are newly added.

We also assume that you have already started the cluster using the appropriate command line or `my.cnf` options, and that running `SHOW` in the management client produces output similar to what is shown here:

```
-- NDB Cluster -- Management Client --
ndb_mgm> SHOW
Connected to Management Server at: 198.51.100.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @198.51.100.1  (5.5.58-ndb-7.2.32, Nodegroup: 0, *)
id=2    @198.51.100.2  (5.5.58-ndb-7.2.32, Nodegroup: 0)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @198.51.100.10  (5.5.58-ndb-7.2.32)

[mysqld(API)]   2 node(s)
id=20   @198.51.100.20  (5.5.58-ndb-7.2.32)
id=21   @198.51.100.21  (5.5.58-ndb-7.2.32)
```

Finally, we assume that the cluster contains a single `NDBCLUSTER` table created as shown here:

```
USE n;

CREATE TABLE ips (
    id BIGINT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    country_code CHAR(2) NOT NULL,
    type CHAR(4) NOT NULL,
    ip_address VARCHAR(15) NOT NULL,
    addresses BIGINT UNSIGNED DEFAULT NULL,
    date BIGINT UNSIGNED DEFAULT NULL
)   ENGINE NDBCLUSTER;
```

The memory usage and related information shown later in this section was generated after inserting approximately 50000 rows into this table.

Note

In this example, we show the single-threaded `ndbd` being used for the data node processes. However—beginning with NDB 7.0.4—you can also apply this example, if you are using the multi-threaded `ndbmtd` by substituting `ndbmtd` for `ndbd` wherever it appears in the steps that follow. (Bug #43108)

Step 1: Update configuration file. Open the cluster global configuration file in a text editor and add `[ndbd]` sections corresponding to the 2 new data nodes. (We give these data nodes IDs 3 and 4, and assume that they are to be run on host machines at addresses 198.51.100.3 and 198.51.100.4, respectively.) After you have added the new sections, the contents of the `config.ini` file should look like what is shown here, where the additions to the file are shown in bold type:

```
[ndbd default]
DataMemory = 100M
IndexMemory = 100M
NoOfReplicas = 2
DataDir = /usr/local/mysql/var/mysql-cluster

[ndbd]
Id = 1
HostName = 198.51.100.1

[ndbd]
Id = 2
HostName = 198.51.100.2

[ndbd]
Id = 3
HostName = 198.51.100.3

[ndbd]
Id = 4
HostName = 198.51.100.4

[mgm]
HostName = 198.51.100.10
Id = 10

[api]
Id=20
HostName = 198.51.100.20

[api]
Id=21
HostName = 198.51.100.21
```

Once you have made the necessary changes, save the file.

Step 2: Restart the management server. Restarting the cluster management server requires that you issue separate commands to stop the management server and then to start it again, as follows:

1. Stop the management server using the management client `STOP` command, as shown here:

   ```
   ndb_mgm> 10 STOP
   Node 10 has shut down.
   Disconnecting to allow Management Server to shutdown

   shell>
   ```

2. Because shutting down the management server causes the management client to terminate, you must start the management server from the system shell. For simplicity, we assume that `config.ini` is in the same directory as the management server binary, but in practice, you must supply the correct path to the configuration file. You must also supply the `--reload` or `--initial` option so that the management server reads the new configuration from the file rather than its

configuration cache. If your shell's current directory is also the same as the directory where the management server binary is located, then you can invoke the management server as shown here:

```
shell> ndb_mgmd -f config.ini --reload
2008-12-08 17:29:23 [MgmSrvr] INFO     -- NDB Cluster Management Server. 5.5.58-ndb-7.2.32
2008-12-08 17:29:23 [MgmSrvr] INFO     -- Reading cluster configuration from 'config.ini'
```

If you check the output of `SHOW` in the management client after restarting the `ndb_mgm` process, you should now see something like this:

```
-- NDB Cluster -- Management Client --
ndb_mgm> SHOW
Connected to Management Server at: 198.51.100.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @198.51.100.1  (5.5.58-ndb-7.2.32, Nodegroup: 0, *)
id=2    @198.51.100.2  (5.5.58-ndb-7.2.32, Nodegroup: 0)
id=3 (not connected, accepting connect from 198.51.100.3)
id=4 (not connected, accepting connect from 198.51.100.4)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @198.51.100.10  (5.5.58-ndb-7.2.32)

[mysqld(API)]   2 node(s)
id=20   @198.51.100.20  (5.5.58-ndb-7.2.32)
id=21   @198.51.100.21  (5.5.58-ndb-7.2.32)
```

Step 3: Perform a rolling restart of the existing data nodes. This step can be accomplished entirely within the cluster management client using the `RESTART` command, as shown here:

```
ndb_mgm> 1 RESTART
Node 1: Node shutdown initiated
Node 1: Node shutdown completed, restarting, no start.
Node 1 is being restarted

ndb_mgm> Node 1: Start initiated (version 7.2.32)
Node 1: Started (version 7.2.32)

ndb_mgm> 2 RESTART
Node 2: Node shutdown initiated
Node 2: Node shutdown completed, restarting, no start.
Node 2 is being restarted

ndb_mgm> Node 2: Start initiated (version 7.2.32)

ndb_mgm> Node 2: Started (version 7.2.32)
```

Important

After issuing each `X RESTART` command, wait until the management client reports `Node X: Started (version ...)` *before* proceeding any further.

You can verify that all existing data nodes were restarted using the updated configuration by checking the `ndbinfo.nodes` table in the `mysql` client.

Step 4: Perform a rolling restart of all cluster API nodes. Shut down and restart each MySQL server acting as an SQL node in the cluster using `mysqladmin shutdown` followed by `mysqld_safe` (or another startup script). This should be similar to what is shown here, where *`password`* is the MySQL `root` password for a given MySQL server instance:

```
shell> mysqladmin -uroot -ppassword shutdown
081208 20:19:56 mysqld_safe mysqld from pid file
/usr/local/mysql/var/tonfisk.pid ended
```

```
shell> mysqld_safe --ndbcluster --ndb-connectstring=198.51.100.10 &
081208 20:20:06 mysqld_safe Logging to '/usr/local/mysql/var/tonfisk.err'.
081208 20:20:06 mysqld_safe Starting mysqld daemon with databases
from /usr/local/mysql/var
```

Of course, the exact input and output depend on how and where MySQL is installed on the system, as well as which options you choose to start it (and whether or not some or all of these options are specified in a `my.cnf` file).

Step 5: Perform an initial start of the new data nodes. From a system shell on each of the hosts for the new data nodes, start the data nodes as shown here, using the `--initial` option:

```
shell> ndbd -c 198.51.100.10 --initial
```

Note

Unlike the case with restarting the existing data nodes, you can start the new data nodes concurrently; you do not need to wait for one to finish starting before starting the other.

Wait until both of the new data nodes have started before proceeding with the next step. Once the new data nodes have started, you can see in the output of the management client `SHOW` command that they do not yet belong to any node group (as indicated with bold type here):

```
ndb_mgm> SHOW
Connected to Management Server at: 198.51.100.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @198.51.100.1  (5.5.58-ndb-7.2.32, Nodegroup: 0, *)
id=2    @198.51.100.2  (5.5.58-ndb-7.2.32, Nodegroup: 0)
id=3    @198.51.100.3  (5.5.58-ndb-7.2.32, no nodegroup)
id=4    @198.51.100.4  (5.5.58-ndb-7.2.32, no nodegroup)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @198.51.100.10  (5.5.58-ndb-7.2.32)

[mysqld(API)]   2 node(s)
id=20   @198.51.100.20  (5.5.58-ndb-7.2.32)
id=21   @198.51.100.21  (5.5.58-ndb-7.2.32)
```

Step 6: Create a new node group. You can do this by issuing a `CREATE NODEGROUP` command in the cluster management client. This command takes as its argument a comma-separated list of the node IDs of the data nodes to be included in the new node group, as shown here:

```
ndb_mgm> CREATE NODEGROUP 3,4
Nodegroup 1 created
```

By issuing `SHOW` again, you can verify that data nodes 3 and 4 have joined the new node group (again indicated in bold type):

```
ndb_mgm> SHOW
Connected to Management Server at: 198.51.100.10:1186
Cluster Configuration
---------------------
[ndbd(NDB)]     2 node(s)
id=1    @198.51.100.1  (5.5.58-ndb-7.2.32, Nodegroup: 0, *)
id=2    @198.51.100.2  (5.5.58-ndb-7.2.32, Nodegroup: 0)
id=3    @198.51.100.3  (5.5.58-ndb-7.2.32, Nodegroup: 1)
id=4    @198.51.100.4  (5.5.58-ndb-7.2.32, Nodegroup: 1)

[ndb_mgmd(MGM)] 1 node(s)
id=10   @198.51.100.10  (5.5.58-ndb-7.2.32)
```

```
[mysqld(API)]   2 node(s)
id=20   @198.51.100.20  (5.5.58-ndb-7.2.32)
id=21   @198.51.100.21  (5.5.58-ndb-7.2.32)
```

Step 7: Redistribute cluster data. When a node group is created, existing data and indexes are not automatically distributed to the new node group's data nodes, as you can see by issuing the appropriate `REPORT` command in the management client:

```
ndb_mgm> ALL REPORT MEMORY

Node 1: Data usage is 5%(177 32K pages of total 3200)
Node 1: Index usage is 0%(108 8K pages of total 12832)
Node 2: Data usage is 5%(177 32K pages of total 3200)
Node 2: Index usage is 0%(108 8K pages of total 12832)
Node 3: Data usage is 0%(0 32K pages of total 3200)
Node 3: Index usage is 0%(0 8K pages of total 12832)
Node 4: Data usage is 0%(0 32K pages of total 3200)
Node 4: Index usage is 0%(0 8K pages of total 12832)
```

By using `ndb_desc` with the `-p` option, which causes the output to include partitioning information, you can see that the table still uses only 2 partitions (in the `Per partition info` section of the output, shown here in bold text):

```
shell> ndb_desc -c 198.51.100.10 -d n ips -p
-- ips --
Version: 1
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 6
Number of primary keys: 1
Length of frm data: 340
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 2
TableStatus: Retrieved
-- Attributes --
id Bigint PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
country_code Char(2;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
type Char(4;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
ip_address Varchar(15;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
addresses Bigunsigned NULL AT=FIXED ST=MEMORY
date Bigunsigned NULL AT=FIXED ST=MEMORY

-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex

-- Per partition info --
Partition   Row count   Commit count  Frag fixed memory   Frag varsized memory
0           26086       26086         1572864             557056
1           26329       26329         1605632             557056

NDBT_ProgramExit: 0 - OK
```

You can cause the data to be redistributed among all of the data nodes by performing, for each `NDB` table, an `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement in the `mysql` client.

Important

`ALTER ONLINE TABLE ... REORGANIZE PARTITION` does not work on tables that were created with the `MAX_ROWS` option. Instead, use `ALTER ONLINE TABLE ... MAX_ROWS=...` to reorganize such tables.

After issuing the statement `ALTER ONLINE TABLE ips REORGANIZE PARTITION`, you can see using `ndb_desc` that the data for this table is now stored using 4 partitions, as shown here (with the relevant portions of the output in bold type):

```
shell> ndb_desc -c 198.51.100.10 -d n ips -p
-- ips --
Version: 16777217
Fragment type: 9
K Value: 6
Min load factor: 78
Max load factor: 80
Temporary table: no
Number of attributes: 6
Number of primary keys: 1
Length of frm data: 341
Row Checksum: 1
Row GCI: 1
SingleUserMode: 0
ForceVarPart: 1
FragmentCount: 4
TableStatus: Retrieved
-- Attributes --
id Bigint PRIMARY KEY DISTRIBUTION KEY AT=FIXED ST=MEMORY AUTO_INCR
country_code Char(2;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
type Char(4;latin1_swedish_ci) NOT NULL AT=FIXED ST=MEMORY
ip_address Varchar(15;latin1_swedish_ci) NOT NULL AT=SHORT_VAR ST=MEMORY
addresses Bigunsigned NULL AT=FIXED ST=MEMORY
date Bigunsigned NULL AT=FIXED ST=MEMORY

-- Indexes --
PRIMARY KEY(id) - UniqueHashIndex
PRIMARY(id) - OrderedIndex

-- Per partition info --
Partition   Row count   Commit count  Frag fixed memory   Frag varsized memory
0           12981       52296         1572864             557056
1           13236       52515         1605632             557056
2           13105       13105         819200              294912
3           13093       13093         819200              294912

NDBT_ProgramExit: 0 - OK
```

Note

Normally, `ALTER [ONLINE] TABLE table_name REORGANIZE PARTITION` is used with a list of partition identifiers and a set of partition definitions to create a new partitioning scheme for a table that has already been explicitly partitioned. Its use here to redistribute data onto a new NDB Cluster node group is an exception in this regard; when used in this way, only the name of the table is used following the `TABLE` keyword, and no other keywords or identifiers follow `REORGANIZE PARTITION`.

For more information, see Section 13.1.7, “ALTER TABLE Syntax”.

In addition, for each table, the `ALTER ONLINE TABLE` statement should be followed by an `OPTIMIZE TABLE` to reclaim wasted space. You can obtain a list of all `NDBCLUSTER` tables using the following query against the `INFORMATION_SCHEMA.TABLES` table:

```
SELECT TABLE_SCHEMA, TABLE_NAME
    FROM INFORMATION_SCHEMA.TABLES
    WHERE ENGINE = 'NDBCLUSTER';
```

Note

The `INFORMATION_SCHEMA.TABLES.ENGINE` value for an NDB Cluster table is always `NDBCLUSTER`, regardless of whether the `CREATE TABLE` statement

used to create the table (or `ALTER TABLE` statement used to convert an existing table from a different storage engine) used `NDB` or `NDBCLUSTER` in its `ENGINE` option.

You can see after performing these statements in the output of `ALL REPORT MEMORY` that the data and indexes are now redistributed between all cluster data nodes, as shown here:

```
ndb_mgm> ALL REPORT MEMORY

Node 1: Data usage is 5%(176 32K pages of total 3200)
Node 1: Index usage is 0%(76 8K pages of total 12832)
Node 2: Data usage is 5%(176 32K pages of total 3200)
Node 2: Index usage is 0%(76 8K pages of total 12832)
Node 3: Data usage is 2%(80 32K pages of total 3200)
Node 3: Index usage is 0%(51 8K pages of total 12832)
Node 4: Data usage is 2%(80 32K pages of total 3200)
Node 4: Index usage is 0%(50 8K pages of total 12832)
```

Note

Since only one DDL operation on `NDBCLUSTER` tables can be executed at a time, you must wait for each `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statement to finish before issuing the next one.

It is not necessary to issue `ALTER ONLINE TABLE ... REORGANIZE PARTITION` statements for `NDBCLUSTER` tables created *after* the new data nodes have been added; data added to such tables is distributed among all data nodes automatically. However, in `NDBCLUSTER` tables that existed *prior to* the addition of the new nodes, neither existing nor new data is distributed using the new nodes until these tables have been reorganized using `ALTER ONLINE TABLE ... REORGANIZE PARTITION`.

Alternative procedure, without rolling restart. It is possible to avoid the need for a rolling restart by configuring the extra data nodes, but not starting them, when first starting the cluster. We assume, as before, that you wish to start with two data nodes—nodes 1 and 2—in one node group and later to expand the cluster to four data nodes, by adding a second node group consisting of nodes 3 and 4:

```
[ndbd default]
DataMemory = 100M
IndexMemory = 100M
NoOfReplicas = 2
DataDir = /usr/local/mysql/var/mysql-cluster

[ndbd]
Id = 1
HostName = 198.51.100.1

[ndbd]
Id = 2
HostName = 198.51.100.2

[ndbd]
Id = 3
HostName = 198.51.100.3
Nodegroup = 65536

[ndbd]
Id = 4
HostName = 198.51.100.4
Nodegroup = 65536

[mgm]
HostName = 198.51.100.10
Id = 10

[api]
Id=20
HostName = 198.51.100.20
```

```
[api]
Id=21
HostName = 198.51.100.21
```

Note

In NDB Cluster 7.2, it is no longer necessary to perform the initial start of the cluster using `--nowait-nodes` option with `ndbd` or `ndbmtd` as it was in some earlier versions of NDB Cluster.

The data nodes to be brought online at a later time (nodes 3 and 4) can be configured with `NodeGroup = 65536`, in which case nodes 1 and 2 can each be started as shown here:

```
shell> ndbd -c 198.51.100.10 --initial
```

The data nodes configured with `NodeGroup = 65536` are treated by the management server as though you had started nodes 1 and 2 using `--nowait-nodes=3,4` after waiting for a period of time determined by the setting for the `StartNoNodeGroupTimeout` data node configuration parameter. By default, this is 15 seconds (15000 milliseconds).

Note

`StartNoNodegroupTimeout` must be the same for all data nodes in the cluster; for this reason, you should always set it in the `[ndbd default]` section of the `config.ini` file, rather than for individual data nodes.

When you are ready to add the second node group, you need only perform the following additional steps:

1. Start data nodes 3 and 4, invoking the data node process once for each new node:

   ```
   shell> ndbd -c 198.51.100.10 --initial
   ```

2. Issue the appropriate `CREATE NODEGROUP` command in the management client:

   ```
   ndb_mgm> CREATE NODEGROUP 3,4
   ```

3. In the `mysql` client, issue `ALTER ONLINE TABLE ... REORGANIZE PARTITION` and `OPTIMIZE TABLE` statements for each existing `NDBCLUSTER` table. (As noted elsewhere in this section, existing NDB Cluster tables cannot use the new nodes for data distribution until this has been done.)

18.5.14 Distributed MySQL Privileges for NDB Cluster

NDB Cluster 7.2 introduces support for distributing MySQL users and privileges across all SQL nodes in an NDB Cluster. This support is not enabled by default; you should follow the procedure outlined in this section in order to do so.

Normally, each MySQL server's user privilege tables in the `mysql` database must use the `MyISAM` storage engine, which means that a user account and its associated privileges created on one SQL node are not available on the cluster's other SQL nodes. In NDB Cluster 7.2 and later, an SQL file `ndb_dist_priv.sql` is provided with the NDB Cluster distribution. This file can be found in the `share` directory in the MySQL installation directory.

The first step in enabling distributed privileges is to load this script into a MySQL Server that functions as an SQL node (which we refer to after this as the *target* SQL node or MySQL Server). You can do this by executing the following command from the system shell on the target SQL node after changing to its MySQL installation directory (where *`options`* stands for any additional options needed to connect to this SQL node):

```
shell> mysql options -uroot < share/ndb_dist_priv.sql
```

Importing `ndb_dist_priv.sql` creates a number of stored routines (six stored procedures and one stored function) in the `mysql` database on the target SQL node. After connecting to the SQL node in the `mysql` client (as the MySQL `root` user), you can verify that these were created as shown here:

```
mysql> SELECT ROUTINE_NAME, ROUTINE_SCHEMA, ROUTINE_TYPE
    ->     FROM INFORMATION_SCHEMA.ROUTINES
    ->     WHERE ROUTINE_NAME LIKE 'mysql_cluster%'
    ->     ORDER BY ROUTINE_TYPE;
+-----------------------------------------+----------------+--------------+
| ROUTINE_NAME                            | ROUTINE_SCHEMA | ROUTINE_TYPE |
+-----------------------------------------+----------------+--------------+
| mysql_cluster_privileges_are_distributed | mysql          | FUNCTION     |
| mysql_cluster_backup_privileges         | mysql          | PROCEDURE    |
| mysql_cluster_move_grant_tables         | mysql          | PROCEDURE    |
| mysql_cluster_move_privileges           | mysql          | PROCEDURE    |
| mysql_cluster_restore_local_privileges  | mysql          | PROCEDURE    |
| mysql_cluster_restore_privileges        | mysql          | PROCEDURE    |
| mysql_cluster_restore_privileges_from_local | mysql          | PROCEDURE    |
+-----------------------------------------+----------------+--------------+

7 rows in set (0.01 sec)
```

The stored procedure named `mysql_cluster_move_privileges` creates backup copies of the existing privilege tables, then converts them to `NDB`.

`mysql_cluster_move_privileges` performs the backup and conversion in two steps. The first step is to call `mysql_cluster_backup_privileges`, which creates two sets of copies in the `mysql` database:

- A set of local copies that use the `MyISAM` storage engine. Their names are generated by adding the suffix `_backup` to the original privilege table names.
- A set of distributed copies that use the `NDBCLUSTER` storage engine. These tables are named by prefixing `ndb_` and appending `_backup` to the names of the original tables.

After the copies are created, `mysql_cluster_move_privileges` invokes `mysql_cluster_move_grant_tables`, which contains the `ALTER TABLE ... ENGINE = NDB` statements that convert the mysql system tables to `NDB`.

Normally, you should not invoke either `mysql_cluster_backup_privileges` or `mysql_cluster_move_grant_tables` manually; these stored procedures are intended only for use by `mysql_cluster_move_privileges`.

Although the original privilege tables are backed up automatically, it is always a good idea to create backups manually of the existing privilege tables on all affected SQL nodes before proceeding. You can do this using `mysqldump` in a manner similar to what is shown here:

```
shell> mysqldump options -uroot \
    mysql host user db tables_priv columns_priv procs_priv proxies_priv > backup_file
```

To perform the conversion, you must be connected to the target SQL node using the `mysql` client (again, as the MySQL `root` user). Invoke the stored procedure like this:

```
mysql> CALL mysql.mysql_cluster_move_privileges();
Query OK, 0 rows affected (22.32 sec)
```

Depending on the number of rows in the privilege tables, this procedure may take some time to execute. If some of the privilege tables are empty, you may see one or more `No data - zero rows`

`fetched, selected, or processed` warnings when `mysql_cluster_move_privileges` returns. In such cases, the warnings may be safely ignored. To verify that the conversion was successful, you can use the stored function `mysql_cluster_privileges_are_distributed` as shown here:

```
mysql> SELECT CONCAT(
    ->    'Conversion ',
    ->    IF(mysql.mysql_cluster_privileges_are_distributed(), 'succeeded', 'failed'),
    ->    '.')
    ->    AS Result;
+----------------------+
| Result               |
+----------------------+
| Conversion succeeded. |
+----------------------+
1 row in set (0.00 sec)
```

`mysql_cluster_privileges_are_distributed` checks for the existence of the distributed privilege tables and returns `1` if all of the privilege tables are distributed; otherwise, it returns `0`.

You can verify that the backups have been created using a query such as this one:

```
mysql> SELECT TABLE_NAME, ENGINE FROM INFORMATION_SCHEMA.TABLES
    ->     WHERE TABLE_SCHEMA = 'mysql' AND TABLE_NAME LIKE '%backup'
    ->     ORDER BY ENGINE;
+-------------------------+------------+
| TABLE_NAME              | ENGINE     |
+-------------------------+------------+
| columns_priv_backup     | MyISAM     |
| user_backup             | MyISAM     |
| tables_priv_backup      | MyISAM     |
| proxies_priv_backup     | MyISAM     |
| procs_priv_backup       | MyISAM     |
| host_backup             | MyISAM     |
| db_backup               | MyISAM     |
| ndb_user_backup         | ndbcluster |
| ndb_tables_priv_backup  | ndbcluster |
| ndb_proxies_priv_backup | ndbcluster |
| ndb_procs_priv_backup   | ndbcluster |
| ndb_host_backup         | ndbcluster |
| ndb_db_backup           | ndbcluster |
| ndb_columns_priv_backup | ndbcluster |
+-------------------------+------------+
14 rows in set (0.02 sec)
```

Once the conversion to distributed privileges has been made, any time a MySQL user account is created, dropped, or has its privileges updated on any SQL node, the changes take effect immediately on all other MySQL servers attached to the cluster. Once privileges are distributed, any new MySQL Servers that connect to the cluster automatically participate in the distribution.

Note

For clients connected to SQL nodes at the time that `mysql_cluster_move_privileges` is executed, you may need to execute `FLUSH PRIVILEGES` on those SQL nodes, or to disconnect and then reconnect the clients, in order for those clients to be able to see the changes in privileges.

All MySQL user privileges are distributed across all connected MySQL Servers. This includes any privileges associated with views and stored routines, even though distribution of views and stored routines themselves is not currently supported.

In the event that an SQL node becomes disconnected from the cluster while `mysql_cluster_move_privileges` is running, you must drop its privilege tables after reconnecting to the cluster, using a statement such as `DROP TABLE IF EXISTS mysql.user mysql.db`

`mysql.tables_priv mysql.columns_priv mysql.procs_priv`. This causes the SQL node to use the shared privilege tables rather than its own local versions of them. This is not needed when connecting a new SQL node to the cluster for the first time.

In the event of an initial restart of the entire cluster (all data nodes shut down, then started again with `--initial`), the shared privilege tables are lost. If this happens, you can restore them using the original target SQL node either from the backups made by `mysql_cluster_move_privileges` or from a dump file created with `mysqldump`. If you need to use a new MySQL Server to perform the restoration, you should start it with `--skip-grant-tables` when connecting to the cluster for the first time; after this, you can restore the privilege tables locally, then distribute them again using `mysql_cluster_move_privileges`. After restoring and distributing the tables, you should restart this MySQL Server without the `--skip-grant-tables` option.

You can also restore the distributed tables using `ndb_restore --restore-privilege-tables` from a backup made using `START BACKUP` in the `ndb_mgm` client. (The `MyISAM` tables created by `mysql_cluster_move_privileges` are not backed up by the `START BACKUP` command.) `ndb_restore` does not restore the privilege tables by default; the `--restore-privilege-tables` option causes it to do so.

You can restore the SQL node's local privileges using either of two procedures. `mysql_cluster_restore_privileges` works as follows:

1. If copies of the `mysql.ndb_*_backup` tables are available, attempt to restore the system tables from these.
2. Otherwise, attempt to restore the system tables from the local backups named `*_backup` (without the `ndb_` prefix).

The other procedure, named `mysql_cluster_restore_local_privileges`, restores the system tables from the local backups only, without checking the `ndb_*` backups.

The system tables re-created by `mysql_cluster_restore_privileges` or `mysql_cluster_restore_local_privileges` use the MySQL server default storage engine; they are not shared or distributed in any way, and do not use NDB Cluster's `NDB` storage engine.

The additional stored procedure `mysql_cluster_restore_privileges_from_local` is intended for the use of `mysql_cluster_restore_privileges` and `mysql_cluster_restore_local_privileges`. It should not be invoked directly.

Important

Applications that access NDB Cluster data directly, including NDB API and ClusterJ applications, are not subject to the MySQL privilege system. This means that, once you have distributed the grant tables, they can be freely accessed by such applications, just as they can any other `NDB` tables. In particular, you should keep in mind that *NDB API and ClusterJ applications can read and write user names, host names, password hashes, and any other contents of the distributed grant tables without any restrictions*.

18.5.15 NDB API Statistics Counters and Variables

A number of types of statistical counters relating to actions performed by or affecting `Ndb` objects are available. Such actions include starting and closing (or aborting) transactions; primary key and unique key operations; table, range, and pruned scans; threads blocked while waiting for the completion of various operations; and data and events sent and received by `NDBCLUSTER`. The counters are incremented inside the NDB kernel whenever NDB API calls are made or data is sent to or received by the data nodes. `mysqld` exposes these counters as system status variables; their values can be read in the output of `SHOW STATUS`, or by querying the `INFORMATION_SCHEMA.SESSION_STATUS` or

`INFORMATION_SCHEMA.GLOBAL_STATUS` table. By comparing the values before and after statements operating on `NDB` tables, you can observe the corresponding actions taken on the API level, and thus the cost of performing the statement.

You can list all of these status variables using the following `SHOW STATUS` statement:

```
mysql> SHOW STATUS LIKE 'ndb_api%';
+-----------------------------------------------+----------+
| Variable_name                                 | Value    |
+-----------------------------------------------+----------+
| Ndb_api_wait_exec_complete_count_session      | 0        |
| Ndb_api_wait_scan_result_count_session        | 0        |
| Ndb_api_wait_meta_request_count_session       | 0        |
| Ndb_api_wait_nanos_count_session              | 0        |
| Ndb_api_bytes_sent_count_session              | 0        |
| Ndb_api_bytes_received_count_session          | 0        |
| Ndb_api_trans_start_count_session             | 0        |
| Ndb_api_trans_commit_count_session            | 0        |
| Ndb_api_trans_abort_count_session             | 0        |
| Ndb_api_trans_close_count_session             | 0        |
| Ndb_api_pk_op_count_session                   | 0        |
| Ndb_api_uk_op_count_session                   | 0        |
| Ndb_api_table_scan_count_session              | 0        |
| Ndb_api_range_scan_count_session              | 0        |
| Ndb_api_pruned_scan_count_session             | 0        |
| Ndb_api_scan_batch_count_session              | 0        |
| Ndb_api_read_row_count_session                | 0        |
| Ndb_api_trans_local_read_row_count_session    | 0        |
| Ndb_api_event_data_count_injector             | 0        |
| Ndb_api_event_nondata_count_injector          | 0        |
| Ndb_api_event_bytes_count_injector            | 0        |
| Ndb_api_wait_exec_complete_count_slave        | 0        |
| Ndb_api_wait_scan_result_count_slave          | 0        |
| Ndb_api_wait_meta_request_count_slave         | 0        |
| Ndb_api_wait_nanos_count_slave                | 0        |
| Ndb_api_bytes_sent_count_slave                | 0        |
| Ndb_api_bytes_received_count_slave            | 0        |
| Ndb_api_trans_start_count_slave               | 0        |
| Ndb_api_trans_commit_count_slave              | 0        |
| Ndb_api_trans_abort_count_slave               | 0        |
| Ndb_api_trans_close_count_slave               | 0        |
| Ndb_api_pk_op_count_slave                     | 0        |
| Ndb_api_uk_op_count_slave                     | 0        |
| Ndb_api_table_scan_count_slave                | 0        |
| Ndb_api_range_scan_count_slave                | 0        |
| Ndb_api_pruned_scan_count_slave               | 0        |
| Ndb_api_scan_batch_count_slave                | 0        |
| Ndb_api_read_row_count_slave                  | 0        |
| Ndb_api_trans_local_read_row_count_slave      | 0        |
| Ndb_api_wait_exec_complete_count              | 2        |
| Ndb_api_wait_scan_result_count                | 3        |
| Ndb_api_wait_meta_request_count               | 27       |
| Ndb_api_wait_nanos_count                      | 45612023 |
| Ndb_api_bytes_sent_count                      | 992      |
| Ndb_api_bytes_received_count                  | 9640     |
| Ndb_api_trans_start_count                     | 2        |
| Ndb_api_trans_commit_count                    | 1        |
| Ndb_api_trans_abort_count                     | 0        |
| Ndb_api_trans_close_count                     | 2        |
| Ndb_api_pk_op_count                           | 1        |
| Ndb_api_uk_op_count                           | 0        |
| Ndb_api_table_scan_count                      | 1        |
| Ndb_api_range_scan_count                      | 0        |
| Ndb_api_pruned_scan_count                     | 0        |
| Ndb_api_scan_batch_count                      | 0        |
| Ndb_api_read_row_count                        | 1        |
| Ndb_api_trans_local_read_row_count            | 1        |
| Ndb_api_event_data_count                      | 0        |
| Ndb_api_event_nondata_count                   | 0        |
| Ndb_api_event_bytes_count                     | 0        |
+-----------------------------------------------+----------+
```

```
60 rows in set (0.02 sec)
```

These status variables are also available from the `SESSION_STATUS` and `GLOBAL_STATUS` tables of the `INFORMATION_SCHEMA` database, as shown here:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.SESSION_STATUS
    ->   WHERE VARIABLE_NAME LIKE 'ndb_api%';
+-------------------------------------------+----------------+
| VARIABLE_NAME                             | VARIABLE_VALUE |
+-------------------------------------------+----------------+
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SESSION  | 2              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SESSION    | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SESSION   | 1              |
| NDB_API_WAIT_NANOS_COUNT_SESSION          | 8144375        |
| NDB_API_BYTES_SENT_COUNT_SESSION          | 68             |
| NDB_API_BYTES_RECEIVED_COUNT_SESSION      | 84             |
| NDB_API_TRANS_START_COUNT_SESSION         | 1              |
| NDB_API_TRANS_COMMIT_COUNT_SESSION        | 1              |
| NDB_API_TRANS_ABORT_COUNT_SESSION         | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SESSION         | 1              |
| NDB_API_PK_OP_COUNT_SESSION               | 1              |
| NDB_API_UK_OP_COUNT_SESSION               | 0              |
| NDB_API_TABLE_SCAN_COUNT_SESSION          | 0              |
| NDB_API_RANGE_SCAN_COUNT_SESSION          | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SESSION         | 0              |
| NDB_API_SCAN_BATCH_COUNT_SESSION          | 0              |
| NDB_API_READ_ROW_COUNT_SESSION            | 1              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SESSION | 1              |
| NDB_API_EVENT_DATA_COUNT_INJECTOR         | 0              |
| NDB_API_EVENT_NONDATA_COUNT_INJECTOR      | 0              |
| NDB_API_EVENT_BYTES_COUNT_INJECTOR        | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SLAVE    | 0              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SLAVE      | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SLAVE     | 0              |
| NDB_API_WAIT_NANOS_COUNT_SLAVE            | 0              |
| NDB_API_BYTES_SENT_COUNT_SLAVE            | 0              |
| NDB_API_BYTES_RECEIVED_COUNT_SLAVE        | 0              |
| NDB_API_TRANS_START_COUNT_SLAVE           | 0              |
| NDB_API_TRANS_COMMIT_COUNT_SLAVE          | 0              |
| NDB_API_TRANS_ABORT_COUNT_SLAVE           | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SLAVE           | 0              |
| NDB_API_PK_OP_COUNT_SLAVE                 | 0              |
| NDB_API_UK_OP_COUNT_SLAVE                 | 0              |
| NDB_API_TABLE_SCAN_COUNT_SLAVE            | 0              |
| NDB_API_RANGE_SCAN_COUNT_SLAVE            | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SLAVE           | 0              |
| NDB_API_SCAN_BATCH_COUNT_SLAVE            | 0              |
| NDB_API_READ_ROW_COUNT_SLAVE              | 0              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SLAVE  | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT          | 4              |
| NDB_API_WAIT_SCAN_RESULT_COUNT            | 3              |
| NDB_API_WAIT_META_REQUEST_COUNT           | 28             |
| NDB_API_WAIT_NANOS_COUNT                  | 53756398       |
| NDB_API_BYTES_SENT_COUNT                  | 1060           |
| NDB_API_BYTES_RECEIVED_COUNT              | 9724           |
| NDB_API_TRANS_START_COUNT                 | 3              |
| NDB_API_TRANS_COMMIT_COUNT                | 2              |
| NDB_API_TRANS_ABORT_COUNT                 | 0              |
| NDB_API_TRANS_CLOSE_COUNT                 | 3              |
| NDB_API_PK_OP_COUNT                       | 2              |
| NDB_API_UK_OP_COUNT                       | 0              |
| NDB_API_TABLE_SCAN_COUNT                  | 1              |
| NDB_API_RANGE_SCAN_COUNT                  | 0              |
| NDB_API_PRUNED_SCAN_COUNT                 | 0              |
| NDB_API_SCAN_BATCH_COUNT                  | 0              |
| NDB_API_READ_ROW_COUNT                    | 2              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT        | 2              |
| NDB_API_EVENT_DATA_COUNT                  | 0              |
| NDB_API_EVENT_NONDATA_COUNT               | 0              |
| NDB_API_EVENT_BYTES_COUNT                 | 0              |
+-------------------------------------------+----------------+
```

```
60 rows in set (0.00 sec)

mysql> SELECT * FROM INFORMATION_SCHEMA.GLOBAL_STATUS
    ->     WHERE VARIABLE_NAME LIKE 'ndb_api%';
+-----------------------------------------+----------------+
| VARIABLE_NAME                           | VARIABLE_VALUE |
+-----------------------------------------+----------------+
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SESSION   | 2              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SESSION     | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SESSION    | 1              |
| NDB_API_WAIT_NANOS_COUNT_SESSION           | 8144375        |
| NDB_API_BYTES_SENT_COUNT_SESSION           | 68             |
| NDB_API_BYTES_RECEIVED_COUNT_SESSION       | 84             |
| NDB_API_TRANS_START_COUNT_SESSION          | 1              |
| NDB_API_TRANS_COMMIT_COUNT_SESSION         | 1              |
| NDB_API_TRANS_ABORT_COUNT_SESSION          | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SESSION          | 1              |
| NDB_API_PK_OP_COUNT_SESSION                | 1              |
| NDB_API_UK_OP_COUNT_SESSION                | 0              |
| NDB_API_TABLE_SCAN_COUNT_SESSION           | 0              |
| NDB_API_RANGE_SCAN_COUNT_SESSION           | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SESSION          | 0              |
| NDB_API_SCAN_BATCH_COUNT_SESSION           | 0              |
| NDB_API_READ_ROW_COUNT_SESSION             | 1              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SESSION | 1              |
| NDB_API_EVENT_DATA_COUNT_INJECTOR          | 0              |
| NDB_API_EVENT_NONDATA_COUNT_INJECTOR       | 0              |
| NDB_API_EVENT_BYTES_COUNT_INJECTOR         | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT_SLAVE     | 0              |
| NDB_API_WAIT_SCAN_RESULT_COUNT_SLAVE       | 0              |
| NDB_API_WAIT_META_REQUEST_COUNT_SLAVE      | 0              |
| NDB_API_WAIT_NANOS_COUNT_SLAVE             | 0              |
| NDB_API_BYTES_SENT_COUNT_SLAVE             | 0              |
| NDB_API_BYTES_RECEIVED_COUNT_SLAVE         | 0              |
| NDB_API_TRANS_START_COUNT_SLAVE            | 0              |
| NDB_API_TRANS_COMMIT_COUNT_SLAVE           | 0              |
| NDB_API_TRANS_ABORT_COUNT_SLAVE            | 0              |
| NDB_API_TRANS_CLOSE_COUNT_SLAVE            | 0              |
| NDB_API_PK_OP_COUNT_SLAVE                  | 0              |
| NDB_API_UK_OP_COUNT_SLAVE                  | 0              |
| NDB_API_TABLE_SCAN_COUNT_SLAVE             | 0              |
| NDB_API_RANGE_SCAN_COUNT_SLAVE             | 0              |
| NDB_API_PRUNED_SCAN_COUNT_SLAVE            | 0              |
| NDB_API_SCAN_BATCH_COUNT_SLAVE             | 0              |
| NDB_API_READ_ROW_COUNT_SLAVE               | 0              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT_SLAVE   | 0              |
| NDB_API_WAIT_EXEC_COMPLETE_COUNT           | 4              |
| NDB_API_WAIT_SCAN_RESULT_COUNT             | 3              |
| NDB_API_WAIT_META_REQUEST_COUNT            | 28             |
| NDB_API_WAIT_NANOS_COUNT                   | 53756398       |
| NDB_API_BYTES_SENT_COUNT                   | 1060           |
| NDB_API_BYTES_RECEIVED_COUNT               | 9724           |
| NDB_API_TRANS_START_COUNT                  | 3              |
| NDB_API_TRANS_COMMIT_COUNT                 | 2              |
| NDB_API_TRANS_ABORT_COUNT                  | 0              |
| NDB_API_TRANS_CLOSE_COUNT                  | 3              |
| NDB_API_PK_OP_COUNT                        | 2              |
| NDB_API_UK_OP_COUNT                        | 0              |
| NDB_API_TABLE_SCAN_COUNT                   | 1              |
| NDB_API_RANGE_SCAN_COUNT                   | 0              |
| NDB_API_PRUNED_SCAN_COUNT                  | 0              |
| NDB_API_SCAN_BATCH_COUNT                   | 0              |
| NDB_API_READ_ROW_COUNT                     | 2              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT         | 2              |
| NDB_API_EVENT_DATA_COUNT                   | 0              |
| NDB_API_EVENT_NONDATA_COUNT                | 0              |
| NDB_API_EVENT_BYTES_COUNT                  | 0              |
+-----------------------------------------+----------------+
60 rows in set (0.00 sec)
```

Each `Ndb` object has its own counters. NDB API applications can read the values of the counters for use in optimization or monitoring. For multi-threaded clients which use more than one `Ndb` object concurrently, it is also possible to obtain a summed view of counters from all `Ndb` objects belonging to a given `Ndb_cluster_connection`.

Four sets of these counters are exposed. One set applies to the current session only; the other 3 are global. *This is in spite of the fact that their values can be obtained as either session or global status variables in the `mysql` client*. This means that specifying the `SESSION` or `GLOBAL` keyword with `SHOW STATUS` has no effect on the values reported for NDB API statistics status variables, and the value for each of these variables is the same whether the value is obtained from the equivalent column of the `SESSION_STATUS` or the `GLOBAL_STATUS` table.

- *Session counters (session specific)*

  Session counters relate to the `Ndb` objects in use by (only) the current session. Use of such objects by other MySQL clients does not influence these counts.

  In order to minimize confusion with standard MySQL session variables, we refer to the variables that correspond to these NDB API session counters as "`_session` variables", with a leading underscore.

- *Slave counters (global)*

  This set of counters relates to the `Ndb` objects used by the replication slave SQL thread, if any. If this `mysqld` does not act as a replication slave, or does not use `NDB` tables, then all of these counts are 0.

  We refer to the related status variables as "`_slave` variables" (with a leading underscore).

- *Injector counters (global)*

  Injector counters relate to the `Ndb` object used to listen to cluster events by the binary log injector thread. Even when not writing a binary log, `mysqld` processes attached to an NDB Cluster continue to listen for some events, such as schema changes.

  We refer to the status variables that correspond to NDB API injector counters as "`_injector` variables" (with a leading underscore).

- *Server (Global) counters (global)*

  This set of counters relates to all `Ndb` objects currently used by this `mysqld`. This includes all MySQL client applications, the slave SQL thread (if any), the binlog injector, and the `NDB` utility thread.

  We refer to the status variables that correspond to these counters as "global variables" or "`mysqld`-level variables".

You can obtain values for a particular set of variables by additionally filtering for the substring `session`, `slave`, or `injector` in the variable name (along with the common prefix `Ndb_api`). For `_session` variables, this can be done as shown here:

```
mysql> SHOW STATUS LIKE 'ndb_api%session';
+-----------------------------------------+---------+
| Variable_name                           | Value   |
+-----------------------------------------+---------+
| Ndb_api_wait_exec_complete_count_session   | 2       |
| Ndb_api_wait_scan_result_count_session     | 0       |
| Ndb_api_wait_meta_request_count_session    | 1       |
| Ndb_api_wait_nanos_count_session           | 8144375 |
| Ndb_api_bytes_sent_count_session           | 68      |
| Ndb_api_bytes_received_count_session       | 84      |
| Ndb_api_trans_start_count_session          | 1       |
| Ndb_api_trans_commit_count_session         | 1       |
| Ndb_api_trans_abort_count_session          | 0       |
```

```
| Ndb_api_trans_close_count_session          | 1       |
| Ndb_api_pk_op_count_session                | 1       |
| Ndb_api_uk_op_count_session                | 0       |
| Ndb_api_table_scan_count_session           | 0       |
| Ndb_api_range_scan_count_session           | 0       |
| Ndb_api_pruned_scan_count_session          | 0       |
| Ndb_api_scan_batch_count_session           | 0       |
| Ndb_api_read_row_count_session             | 1       |
| Ndb_api_trans_local_read_row_count_session | 1       |
+--------------------------------------------+---------+
18 rows in set (0.50 sec)
```

To obtain a listing of the NDB API `mysqld`-level status variables, filter for variable names beginning with `ndb_api` and ending in `_count`, like this:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.SESSION_STATUS
    ->     WHERE VARIABLE_NAME LIKE 'ndb_api%count';
+-----------------------------------+----------------+
| VARIABLE_NAME                     | VARIABLE_VALUE |
+-----------------------------------+----------------+
| NDB_API_WAIT_EXEC_COMPLETE_COUNT  | 4              |
| NDB_API_WAIT_SCAN_RESULT_COUNT    | 3              |
| NDB_API_WAIT_META_REQUEST_COUNT   | 28             |
| NDB_API_WAIT_NANOS_COUNT          | 53756398       |
| NDB_API_BYTES_SENT_COUNT          | 1060           |
| NDB_API_BYTES_RECEIVED_COUNT      | 9724           |
| NDB_API_TRANS_START_COUNT         | 3              |
| NDB_API_TRANS_COMMIT_COUNT        | 2              |
| NDB_API_TRANS_ABORT_COUNT         | 0              |
| NDB_API_TRANS_CLOSE_COUNT         | 3              |
| NDB_API_PK_OP_COUNT               | 2              |
| NDB_API_UK_OP_COUNT               | 0              |
| NDB_API_TABLE_SCAN_COUNT          | 1              |
| NDB_API_RANGE_SCAN_COUNT          | 0              |
| NDB_API_PRUNED_SCAN_COUNT         | 0              |
| NDB_API_SCAN_BATCH_COUNT          | 0              |
| NDB_API_READ_ROW_COUNT            | 2              |
| NDB_API_TRANS_LOCAL_READ_ROW_COUNT | 2              |
| NDB_API_EVENT_DATA_COUNT          | 0              |
| NDB_API_EVENT_NONDATA_COUNT       | 0              |
| NDB_API_EVENT_BYTES_COUNT         | 0              |
+-----------------------------------+----------------+
21 rows in set (0.09 sec)
```

Not all counters are reflected in all 4 sets of status variables. For the event counters `DataEventsRecvdCount`, `NondataEventsRecvdCount`, and `EventBytesRecvdCount`, only `_injector` and `mysqld`-level NDB API status variables are available:

```
mysql> SHOW STATUS LIKE 'ndb_api%event%';
+---------------------------------------+-------+
| Variable_name                         | Value |
+---------------------------------------+-------+
| Ndb_api_event_data_count_injector     | 0     |
| Ndb_api_event_nondata_count_injector  | 0     |
| Ndb_api_event_bytes_count_injector    | 0     |
| Ndb_api_event_data_count              | 0     |
| Ndb_api_event_nondata_count           | 0     |
| Ndb_api_event_bytes_count             | 0     |
+---------------------------------------+-------+
6 rows in set (0.00 sec)
```

`_injector` status variables are not implemented for any other NDB API counters, as shown here:

```
mysql> SHOW STATUS LIKE 'ndb_api%injector%';
+---------------------------------------+-------+
| Variable_name                         | Value |
+---------------------------------------+-------+
| Ndb_api_event_data_count_injector     | 0     |
```

```
| Ndb_api_event_nondata_count_injector | 0     |
| Ndb_api_event_bytes_count_injector   | 0     |
+--------------------------------------+-------+
3 rows in set (0.00 sec)
```

The names of the status variables can easily be associated with the names of the corresponding counters. Each NDB API statistics counter is listed in the following table with a description as well as the names of any MySQL server status variables corresponding to this counter.

Counter Name	Description
	Status Variables (by statistic type): • **Session** • **Slave** • **Injector** • **Server**
WaitExecCompleteCount	Number of times thread has been blocked while waiting for execution of an operation to complete. Includes all `execute()` calls as well as implicit executes for blob operations and auto-increment not visible to clients.
	• Ndb_api_wait_exec_complete_count_session • Ndb_api_wait_exec_complete_count_slave • [none] • Ndb_api_wait_exec_complete_count
WaitScanResultCount	Number of times thread has been blocked while waiting for a scan-based signal, such waiting for additional results, or for a scan to close.
	• Ndb_api_wait_scan_result_count_session • Ndb_api_wait_scan_result_count_slave • [none] • Ndb_api_wait_scan_result_count
WaitMetaRequestCount	Number of times thread has been blocked waiting for a metadata-based signal; this can occur when waiting for a DDL operation or for an epoch to be started (or ended).
	• Ndb_api_wait_meta_request_count_session • Ndb_api_wait_meta_request_count_slave • [none] • Ndb_api_wait_meta_request_count
WaitNanosCount	Total time (in nanoseconds) spent waiting for some type of signal from the data nodes.
	• Ndb_api_wait_nanos_count_session • Ndb_api_wait_nanos_count_slave • [none]

Counter Name	Description
	Status Variables (by statistic type): • **Session** • **Slave** • **Injector** • **Server**
	• Ndb_api_wait_nanos_count
BytesSentCount	Amount of data (in bytes) sent to the data nodes
	• Ndb_api_bytes_sent_count_session • Ndb_api_bytes_sent_count_slave • [none] • Ndb_api_bytes_sent_count
BytesRecvdCount	Amount of data (in bytes) received from the data nodes
	• Ndb_api_bytes_received_count_session • Ndb_api_bytes_received_count_slave • [none] • Ndb_api_bytes_received_count
TransStartCount	Number of transactions started.
	• Ndb_api_trans_start_count_session • Ndb_api_trans_start_count_slave • [none] • Ndb_api_trans_start_count
TransCommitCount	Number of transactions committed.
	• Ndb_api_trans_commit_count_session • Ndb_api_trans_commit_count_slave • [none] • Ndb_api_trans_commit_count
TransAbortCount	Number of transactions aborted.
	• Ndb_api_trans_abort_count_session • Ndb_api_trans_abort_count_slave • [none] • Ndb_api_trans_abort_count
TransCloseCount	Number of transactions aborted. (This value may be greater than the sum of TransCommitCount and TransAbortCount.)
	• Ndb_api_trans_close_count_session • Ndb_api_trans_close_count_slave

Counter Name	Description
	Status Variables (by statistic type): • **Session** • **Slave** • **Injector** • **Server**
	• [none] • `Ndb_api_trans_close_count`
`PkOpCount`	Number of operations based on or using primary keys. This count includes blob-part table operations, implicit unlocking operations, and auto-increment operations, as well as primary key operations normally visible to MySQL clients.
	• `Ndb_api_pk_op_count_session` • `Ndb_api_pk_op_count_slave` • [none] • `Ndb_api_pk_op_count`
`UkOpCount`	Number of operations based on or using unique keys.
	• `Ndb_api_uk_op_count_session` • `Ndb_api_uk_op_count_slave` • [none] • `Ndb_api_uk_op_count`
`TableScanCount`	Number of table scans that have been started. This includes scans of internal tables.
	• `Ndb_api_table_scan_count_session` • `Ndb_api_table_scan_count_slave` • [none] • `Ndb_api_table_scan_count`
`RangeScanCount`	Number of range scans that have been started.
	• `Ndb_api_range_scan_count_session` • `Ndb_api_range_scan_count_slave` • [none] • `Ndb_api_range_scan_count`
`PrunedScanCount`	Number of scans that have been pruned to a single partition.
	• `Ndb_api_pruned_scan_count_session` • `Ndb_api_pruned_scan_count_slave` • [none]

Counter Name	Description
	Status Variables (by statistic type): • **Session** • **Slave** • **Injector** • **Server**
	• Ndb_api_pruned_scan_count
ScanBatchCount	Number of batches of rows received. (A *batch* in this context is a set of scan results from a single fragment.)
	• Ndb_api_scan_batch_count_session • Ndb_api_scan_batch_count_slave • [none] • Ndb_api_scan_batch_count
ReadRowCount	Total number of rows that have been read. Includes rows read using primary key, unique key, and scan operations.
	• Ndb_api_read_row_count_session • Ndb_api_read_row_count_slave • [none] • Ndb_api_read_row_count
TransLocalReadRowCount	Number of rows read from the data same node on which the transaction was being run.
	• Ndb_api_trans_local_read_row_count_session • Ndb_api_trans_local_read_row_count_slave • [none] • Ndb_api_trans_local_read_row_count
DataEventsRecvdCount	Number of row change events received.
	• [none] • [none] • Ndb_api_event_data_count_injector • Ndb_api_event_data_count
NondataEventsRecvdCount	Number of events received, other than row change events.
	• [none] • [none] • Ndb_api_event_nondata_count_injector • Ndb_api_event_nondata_count
EventBytesRecvdCount	Number of bytes of events received.
	• [none]

Counter Name	Description
	Status Variables (by statistic type): • **Session** • **Slave** • **Injector** • **Server**
	• [none] • `Ndb_api_event_bytes_count_injector` • `Ndb_api_event_bytes_count`

To see all counts of committed transactions—that is, all `TransCommitCount` counter status variables—you can filter the results of `SHOW STATUS` for the substring `trans_commit_count`, like this:

```
mysql> SHOW STATUS LIKE '%trans_commit_count%';
+-----------------------------------+-------+
| Variable_name                     | Value |
+-----------------------------------+-------+
| Ndb_api_trans_commit_count_session | 1     |
| Ndb_api_trans_commit_count_slave   | 0     |
| Ndb_api_trans_commit_count         | 2     |
+-----------------------------------+-------+
3 rows in set (0.00 sec)
```

From this you can determine that 1 transaction has been committed in the current `mysql` client session, and 2 transactions have been committed on this `mysqld` since it was last restarted.

You can see how various NDB API counters are incremented by a given SQL statement by comparing the values of the corresponding `_session` status variables immediately before and after performing the statement. In this example, after getting the initial values from `SHOW STATUS`, we create in the `test` database an `NDB` table, named `t`, that has a single column:

```
mysql> SHOW STATUS LIKE 'ndb_api%session%';
+-----------------------------------------+--------+
| Variable_name                           | Value  |
+-----------------------------------------+--------+
| Ndb_api_wait_exec_complete_count_session   | 2      |
| Ndb_api_wait_scan_result_count_session     | 0      |
| Ndb_api_wait_meta_request_count_session    | 3      |
| Ndb_api_wait_nanos_count_session           | 820705 |
| Ndb_api_bytes_sent_count_session           | 132    |
| Ndb_api_bytes_received_count_session       | 372    |
| Ndb_api_trans_start_count_session          | 1      |
| Ndb_api_trans_commit_count_session         | 1      |
| Ndb_api_trans_abort_count_session          | 0      |
| Ndb_api_trans_close_count_session          | 1      |
| Ndb_api_pk_op_count_session                | 1      |
| Ndb_api_uk_op_count_session                | 0      |
| Ndb_api_table_scan_count_session           | 0      |
| Ndb_api_range_scan_count_session           | 0      |
| Ndb_api_pruned_scan_count_session          | 0      |
| Ndb_api_scan_batch_count_session           | 0      |
| Ndb_api_read_row_count_session             | 1      |
| Ndb_api_trans_local_read_row_count_session | 1      |
+-----------------------------------------+--------+
18 rows in set (0.00 sec)

mysql> USE test;
Database changed
mysql> CREATE TABLE t (c INT) ENGINE NDBCLUSTER;
```

```
Query OK, 0 rows affected (0.85 sec)
```

Now you can execute a new `SHOW STATUS` statement and observe the changes, as shown here (with the changed rows highlighted in the output):

```
mysql> SHOW STATUS LIKE 'ndb_api%session%';
+-----------------------------------------+-----------+
| Variable_name                           | Value     |
+-----------------------------------------+-----------+
| Ndb_api_wait_exec_complete_count_session   | 8         |
| Ndb_api_wait_scan_result_count_session     | 0         |
| Ndb_api_wait_meta_request_count_session    | 17        |
| Ndb_api_wait_nanos_count_session           | 706871709 |
| Ndb_api_bytes_sent_count_session           | 2376      |
| Ndb_api_bytes_received_count_session       | 3844      |
| Ndb_api_trans_start_count_session          | 4         |
| Ndb_api_trans_commit_count_session         | 4         |
| Ndb_api_trans_abort_count_session          | 0         |
| Ndb_api_trans_close_count_session          | 4         |
| Ndb_api_pk_op_count_session                | 6         |
| Ndb_api_uk_op_count_session                | 0         |
| Ndb_api_table_scan_count_session           | 0         |
| Ndb_api_range_scan_count_session           | 0         |
| Ndb_api_pruned_scan_count_session          | 0         |
| Ndb_api_scan_batch_count_session           | 0         |
| Ndb_api_read_row_count_session             | 2         |
| Ndb_api_trans_local_read_row_count_session | 1         |
+-----------------------------------------+-----------+
18 rows in set (0.00 sec)
```

Similarly, you can see the changes in the NDB API statistics counters caused by inserting a row into `t`: Insert the row, then run the same `SHOW STATUS` statement used in the previous example, as shown here:

```
mysql> INSERT INTO t VALUES (100);
Query OK, 1 row affected (0.00 sec)

mysql> SHOW STATUS LIKE 'ndb_api%session%';
+-----------------------------------------+-----------+
| Variable_name                           | Value     |
+-----------------------------------------+-----------+
| Ndb_api_wait_exec_complete_count_session   | 11        |
| Ndb_api_wait_scan_result_count_session     | 6         |
| Ndb_api_wait_meta_request_count_session    | 20        |
| Ndb_api_wait_nanos_count_session           | 707370418 |
| Ndb_api_bytes_sent_count_session           | 2724      |
| Ndb_api_bytes_received_count_session       | 4116      |
| Ndb_api_trans_start_count_session          | 7         |
| Ndb_api_trans_commit_count_session         | 6         |
| Ndb_api_trans_abort_count_session          | 0         |
| Ndb_api_trans_close_count_session          | 7         |
| Ndb_api_pk_op_count_session                | 8         |
| Ndb_api_uk_op_count_session                | 0         |
| Ndb_api_table_scan_count_session           | 1         |
| Ndb_api_range_scan_count_session           | 0         |
| Ndb_api_pruned_scan_count_session          | 0         |
| Ndb_api_scan_batch_count_session           | 0         |
| Ndb_api_read_row_count_session             | 3         |
| Ndb_api_trans_local_read_row_count_session | 2         |
+-----------------------------------------+-----------+
18 rows in set (0.00 sec)
```

We can make a number of observations from these results:

- Although we created `t` with no explicit primary key, 5 primary key operations were performed in doing so (the difference in the “before” and “after” values of `Ndb_api_pk_op_count_session`, or 6 minus 1). This reflects the creation of the hidden primary key that is a feature of all tables using the `NDB` storage engine.

- By comparing successive values for `Ndb_api_wait_nanos_count_session`, we can see that the NDB API operations implementing the `CREATE TABLE` statement waited much longer (706871709 - 820705 = 706051004 nanoseconds, or approximately 0.7 second) for responses from the data nodes than those executed by the `INSERT` (707370418 - 706871709 = 498709 ns or roughly .0005 second). The execution times reported for these statements in the `mysql` client correlate roughly with these figures.

  On platforms without sufficient (nanosecond) time resolution, small changes in the value of the `WaitNanosCount` NDB API counter due to SQL statements that execute very quickly may not always be visible in the values of `Ndb_api_wait_nanos_count_session`, `Ndb_api_wait_nanos_count_slave`, or `Ndb_api_wait_nanos_count`.

- The `INSERT` statement incremented both the `ReadRowCount` and `TransLocalReadRowCount` NDB API statistics counters, as reflected by the increased values of `Ndb_api_read_row_count_session` and `Ndb_api_trans_local_read_row_count_session`.

18.6 NDB Cluster Replication

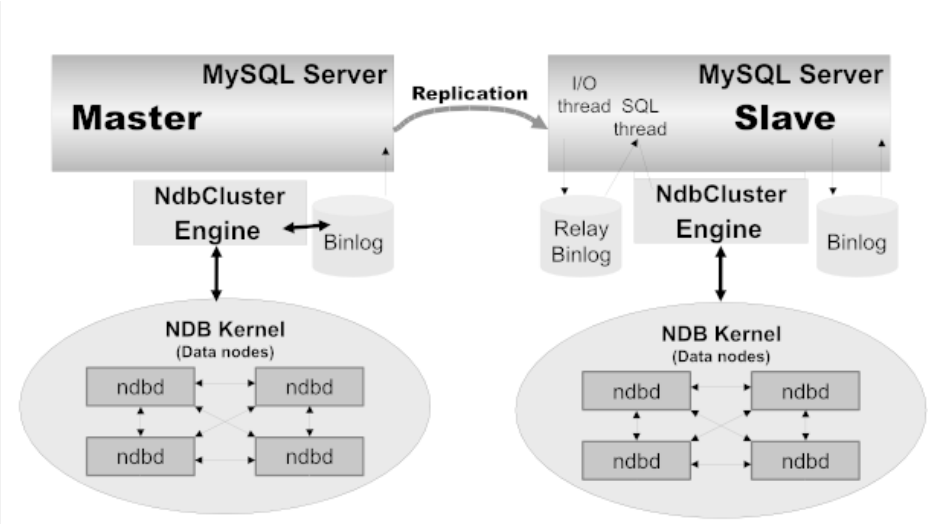
NDB Cluster supports *asynchronous replication*, more usually referred to simply as “replication”. This section explains how to set up and manage a configuration in which one group of computers operating as an NDB Cluster replicates to a second computer or group of computers. We assume some familiarity on the part of the reader with standard MySQL replication as discussed elsewhere in this Manual. (See Chapter 17, *Replication*).

Note

Semisynchronous replication is not supported by the `NDB` storage engine.

Normal (non-clustered) replication involves a “master” server and a “slave” server, the master being the source of the operations and data to be replicated and the slave being the recipient of these. In NDB Cluster, replication is conceptually very similar but can be more complex in practice, as it may be extended to cover a number of different configurations including replicating between two complete clusters. Although an NDB Cluster itself depends on the `NDB` storage engine for clustering functionality, it is not necessary to use `NDB` as the storage engine for the slave's copies of the replicated tables (see Replication from NDB to other storage engines). However, for maximum availability, it is possible (and preferable) to replicate from one NDB Cluster to another, and it is this scenario that we discuss, as shown in the following figure:

Figure 18.11 NDB Cluster-to-Cluster Replication Layout



In this scenario, the replication process is one in which successive states of a master cluster are logged and saved to a slave cluster. This process is accomplished by a special thread known as the NDB binary log injector thread, which runs on each MySQL server and produces a binary log (`binlog`). This thread ensures that all changes in the cluster producing the binary log—and not just those changes that are effected through the MySQL Server—are inserted into the binary log with the correct serialization order. We refer to the MySQL replication master and replication slave servers as replication servers or replication nodes, and the data flow or line of communication between them as a *replication channel*.

For information about performing point-in-time recovery with NDB Cluster and NDB Cluster Replication, see Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”.

NDB API _slave status variables. NDB API counters can provide enhanced monitoring capabilities on NDB Cluster replication slaves. These are implemented as NDB statistics `_slave` status variables, as seen in the output of `SHOW STATUS`, or in the results of queries against the `SESSION_STATUS` or `GLOBAL_STATUS` table in a `mysql` client session connected to a MySQL Server that is acting as a slave in NDB Cluster Replication. By comparing the values of these status variables before and after the execution of statements affecting replicated `NDB` tables, you can observe the corresponding actions taken on the NDB API level by the slave, which can be useful when monitoring or troubleshooting NDB Cluster Replication. Section 18.5.15, “NDB API Statistics Counters and Variables”, provides additional information.

Replication from NDB to non-NDB tables. It is possible to replicate `NDB` tables from an NDB Cluster acting as the master to tables using other MySQL storage engines such as `InnoDB` or `MyISAM` on a slave `mysqld`. This is subject to a number of conditions; see Replication from NDB to other storage engines, and Replication from NDB to a nontransactional storage engine, for more information.

18.6.1 NDB Cluster Replication: Abbreviations and Symbols

Throughout this section, we use the following abbreviations or symbols for referring to the master and slave clusters, and to processes and commands run on the clusters or cluster nodes:

Symbol or Abbreviation	Description (Refers to...)
M	The cluster serving as the (primary) replication master
S	The cluster acting as the (primary) replication slave
`shell`*M*`>`	Shell command to be issued on the master cluster
`mysql`*M*`>`	MySQL client command issued on a single MySQL server running as an SQL node on the master cluster
`mysql`*M*`*>`	MySQL client command to be issued on all SQL nodes participating in the replication master cluster
`shell`*S*`>`	Shell command to be issued on the slave cluster
`mysql`*S*`>`	MySQL client command issued on a single MySQL server running as an SQL node on the slave cluster
`mysql`*S*`*>`	MySQL client command to be issued on all SQL nodes participating in the replication slave cluster
C	Primary replication channel
C'	Secondary replication channel
M'	Secondary replication master
S'	Secondary replication slave

18.6.2 General Requirements for NDB Cluster Replication

A replication channel requires two MySQL servers acting as replication servers (one each for the master and slave). For example, this means that in the case of a replication setup with two replication channels (to provide an extra channel for redundancy), there will be a total of four replication nodes, two per cluster.

Replication of an NDB Cluster as described in this section and those following is dependent on row-based replication. This means that the replication master MySQL server must be running with `--binlog-format=ROW` or `--binlog-format=MIXED`, as described in Section 18.6.6, "Starting NDB Cluster Replication (Single Replication Channel)". For general information about row-based replication, see Section 17.1.2, "Replication Formats".

Important

If you attempt to use NDB Cluster Replication with `--binlog-format=STATEMENT`, replication fails to work properly because the `ndb_binlog_index` table on the master and the `epoch` column of the `ndb_apply_status` table on the slave are not updated (see Section 18.6.4, "NDB Cluster Replication Schema and Tables"). Instead, only updates on the MySQL server acting as the replication master propagate to the slave, and no updates from any other SQL nodes on the master cluster are replicated.

Beginning with NDB 7.2.13, the default value for the `--binlog-format` option is `MIXED`. (Bug #16417224)

In NDB 7.2.12 and earlier NDB Cluster 7.2 releases, the default for `--binlog-format` was `STATEMENT`; this meant that you were required to change the binary logging format to `ROW` (or `MIXED`) manually on all MySQL Servers on the master NDB Cluster, prior to starting NDB Cluster replication. If necessary, you can do this on startup using the `--binlog-format` option, or at runtime by setting the global `binlog_format` system variable. Using the startup option is preferred in such cases.

Each MySQL server used for replication in either cluster must be uniquely identified among all the MySQL replication servers participating in either cluster (you cannot have replication servers on both the master and slave clusters sharing the same ID). This can be done by starting each SQL node using the `--server-id=id` option, where *`id`* is a unique integer. Although it is not strictly necessary, we will assume for purposes of this discussion that all NDB Cluster binaries are of the same release version.

It is generally true in MySQL Replication that both MySQL servers (`mysqld` processes) involved must be compatible with one another with respect to both the version of the replication protocol used and the SQL feature sets which they support (see Section 17.4.2, "Replication Compatibility Between MySQL Versions"). It is due to such differences between the binaries in the NDB Cluster and MySQL Server 5.5 distributions that NDB Cluster Replication has the additional requirement that both `mysqld` binaries come from an NDB Cluster distribution. The simplest and easiest way to assure that the `mysqld` servers are compatible is to use the same NDB Cluster distribution for all master and slave `mysqld` binaries.

We assume that the slave server or cluster is dedicated to replication of the master, and that no other data is being stored on it.

All `NDB` tables being replicated must be created using a MySQL server and client. Tables and other database objects created using the NDB API (with, for example, `Dictionary::createTable()`) are not visible to a MySQL server and so are not replicated. Updates by NDB API applications to existing tables that were created using a MySQL server can be replicated.

Note

It is possible to replicate an NDB Cluster using statement-based replication. However, in this case, the following restrictions apply:

- All updates to data rows on the cluster acting as the master must be directed to a single MySQL server.
- It is not possible to replicate a cluster using multiple simultaneous MySQL replication processes.
- Only changes made at the SQL level are replicated.

These are in addition to the other limitations of statement-based replication as opposed to row-based replication; see Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”, for more specific information concerning the differences between the two replication formats.

18.6.3 Known Issues in NDB Cluster Replication

This section discusses known problems or issues when using replication with NDB Cluster 7.2.

Loss of master-slave connection. A loss of connection can occur either between the replication master SQL node and the replication slave SQL node, or between the replication master SQL node and the data nodes in the master cluster. In the latter case, this can occur not only as a result of loss of physical connection (for example, a broken network cable), but due to the overflow of data node event buffers; if the SQL node is too slow to respond, it may be dropped by the cluster (this is controllable to some degree by adjusting the `MaxBufferedEpochs` and `TimeBetweenEpochs` configuration parameters). If this occurs, *it is entirely possible for new data to be inserted into the master cluster without being recorded in the replication master's binary log*. For this reason, to guarantee high availability, it is extremely important to maintain a backup replication channel, to monitor the primary channel, and to fail over to the secondary replication channel when necessary to keep the slave cluster synchronized with the master. NDB Cluster is not designed to perform such monitoring on its own; for this, an external application is required.

The replication master issues a “gap” event when connecting or reconnecting to the master cluster. (A gap event is a type of “incident event,” which indicates an incident that occurs that affects the contents of the database but that cannot easily be represented as a set of changes. Examples of incidents are server crashes, database resynchronization, (some) software updates, and (some) hardware changes.) When the slave encounters a gap in the replication log, it stops with an error message. This message is available in the output of `SHOW SLAVE STATUS`, and indicates that the SQL thread has stopped due to an incident registered in the replication stream, and that manual intervention is required. See Section 18.6.8, “Implementing Failover with NDB Cluster Replication”, for more information about what to do in such circumstances.

Important

Because NDB Cluster is not designed on its own to monitor replication status or provide failover, if high availability is a requirement for the slave server or cluster, then you must set up multiple replication lines, monitor the master `mysqld` on the primary replication line, and be prepared fail over to a secondary line if and as necessary. This must be done manually, or possibly by means of a third-party application. For information about implementing this type of setup, see Section 18.6.7, “Using Two Replication Channels for NDB Cluster Replication”, and Section 18.6.8, “Implementing Failover with NDB Cluster Replication”.

However, if you are replicating from a standalone MySQL server to an NDB Cluster, one channel is usually sufficient.

Circular replication. NDB Cluster Replication supports circular replication, as shown in the next example. The replication setup involves three NDB Clusters numbered 1, 2, and 3, in which Cluster

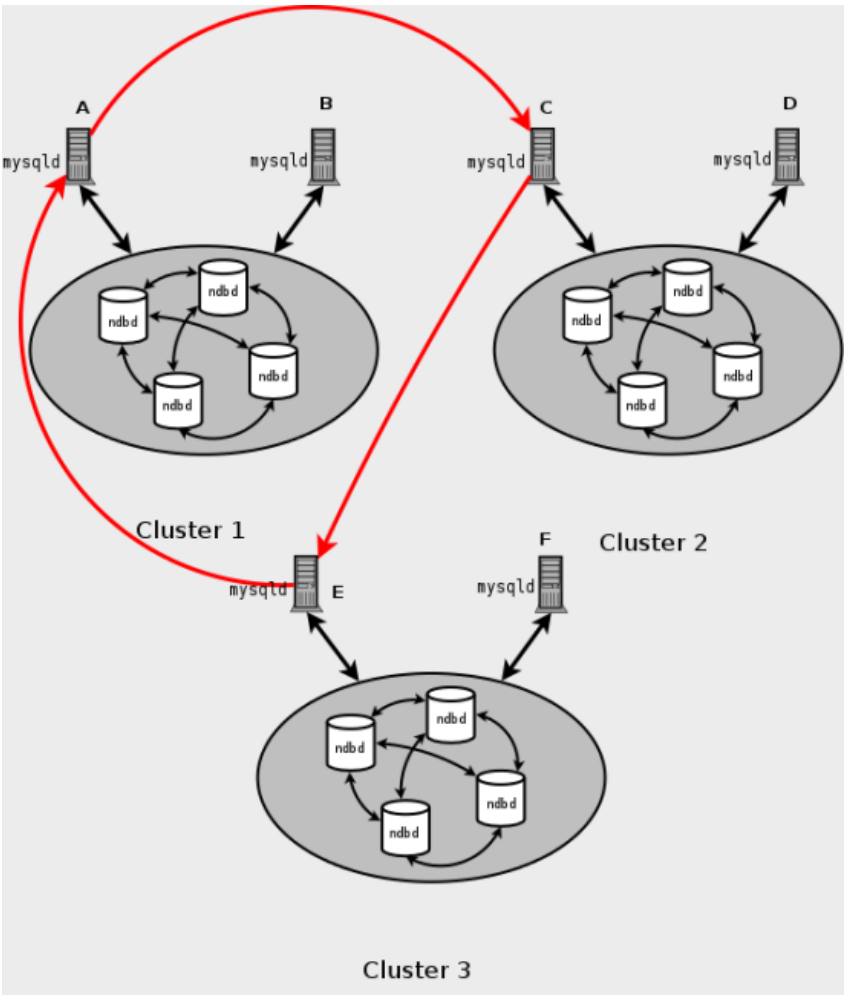
1 acts as the replication master for Cluster 2, Cluster 2 acts as the master for Cluster 3, and Cluster 3 acts as the master for Cluster 1, thus completing the circle. Each NDB Cluster has two SQL nodes, with SQL nodes A and B belonging to Cluster 1, SQL nodes C and D belonging to Cluster 2, and SQL nodes E and F belonging to Cluster 3.

Circular replication using these clusters is supported as long as the following conditions are met:

- The SQL nodes on all masters and slaves are the same
- All SQL nodes acting as replication masters and slaves are started using the `--log-slave-updates` option

This type of circular replication setup is shown in the following diagram:

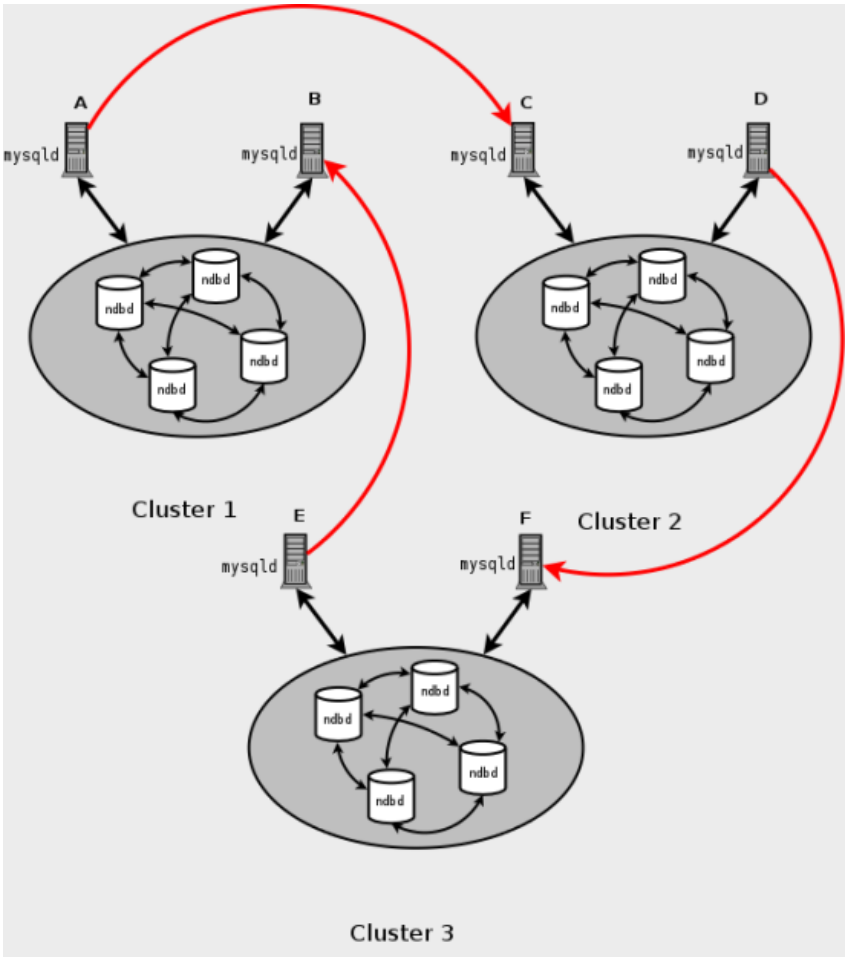
Figure 18.12 NDB Cluster Circular Replication With All Masters As Slaves



In this scenario, SQL node A in Cluster 1 replicates to SQL node C in Cluster 2; SQL node C replicates to SQL node E in Cluster 3; SQL node E replicates to SQL node A. In other words, the replication line (indicated by the red arrows in the diagram) directly connects all SQL nodes used as replication masters and slaves.

It should also be possible to set up circular replication in which not all master SQL nodes are also slaves, as shown here:

Figure 18.13 NDB Cluster Circular Replication Where Not All Masters Are Slaves



In this case, different SQL nodes in each cluster are used as replication masters and slaves. However, you must *not* start any of the SQL nodes using `--log-slave-updates`. This type of circular replication scheme for NDB Cluster, in which the line of replication (again indicated by the red arrows in the diagram) is discontinuous, should be possible, but it should be noted that it has not yet been thoroughly tested and must therefore still be considered experimental.

Note

The `NDB` storage engine uses *idempotent execution mode*, which suppresses duplicate-key and other errors that otherwise break circular replication of NDB Cluster. This is equivalent to setting the global `slave_exec_mode` system variable to `IDEMPOTENT`, although this is not necessary in NDB Cluster replication, since NDB Cluster sets this variable automatically and ignores any attempts to set it explicitly.

NDB Cluster replication and primary keys. In the event of a node failure, errors in replication of `NDB` tables without primary keys can still occur, due to the possibility of duplicate rows being inserted in such cases. For this reason, it is highly recommended that all `NDB` tables being replicated have primary keys.

NDB Cluster Replication and Unique Keys. In older versions of NDB Cluster, operations that updated values of unique key columns of `NDB` tables could result in duplicate-key errors when replicated. This issue is solved for replication between `NDB` tables by deferring unique key checks until after all table row updates have been performed.

Deferring constraints in this way is currently supported only by NDB. Thus, updates of unique keys when replicating from NDB to a different storage engine such as MyISAM or InnoDB are still not supported.

The problem encountered when replicating without deferred checking of unique key updates can be illustrated using NDB table such as t, is created and populated on the master (and replicated to a slave that does not support deferred unique key updates) as shown here:

```
CREATE TABLE t (
    p INT PRIMARY KEY,
    c INT,
    UNIQUE KEY u (c)
)   ENGINE NDB;

INSERT INTO t
    VALUES (1,1), (2,2), (3,3), (4,4), (5,5);
```

The following UPDATE statement on t succeeded on the master, since the rows affected are processed in the order determined by the ORDER BY option, performed over the entire table:

```
UPDATE t SET c = c - 1 ORDER BY p;
```

However, the same statement failed with a duplicate key error or other constraint violation on the slave, because the ordering of the row updates was done for one partition at a time, rather than for the table as a whole.

Note

Every NDB table is implicitly partitioned by key when it is created. See Section 19.2.5, “KEY Partitioning”, for more information.

Restarting with --initial. Restarting the cluster with the --initial option causes the sequence of GCI and epoch numbers to start over from 0. (This is generally true of NDB Cluster and not limited to replication scenarios using NDB.) The MySQL servers involved in replication should in this case be restarted. After this, you should use the RESET MASTER and RESET SLAVE statements to clear the invalid ndb_binlog_index and ndb_apply_status tables, respectively.

Replication from NDB to other storage engines. It is possible to replicate an NDB table on the master to a table using a different storage engine on the slave, taking into account the restrictions listed here:

- Multi-master and circular replication are not supported (tables on both the master and the slave must use the NDB storage engine for this to work).
- Using a storage engine which does not perform binary logging for slave tables requires special handling.
- Use of a nontransactional storage engine for slave tables also requires special handling.
- The master mysqld must be started with --ndb-log-update-as-write=0 or --ndb-log-update-as-write=OFF.

The next few paragraphs provide additional information about each of the issues just described.

Multiple masters not supported when replicating NDB to other storage engines. For replication from NDB to a different storage engine, the relationship between the two databases must be a simple master-slave one. This means that circular or master-master replication is not supported between NDB Cluster and other storage engines.

In addition, it is not possible to configure more than one replication channel when replicating between NDB and a different storage engine. (However, an NDB Cluster database *can* simultaneously replicate

to multiple slave NDB Cluster databases.) If the master uses NDB tables, it is still possible to have more than one MySQL Server maintain a binary log of all changes; however, for the slave to change masters (fail over), the new master-slave relationship must be explicitly defined on the slave.

Replicating NDB to a slave storage engine that does not perform binary logging. If you attempt to replicate from an NDB Cluster to a slave that uses a storage engine that does not handle its own binary logging, the replication process aborts with the error `Binary logging not possible ... Statement cannot be written atomically since more than one engine involved and at least one engine is self-logging` (Error 1595). It is possible to work around this issue in one of the following ways:

- **Turn off binary logging on the slave.** This can be accomplished by setting `sql_log_bin = 0`.
- **Change the storage engine used for the mysql.ndb_apply_status table.** Causing this table to use an engine that does not handle its own binary logging can also eliminate the conflict. This can be done by issuing a statement such as `ALTER TABLE mysql.ndb_apply_status ENGINE=MyISAM` on the slave. It is safe to do this when using a non-NDB storage engine on the slave, since you do not then need to worry about keeping multiple slave SQL nodes synchronized.
- **Filter out changes to the mysql.ndb_apply_status table on the slave.** This can be done by starting the slave SQL node with `--replicate-ignore-table=mysql.ndb_apply_status`. If you need for other tables to be ignored by replication, you might wish to use an appropriate `--replicate-wild-ignore-table` option instead.

Important

You should *not* disable replication or binary logging of `mysql.ndb_apply_status` or change the storage engine used for this table when replicating from one NDB Cluster to another. See Replication and binary log filtering rules with replication between NDB Clusters, for details.

Replication from NDB to a nontransactional storage engine. When replicating from NDB to a nontransactional storage engine such as MyISAM, you may encounter unnecessary duplicate key errors when replicating `INSERT ... ON DUPLICATE KEY UPDATE` statements. You can suppress these by using `--ndb-log-update-as-write=0`, which forces updates to be logged as writes (rather than as updates).

In addition, when replicating from NDB to a storage engine that does not implement transactions, if the slave fails to apply any row changes from a given transaction, it does not roll back the rest of the transaction. (This is true when replicating tables using any transactional storage engine—not only NDB—to a nontransactional storage engine.) Because of this, it cannot be guaranteed that transactional consistency will be maintained on the slave in such cases.

Replication and binary log filtering rules with replication between NDB Clusters. If you are using any of the options `--replicate-do-*`, `--replicate-ignore-*`, `--binlog-do-db`, or `--binlog-ignore-db` to filter databases or tables being replicated, care must be taken not to block replication or binary logging of the `mysql.ndb_apply_status`, which is required for replication between NDB Clusters to operate properly. In particular, you must keep in mind the following:

1. Using `--replicate-do-db=`*`db_name`* (and no other `--replicate-do-*` or `--replicate-ignore-*` options) means that *only* tables in database *`db_name`* are replicated. In this case, you should also use `--replicate-do-db=mysql`, `--binlog-do-db=mysql`, or `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is populated on slaves.

   Using `--binlog-do-db=`*`db_name`* (and no other `--binlog-do-db` options) means that changes *only* to tables in database *`db_name`* are written to the binary log. In this case, you should also use `--replicate-do-db=mysql`, `--binlog-do-db=mysql`, or `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is populated on slaves.

2. Using `--replicate-ignore-db=mysql` means that no tables in the `mysql` database are replicated. In this case, you should also use `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is replicated.

   Using `--binlog-ignore-db=mysql` means that no changes to tables in the `mysql` database are written to the binary log. In this case, you should also use `--replicate-do-table=mysql.ndb_apply_status` to ensure that `mysql.ndb_apply_status` is replicated.

You should also remember that each replication rule requires the following:

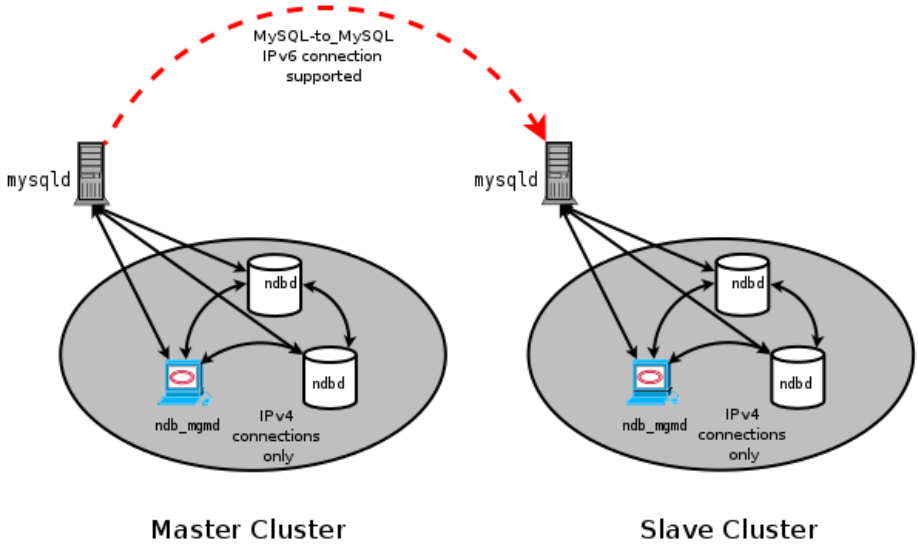
1. Its own `--replicate-do-*` or `--replicate-ignore-*` option, and that multiple rules cannot be expressed in a single replication filtering option. For information about these rules, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

2. Its own `--binlog-do-db` or `--binlog-ignore-db` option, and that multiple rules cannot be expressed in a single binary log filtering option. For information about these rules, see Section 5.4.4, “The Binary Log”.

If you are replicating an NDB Cluster to a slave that uses a storage engine other than `NDB`, the considerations just given previously may not apply, as discussed elsewhere in this section.

NDB Cluster Replication and IPv6. Currently, the NDB API and MGM API do not support IPv6. However, MySQL Servers—including those acting as SQL nodes in an NDB Cluster—can use IPv6 to contact other MySQL Servers. This means that you can replicate between NDB Clusters using IPv6 to connect the master and slave SQL nodes as shown by the dotted arrow in the following diagram:

Figure 18.14 Replication Between SQL Nodes Connected Using IPv6



However, all connections originating *within* the NDB Cluster—represented in the preceding diagram by solid arrows—must use IPv4. In other words, all NDB Cluster data nodes, management servers, and management clients must be accessible from one another using IPv4. In addition, SQL nodes must use IPv4 to communicate with the cluster.

Since there is currently no support in the NDB and MGM APIs for IPv6, any applications written using these APIs must also make all connections using IPv4.

Attribute promotion and demotion. NDB Cluster Replication includes support for attribute promotion and demotion. The implementation of the latter distinguishes between lossy and non-lossy type conversions, and their use on the slave can be controlled by setting the `slave_type_conversions` global server system variable.

For more information about attribute promotion and demotion in NDB Cluster, see Row-based replication: attribute promotion and demotion.

18.6.4 NDB Cluster Replication Schema and Tables

Replication in NDB Cluster makes use of a number of dedicated tables in the `mysql` database on each MySQL Server instance acting as an SQL node in both the cluster being replicated and the replication slave (whether the slave is a single server or a cluster). These tables are created during the MySQL installation process by the `mysql_install_db` script, and include a table for storing the binary log's indexing data. Since the `ndb_binlog_index` table is local to each MySQL server and does not participate in clustering, it uses the `MyISAM` storage engine. This means that it must be created separately on each `mysqld` participating in the master cluster. (However, the binary log itself contains updates from all MySQL servers in the cluster to be replicated.) This table is defined as follows:

```
CREATE TABLE `ndb_binlog_index` (
    `Position` BIGINT(20) UNSIGNED NOT NULL,
    `File` VARCHAR(255) NOT NULL,
    `epoch` BIGINT(20) UNSIGNED NOT NULL,
    `inserts` INT(10) UNSIGNED NOT NULL,
    `updates` INT(10) UNSIGNED NOT NULL,
    `deletes` INT(10) UNSIGNED NOT NULL,
    `schemaops` INT(10) UNSIGNED NOT NULL,
    `orig_server_id` INT(10) UNSIGNED NOT NULL,
    `orig_epoch` BIGINT(20) UNSIGNED NOT NULL,
    `gci` INT(10) UNSIGNED NOT NULL,
    `next_position` bigint(20) unsigned NOT NULL,
    `next_file` varchar(255) NOT NULL,
    PRIMARY KEY (`epoch`,`orig_server_id`,`orig_epoch`)
) ENGINE=MyISAM DEFAULT CHARSET=latin1;
```

The size of this table is dependent on the number of epochs per binary log file and the number of binary log files. The number of epochs per binary log file normally depends on the amount of binary log generated per epoch and the size of the binary log file, with smaller epochs resulting in more epochs per file. You should be aware that empty epochs produce inserts to the `ndb_binlog_index` table, even when the `--ndb-log-empty-epochs` option is `OFF`, meaning that the number of entries per file depends on the length of time that the file is in use; that is,

```
[number of epochs per file] = [time spent per file] / TimeBetweenEpochs
```

A busy NDB Cluster writes to the binary log regularly and presumably rotates binary log files more quickly than a quiet one. This means that a “quiet” NDB Cluster with `--ndb-log-empty-epochs=ON` can actually have a much higher number of `ndb_binlog_index` rows per file than one with a great deal of activity.

When `mysqld` is started with the `--ndb-log-orig` option, the `orig_server_id` and `orig_epoch` columns store, respectively, the ID of the server on which the event originated and the epoch in which the event took place on the originating server, which is useful in NDB Cluster replication setups employing multiple masters. The `SELECT` statement used to find the closest binary log position to the highest applied epoch on the slave in a multi-master setup (see Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”) employs these two columns, which are not indexed. This can lead to performance issues when trying to fail over, since the query must perform a table scan, especially when the master has been running with `--ndb-log-empty-epochs=ON`. You can improve multi-master failover times by adding an index to these columns, as shown here:

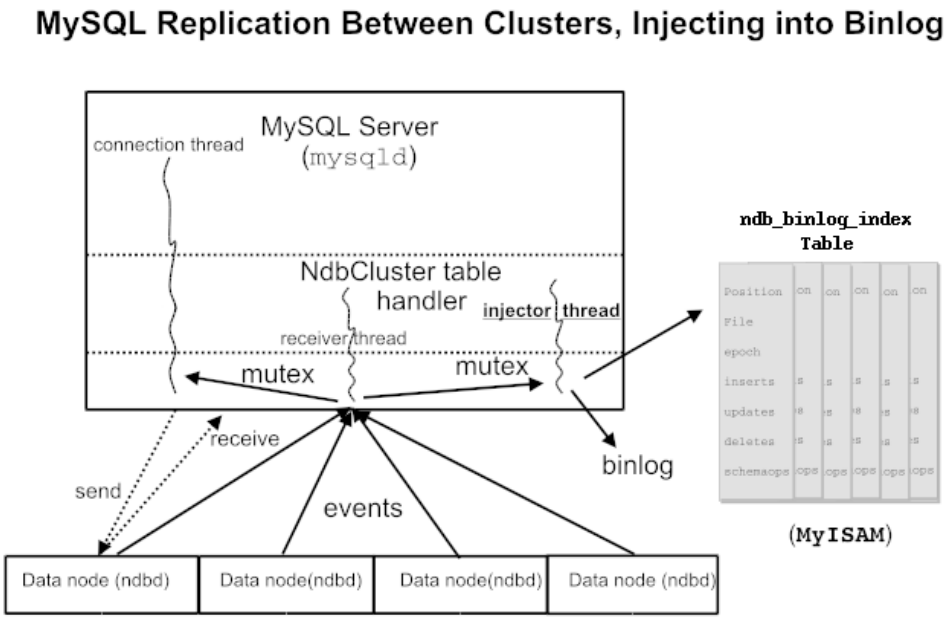
```
ALTER TABLE mysql.ndb_binlog_index
    ADD INDEX orig_lookup USING BTREE (orig_server_id, orig_epoch);
```

Adding this index provides no benefit when replicating from a single master to a single slave, since the query used to get the binary log position in such cases makes no use of `orig_server_id` or `orig_epoch`.

The `next_position` and `next_file` columns were added in NDB 7.2.6; see Section 18.6.8, “Implementing Failover with NDB Cluster Replication”, for more information about using these columns.

The following figure shows the relationship of the NDB Cluster replication master server, its binary log injector thread, and the `mysql.ndb_binlog_index` table.

Figure 18.15 The Replication Master Cluster



An additional table, named `ndb_apply_status`, is used to keep a record of the operations that have been replicated from the master to the slave. Unlike the case with `ndb_binlog_index`, the data in this table is not specific to any one SQL node in the (slave) cluster, and so `ndb_apply_status` can use the `NDBCLUSTER` storage engine, as shown here:

```
CREATE TABLE `ndb_apply_status` (
    `server_id`   INT(10) UNSIGNED NOT NULL,
    `epoch`       BIGINT(20) UNSIGNED NOT NULL,
    `log_name`    VARCHAR(255) CHARACTER SET latin1 COLLATE latin1_bin NOT NULL,
    `start_pos`   BIGINT(20) UNSIGNED NOT NULL,
    `end_pos`     BIGINT(20) UNSIGNED NOT NULL,
    PRIMARY KEY (`server_id`) USING HASH
) ENGINE=NDBCLUSTER   DEFAULT CHARSET=latin1;
```

The `ndb_apply_status` table is populated only on slaves, which means that, on the master, this table never contains any rows; thus, there is no need to allow for `DataMemory` or `IndexMemory` to be allotted to `ndb_apply_status` there.

Because this table is populated from data originating on the master, it should be allowed to replicate; any replication filtering or binary log filtering rules that inadvertently prevent the slave from updating `ndb_apply_status` or the master from writing into the binary log may prevent replication between clusters from operating properly. For more information about potential problems arising from such filtering rules, see Replication and binary log filtering rules with replication between NDB Clusters.

The `ndb_binlog_index` and `ndb_apply_status` tables are created in the `mysql` database because they should not be explicitly replicated by the user. User intervention is normally not

required to create or maintain either of these tables, since both `ndb_binlog_index` and the `ndb_apply_status` are maintained by the `NDB` binary log (binlog) injector thread. This keeps the master `mysqld` process updated to changes performed by the `NDB` storage engine. The `NDB` *binlog injector thread* receives events directly from the `NDB` storage engine. The `NDB` injector is responsible for capturing all the data events within the cluster, and ensures that all events which change, insert, or delete data are recorded in the `ndb_binlog_index` table. The slave I/O thread transfers the events from the master's binary log to the slave's relay log.

However, it is advisable to check for the existence and integrity of these tables as an initial step in preparing an NDB Cluster for replication. It is possible to view event data recorded in the binary log by querying the `mysql.ndb_binlog_index` table directly on the master. This can be also be accomplished using the `SHOW BINLOG EVENTS` statement on either the replication master or slave MySQL servers. (See Section 13.7.5.3, “SHOW BINLOG EVENTS Syntax”.)

You can also obtain useful information from the output of `SHOW ENGINE NDB STATUS`.

The `ndb_schema` table is used to track schema changes made to `NDB` tables. It is defined as shown here:

```
CREATE TABLE ndb_schema (
    `db` VARBINARY(63) NOT NULL,
    `name` VARBINARY(63) NOT NULL,
    `slock` BINARY(32) NOT NULL,
    `query` BLOB NOT NULL,
    `node_id` INT UNSIGNED NOT NULL,
    `epoch` BIGINT UNSIGNED NOT NULL,
    `id` INT UNSIGNED NOT NULL,
    `version` INT UNSIGNED NOT NULL,
    `type` INT UNSIGNED NOT NULL,
    PRIMARY KEY USING HASH (db,name)
) ENGINE=NDB   DEFAULT CHARSET=latin1;
```

Unlike the two tables previously mentioned in this section, the `ndb_schema` table is not visible either to MySQL `SHOW` statements, or in any `INFORMATION_SCHEMA` tables; however, it can be seen in the output of `ndb_show_tables`, as shown here:

```
shell> ndb_show_tables -t 2
id    type                state    logging database     schema   name
4     UserTable           Online   Yes     mysql        def      ndb_apply_status
5     UserTable           Online   Yes     ndbworld     def      city
6     UserTable           Online   Yes     ndbworld     def      country
3     UserTable           Online   Yes     mysql        def      NDB$BLOB_2_3
7     UserTable           Online   Yes     ndbworld     def      countrylanguage
2     UserTable           Online   Yes     mysql        def      ndb_schema

NDBT_ProgramExit: 0 - OK
```

It is also possible to `SELECT` from this table in `mysql` and other MySQL client applications, as shown here:

```
mysql> SELECT * FROM mysql.ndb_schema WHERE name='city' \G
*************************** 1. row ***************************
     db: ndbworld
   name: city
  slock:
  query: alter table City engine=ndb
node_id: 4
  epoch: 0
     id: 0
version: 0
   type: 7
1 row in set (0.00 sec)
```

This can sometimes be useful when debugging applications.

Note

When performing schema changes on `NDB` tables, applications should wait until the `ALTER TABLE` statement has returned in the MySQL client connection that issued the statement before attempting to use the updated definition of the table.

If the `ndb_apply_status` table or the `ndb_schema` table does not exist on the slave, `ndb_restore` re-creates the missing table or tables (Bug #14612).

Conflict resolution for NDB Cluster Replication requires the presence of an additional `mysql.ndb_replication` table. Currently, this table must be created manually. For information about how to do this, see Section 18.6.11, “NDB Cluster Replication Conflict Resolution”.

18.6.5 Preparing the NDB Cluster for Replication

Preparing the NDB Cluster for replication consists of the following steps:

1. Check all MySQL servers for version compatibility (see Section 18.6.2, “General Requirements for NDB Cluster Replication”).
2. Create a slave account on the master Cluster with the appropriate privileges:

```
mysqlM> GRANT REPLICATION SLAVE
     -> ON *.* TO 'slave_user'@'slave_host'
     -> IDENTIFIED BY 'slave_password';
```

   In the previous statement, *`slave_user`* is the slave account user name, *`slave_host`* is the host name or IP address of the replication slave, and *`slave_password`* is the password to assign to this account.

   For example, to create a slave user account with the name `myslave`, logging in from the host named `rep-slave`, and using the password `53cr37`, use the following `GRANT` statement:

```
mysqlM> GRANT REPLICATION SLAVE
     -> ON *.* TO 'myslave'@'rep-slave'
     -> IDENTIFIED BY '53cr37';
```

   For security reasons, it is preferable to use a unique user account—not employed for any other purpose—for the replication slave account.

3. Configure the slave to use the master. Using the MySQL Monitor, this can be accomplished with the `CHANGE MASTER TO` statement:

```
mysqlS> CHANGE MASTER TO
     -> MASTER_HOST='master_host',
     -> MASTER_PORT=master_port,
     -> MASTER_USER='slave_user',
     -> MASTER_PASSWORD='slave_password';
```

   In the previous statement, *`master_host`* is the host name or IP address of the replication master, *`master_port`* is the port for the slave to use for connecting to the master, *`slave_user`* is the user name set up for the slave on the master, and *`slave_password`* is the password set for that user account in the previous step.

   For example, to tell the slave to replicate from the MySQL server whose host name is `rep-master`, using the replication slave account created in the previous step, use the following statement:

```
mysqlS> CHANGE MASTER TO
```

```
    -> MASTER_HOST='rep-master',
    -> MASTER_PORT=3306,
    -> MASTER_USER='myslave',
    -> MASTER_PASSWORD='53cr37';
```

For a complete list of options that can be used with this statement, see Section 13.4.2.1, “CHANGE MASTER TO Syntax”.

To provide replication backup capability, you also need to add an `--ndb-connectstring` option to the slave's `my.cnf` file prior to starting the replication process. See Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”, for details.

For additional options that can be set in `my.cnf` for replication slaves, see Section 17.1.3, “Replication and Binary Logging Options and Variables”.

4. If the master cluster is already in use, you can create a backup of the master and load this onto the slave to cut down on the amount of time required for the slave to synchronize itself with the master. If the slave is also running NDB Cluster, this can be accomplished using the backup and restore procedure described in Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”.

   ```
   ndb-connectstring=management_host[:port]
   ```

   In the event that you are *not* using NDB Cluster on the replication slave, you can create a backup with this command on the replication master:

   ```
   shellM> mysqldump --master-data=1
   ```

   Then import the resulting data dump onto the slave by copying the dump file over to the slave. After this, you can use the `mysql` client to import the data from the dumpfile into the slave database as shown here, where *`dump_file`* is the name of the file that was generated using `mysqldump` on the master, and *`db_name`* is the name of the database to be replicated:

   ```
   shellS> mysql -u root -p db_name < dump_file
   ```

   For a complete list of options to use with `mysqldump`, see Section 4.5.4, “`mysqldump` — A Database Backup Program”.

   Note

   If you copy the data to the slave in this fashion, you should make sure that the slave is started with the `--skip-slave-start` option on the command line, or else include `skip-slave-start` in the slave's `my.cnf` file to keep it from trying to connect to the master to begin replicating before all the data has been loaded. Once the data loading has completed, follow the additional steps outlined in the next two sections.

5. Ensure that each MySQL server acting as a replication master is configured with a unique server ID, and with binary logging enabled, using the row format. (See Section 17.1.2, “Replication Formats”.) These options can be set either in the master server's `my.cnf` file, or on the command line when starting the master `mysqld` process. See Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”, for information regarding the latter option.

18.6.6 Starting NDB Cluster Replication (Single Replication Channel)

This section outlines the procedure for starting NDB Cluster replication using a single replication channel.

1. Start the MySQL replication master server by issuing this command:

   ```
   ```

```
shellM> mysqld --ndbcluster --server-id=id \
        --log-bin &
```

If the master is running NDB 7.2.12 or earlier, it must also be started with `--binlog-format=ROW` (or `MIXED`). (Bug #16417224)

In the previous statement, *`id`* is this server's unique ID (see Section 18.6.2, “General Requirements for NDB Cluster Replication”). This starts the server's `mysqld` process with binary logging enabled using the proper logging format.

Note

You can also start the master with `--binlog-format=MIXED`, in which case row-based replication is used automatically when replicating between clusters. `STATEMENT` based binary logging is not supported for NDB Cluster Replication (see Section 18.6.2, “General Requirements for NDB Cluster Replication”).

2. Start the MySQL replication slave server as shown here:

```
shellS> mysqld --ndbcluster --server-id=id &
```

In the command just shown, *`id`* is the slave server's unique ID. It is not necessary to enable logging on the replication slave.

Note

You should use the `--skip-slave-start` option with this command or else you should include `skip-slave-start` in the slave server's `my.cnf` file, unless you want replication to begin immediately. With the use of this option, the start of replication is delayed until the appropriate `START SLAVE` statement has been issued, as explained in Step 4 below.

3. It is necessary to synchronize the slave server with the master server's replication binary log. If binary logging has not previously been running on the master, run the following statement on the slave:

```
mysqlS> CHANGE MASTER TO
     -> MASTER_LOG_FILE='',
     -> MASTER_LOG_POS=4;
```

This instructs the slave to begin reading the master's binary log from the log's starting point. Otherwise—that is, if you are loading data from the master using a backup—see Section 18.6.8, “Implementing Failover with NDB Cluster Replication”, for information on how to obtain the correct values to use for `MASTER_LOG_FILE` and `MASTER_LOG_POS` in such cases.

4. Finally, you must instruct the slave to begin applying replication by issuing this command from the `mysql` client on the replication slave:

```
mysqlS> START SLAVE;
```

This also initiates the transmission of replication data from the master to the slave.

It is also possible to use two replication channels, in a manner similar to the procedure described in the next section; the differences between this and using a single replication channel are covered in Section 18.6.7, “Using Two Replication Channels for NDB Cluster Replication”.

It is also possible to improve cluster replication performance by enabling *batched updates*. This can be accomplished by setting the `slave_allow_batching` system variable on the slave `mysqld` processes. Normally, updates are applied as soon as they are received. However, the use of batching

causes updates to be applied in 32 KB batches, which can result in higher throughput and less CPU usage, particularly where individual updates are relatively small.

Note

Slave batching works on a per-epoch basis; updates belonging to more than one transaction can be sent as part of the same batch.

All outstanding updates are applied when the end of an epoch is reached, even if the updates total less than 32 KB.

Batching can be turned on and off at runtime. To activate it at runtime, you can use either of these two statements:

```
SET GLOBAL slave_allow_batching = 1;
SET GLOBAL slave_allow_batching = ON;
```

If a particular batch causes problems (such as a statement whose effects do not appear to be replicated correctly), slave batching can be deactivated using either of the following statements:

```
SET GLOBAL slave_allow_batching = 0;
SET GLOBAL slave_allow_batching = OFF;
```

You can check whether slave batching is currently being used by means of an appropriate `SHOW VARIABLES` statement, like this one:

```
mysql> SHOW VARIABLES LIKE 'slave%';
+---------------------------+-------+
| Variable_name             | Value |
+---------------------------+-------+
| slave_allow_batching      | ON    |
| slave_compressed_protocol | OFF   |
| slave_load_tmpdir         | /tmp  |
| slave_net_timeout         | 3600  |
| slave_skip_errors         | OFF   |
| slave_transaction_retries | 10    |
+---------------------------+-------+
6 rows in set (0.00 sec)
```

18.6.7 Using Two Replication Channels for NDB Cluster Replication

In a more complete example scenario, we envision two replication channels to provide redundancy and thereby guard against possible failure of a single replication channel. This requires a total of four replication servers, two masters for the master cluster and two slave servers for the slave cluster. For purposes of the discussion that follows, we assume that unique identifiers are assigned as shown here:

Server ID	Description
1	Master - primary replication channel (*M*)
2	Master - secondary replication channel (*M'*)
3	Slave - primary replication channel (*S*)
4	Slave - secondary replication channel (*S'*)

Setting up replication with two channels is not radically different from setting up a single replication channel. First, the `mysqld` processes for the primary and secondary replication masters must be started, followed by those for the primary and secondary slaves. Then the replication processes may be initiated by issuing the `START SLAVE` statement on each of the slaves. The commands and the order in which they need to be issued are shown here:

1. Start the primary replication master:

```
shellM> mysqld --ndbcluster --server-id=1 \
               --log-bin &
```

For NDB 7.2.12 and earlier, you should use the following (Bug #16417224):

```
shellM> mysqld --ndbcluster --server-id=1 \
               --log-bin --binlog-format=ROW &
```

2. Start the secondary replication master:

```
shellM'> mysqld --ndbcluster --server-id=2 \
               --log-bin &
```

For NDB 7.2.12 and earlier, you should use this instead (Bug #16417224):

```
shellM'> mysqld --ndbcluster --server-id=2 \
               --log-bin --binlog-format=ROW &
```

3. Start the primary replication slave server:

```
shellS> mysqld --ndbcluster --server-id=3 \
               --skip-slave-start &
```

4. Start the secondary replication slave:

```
shellS'> mysqld --ndbcluster --server-id=4 \
                --skip-slave-start &
```

5. Finally, initiate replication on the primary channel by executing the `START SLAVE` statement on the primary slave as shown here:

```
mysqlS> START SLAVE;
```

Warning

Only the primary channel is to be started at this point. The secondary replication channel is to be started only in the event that the primary replication channel fails, as described in Section 18.6.8, “Implementing Failover with NDB Cluster Replication”. Running multiple replication channels simultaneously can result in unwanted duplicate records being created on the replication slaves.

As mentioned previously, it is not necessary to enable binary logging on replication slaves.

18.6.8 Implementing Failover with NDB Cluster Replication

In the event that the primary Cluster replication process fails, it is possible to switch over to the secondary replication channel. The following procedure describes the steps required to accomplish this.

1. Obtain the time of the most recent global checkpoint (GCP). That is, you need to determine the most recent epoch from the `ndb_apply_status` table on the slave cluster, which can be found using the following query:

```
mysqlS'> SELECT @latest:=MAX(epoch)
      ->        FROM mysql.ndb_apply_status;
```

In a circular replication topology, with a master and a slave running on each host, when you are using `ndb_log_apply_status=1`, NDB Cluster epochs are written in the slave binary logs. This means that the `ndb_apply_status` table contains information for the slave on this host as well as for any other host which acts as a slave of the master running on this host.

In this case, you need to determine the latest epoch on this slave to the exclusion of any epochs from any other slaves in this slave's binary log that were not listed in the `IGNORE_SERVER_IDS` options of the `CHANGE MASTER TO` statement used to set up this slave. The reason for excluding such epochs is that rows in the `mysql.ndb_apply_status` table whose server IDs have a match in the `IGNORE_SERVER_IDS` list used with the CHANGE MASTER TO statement used to prepare this slave's master are also considered to be from local servers, in addition to those having the slave's own server ID. You can retrieve this list as `Replicate_Ignore_Server_Ids` from the output of `SHOW SLAVE STATUS`. We assume that you have obtained this list and are substituting it for *`ignore_server_ids`* in the query shown here, which like the previous version of the query, selects the greatest epoch into a variable named `@latest`:

```
mysqlS'> SELECT @latest:=MAX(epoch)
      ->        FROM mysql.ndb_apply_status
      ->        WHERE server_id NOT IN (ignore_server_ids);
```

In some cases, it may be simpler or more efficient (or both) to use a list of the server IDs to be included and `server_id IN server_id_list` in the `WHERE` condition of the preceding query.

2. Using the information obtained from the query shown in Step 1, obtain the corresponding records from the `ndb_binlog_index` table on the master cluster.

   Prior to NDB 7.2.6, you should use the following query to accomplish this task:

```
mysqlM'> SELECT
      ->     @file:=SUBSTRING_INDEX(File, '/', -1),
      ->     @pos:=Position
      -> FROM mysql.ndb_binlog_index
      -> WHERE epoch > @latest
      -> ORDER BY epoch ASC LIMIT 1;
```

   Beginning with NDB 7.2.6, you can take advantage of the improved binary logging of DDL statements implemented in those and later versions by using the following query to obtain the needed records from the master's `ndb_binlog_index` table:

```
mysqlM'> SELECT
      ->     @file:=SUBSTRING_INDEX(next_file, '/', -1),
      ->     @pos:=next_position
      -> FROM mysql.ndb_binlog_index
      -> WHERE epoch = @latest
      -> ORDER BY epoch ASC LIMIT 1;
```

   In either case, these are the records saved on the master since the failure of the primary replication channel. We have employed a user variable `@latest` here to represent the value obtained in Step 1. Of course, it is not possible for one `mysqld` instance to access user variables set on another server instance directly. These values must be “plugged in” to the second query manually or in application code.

Important

If (and only if) you use the second of the two queries just shown against `ndb_binlog_index` (that is, the query that employs the `next_position` and `next_file` columns), you must ensure that the slave `mysqld` is started with `--slave-skip-errors=ddl_exist_errors` before

executing `START SLAVE`. Otherwise, replication may stop with duplicate DDL errors.

3. Now it is possible to synchronize the secondary channel by running the following query on the secondary slave server:

```
mysqlS'> CHANGE MASTER TO
      ->     MASTER_LOG_FILE='@file',
      ->     MASTER_LOG_POS=@pos;
```

Again we have employed user variables (in this case `@file` and `@pos`) to represent the values obtained in Step 2 and applied in Step 3; in practice these values must be inserted manually or using application code that can access both of the servers involved.

Note

`@file` is a string value such as `'/var/log/mysql/replication-master-bin.00001'`, and so must be quoted when used in SQL or application code. However, the value represented by `@pos` must *not* be quoted. Although MySQL normally attempts to convert strings to numbers, this case is an exception.

4. You can now initiate replication on the secondary channel by issuing the appropriate command on the secondary slave `mysqld`:

```
mysqlS'> START SLAVE;
```

Once the secondary replication channel is active, you can investigate the failure of the primary and effect repairs. The precise actions required to do this will depend upon the reasons for which the primary channel failed.

Warning

The secondary replication channel is to be started only if and when the primary replication channel has failed. Running multiple replication channels simultaneously can result in unwanted duplicate records being created on the replication slaves.

If the failure is limited to a single server, it should (in theory) be possible to replicate from *`M`* to *`S'`*, or from *`M'`* to *`S`*; however, this has not yet been tested.

18.6.9 NDB Cluster Backups With NDB Cluster Replication

This section discusses making backups and restoring from them using NDB Cluster replication. We assume that the replication servers have already been configured as covered previously (see Section 18.6.5, “Preparing the NDB Cluster for Replication”, and the sections immediately following). This having been done, the procedure for making a backup and then restoring from it is as follows:

1. There are two different methods by which the backup may be started.

   - **Method A.** This method requires that the cluster backup process was previously enabled on the master server, prior to starting the replication process. This can be done by including the following line in a `[mysql_cluster]` section in the `my.cnf file`, where *`management_host`* is the IP address or host name of the `NDB` management server for the master cluster, and *`port`* is the management server's port number:

     ```
     ndb-connectstring=management_host[:port]
     ```

Note

The port number needs to be specified only if the default port (1186) is not being used. See Section 18.2.3, “Initial Configuration of NDB Cluster”, for more information about ports and port allocation in NDB Cluster.

In this case, the backup can be started by executing this statement on the replication master:

```
shellM> ndb_mgm -e "START BACKUP"
```

- **Method B.** If the `my.cnf` file does not specify where to find the management host, you can start the backup process by passing this information to the `NDB` management client as part of the `START BACKUP` command. This can be done as shown here, where *`management_host`* and *`port`* are the host name and port number of the management server:

  ```
  shellM> ndb_mgm management_host:port -e "START BACKUP"
  ```

  In our scenario as outlined earlier (see Section 18.6.5, “Preparing the NDB Cluster for Replication”), this would be executed as follows:

  ```
  shellM> ndb_mgm rep-master:1186 -e "START BACKUP"
  ```

2. Copy the cluster backup files to the slave that is being brought on line. Each system running an `ndbd` process for the master cluster will have cluster backup files located on it, and *all* of these files must be copied to the slave to ensure a successful restore. The backup files can be copied into any directory on the computer where the slave management host resides, so long as the MySQL and NDB binaries have read permissions in that directory. In this case, we will assume that these files have been copied into the directory `/var/BACKUPS/BACKUP-1`.

   It is not necessary that the slave cluster have the same number of `ndbd` processes (data nodes) as the master; however, it is highly recommended this number be the same. It *is* necessary that the slave be started with the `--skip-slave-start` option, to prevent premature startup of the replication process.

3. Create any databases on the slave cluster that are present on the master cluster that are to be replicated to the slave.

   Important

   A `CREATE DATABASE` (or `CREATE SCHEMA`) statement corresponding to each database to be replicated must be executed on each SQL node in the slave cluster.

4. Reset the slave cluster using this statement in the MySQL Monitor:

   ```
   mysqlS> RESET SLAVE;
   ```

5. You can now start the cluster restoration process on the replication slave using the `ndb_restore` command for each backup file in turn. For the first of these, it is necessary to include the `-m` option to restore the cluster metadata:

   ```
   shellS> ndb_restore -c slave_host:port -n node-id \
           -b backup-id -m -r dir
   ```

   `dir` is the path to the directory where the backup files have been placed on the replication slave. For the `ndb_restore` commands corresponding to the remaining backup files, the `-m` option should *not* be used.

For restoring from a master cluster with four data nodes (as shown in the figure in Section 18.6, “NDB Cluster Replication”) where the backup files have been copied to the directory `/var/BACKUPS/BACKUP-1`, the proper sequence of commands to be executed on the slave might look like this:

```
shellS> ndb_restore -c rep-slave:1186 -n 2 -b 1 -m \
        -r ./var/BACKUPS/BACKUP-1
shellS> ndb_restore -c rep-slave:1186 -n 3 -b 1 \
        -r ./var/BACKUPS/BACKUP-1
shellS> ndb_restore -c rep-slave:1186 -n 4 -b 1 \
        -r ./var/BACKUPS/BACKUP-1
shellS> ndb_restore -c rep-slave:1186 -n 5 -b 1 -e \
        -r ./var/BACKUPS/BACKUP-1
```

Important

The `-e` (or `--restore_epoch`) option in the final invocation of `ndb_restore` in this example is required in order that the epoch is written to the slave `mysql.ndb_apply_status`. Without this information, the slave will not be able to synchronize properly with the master. (See Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”.)

6. Now you need to obtain the most recent epoch from the `ndb_apply_status` table on the slave (as discussed in Section 18.6.8, “Implementing Failover with NDB Cluster Replication”):

```
mysqlS> SELECT @latest:=MAX(epoch)
        FROM mysql.ndb_apply_status;
```

7. Using `@latest` as the epoch value obtained in the previous step, you can obtain the correct starting position `@pos` in the correct binary log file `@file` from the master's `mysql.ndb_binlog_index` table using the query shown here:

```
mysqlM> SELECT
     ->     @file:=SUBSTRING_INDEX(File, '/', -1),
     ->     @pos:=Position
     -> FROM mysql.ndb_binlog_index
     -> WHERE epoch > @latest
     -> ORDER BY epoch ASC LIMIT 1;
```

In the event that there is currently no replication traffic, you can get this information by running `SHOW MASTER STATUS` on the master and using the value in the `Position` column for the file whose name has the suffix with the greatest value for all files shown in the `File` column. However, in this case, you must determine this and supply it in the next step manually or by parsing the output with a script.

8. Using the values obtained in the previous step, you can now issue the appropriate `CHANGE MASTER TO` statement in the slave's `mysql` client:

```
mysqlS> CHANGE MASTER TO
     ->     MASTER_LOG_FILE='@file',
     ->     MASTER_LOG_POS=@pos;
```

9. Now that the slave “knows” from what point in which binary log file to start reading data from the master, you can cause the slave to begin replicating with this standard MySQL statement:

```
mysqlS> START SLAVE;
```

To perform a backup and restore on a second replication channel, it is necessary only to repeat these steps, substituting the host names and IDs of the secondary master and slave for those of the primary

master and slave replication servers where appropriate, and running the preceding statements on them.

For additional information on performing Cluster backups and restoring Cluster from backups, see Section 18.5.3, “Online Backup of NDB Cluster”.

18.6.9.1 NDB Cluster Replication: Automating Synchronization of the Replication Slave to the Master Binary Log

It is possible to automate much of the process described in the previous section (see Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”). The following Perl script `reset-slave.pl` serves as an example of how you can do this.

```
#!/user/bin/perl -w

#  file: reset-slave.pl

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#  it under the terms of the GNU General Public License as published by
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#  along with this program; if not, write to:
#  Free Software Foundation, Inc.
#  59 Temple Place, Suite 330
#  Boston, MA 02111-1307 USA
#
#  Version 1.1


######################### Includes ###############################

use DBI;

######################### Globals ################################

my  $m_host='';
my  $m_port='';
my  $m_user='';
my  $m_pass='';
my  $s_host='';
my  $s_port='';
my  $s_user='';
my  $s_pass='';
my  $dbhM='';
my  $dbhS='';

######################### Sub Prototypes #########################

sub CollectCommandPromptInfo;
sub ConnectToDatabases;
sub DisconnectFromDatabases;
sub GetSlaveEpoch;
sub GetMasterInfo;
sub UpdateSlave;

######################### Program Main ###########################

CollectCommandPromptInfo;
ConnectToDatabases;
GetSlaveEpoch;
```

```
GetMasterInfo;
UpdateSlave;
DisconnectFromDatabases;

################## Collect Command Prompt Info ##################

sub CollectCommandPromptInfo
{
  ### Check that user has supplied correct number of command line args
  die "Usage:\n
       reset-slave >master MySQL host< >master MySQL port< \n
                   >master user< >master pass< >slave MySQL host< \n
                   >slave MySQL port< >slave user< >slave pass< \n
       All 8 arguments must be passed. Use BLANK for NULL passwords\n"
       unless @ARGV == 8;

  $m_host  =  $ARGV[0];
  $m_port  =  $ARGV[1];
  $m_user  =  $ARGV[2];
  $m_pass  =  $ARGV[3];
  $s_host  =  $ARGV[4];
  $s_port  =  $ARGV[5];
  $s_user  =  $ARGV[6];
  $s_pass  =  $ARGV[7];

  if ($m_pass eq "BLANK") { $m_pass = '';}
  if ($s_pass eq "BLANK") { $s_pass = '';}
}

###############  Make connections to both databases #############

sub ConnectToDatabases
{
  ### Connect to both master and slave cluster databases

  ### Connect to master
  $dbhM
    = DBI->connect(
    "dbi:mysql:database=mysql;host=$m_host;port=$m_port",
    "$m_user", "$m_pass")
      or die "Can't connect to Master Cluster MySQL process!
              Error: $DBI::errstr\n";

  ### Connect to slave
  $dbhS
    = DBI->connect(
          "dbi:mysql:database=mysql;host=$s_host",
          "$s_user", "$s_pass")
    or die "Can't connect to Slave Cluster MySQL process!
            Error: $DBI::errstr\n";
}

################  Disconnect from both databases ################

sub DisconnectFromDatabases
{
  ### Disconnect from master

  $dbhM->disconnect
  or warn " Disconnection failed: $DBI::errstr\n";

  ### Disconnect from slave

  $dbhS->disconnect
  or warn " Disconnection failed: $DBI::errstr\n";
}

######################  Find the last good GCI ##################

sub GetSlaveEpoch
{
  $sth = $dbhS->prepare("SELECT MAX(epoch)
```

```
                        FROM mysql.ndb_apply_status;")
      or die "Error while preparing to select epoch from slave: ",
             $dbhS->errstr;

  $sth->execute
      or die "Selecting epoch from slave error: ", $sth->errstr;

  $sth->bind_col (1, \$epoch);
  $sth->fetch;
  print "\tSlave Epoch =  $epoch\n";
  $sth->finish;
}

#######  Find the position of the last GCI in the binary log ########

sub GetMasterInfo
{
  $sth = $dbhM->prepare("SELECT
                          SUBSTRING_INDEX(File, '/', -1), Position
                        FROM mysql.ndb_binlog_index
                        WHERE epoch > $epoch
                        ORDER BY epoch ASC LIMIT 1;")
      or die "Prepare to select from master error: ", $dbhM->errstr;

  $sth->execute
      or die "Selecting from master error: ", $sth->errstr;

  $sth->bind_col (1, \$binlog);
  $sth->bind_col (2, \$binpos);
  $sth->fetch;
  print "\tMaster binary log =  $binlog\n";
  print "\tMaster binary log position =  $binpos\n";
  $sth->finish;
}

##########  Set the slave to process from that location #########

sub UpdateSlave
{
  $sth = $dbhS->prepare("CHANGE MASTER TO
                        MASTER_LOG_FILE='$binlog',
                        MASTER_LOG_POS=$binpos;")
      or die "Prepare to CHANGE MASTER error: ", $dbhS->errstr;

  $sth->execute
       or die "CHANGE MASTER on slave error: ", $sth->errstr;
  $sth->finish;
  print "\tSlave has been updated. You may now start the slave.\n";
}

# end reset-slave.pl
```

18.6.9.2 Point-In-Time Recovery Using NDB Cluster Replication

Point-in-time recovery—that is, recovery of data changes made since a given point in time—is performed after restoring a full backup that returns the server to its state when the backup was made. Performing point-in-time recovery of NDB Cluster tables with NDB Cluster and NDB Cluster Replication can be accomplished using a native `NDB` data backup (taken by issuing `CREATE BACKUP` in the `ndb_mgm` client) and restoring the `ndb_binlog_index` table (from a dump made using `mysqldump`).

To perform point-in-time recovery of NDB Cluster, it is necessary to follow the steps shown here:

1. Back up all `NDB` databases in the cluster, using the `START BACKUP` command in the `ndb_mgm` client (see Section 18.5.3, “Online Backup of NDB Cluster”).

2. At some later point, prior to restoring the cluster, make a backup of the `mysql.ndb_binlog_index` table. It is probably simplest to use `mysqldump` for this task. Also back up the binary log files at this time.

This backup should be updated regularly—perhaps even hourly—depending on your needs.

3. (*Catastrophic failure or error occurs*.)

4. Locate the last known good backup.

5. Clear the data node file systems (using `ndbd --initial` or `ndbmtd --initial`).

   Note

   NDB Cluster Disk Data tablespace and log files are not removed by `--initial`. You must delete these manually.

6. Use `DROP TABLE` or `TRUNCATE TABLE` with the `mysql.ndb_binlog_index` table.

7. Execute `ndb_restore`, restoring all data. You must include the `--restore_epoch` option when you run `ndb_restore`, so that the `ndb_apply_status` table is populated correctly. (See Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”, for more information.)

8. Restore the `ndb_binlog_index` table from the output of `mysqldump` and restore the binary log files from backup, if necessary.

9. Find the epoch applied most recently—that is, the maximum `epoch` column value in the `ndb_apply_status` table—as the user variable `@LATEST_EPOCH` (emphasized):

   ```
   SELECT @LATEST_EPOCH:=MAX(epoch)
       FROM mysql.ndb_apply_status;
   ```

10. Find the latest binary log file (`@FIRST_FILE`) and position (`Position` column value) within this file that correspond to `@LATEST_EPOCH` in the `ndb_binlog_index` table:

    ```
    SELECT Position, @FIRST_FILE:=File
        FROM mysql.ndb_binlog_index
        WHERE epoch > @LATEST_EPOCH ORDER BY epoch ASC LIMIT 1;
    ```

11. Using `mysqlbinlog`, replay the binary log events from the given file and position up to the point of the failure. (See Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”.)

See also Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”, for more information about the binary log, replication, and incremental recovery.

18.6.10 NDB Cluster Replication: Multi-Master and Circular Replication

It is possible to use NDB Cluster in multi-master replication, including circular replication between a number of NDB Clusters.

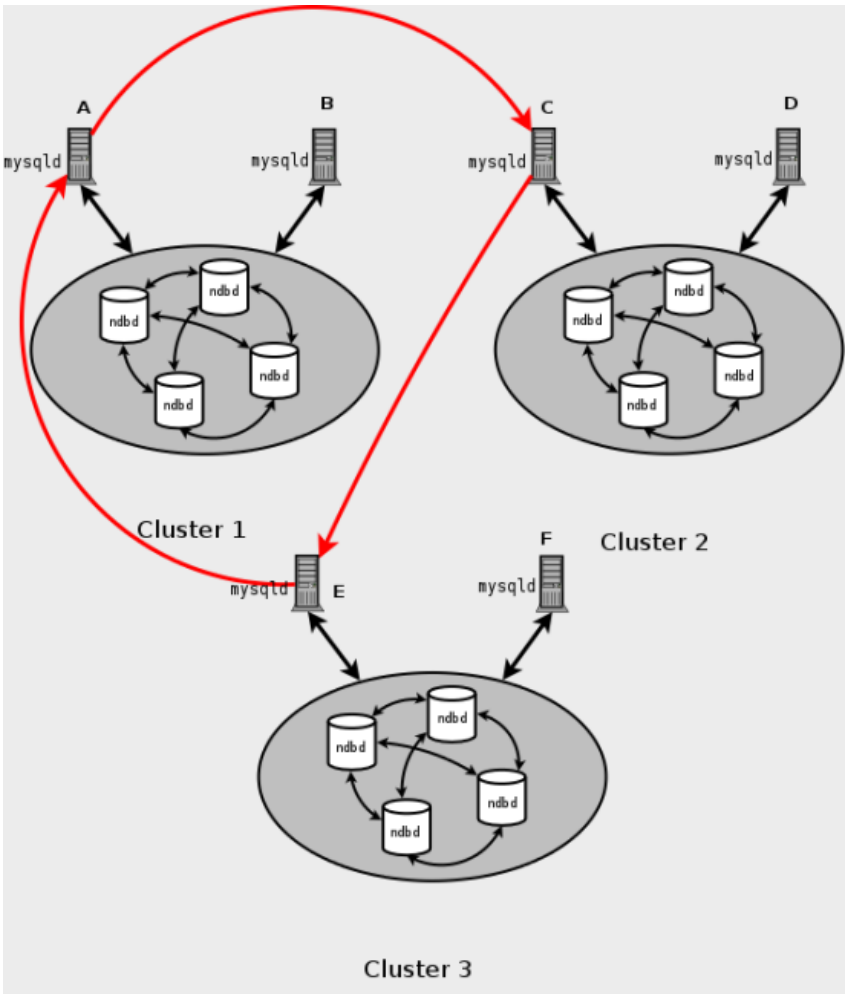
Circular replication example. In the next few paragraphs we consider the example of a replication setup involving three NDB Clusters numbered 1, 2, and 3, in which Cluster 1 acts as the replication master for Cluster 2, Cluster 2 acts as the master for Cluster 3, and Cluster 3 acts as the master for Cluster 1. Each cluster has two SQL nodes, with SQL nodes A and B belonging to Cluster 1, SQL nodes C and D belonging to Cluster 2, and SQL nodes E and F belonging to Cluster 3.

Circular replication using these clusters is supported as long as the following conditions are met:

- The SQL nodes on all masters and slaves are the same
- All SQL nodes acting as replication masters and slaves are started using the `--log-slave-updates` option

This type of circular replication setup is shown in the following diagram:

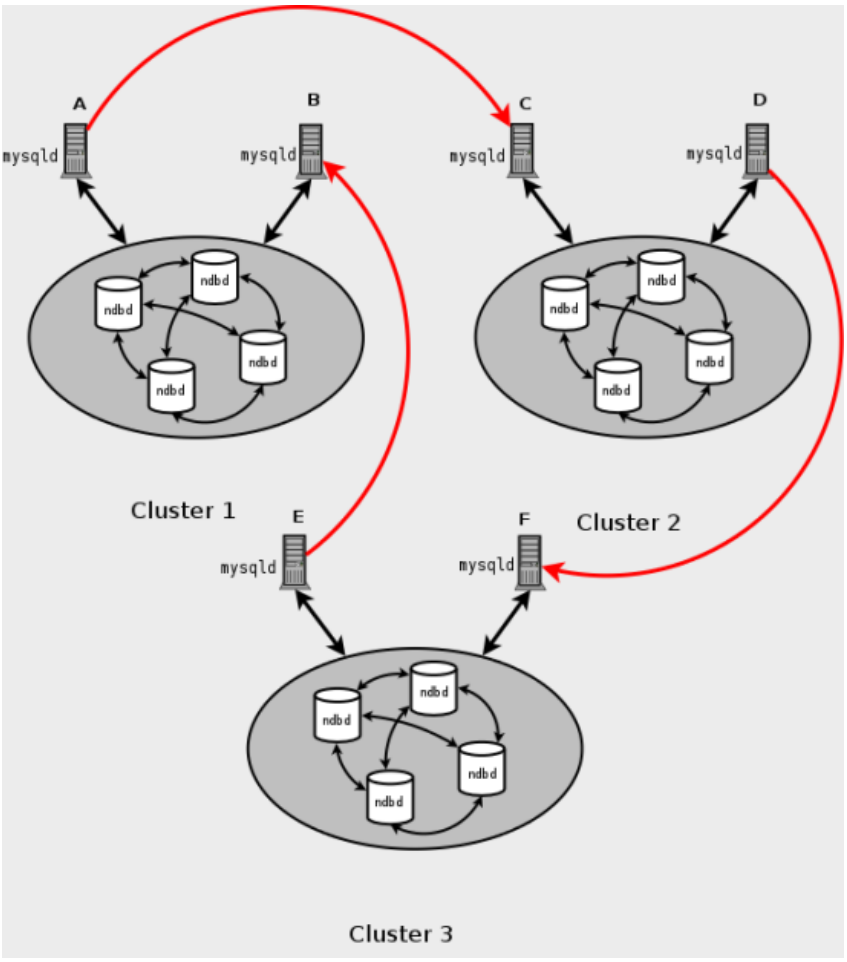
Figure 18.16 NDB Cluster Circular Replication with All Masters As Slaves



In this scenario, SQL node A in Cluster 1 replicates to SQL node C in Cluster 2; SQL node C replicates to SQL node E in Cluster 3; SQL node E replicates to SQL node A. In other words, the replication line (indicated by the red arrows in the diagram) directly connects all SQL nodes used as replication masters and slaves.

It is also possible to set up circular replication in such a way that not all master SQL nodes are also slaves, as shown here:

Figure 18.17 NDB Cluster Circular Replication Where Not All Masters Are Slaves



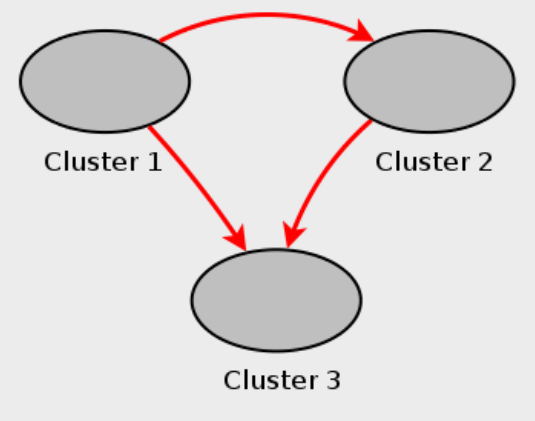
In this case, different SQL nodes in each cluster are used as replication masters and slaves. However, you must *not* start any of the SQL nodes using `--log-slave-updates`. This type of circular replication scheme for NDB Cluster, in which the line of replication (again indicated by the red arrows in the diagram) is discontinuous, should be possible, but it should be noted that it has not yet been thoroughly tested and must therefore still be considered experimental.

Using NDB-native backup and restore to initialize a slave NDB Cluster. When setting up circular replication, it is possible to initialize the slave cluster by using the management client `BACKUP` command on one NDB Cluster to create a backup and then applying this backup on another NDB Cluster using `ndb_restore`. However, this does not automatically create binary logs on the second NDB Cluster's SQL node acting as the replication slave. In order to cause the binary logs to be created, you must issue a `SHOW TABLES` statement on that SQL node; this should be done prior to running `START SLAVE`.

This is a known issue which we intend to address in a future release.

Multi-master failover example. In this section, we discuss failover in a multi-master NDB Cluster replication setup with three NDB Clusters having server IDs 1, 2, and 3. In this scenario, Cluster 1 replicates to Clusters 2 and 3; Cluster 2 also replicates to Cluster 3. This relationship is shown here:

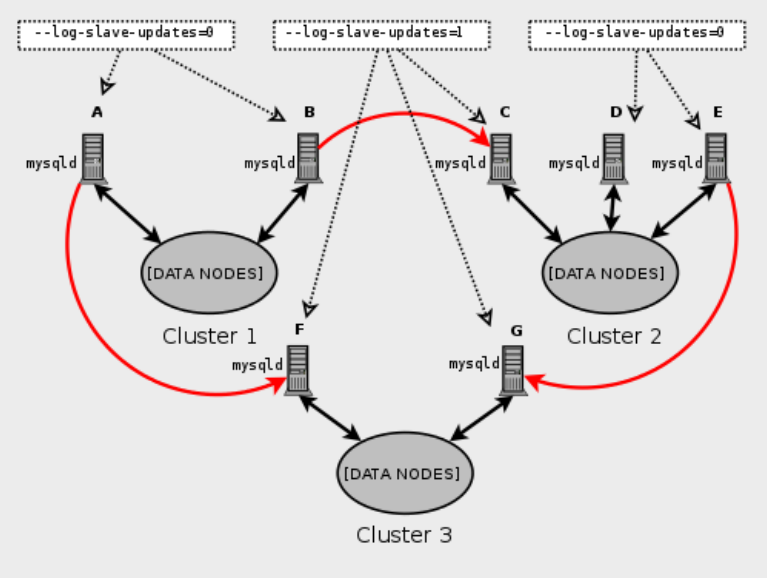
Figure 18.18 NDB Cluster Multi-Master Replication With 3 Masters



In other words, data replicates from Cluster 1 to Cluster 3 through 2 different routes: directly, and by way of Cluster 2.

Not all MySQL servers taking part in multi-master replication must act as both master and slave, and a given NDB Cluster might use different SQL nodes for different replication channels. Such a case is shown here:

Figure 18.19 NDB Cluster Multi-Master Replication, With MySQL Servers



MySQL servers acting as replication slaves must be run with the `--log-slave-updates` option. Which `mysqld` processes require this option is also shown in the preceding diagram.

Note

Using the `--log-slave-updates` option has no effect on servers not being run as replication slaves.

The need for failover arises when one of the replicating clusters goes down. In this example, we consider the case where Cluster 1 is lost to service, and so Cluster 3 loses 2 sources of updates from Cluster 1. Because replication between NDB Clusters is asynchronous, there is no guarantee that Cluster 3's updates originating directly from Cluster 1 are more recent than those received through Cluster 2. You can handle this by ensuring that Cluster 3 catches up to Cluster 2 with regard to updates from Cluster 1. In terms of MySQL servers, this means that you need to replicate any outstanding updates from MySQL server C to server F.

On server C, perform the following queries:

```
mysqlC> SELECT @latest:=MAX(epoch)
     ->     FROM mysql.ndb_apply_status
     ->     WHERE server_id=1;

mysqlC> SELECT
     ->     @file:=SUBSTRING_INDEX(File, '/', -1),
     ->     @pos:=Position
     ->     FROM mysql.ndb_binlog_index
     ->     WHERE orig_epoch >= @latest
     ->     AND orig_server_id = 1
     ->     ORDER BY epoch ASC LIMIT 1;
```

Note

You can improve the performance of this query, and thus likely speed up failover times significantly, by adding the appropriate index to the `ndb_binlog_index` table. See Section 18.6.4, “NDB Cluster Replication Schema and Tables”, for more information.

Copy over the values for *`@file`* and *`@pos`* manually from server C to server F (or have your application perform the equivalent). Then, on server F, execute the following `CHANGE MASTER TO` statement:

```
mysqlF> CHANGE MASTER TO
     ->     MASTER_HOST = 'serverC'
     ->     MASTER_LOG_FILE='@file',
     ->     MASTER_LOG_POS=@pos;
```

Once this has been done, you can issue a `START SLAVE` statement on MySQL server F, and any missing updates originating from server B will be replicated to server F.

The `CHANGE MASTER TO` statement also supports an `IGNORE_SERVER_IDS` option which takes a comma-separated list of server IDs and causes events originating from the corresponding servers to be ignored. For more information, see Section 13.4.2.1, “CHANGE MASTER TO Syntax”, and Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”. For information about how this option intereacts with the `ndb_log_apply_status` variable, see Section 18.6.8, “Implementing Failover with NDB Cluster Replication”.

18.6.11 NDB Cluster Replication Conflict Resolution

When using a replication setup involving multiple masters (including circular replication), it is possible that different masters may try to update the same row on the slave with different data. Conflict resolution in NDB Cluster Replication provides a means of resolving such conflicts by permitting a user-defined resolution column to be used to determine whether or not an update on a given master should be applied on the slave.

Some types of conflict resolution supported by NDB Cluster (`NDB$OLD()`, `NDB$MAX()`, `NDB$MAX_DELETE_WIN()`) implement this user-defined column as a “timestamp” column (although its type cannot be `TIMESTAMP`, as explained later in this section). These types of conflict resolution are always applied a row-by-row basis rather than a transactional basis. The epoch-based conflict resolution functions introduced in NDB 7.2.1 (`NDB$EPOCH()` and `NDB$EPOCH_TRANS()`) compare the order in which epochs are replicated (and thus these functions are transactional). Different methods can be used to compare resolution column values on the slave when conflicts occur, as explained later in this section; the method used can be set on a per-table basis.

You should also keep in mind that it is the application's responsibility to ensure that the resolution column is correctly populated with relevant values, so that the resolution function can make the appropriate choice when determining whether to apply an update.

Requirements. Preparations for conflict resolution must be made on both the master and the slave. These tasks are described in the following list:

- On the master writing the binary logs, you must determine which columns are sent (all columns or only those that have been updated). This is done for the MySQL Server as a whole by applying the `mysqld` startup option `--ndb-log-updated-only` (described later in this section) or on a per-table basis by entries in the `mysql.ndb_replication` table (see The ndb_replication system table).

Note

If you are replicating tables with very large columns (such as `TEXT` or `BLOB` columns), `--ndb-log-updated-only` can also be useful for reducing the size of the master and slave binary logs and avoiding possible replication failures due to exceeding `max_allowed_packet`.

See Section 17.4.1.19, “Replication and max_allowed_packet”, for more information about this issue.

- On the slave, you must determine which type of conflict resolution to apply (“latest timestamp wins”, “same timestamp wins”, “primary wins”, “primary wins, complete transaction”, or none). This is done using the `mysql.ndb_replication` system table, on a per-table basis (see The ndb_replication system table).
- Prior to NDB 7.2.5, conflict detection and resolution did not always work properly unless set up for `NDB` tables created on the same server only (Bug #13578660).

When using the functions `NDB$OLD()`, `NDB$MAX()`, and `NDB$MAX_DELETE_WIN()` for timestamp-based conflict resolution, we often refer to the column used for determining updates as a “timestamp” column. However, the data type of this column is never `TIMESTAMP`; instead, its data type should be `INT` (`INTEGER`) or `BIGINT`. The “timestamp” column should also be `UNSIGNED` and `NOT NULL`.

The `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` functions discussed later in this section work by comparing the relative order of replication epochs applied on a primary and secondary NDB Cluster, and do not make use of timestamps.

Master column control. We can see update operations in terms of “before” and “after” images—that is, the states of the table before and after the update is applied. Normally, when updating a table with a primary key, the “before” image is not of great interest; however, when we need to determine on a per-update basis whether or not to use the updated values on a replication slave, we need to make sure that both images are written to the master's binary log. This is done with the `--ndb-log-update-as-write` option for `mysqld`, as described later in this section.

Important

Whether logging of complete rows or of updated columns only is done is decided when the MySQL server is started, and cannot be changed online; you must either restart `mysqld`, or start a new `mysqld` instance with different logging options.

Logging Full or Partial Rows (--ndb-log-updated-only Option)

Command-Line Format	`--ndb-log-updated-only`	
System Variable	**Name**	`ndb_log_updated_only`
	Scope	Global
	Dynamic	Yes
Permitted Values	**Type**	boolean
	Default	`ON`

For purposes of conflict resolution, there are two basic methods of logging rows, as determined by the setting of the `--ndb-log-updated-only` option for `mysqld`:

- Log complete rows
- Log only column data that has been updated—that is, column data whose value has been set, regardless of whether or not this value was actually changed. This is the default behavior.

It is usually sufficient—and more efficient—to log updated columns only; however, if you need to log full rows, you can do so by setting `--ndb-log-updated-only` to `0` or `OFF`.

--ndb-log-update-as-write Option: Logging Changed Data as Updates

Command-Line Format	`--ndb-log-update-as-write`	
System Variable	Name	`ndb_log_update_as_write`
	Scope	Global
	Dynamic	Yes
Permitted Values	Type	boolean
	Default	`ON`

The setting of the MySQL Server's `--ndb-log-update-as-write` option determines whether logging is performed with or without the “before” image. Because conflict resolution is done in the MySQL Server's update handler, it is necessary to control logging on the master such that updates are updates and not writes; that is, such that updates are treated as changes in existing rows rather than the writing of new rows (even though these replace existing rows). This option is turned on by default; in other words, updates are treated as writes. (That is, updates are by default written as `write_row` events in the binary log, rather than as `update_row` events.)

To turn off the option, start the master `mysqld` with `--ndb-log-update-as-write=0` or `--ndb-log-update-as-write=OFF`. You must do this when replicating from NDB tables to tables using a different storage engine; see Replication from NDB to other storage engines.

Conflict resolution control. Conflict resolution is usually enabled on the server where conflicts can occur. Like logging method selection, it is enabled by entries in the `mysql.ndb_replication` table.

The ndb_replication system table. To enable conflict resolution, it is necessary to create an `ndb_replication` table in the `mysql` system database on the master, the slave, or both, depending on the conflict resolution type and method to be employed. This table is used to control logging and conflict resolution functions on a per-table basis, and has one row per table involved in replication. `ndb_replication` is created and filled with control information on the server where the conflict is to be resolved. In a simple master-slave setup where data can also be changed locally on the slave this will typically be the slave. In a more complex master-master (2-way) replication schema this will usually be all of the masters involved. Each row in `mysql.ndb_replication` corresponds to a table being replicated, and specifies how to log and resolve conflicts (that is, which conflict resolution function, if any, to use) for that table. The definition of the `mysql.ndb_replication` table is shown here:

```
CREATE TABLE mysql.ndb_replication  (
    db VARBINARY(63),
    table_name VARBINARY(63),
    server_id INT UNSIGNED,
    binlog_type INT UNSIGNED,
    conflict_fn VARBINARY(128),
    PRIMARY KEY USING HASH (db, table_name, server_id)
)   ENGINE=NDB
PARTITION BY KEY(db,table_name);
```

The columns in this table are described in the next few paragraphs.

db. The name of the database containing the table to be replicated.

Beginning with NDB 7.2.5, you may employ either or both of the wildcards `_` and `%` as part of the database name. Matching is similar to what is implemented for the `LIKE` operator.

table_name. The name of the table to be replicated.

Beginning with NDB 7.2.5, the table name may include either or both of the wildcards `_` and `%`. Matching is similar to what is implemented for the `LIKE` operator.

server_id. The unique server ID of the MySQL instance (SQL node) where the table resides.

binlog_type. The type of binary logging to be employed. This is determined as shown in the following table:

Value	Internal Value	Description
0	`NBT_DEFAULT`	Use server default
1	`NBT_NO_LOGGING`	Do not log this table in the binary log
2	`NBT_UPDATED_ONLY`	Only updated attributes are logged
3	`NBT_FULL`	Log full row, even if not updated (MySQL server default behavior)
4	`NBT_USE_UPDATE`	(For generating `NBT_UPDATED_ONLY_USE_UPDATE` and `NBT_FULL_USE_UPDATE` values only—not intended for separate use)
5	[*Not used*]	---
6	`NBT_UPDATED_ONLY_USE_UPDATE` (equal to `NBT_UPDATED_ONLY | NBT_USE_UPDATE`)	Use updated attributes, even if values are unchanged
7	`NBT_FULL_USE_UPDATE` (equal to `NBT_FULL | NBT_USE_UPDATE`)	Use full row, even if values are unchanged

conflict_fn. The conflict resolution function to be applied. This function must be specified as one of those shown in the following list:

- NDB$OLD(column_name)
- NDB$MAX(column_name)
- NDB$MAX_DELETE_WIN()
- NDB$EPOCH() and NDB$EPOCH_TRANS() (NDB 7.2.1 and later)
- NDB$EPOCH_TRANS() (NDB 7.2.1 and later)
- `NULL`: Indicates that conflict resolution is not to be used for the corresponding table.

These functions are described in the next few paragraphs.

NDB$OLD(column_name). If the value of *`column_name`* is the same on both the master and the slave, then the update is applied; otherwise, the update is not applied on the slave and an exception is written to the log. This is illustrated by the following pseudocode:

```
if (master_old_column_value == slave_current_column_value)
  apply_update();
else
  log_exception();
```

This function can be used for “same value wins” conflict resolution. This type of conflict resolution ensures that updates are not applied on the slave from the wrong master.

Important

The column value from the master's “before” image is used by this function.

NDB$MAX(column_name). If the “timestamp” column value for a given row coming from the master is higher than that on the slave, it is applied; otherwise it is not applied on the slave. This is illustrated by the following pseudocode:

```
if (master_new_column_value > slave_current_column_value)
  apply_update();
```

This function can be used for “greatest timestamp wins” conflict resolution. This type of conflict resolution ensures that, in the event of a conflict, the version of the row that was most recently updated is the version that persists.

Important

The column value from the master's “after” image is used by this function.

NDB$MAX_DELETE_WIN(). This is a variation on `NDB$MAX()`. Due to the fact that no timestamp is available for a delete operation, a delete using `NDB$MAX()` is in fact processed as `NDB$OLD`. However, for some use cases, this is not optimal. For `NDB$MAX_DELETE_WIN()`, if the “timestamp” column value for a given row adding or updating an existing row coming from the master is higher than that on the slave, it is applied. However, delete operations are treated as always having the higher value. This is illustrated in the following pseudocode:

```
if ( (master_new_column_value > slave_current_column_value)
       ||
     operation.type == "delete")
  apply_update();
```

This function can be used for “greatest timestamp, delete wins” conflict resolution. This type of conflict resolution ensures that, in the event of a conflict, the version of the row that was deleted or (otherwise) most recently updated is the version that persists.

Note

As with `NDB$MAX()`, the column value from the master's “after” image is the value used by this function.

NDB$EPOCH() and NDB$EPOCH_TRANS(). The `NDB$EPOCH()` function, available beginning with NDB 7.2.1, tracks the order in which replicated epochs are applied on a slave NDB Cluster relative to changes originating on the slave. This relative ordering is used to determine whether changes originating on the slave are concurrent with any changes that originate locally, and are therefore potentially in conflict.

Most of what follows in the description of `NDB$EPOCH()` also applies to `NDB$EPOCH_TRANS()`. Any exceptions are noted in the text.

`NDB$EPOCH()` is asymmetric, operating on one NDB Cluster in a two-cluster circular replication configuration (sometimes referred to as “active-active” replication). We refer here to cluster on which it operates as the primary, and the other as the secondary. The slave on the primary is responsible for detecting and handling conflicts, while the slave on the secondary is not involved in any conflict detection or handling.

When the slave on the primary detects conflicts, it injects events into its own binary log to compensate for these; this ensures that the secondary NDB Cluster eventually realigns itself with the primary and so keeps the primary and secondary from diverging. This compensation and realignment mechanism requires that the primary NDB Cluster always wins any conflicts with the secondary—that is, that the primary's changes are always used rather than those from the secondary in event of a conflict. This “primary always wins” rule has the following implications:

- Operations that change data, once committed on the primary, are fully persistent and will not be undone or rolled back by conflict detection and resolution.

- Data read from the primary is fully consistent. Any changes committed on the Primary (locally or from the slave) will not be reverted later.
- Operations that change data on the secondary may later be reverted if the primary determines that they are in conflict.
- Individual rows read on the secondary are self-consistent at all times, each row always reflecting either a state committed by the secondary, or one committed by the primary.
- Sets of rows read on the secondary may not necessarily be consistent at a given single point in time. For `NDB$EPOCH_TRANS()`, this is a transient state; for `NDB$EPOCH()`, it can be a persistent state.
- Assuming a period of sufficient length without any conflicts, all data on the secondary NDB Cluster (eventually) becomes consistent with the primary's data.

`NDB$EPOCH()` and `NDB$EPOCH_TRANS()` do not require any user schema modifications, or application changes to provide conflict detection. However, careful thought must be given to the schema used, and the access patterns used, to verify that the complete system behaves within specified limits.

Each of the `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` functions can take an optional parameter; this is the number of bits to use to represent the lower 32 bits of the epoch, and should be set to no less than

```
CEIL( LOG2( TimeBetweenGlobalCheckpoints / TimeBetweenEpochs ), 1)
```

For the default values of these configuration parameters (2000 and 100 milliseconds, respectively), this gives a value of 5 bits, so the default value (6) should be sufficient, unless other values are used for `TimeBetweenGlobalCheckpoints`, `TimeBetweenEpochs`, or both. A value that is too small can result in false positives, while one that is too large could lead to excessive wasted space in the database.

Both `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` insert entries for conflicting rows into the relevant exceptions tables, provided that these tables have been defined according to the same exceptions table schema rules as described elsewhere in this section (see NDB$OLD(column_name)). You need to create any exceptions table before creating the table with which it is to be used.

As with the other conflict detection functions discussed in this section, `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` are activated by including relevant entries in the `mysql.ndb_replication` table (see The ndb_replication system table). The roles of the primary and secondary NDB Clusters in this scenario are fully determined by `mysql.ndb_replication` table entries.

Because the conflict detection algorithms employed by `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` are asymmetric, you must use different values for the primary slave's and secondary slave's `server_id` entries.

Prior to NDB 7.2.17, conflict between `DELETE` operations were handled like those for `UPDATE` operations, and within the same epoch were considered in conflict. In NDB 7.2.17 and later, a conflict between `DELETE` operations alone is not sufficient to trigger a conflict using `NDB$EPOCH()` or `NDB$EPOCH_TRANS()`, and the relative placement within epochs does not matter. (Bug #18459944)

Conflict detection status variables. NDB 7.2.1 introduces several status variables that can be used to monitor `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` conflict detection. You can see how many rows have been found in conflict by `NDB$EPOCH()` since this slave was last restarted from the current value of the `Ndb_conflict_fn_epoch` system status variable.

`Ndb_conflict_fn_epoch_trans` provides the number of rows that have been found directly in conflict by `NDB$EPOCH_TRANS()`; the number of rows actually realigned, including those affected due to their membership in or dependency on the same transactions as other conflicting rows, is given by `Ndb_conflict_trans_row_reject_count`.

For more information, see NDB Cluster Status Variables.

Limitations on NDB$EPOCH(). The following limitations currently apply when using `NDB$EPOCH()` to perform conflict detection:

- Conflicts are detected using NDB Cluster epoch boundaries, with granularity proportional to `TimeBetweenEpochs` (default: 100 milliseconds). The minimum conflict window is the minimum time during which concurrent updates to the same data on both clusters always report a conflict. This is always a nonzero length of time, and is roughly proportional to `2 * (latency + queueing + TimeBetweenEpochs)`. This implies that—assuming the default for `TimeBetweenEpochs` and ignoring any latency between clusters (as well as any queuing delays)—the minimum conflict window size is approximately 200 milliseconds. This minimum window should be considered when looking at expected application “race” patterns.

- Additional storage is required for tables using the `NDB$EPOCH()` and `NDB$EPOCH_TRANS()` functions; from 1 to 32 bits extra space per row is required, depending on the value passed to the function.

- Conflicts between delete operations may result in divergence between the primary and secondary. When a row is deleted on both clusters concurrently, the conflict can be detected, but is not recorded, since the row is deleted. This means that further conflicts during the propagation of any subsequent realignment operations will not be detected, which can lead to divergence.

  Deletes should be externally serialized, or routed to one cluster only. Alternatively, a separate row should be updated transactionally with such deletes and any inserts that follow them, so that conflicts can be tracked across row deletes. This may require changes in applications.

- Only two NDB Clusters in a circular “active-active” configuration are currently supported when using `NDB$EPOCH()` or `NDB$EPOCH_TRANS()` for conflict detection.

- Tables having `BLOB` or `TEXT` columns are not currently supported with `NDB$EPOCH()` or `NDB$EPOCH_TRANS()`.

NDB$EPOCH_TRANS(). `NDB$EPOCH_TRANS()` extends the `NDB$EPOCH()` function, and, like `NDB$EPOCH()`, is available beginning with NDB 7.2.1. Conflicts are detected and handled in the same way using the “primary wins all” rule (see NDB$EPOCH() and NDB$EPOCH_TRANS()) but with the extra condition that any other rows updated in the same transaction in which the conflict occurred are also regarded as being in conflict. In other words, where `NDB$EPOCH()` realigns individual conflicting rows on the secondary, `NDB$EPOCH_TRANS()` realigns conflicting transactions.

In addition, any transactions which are detectably dependent on a conflicting transaction are also regarded as being in conflict, these dependencies being determined by the contents of the secondary cluster's binary log. Since the binary log contains only data modification operations (inserts, updates, and deletes), only overlapping data modifications are used to determine dependencies between transactions.

`NDB$EPOCH_TRANS()` is subject to the same conditions and limitations as `NDB$EPOCH()`, and in addition requires that Version 2 binary log row events are used (`--log-bin-use-v1-row-events` equal to 0), which adds a storage overhead of 2 bytes per event in the binary log. In addition, all transaction IDs must be recorded in the secondary's binary log (`--ndb-log-transaction-id` option), which adds a further variable overhead (up to 13 bytes per row).

See NDB$EPOCH() and NDB$EPOCH_TRANS().

Status information. A server status variable `Ndb_conflict_fn_max` provides a count of the number of times that a row was not applied on the current SQL node due to “greatest timestamp wins” conflict resolution since the last time that `mysqld` was started.

The number of times that a row was not applied as the result of “same timestamp wins” conflict resolution on a given `mysqld` since the last time it was restarted is given by the global status variable

`Ndb_conflict_fn_old`. In addition to incrementing `Ndb_conflict_fn_old`, the primary key of the row that was not used is inserted into an *exceptions table*, as explained later in this section.

Conflict resolution exceptions table. To use the `NDB$OLD()` conflict resolution function, it is also necessary to create an exceptions table corresponding to each `NDB` table for which this type of conflict resolution is to be employed. This is also true when using `NDB$EPOCH()` or `NDB$EPOCH_TRANS()` in NDB 7.2.1 and later. The name of this table is that of the table for which conflict resolution is to be applied, with the string `$EX` appended. (For example, if the name of the original table is `mytable`, the name of the corresponding exceptions table name should be `mytable$EX`.) This table is created as follows:

```
CREATE TABLE original_table$EX  (
    server_id INT UNSIGNED,
    master_server_id INT UNSIGNED,
    master_epoch BIGINT UNSIGNED,
    count INT UNSIGNED,

    original_table_pk_columns,

    [additional_columns,]

    PRIMARY KEY(server_id, master_server_id, master_epoch, count)
) ENGINE=NDB;
```

The first four columns are required. The names of the first four columns and the columns matching the original table's primary key columns are not critical; however, we suggest for reasons of clarity and consistency, that you use the names shown here for the `server_id`, `master_server_id`, `master_epoch`, and `count` columns, and that you use the same names as in the original table for the columns matching those in the original table's primary key.

Following these columns, the columns making up the original table's primary key should be copied in the order in which they are used to define the primary key of the original table. The data types for the columns duplicating the primary key columns of the original table should be the same as (or larger than) those of the original columns.

Additional columns may optionally be defined following the copied primary key columns, but not before any of them; any such extra columns cannot be `NOT NULL`. The exceptions table's primary key must be defined as shown.

The exceptions table must use the `NDB` storage engine. An example that uses `NDB$OLD()` with an exceptions table is shown later in this section.

Important

The `mysql.ndb_replication` table is read when a data table is set up for replication, so the row corresponding to a table to be replicated must be inserted into `mysql.ndb_replication` *before* the table to be replicated is created.

Examples

The following examples assume that you have already a working NDB Cluster replication setup, as described in Section 18.6.5, “Preparing the NDB Cluster for Replication”, and Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”.

NDB$MAX() example. Suppose you wish to enable “greatest timestamp wins” conflict resolution on table `test.t1`, using column `mycol` as the “timestamp”. This can be done using the following steps:

1. Make sure that you have started the master `mysqld` with `--ndb-log-update-as-write=OFF`.
2. On the master, perform this `INSERT` statement:

```
INSERT INTO mysql.ndb_replication
    VALUES ('test', 't1', 0, NULL, 'NDB$MAX(mycol)');
```

Inserting a 0 into the `server_id` indicates that all SQL nodes accessing this table should use conflict resolution. If you want to use conflict resolution on a specific `mysqld` only, use the actual server ID.

Inserting `NULL` into the `binlog_type` column has the same effect as inserting 0 (`NBT_DEFAULT`); the server default is used.

3. Create the `test.t1` table:

```
CREATE TABLE test.t1 (
    columns
    mycol INT UNSIGNED,
    columns
) ENGINE=NDB;
```

Now, when updates are done on this table, conflict resolution is applied, and the version of the row having the greatest value for `mycol` is written to the slave.

Note

Other `binlog_type` options—such as `NBT_UPDATED_ONLY_USE_UPDATE` should be used to control logging on the master using the `ndb_replication` table rather than by using command-line options.

NDB$OLD() example. Suppose an `NDB` table such as the one defined here is being replicated, and you wish to enable “same timestamp wins” conflict resolution for updates to this table:

```
CREATE TABLE test.t2  (
    a INT UNSIGNED NOT NULL,
    b CHAR(25) NOT NULL,
    columns,
    mycol INT UNSIGNED NOT NULL,
    columns,
    PRIMARY KEY pk (a, b)
)   ENGINE=NDB;
```

The following steps are required, in the order shown:

1. First—and *prior* to creating `test.t2`—you must insert a row into the `mysql.ndb_replication` table, as shown here:

```
INSERT INTO mysql.ndb_replication
    VALUES ('test', 't2', 0, NULL, 'NDB$OLD(mycol)');
```

Possible values for the `binlog_type` column are shown earlier in this section. The value `'NDB$OLD(mycol)'` should be inserted into the `conflict_fn` column.

2. Create an appropriate exceptions table for `test.t2`. The table creation statement shown here includes all required columns; any additional columns must be declared following these columns, and before the definition of the table's primary key.

```
CREATE TABLE test.t2$EX  (
    server_id INT UNSIGNED,
    master_server_id INT UNSIGNED,
    master_epoch BIGINT UNSIGNED,
    count INT UNSIGNED,
    a INT UNSIGNED NOT NULL,
    b CHAR(25) NOT NULL,

    [additional_columns,]
```

```
    PRIMARY KEY(server_id, master_server_id, master_epoch, count)
)   ENGINE=NDB;
```

3. Create the table `test.t2` as shown previously.

These steps must be followed for every table for which you wish to perform conflict resolution using `NDB$OLD()`. For each such table, there must be a corresponding row in `mysql.ndb_replication`, and there must be an exceptions table in the same database as the table being replicated.

18.7 NDB Cluster Release Notes

NDB Cluster release notes are no longer published in the MySQL Reference Manual.

Release notes for the changes in each release of NDB Cluster are located at NDB Cluster 7.2 Release Notes.

Chapter 19 Partitioning

Table of Contents

19.1 Overview of Partitioning in MySQL 2457
19.2 Partitioning Types 2460
19.2.1 RANGE Partitioning 2462
19.2.2 LIST Partitioning 2466
19.2.3 COLUMNS Partitioning 2468
19.2.4 HASH Partitioning 2475
19.2.5 KEY Partitioning 2478
19.2.6 Subpartitioning 2480
19.2.7 How MySQL Partitioning Handles NULL 2483
19.3 Partition Management 2487
19.3.1 Management of RANGE and LIST Partitions 2488
19.3.2 Management of HASH and KEY Partitions 2494
19.3.3 Maintenance of Partitions 2495
19.3.4 Obtaining Information About Partitions 2496
19.4 Partition Pruning 2498
19.5 Restrictions and Limitations on Partitioning 2502
19.5.1 Partitioning Keys, Primary Keys, and Unique Keys 2508
19.5.2 Partitioning Limitations Relating to Storage Engines 2511
19.5.3 Partitioning Limitations Relating to Functions 2512
19.5.4 Partitioning and Table-Level Locking 2513

This chapter discusses MySQL's implementation of *user-defined partitioning*. You can determine whether your MySQL Server supports partitioning by means of a `SHOW VARIABLES` statement such as this one:

```
mysql> SHOW VARIABLES LIKE '%partition%';

+-------------------+-------+
| Variable_name     | Value |
+-------------------+-------+
| have_partitioning | YES   |
+-------------------+-------+
1 row in set (0.00 sec)
```

Note

The `have_partitioning` variable is deprecated, and removed in MySQL 5.6.1.

You can also check the output of the `SHOW PLUGINS` statement, like this:

```
mysql> SHOW PLUGINS;
+------------+----------+----------------+---------+---------+
| Name       | Status   | Type           | Library | License |
+------------+----------+----------------+---------+---------+
| binlog     | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| partition  | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| ARCHIVE    | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| BLACKHOLE  | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| CSV        | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| FEDERATED  | DISABLED | STORAGE ENGINE | NULL    | GPL     |
| MEMORY     | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| InnoDB     | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| MRG_MYISAM | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
| MyISAM     | ACTIVE   | STORAGE ENGINE | NULL    | GPL     |
```

```
| ndbcluster | DISABLED | STORAGE ENGINE | NULL    | GPL     |
+------------+----------+----------------+---------+---------+
11 rows in set (0.00 sec)
```

You can also check the `INFORMATION_SCHEMA.PLUGINS` table with a query similar to this one:

```
mysql> SELECT
    ->     PLUGIN_NAME as Name,
    ->     PLUGIN_VERSION as Version,
    ->     PLUGIN_STATUS as Status
    -> FROM INFORMATION_SCHEMA.PLUGINS
    -> WHERE PLUGIN_TYPE='STORAGE ENGINE';
+--------------------+---------+--------+
| Name               | Version | Status |
+--------------------+---------+--------+
| binlog             | 1.0     | ACTIVE |
| CSV                | 1.0     | ACTIVE |
| MEMORY             | 1.0     | ACTIVE |
| MRG_MYISAM         | 1.0     | ACTIVE |
| MyISAM             | 1.0     | ACTIVE |
| PERFORMANCE_SCHEMA | 0.1     | ACTIVE |
| BLACKHOLE          | 1.0     | ACTIVE |
| ARCHIVE            | 3.0     | ACTIVE |
| InnoDB             | 5.6     | ACTIVE |
| partition          | 1.0     | ACTIVE |
+--------------------+---------+--------+
10 rows in set (0.00 sec)
```

In either case, if you do not see the `partition` plugin listed with the value `ACTIVE` for the `Status` column in the output (shown in bold text in each of the examples just given), then your version of MySQL was not built with partitioning support.

MySQL 5.5 Community binaries provided by Oracle include partitioning support. For information about partitioning support offered in MySQL Enterprise Edition binaries, see Chapter 25, *MySQL Enterprise Edition*.

To enable partitioning if you are compiling MySQL 5.5 from source, the build must be configured with the `-DWITH_PARTITION_STORAGE_ENGINE` option. For more information, see Section 2.9, “Installing MySQL from Source”.

If your MySQL binary is built with partitioning support, nothing further needs to be done to enable it (for example, no special entries are required in your `my.cnf` file).

If you want to disable partitioning support, you can start the MySQL Server with the `--skip-partition` option, in which case the value of `have_partitioning` is `DISABLED`. When partitioning support is disabled, you can see any existing partitioned tables and drop them (although doing this is not advised), but you cannot otherwise manipulate them or access their data.

See Section 19.1, “Overview of Partitioning in MySQL”, for an introduction to partitioning and partitioning concepts.

MySQL supports several types of partitioning as well as subpartitioning; see Section 19.2, “Partitioning Types”, and Section 19.2.6, “Subpartitioning”.

Section 19.3, “Partition Management”, covers methods of adding, removing, and altering partitions in existing partitioned tables.

Section 19.3.3, “Maintenance of Partitions”, discusses table maintenance commands for use with partitioned tables.

The `PARTITIONS` table in the `INFORMATION_SCHEMA` database provides information about partitions and partitioned tables. See Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”, for more information; for some examples of queries against this table, see Section 19.2.7, “How MySQL Partitioning Handles NULL”.

For known issues with partitioning in MySQL 5.5, see Section 19.5, “Restrictions and Limitations on Partitioning”.

You may also find the following resources to be useful when working with partitioned tables.

Additional Resources. Other sources of information about user-defined partitioning in MySQL include the following:

- MySQL Partitioning Forum

  This is the official discussion forum for those interested in or experimenting with MySQL Partitioning technology. It features announcements and updates from MySQL developers and others. It is monitored by members of the Partitioning Development and Documentation Teams.

- Mikael Ronström's Blog

  MySQL Partitioning Architect and Lead Developer Mikael Ronström frequently posts articles here concerning his work with MySQL Partitioning and NDB Cluster.

- PlanetMySQL

  A MySQL news site featuring MySQL-related blogs, which should be of interest to anyone using my MySQL. We encourage you to check here for links to blogs kept by those working with MySQL Partitioning, or to have your own blog added to those covered.

MySQL 5.5 binaries are available from http://dev.mysql.com/downloads/mysql/5.5.html. However, for the latest partitioning bugfixes and feature additions, you can obtain the source from our GitHub repository. To enable partitioning, the build must be configured with the `-DWITH_PARTITION_STORAGE_ENGINE` option. For more information about building MySQL, see Section 2.9, “Installing MySQL from Source”. If you have problems compiling a partitioning-enabled MySQL 5.5 build, check the MySQL Partitioning Forum and ask for assistance there if you do not find a solution to your problem already posted.

19.1 Overview of Partitioning in MySQL

This section provides a conceptual overview of partitioning in MySQL 5.5.

For information on partitioning restrictions and feature limitations, see Section 19.5, “Restrictions and Limitations on Partitioning”.

The SQL standard does not provide much in the way of guidance regarding the physical aspects of data storage. The SQL language itself is intended to work independently of any data structures or media underlying the schemas, tables, rows, or columns with which it works. Nonetheless, most advanced database management systems have evolved some means of determining the physical location to be used for storing specific pieces of data in terms of the file system, hardware or even both. In MySQL, the `InnoDB` storage engine has long supported the notion of a tablespace, and the MySQL Server, even prior to the introduction of partitioning, could be configured to employ different physical directories for storing different databases (see Section 8.12.3, “Using Symbolic Links”, for an explanation of how this is done).

Partitioning takes this notion a step further, by enabling you to distribute portions of individual tables across a file system according to rules which you can set largely as needed. In effect, different portions of a table are stored as separate tables in different locations. The user-selected rule by which the division of data is accomplished is known as a *partitioning function*, which in MySQL can be the modulus, simple matching against a set of ranges or value lists, an internal hashing function, or a linear hashing function. The function is selected according to the partitioning type specified by the user, and takes as its parameter the value of a user-supplied expression. This expression can be a column value, a function acting on one or more column values, or a set of one or more column values, depending on the type of partitioning that is used.

In the case of RANGE, LIST, and [LINEAR] HASH partitioning, the value of the partitioning column is passed to the partitioning function, which returns an integer value representing the number of the partition in which that particular record should be stored. This function must be nonconstant and nonrandom. It may not contain any queries, but may use an SQL expression that is valid in MySQL, as long as that expression returns either NULL or an integer *intval* such that

```
-MAXVALUE <= intval <= MAXVALUE
```

(MAXVALUE is used to represent the least upper bound for the type of integer in question. -MAXVALUE represents the greatest lower bound.)

For [LINEAR] KEY, RANGE COLUMNS, and LIST COLUMNS partitioning, the partitioning expression consists of a list of one or more columns.

For [LINEAR] KEY partitioning, the partitioning function is supplied by MySQL.

For more information about permitted partitioning column types and partitioning functions, see Section 19.2, “Partitioning Types”, as well as Section 13.1.17, “CREATE TABLE Syntax”, which provides partitioning syntax descriptions and additional examples. For information about restrictions on partitioning functions, see Section 19.5.3, “Partitioning Limitations Relating to Functions”.

This is known as *horizontal partitioning*—that is, different rows of a table may be assigned to different physical partitions. MySQL 5.5 does not support *vertical partitioning*, in which different columns of a table are assigned to different physical partitions. There are no plans at this time to introduce vertical partitioning into MySQL.

For information about determining whether your MySQL Server binary supports user-defined partitioning, see Chapter 19, *Partitioning*.

For creating partitioned tables, you can use most storage engines that are supported by your MySQL server; the MySQL partitioning engine runs in a separate layer and can interact with any of these. In MySQL 5.5, all partitions of the same partitioned table must use the same storage engine; for example, you cannot use MyISAM for one partition and InnoDB for another. However, there is nothing preventing you from using different storage engines for different partitioned tables on the same MySQL server or even in the same database.

MySQL partitioning cannot be used with the MERGE, CSV, or FEDERATED storage engines.

Partitioning by KEY or LINEAR KEY is possible with NDBCLUSTER, but other types of user-defined partitioning are not supported for tables using this storage engine. In addition, an NDBCLUSTER table that employs user-defined partitioning must have an explicit primary key, and any columns referenced in the table's partitioning expression must be part of the primary key. However, if no columns are listed in the PARTITION BY KEY or PARTITION BY LINEAR KEY clause of the CREATE TABLE or ALTER TABLE statement used to create or modify a user-partitioned NDBCLUSTER table, then the table is not required to have an explicit primary key. For more information, see Section 18.1.6.1, “Noncompliance with SQL Syntax in NDB Cluster”.

To employ a particular storage engine for a partitioned table, it is necessary only to use the [STORAGE] ENGINE option just as you would for a nonpartitioned table. However, you should keep in mind that [STORAGE] ENGINE (and other table options) need to be listed *before* any partitioning options are used in a CREATE TABLE statement. This example shows how to create a table that is partitioned by hash into 6 partitions and which uses the InnoDB storage engine:

```
CREATE TABLE ti (id INT, amount DECIMAL(7,2), tr_date DATE)
    ENGINE=INNODB
    PARTITION BY HASH( MONTH(tr_date) )
    PARTITIONS 6;
```

Each PARTITION clause can include a [STORAGE] ENGINE option, but in MySQL 5.5 this has no effect.

Important

Partitioning applies to all data and indexes of a table; you cannot partition only the data and not the indexes, or vice versa, nor can you partition only a portion of the table.

Data and indexes for each partition can be assigned to a specific directory using the `DATA DIRECTORY` and `INDEX DIRECTORY` options for the `PARTITION` clause of the `CREATE TABLE` statement used to create the partitioned table.

The `DATA DIRECTORY` and `INDEX DIRECTORY` options have no effect when defining partitions for tables using the `InnoDB` storage engine.

`DATA DIRECTORY` and `INDEX DIRECTORY` are not supported for individual partitions or subpartitions on Windows. These options are ignored on Windows, except that a warning is generated.

All columns used in the table's partitioning expression must be part of every unique key that the table may have, including any primary key. This means that a table such as this one, created by the following SQL statement, cannot be partitioned:

```
CREATE TABLE tnp (
    id INT NOT NULL AUTO_INCREMENT,
    ref BIGINT NOT NULL,
    name VARCHAR(255),
    PRIMARY KEY pk (id),
    UNIQUE KEY uk (name)
);
```

Because the keys `pk` and `uk` have no columns in common, there are no columns available for use in a partitioning expression. Possible workarounds in this situation include adding the `name` column to the table's primary key, adding the `id` column to `uk`, or simply removing the unique key altogether. See Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”, for more information.

In addition, `MAX_ROWS` and `MIN_ROWS` can be used to determine the maximum and minimum numbers of rows, respectively, that can be stored in each partition. The `MAX_ROWS` option can be useful for causing NDB Cluster tables to be created with extra partitions, thus allowing for greater storage of hash indexes. See the documentation for the `DataMemory` data node configuration parameter, as well as Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”, for more information.

Some advantages of partitioning are listed here:

- Partitioning makes it possible to store more data in one table than can be held on a single disk or file system partition.
- Data that loses its usefulness can often be easily removed from a partitioned table by dropping the partition (or partitions) containing only that data. Conversely, the process of adding new data can in some cases be greatly facilitated by adding one or more new partitions for storing specifically that data.
- Some queries can be greatly optimized in virtue of the fact that data satisfying a given `WHERE` clause can be stored only on one or more partitions, which automatically excludes any remaining partitions from the search. Because partitions can be altered after a partitioned table has been created, you can reorganize your data to enhance frequent queries that may not have been often used when the partitioning scheme was first set up. This ability to exclude non-matching partitions (and thus any rows they contain) is often referred to as *partition pruning*. For more information, see Section 19.4, “Partition Pruning”.

Other benefits usually associated with partitioning include those in the following list. These features are not currently implemented in MySQL Partitioning, but are high on our list of priorities.

- Queries involving aggregate functions such as `SUM()` and `COUNT()` can easily be parallelized. A simple example of such a query might be `SELECT salesperson_id, COUNT(orders) as`

`order_total FROM sales GROUP BY salesperson_id;`. By “parallelized,” we mean that the query can be run simultaneously on each partition, and the final result obtained merely by summing the results obtained for all partitions.

- Achieving greater query throughput in virtue of spreading data seeks over multiple disks.

Be sure to check this section and chapter frequently for updates as MySQL Partitioning development continues.

19.2 Partitioning Types

This section discusses the types of partitioning which are available in MySQL 5.5. These include the types listed here:

- **RANGE partitioning.** This type of partitioning assigns rows to partitions based on column values falling within a given range. See Section 19.2.1, “RANGE Partitioning”. MySQL 5.5 adds an extension, `RANGE COLUMNS`, to this type. See Section 19.2.3.1, “RANGE COLUMNS partitioning”.
- **LIST partitioning.** Similar to partitioning by `RANGE`, except that the partition is selected based on columns matching one of a set of discrete values. See Section 19.2.2, “LIST Partitioning”. MySQL 5.5 adds an extension, `LIST COLUMNS`, to this type. See Section 19.2.3.2, “LIST COLUMNS partitioning”.
- **HASH partitioning.** With this type of partitioning, a partition is selected based on the value returned by a user-defined expression that operates on column values in rows to be inserted into the table. The function may consist of any expression valid in MySQL that yields a nonnegative integer value. An extension to this type, `LINEAR HASH`, is also available. See Section 19.2.4, “HASH Partitioning”.
- **KEY partitioning.** This type of partitioning is similar to partitioning by `HASH`, except that only one or more columns to be evaluated are supplied, and the MySQL server provides its own hashing function. These columns can contain other than integer values, since the hashing function supplied by MySQL guarantees an integer result regardless of the column data type. An extension to this type, `LINEAR KEY`, is also available. See Section 19.2.5, “KEY Partitioning”.

A very common use of database partitioning is to segregate data by date. Some database systems support explicit date partitioning, which MySQL does not implement in 5.5. However, it is not difficult in MySQL to create partitioning schemes based on `DATE`, `TIME`, or `DATETIME` columns, or based on expressions making use of such columns.

When partitioning by `KEY` or `LINEAR KEY`, you can use a `DATE`, `TIME`, or `DATETIME` column as the partitioning column without performing any modification of the column value. For example, this table creation statement is perfectly valid in MySQL:

```
CREATE TABLE members (
    firstname VARCHAR(25) NOT NULL,
    lastname VARCHAR(25) NOT NULL,
    username VARCHAR(16) NOT NULL,
    email VARCHAR(35),
    joined DATE NOT NULL
)
PARTITION BY KEY(joined)
PARTITIONS 6;
```

In MySQL 5.5, it is also possible to use a `DATE` or `DATETIME` column as the partitioning column using `RANGE COLUMNS` and `LIST COLUMNS` partitioning.

MySQL's other partitioning types, however, require a partitioning expression that yields an integer value or `NULL`. If you wish to use date-based partitioning by `RANGE`, `LIST`, `HASH`, or `LINEAR HASH`, you can simply employ a function that operates on a `DATE`, `TIME`, or `DATETIME` column and returns such a value, as shown here:

```
CREATE TABLE members (
    firstname VARCHAR(25) NOT NULL,
    lastname VARCHAR(25) NOT NULL,
    username VARCHAR(16) NOT NULL,
    email VARCHAR(35),
    joined DATE NOT NULL
)
PARTITION BY RANGE( YEAR(joined) ) (
    PARTITION p0 VALUES LESS THAN (1960),
    PARTITION p1 VALUES LESS THAN (1970),
    PARTITION p2 VALUES LESS THAN (1980),
    PARTITION p3 VALUES LESS THAN (1990),
    PARTITION p4 VALUES LESS THAN MAXVALUE
);
```

Additional examples of partitioning using dates may be found in the following sections of this chapter:

- Section 19.2.1, “RANGE Partitioning”
- Section 19.2.4, “HASH Partitioning”
- Section 19.2.4.1, “LINEAR HASH Partitioning”

For more complex examples of date-based partitioning, see the following sections:

- Section 19.4, “Partition Pruning”
- Section 19.2.6, “Subpartitioning”

MySQL partitioning is optimized for use with the `TO_DAYS()`, `YEAR()`, and `TO_SECONDS()` functions. However, you can use other date and time functions that return an integer or `NULL`, such as `WEEKDAY()`, `DAYOFYEAR()`, or `MONTH()`. See Section 12.7, “Date and Time Functions”, for more information about such functions.

It is important to remember—regardless of the type of partitioning that you use—that partitions are always numbered automatically and in sequence when created, starting with `0`. When a new row is inserted into a partitioned table, it is these partition numbers that are used in identifying the correct partition. For example, if your table uses 4 partitions, these partitions are numbered `0`, `1`, `2`, and `3`. For the `RANGE` and `LIST` partitioning types, it is necessary to ensure that there is a partition defined for each partition number. For `HASH` partitioning, the user-supplied expression must evaluate to an integer value greater than `0`. For `KEY` partitioning, this issue is taken care of automatically by the hashing function which the MySQL server employs internally.

Names of partitions generally follow the rules governing other MySQL identifiers, such as those for tables and databases. However, you should note that partition names are not case-sensitive. For example, the following `CREATE TABLE` statement fails as shown:

```
mysql> CREATE TABLE t2 (val INT)
    -> PARTITION BY LIST(val)(
    ->     PARTITION mypart VALUES IN (1,3,5),
    ->     PARTITION MyPart VALUES IN (2,4,6)
    -> );
ERROR 1488 (HY000): Duplicate partition name mypart
```

Failure occurs because MySQL sees no difference between the partition names `mypart` and `MyPart`.

When you specify the number of partitions for the table, this must be expressed as a positive, nonzero integer literal with no leading zeros, and may not be an expression such as `0.8E+01` or `6-2`, even if it evaluates to an integer value. Decimal fractions are not permitted.

In the sections that follow, we do not necessarily provide all possible forms for the syntax that can be used for creating each partition type; this information may be found in Section 13.1.17, “CREATE TABLE Syntax”.

19.2.1 RANGE Partitioning

A table that is partitioned by range is partitioned in such a way that each partition contains rows for which the partitioning expression value lies within a given range. Ranges should be contiguous but not overlapping, and are defined using the `VALUES LESS THAN` operator. For the next few examples, suppose that you are creating a table such as the following to hold personnel records for a chain of 20 video stores, numbered 1 through 20:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
);
```

Note

The `employees` table used here has no primary or unique keys. While the examples work as shown for purposes of the present discussion, you should keep in mind that tables are extremely likely in practice to have primary keys, unique keys, or both, and that allowable choices for partitioning columns depend on the columns used for these keys, if any are present. For a discussion of these issues, see Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”.

This table can be partitioned by range in a number of ways, depending on your needs. One way would be to use the `store_id` column. For instance, you might decide to partition the table 4 ways by adding a `PARTITION BY RANGE` clause as shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
)
PARTITION BY RANGE (store_id) (
    PARTITION p0 VALUES LESS THAN (6),
    PARTITION p1 VALUES LESS THAN (11),
    PARTITION p2 VALUES LESS THAN (16),
    PARTITION p3 VALUES LESS THAN (21)
);
```

In this partitioning scheme, all rows corresponding to employees working at stores 1 through 5 are stored in partition `p0`, to those employed at stores 6 through 10 are stored in partition `p1`, and so on. Note that each partition is defined in order, from lowest to highest. This is a requirement of the `PARTITION BY RANGE` syntax; you can think of it as being analogous to a series of `if ... elseif ...` statements in C or Java in this regard.

It is easy to determine that a new row containing the data `(72, 'Mitchell', 'Wilson', '1998-06-25', NULL, 13)` is inserted into partition `p2`, but what happens when your chain adds a 21st store? Under this scheme, there is no rule that covers a row whose `store_id` is greater than 20, so an error results because the server does not know where to place it. You can keep this from occurring by using a “catchall” `VALUES LESS THAN` clause in the `CREATE TABLE` statement that provides for all values greater than the highest value explicitly named:

```
CREATE TABLE employees (
    id INT NOT NULL,
```

```
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
)
PARTITION BY RANGE (store_id) (
    PARTITION p0 VALUES LESS THAN (6),
    PARTITION p1 VALUES LESS THAN (11),
    PARTITION p2 VALUES LESS THAN (16),
    PARTITION p3 VALUES LESS THAN MAXVALUE
);
```

Note

Another way to avoid an error when no matching value is found is to use the `IGNORE` keyword as part of the `INSERT` statement. For an example, see Section 19.2.2, “LIST Partitioning”. Also see Section 13.2.5, “INSERT Syntax”, for general information about `IGNORE`.

`MAXVALUE` represents an integer value that is always greater than the largest possible integer value (in mathematical language, it serves as a *least upper bound*). Now, any rows whose `store_id` column value is greater than or equal to 16 (the highest value defined) are stored in partition `p3`. At some point in the future—when the number of stores has increased to 25, 30, or more—you can use an `ALTER TABLE` statement to add new partitions for stores 21-25, 26-30, and so on (see Section 19.3, “Partition Management”, for details of how to do this).

In much the same fashion, you could partition the table based on employee job codes—that is, based on ranges of `job_code` column values. For example—assuming that two-digit job codes are used for regular (in-store) workers, three-digit codes are used for office and support personnel, and four-digit codes are used for management positions—you could create the partitioned table using the following statement:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
)
PARTITION BY RANGE (job_code) (
    PARTITION p0 VALUES LESS THAN (100),
    PARTITION p1 VALUES LESS THAN (1000),
    PARTITION p2 VALUES LESS THAN (10000)
);
```

In this instance, all rows relating to in-store workers would be stored in partition `p0`, those relating to office and support staff in `p1`, and those relating to managers in partition `p2`.

It is also possible to use an expression in `VALUES LESS THAN` clauses. However, MySQL must be able to evaluate the expression's return value as part of a `LESS THAN` (`<`) comparison.

Rather than splitting up the table data according to store number, you can use an expression based on one of the two `DATE` columns instead. For example, let us suppose that you wish to partition based on the year that each employee left the company; that is, the value of `YEAR(separated)`. An example of a `CREATE TABLE` statement that implements such a partitioning scheme is shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
```

```
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY RANGE ( YEAR(separated) ) (
    PARTITION p0 VALUES LESS THAN (1991),
    PARTITION p1 VALUES LESS THAN (1996),
    PARTITION p2 VALUES LESS THAN (2001),
    PARTITION p3 VALUES LESS THAN MAXVALUE
);
```

In this scheme, for all employees who left before 1991, the rows are stored in partition `p0`; for those who left in the years 1991 through 1995, in `p1`; for those who left in the years 1996 through 2000, in `p2`; and for any workers who left after the year 2000, in `p3`.

It is also possible to partition a table by `RANGE`, based on the value of a `TIMESTAMP` column, using the `UNIX_TIMESTAMP()` function, as shown in this example:

```
CREATE TABLE quarterly_report_status (
    report_id INT NOT NULL,
    report_status VARCHAR(20) NOT NULL,
    report_updated TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP
)
PARTITION BY RANGE ( UNIX_TIMESTAMP(report_updated) ) (
    PARTITION p0 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-01-01 00:00:00') ),
    PARTITION p1 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-04-01 00:00:00') ),
    PARTITION p2 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-07-01 00:00:00') ),
    PARTITION p3 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-10-01 00:00:00') ),
    PARTITION p4 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-01-01 00:00:00') ),
    PARTITION p5 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-04-01 00:00:00') ),
    PARTITION p6 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-07-01 00:00:00') ),
    PARTITION p7 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-10-01 00:00:00') ),
    PARTITION p8 VALUES LESS THAN ( UNIX_TIMESTAMP('2010-01-01 00:00:00') ),
    PARTITION p9 VALUES LESS THAN (MAXVALUE)
);
```

Any other expressions involving `TIMESTAMP` values are not permitted. (See Bug #42849.)

Range partitioning is particularly useful when one or more of the following conditions is true:

- You want or need to delete “old” data. If you are using the partitioning scheme shown previously for the `employees` table, you can simply use `ALTER TABLE employees DROP PARTITION p0;` to delete all rows relating to employees who stopped working for the firm prior to 1991. (See Section 13.1.7, “ALTER TABLE Syntax”, and Section 19.3, “Partition Management”, for more information.) For a table with a great many rows, this can be much more efficient than running a `DELETE` query such as `DELETE FROM employees WHERE YEAR(separated) <= 1990;`.
- You want to use a column containing date or time values, or containing values arising from some other series.
- You frequently run queries that depend directly on the column used for partitioning the table. For example, when executing a query such as `EXPLAIN PARTITIONS SELECT COUNT(*) FROM employees WHERE separated BETWEEN '2000-01-01' AND '2000-12-31' GROUP BY store_id;`, MySQL can quickly determine that only partition `p2` needs to be scanned because the remaining partitions cannot contain any records satisfying the `WHERE` clause. See Section 19.4, “Partition Pruning”, for more information about how this is accomplished.

A variant on this type of partitioning, `RANGE COLUMNS` partitioning, was introduced in MySQL 5.5.0. Partitioning by `RANGE COLUMNS` makes it possible to employ multiple columns for defining partitioning ranges that apply both to placement of rows in partitions and for determining the inclusion or exclusion of specific partitions when performing partition pruning. See Section 19.2.3.1, “RANGE COLUMNS partitioning”, for more information.

Partitioning schemes based on time intervals. If you wish to implement a partitioning scheme based on ranges or intervals of time in MySQL 5.5, you have two options:

1. Partition the table by `RANGE`, and for the partitioning expression, employ a function operating on a `DATE`, `TIME`, or `DATETIME` column and returning an integer value, as shown here:

```
CREATE TABLE members (
    firstname VARCHAR(25) NOT NULL,
    lastname VARCHAR(25) NOT NULL,
    username VARCHAR(16) NOT NULL,
    email VARCHAR(35),
    joined DATE NOT NULL
)
PARTITION BY RANGE( YEAR(joined) ) (
    PARTITION p0 VALUES LESS THAN (1960),
    PARTITION p1 VALUES LESS THAN (1970),
    PARTITION p2 VALUES LESS THAN (1980),
    PARTITION p3 VALUES LESS THAN (1990),
    PARTITION p4 VALUES LESS THAN MAXVALUE
);
```

   Beginning with MySQL 5.5.1, it is also possible to partition a table by `RANGE` based on the value of a `TIMESTAMP` column, using the `UNIX_TIMESTAMP()` function, as shown in this example:

```
CREATE TABLE quarterly_report_status (
    report_id INT NOT NULL,
    report_status VARCHAR(20) NOT NULL,
    report_updated TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP
)
PARTITION BY RANGE ( UNIX_TIMESTAMP(report_updated) ) (
    PARTITION p0 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-01-01 00:00:00') ),
    PARTITION p1 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-04-01 00:00:00') ),
    PARTITION p2 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-07-01 00:00:00') ),
    PARTITION p3 VALUES LESS THAN ( UNIX_TIMESTAMP('2008-10-01 00:00:00') ),
    PARTITION p4 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-01-01 00:00:00') ),
    PARTITION p5 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-04-01 00:00:00') ),
    PARTITION p6 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-07-01 00:00:00') ),
    PARTITION p7 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-10-01 00:00:00') ),
    PARTITION p8 VALUES LESS THAN ( UNIX_TIMESTAMP('2010-01-01 00:00:00') ),
    PARTITION p9 VALUES LESS THAN (MAXVALUE)
);
```

   Also beginning with MySQL 5.5.1, any other expressions involving `TIMESTAMP` values are not permitted. (See Bug #42849.)

   Note

   It is also possible in MySQL 5.5.1 and later to use `UNIX_TIMESTAMP(timestamp_column)` as a partitioning expression for tables that are partitioned by `LIST`. However, it is usually not practical to do so.

2. Partition the table by `RANGE COLUMNS`, using a `DATE` or `DATETIME` column as the partitioning column. For example, the `members` table could be defined using the `joined` column directly, as shown here:

```
CREATE TABLE members (
    firstname VARCHAR(25) NOT NULL,
    lastname VARCHAR(25) NOT NULL,
    username VARCHAR(16) NOT NULL,
    email VARCHAR(35),
    joined DATE NOT NULL
)
PARTITION BY RANGE COLUMNS(joined) (
    PARTITION p0 VALUES LESS THAN ('1960-01-01'),
    PARTITION p1 VALUES LESS THAN ('1970-01-01'),
    PARTITION p2 VALUES LESS THAN ('1980-01-01'),
    PARTITION p3 VALUES LESS THAN ('1990-01-01'),
    PARTITION p4 VALUES LESS THAN MAXVALUE
```

```
);
```

Note

The use of partitioning columns employing date or time types other than `DATE` or `DATETIME` is not supported with `RANGE COLUMNS`.

19.2.2 LIST Partitioning

List partitioning in MySQL is similar to range partitioning in many ways. As in partitioning by `RANGE`, each partition must be explicitly defined. The chief difference between the two types of partitioning is that, in list partitioning, each partition is defined and selected based on the membership of a column value in one of a set of value lists, rather than in one of a set of contiguous ranges of values. This is done by using `PARTITION BY LIST(expr)` where *`expr`* is a column value or an expression based on a column value and returning an integer value, and then defining each partition by means of a `VALUES IN (value_list)`, where *`value_list`* is a comma-separated list of integers.

Note

In MySQL 5.5, it is possible to match against only a list of integers (and possibly `NULL`—see Section 19.2.7, “How MySQL Partitioning Handles NULL”) when partitioning by `LIST`.

However, beginning with MySQL 5.5.0, other column types may be used in value lists when employing `LIST COLUMN` partitioning, which is described later in this section.

Unlike the case with partitions defined by range, list partitions do not need to be declared in any particular order. For more detailed syntactical information, see Section 13.1.17, “CREATE TABLE Syntax”.

For the examples that follow, we assume that the basic definition of the table to be partitioned is provided by the `CREATE TABLE` statement shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
);
```

(This is the same table used as a basis for the examples in Section 19.2.1, “RANGE Partitioning”.)

Suppose that there are 20 video stores distributed among 4 franchises as shown in the following table.

Region	Store ID Numbers
North	3, 5, 6, 9, 17
East	1, 2, 10, 11, 19, 20
West	4, 12, 13, 14, 18
Central	7, 8, 15, 16

To partition this table in such a way that rows for stores belonging to the same region are stored in the same partition, you could use the `CREATE TABLE` statement shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
```

```
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY LIST(store_id) (
    PARTITION pNorth VALUES IN (3,5,6,9,17),
    PARTITION pEast VALUES IN (1,2,10,11,19,20),
    PARTITION pWest VALUES IN (4,12,13,14,18),
    PARTITION pCentral VALUES IN (7,8,15,16)
);
```

This makes it easy to add or drop employee records relating to specific regions to or from the table. For instance, suppose that all stores in the West region are sold to another company. Beginning with MySQL 5.5.0, all rows relating to employees working at stores in that region can be deleted with the query `ALTER TABLE employees TRUNCATE PARTITION pWest`, which can be executed much more efficiently than the equivalent `DELETE` statement `DELETE FROM employees WHERE store_id IN (4,12,13,14,18);`. (Using `ALTER TABLE employees DROP PARTITION pWest` would also delete all of these rows, but would also remove the partition `pWest` from the definition of the table; you would need to use an `ALTER TABLE ... ADD PARTITION` statement to restore the table's original partitioning scheme.)

As with `RANGE` partitioning, it is possible to combine `LIST` partitioning with partitioning by hash or key to produce a composite partitioning (subpartitioning). See Section 19.2.6, “Subpartitioning”.

Unlike the case with `RANGE` partitioning, there is no “catch-all” such as `MAXVALUE`; all expected values for the partitioning expression should be covered in `PARTITION ... VALUES IN (...)` clauses. An `INSERT` statement containing an unmatched partitioning column value fails with an error, as shown in this example:

```
mysql> CREATE TABLE h2 (
    ->   c1 INT,
    ->   c2 INT
    -> )
    -> PARTITION BY LIST(c1) (
    ->   PARTITION p0 VALUES IN (1, 4, 7),
    ->   PARTITION p1 VALUES IN (2, 5, 8)
    -> );
Query OK, 0 rows affected (0.11 sec)

mysql> INSERT INTO h2 VALUES (3, 5);
ERROR 1525 (HY000): Table has no partition for value 3
```

When inserting multiple rows using a single `INSERT` statement the behavior depends on whether the table uses a transactional storage engine. For an `InnoDB` table, the statement is considered a single transaction, so the presence of any unmatched values causes the statement to fail completely, and no rows are inserted. For a table using a nontransactional storage engine such as `MyISAM`, any rows coming before the row containing the unmatched value are inserted, but any coming after it are not.

You can cause this type of error to be ignored by using the `IGNORE` keyword. If you do so, rows containing unmatched partitioning column values are not inserted, but any rows with matching values *are* inserted, and no errors are reported:

```
mysql> TRUNCATE h2;
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM h2;
Empty set (0.00 sec)

mysql> INSERT IGNORE INTO h2 VALUES (2, 5), (6, 10), (7, 5), (3, 1), (1, 9);
Query OK, 3 rows affected (0.00 sec)
Records: 5  Duplicates: 2  Warnings: 0

mysql> SELECT * FROM h2;
```

```
+------+------+
| c1   | c2   |
+------+------+
|    7 |    5 |
|    1 |    9 |
|    2 |    5 |
+------+------+
3 rows in set (0.00 sec)
```

MySQL 5.5 provides support for `LIST COLUMNS` partitioning. This is a variant of `LIST` partitioning that enables you to use columns of types other than integer types for partitioning columns, as well as to use multiple columns as partitioning keys. For more information, see Section 19.2.3.2, “LIST COLUMNS partitioning”.

19.2.3 COLUMNS Partitioning

The next two sections discuss *`COLUMNS` partitioning*, which are variants on `RANGE` and `LIST` partitioning that were introduced in MySQL 5.5.0. `COLUMNS` partitioning enables the use of multiple columns in partitioning keys. All of these columns are taken into account both for the purpose of placing rows in partitions and for the determination of which partitions are to be checked for matching rows in partition pruning.

In addition, both `RANGE COLUMNS` partitioning and `LIST COLUMNS` partitioning support the use of non-integer columns for defining value ranges or list members. The permitted data types are shown in the following list:

- All integer types: `TINYINT`, `SMALLINT`, `MEDIUMINT`, `INT` (`INTEGER`), and `BIGINT`. (This is the same as with partitioning by `RANGE` and `LIST`.)

  Other numeric data types (such as `DECIMAL` or `FLOAT`) are not supported as partitioning columns.

- `DATE` and `DATETIME`.

  Columns using other data types relating to dates or times are not supported as partitioning columns.

- The following string types: `CHAR`, `VARCHAR`, `BINARY`, and `VARBINARY`.

  `TEXT` and `BLOB` columns are not supported as partitioning columns.

The discussions of `RANGE COLUMNS` and `LIST COLUMNS` partitioning in the next two sections assume that you are already familiar with partitioning based on ranges and lists as supported in MySQL 5.1 and later; for more information about these, see Section 19.2.1, “RANGE Partitioning”, and Section 19.2.2, “LIST Partitioning”, respectively.

19.2.3.1 RANGE COLUMNS partitioning

Range columns partitioning is similar to range partitioning, but enables you to define partitions using ranges based on multiple column values. In addition, you can define the ranges using columns of types other than integer types.

`RANGE COLUMNS` partitioning differs significantly from `RANGE` partitioning in the following ways:

- `RANGE COLUMNS` does not accept expressions, only names of columns.
- `RANGE COLUMNS` accepts a list of one or more columns.

  `RANGE COLUMNS` partitions are based on comparisons between *tuples* (lists of column values) rather than comparisons between scalar values. Placement of rows in `RANGE COLUMNS` partitions is also based on comparisons between tuples; this is discussed further later in this section.

- `RANGE COLUMNS` partitioning columns are not restricted to integer columns; string, `DATE` and `DATETIME` columns can also be used as partitioning columns. (See Section 19.2.3, “COLUMNS Partitioning”, for details.)

The basic syntax for creating a table partitioned by RANGE COLUMNS is shown here:

```
CREATE TABLE table_name
PARTITIONED BY RANGE COLUMNS(column_list) (
    PARTITION partition_name VALUES LESS THAN (value_list)[,
    PARTITION partition_name VALUES LESS THAN (value_list)][,
    ...]
)

column_list:
    column_name[, column_name][, ...]

value_list:
    value[, value][, ...]
```

Note

Not all CREATE TABLE options that can be used when creating partitioned tables are shown here. For complete information, see Section 13.1.17, “CREATE TABLE Syntax”.

In the syntax just shown, *column_list* is a list of one or more columns (sometimes called a *partitioning column list*), and *value_list* is a list of values (that is, it is a *partition definition value list*). A *value_list* must be supplied for each partition definition, and each *value_list* must have the same number of values as the *column_list* has columns. Generally speaking, if you use *N* columns in the COLUMNS clause, then each VALUES LESS THAN clause must also be supplied with a list of *N* values.

The elements in the partitioning column list and in the value list defining each partition must occur in the same order. In addition, each element in the value list must be of the same data type as the corresponding element in the column list. However, the order of the column names in the partitioning column list and the value lists does not have to be the same as the order of the table column definitions in the main part of the CREATE TABLE statement. As with table partitioned by RANGE, you can use MAXVALUE to represent a value such that any legal value inserted into a given column is always less than this value. Here is an example of a CREATE TABLE statement that helps to illustrate all of these points:

```
mysql> CREATE TABLE rcx (
    ->     a INT,
    ->     b INT,
    ->     c CHAR(3),
    ->     d INT
    -> )
    -> PARTITION BY RANGE COLUMNS(a,d,c) (
    ->     PARTITION p0 VALUES LESS THAN (5,10,'ggg'),
    ->     PARTITION p1 VALUES LESS THAN (10,20,'mmm'),
    ->     PARTITION p2 VALUES LESS THAN (15,30,'sss'),
    ->     PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE,MAXVALUE)
    -> );
Query OK, 0 rows affected (0.15 sec)
```

Table rcx contains the columns a, b, c, d. The partitioning column list supplied to the COLUMNS clause uses 3 of these columns, in the order a, d, c. Each value list used to define a partition contains 3 values in the same order; that is, each value list tuple has the form (INT, INT, CHAR(3)), which corresponds to the data types used by columns a, d, and c (in that order).

Placement of rows into partitions is determined by comparing the tuple from a row to be inserted that matches the column list in the COLUMNS clause with the tuples used in the VALUES LESS THAN clauses to define partitions of the table. Because we are comparing tuples (that is, lists or sets of values) rather than scalar values, the semantics of VALUES LESS THAN as used with RANGE COLUMNS partitions differs somewhat from the case with simple RANGE partitions. In RANGE partitioning, a row generating an expression value that is equal to a limiting value in a VALUES LESS THAN is never placed in the corresponding partition; however, when using RANGE COLUMNS partitioning, it is

sometimes possible for a row whose partitioning column list's first element is equal in value to the that of the first element in a `VALUES LESS THAN` value list to be placed in the corresponding partition.

Consider the `RANGE` partitioned table created by this statement:

```
CREATE TABLE r1 (
    a INT,
    b INT
)
PARTITION BY RANGE (a)  (
    PARTITION p0 VALUES LESS THAN (5),
    PARTITION p1 VALUES LESS THAN (MAXVALUE)
);
```

If we insert 3 rows into this table such that the column value for `a` is `5` for each row, all 3 rows are stored in partition `p1` because the `a` column value is in each case not less than 5, as we can see by executing the proper query against the `INFORMATION_SCHEMA.PARTITIONS` table:

```
mysql> INSERT INTO r1 VALUES (5,10), (5,11), (5,12);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT PARTITION_NAME,TABLE_ROWS
    ->     FROM INFORMATION_SCHEMA.PARTITIONS
    ->     WHERE TABLE_NAME = 'r1';
+----------------+------------+
| PARTITION_NAME | TABLE_ROWS |
+----------------+------------+
| p0             |          0 |
| p1             |          3 |
+----------------+------------+
2 rows in set (0.00 sec)
```

Now consider a similar table `rc1` that uses `RANGE COLUMNS` partitioning with both columns `a` and `b` referenced in the `COLUMNS` clause, created as shown here:

```
CREATE TABLE rc1 (
    a INT,
    b INT
)
PARTITION BY RANGE COLUMNS(a, b) (
    PARTITION p0 VALUES LESS THAN (5, 12),
    PARTITION p3 VALUES LESS THAN (MAXVALUE, MAXVALUE)
);
```

If we insert exactly the same rows into `rc1` as we just inserted into `r1`, the distribution of the rows is quite different:

```
mysql> INSERT INTO rc1 VALUES (5,10), (5,11), (5,12);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT PARTITION_NAME,TABLE_ROWS
    ->     FROM INFORMATION_SCHEMA.PARTITIONS
    ->     WHERE TABLE_NAME = 'rc1';
+--------------+----------------+------------+
| TABLE_SCHEMA | PARTITION_NAME | TABLE_ROWS |
+--------------+----------------+------------+
| p            | p0             |          2 |
| p            | p1             |          1 |
+--------------+----------------+------------+
2 rows in set (0.00 sec)
```

This is because we are comparing rows rather than scalar values. We can compare the row values inserted with the limiting row value from the `VALUES THAN LESS THAN` clause used to define partition `p0` in table `rc1`, like this:

```
mysql> SELECT (5,10) < (5,12), (5,11) < (5,12), (5,12) < (5,12);
+----------------+----------------+----------------+
| (5,10) < (5,12) | (5,11) < (5,12) | (5,12) < (5,12) |
+----------------+----------------+----------------+
|              1 |              1 |              0 |
+----------------+----------------+----------------+
1 row in set (0.00 sec)
```

The 2 tuples `(5,10)` and `(5,11)` evaluate as less than `(5,12)`, so they are stored in partition `p0`. Since 5 is not less than 5 and 12 is not less than 12, `(5,12)` is considered not less than `(5,12)`, and is stored in partition `p1`.

The `SELECT` statement in the preceding example could also have been written using explicit row constructors, like this:

```
SELECT ROW(5,10) < ROW(5,12), ROW(5,11) < ROW(5,12), ROW(5,12) < ROW(5,12);
```

For more information about the use of row constructors in MySQL, see Section 13.2.10.5, “Row Subqueries”.

For a table partitioned by `RANGE COLUMNS` using only a single partitioning column, the storing of rows in partitions is the same as that of an equivalent table that is partitioned by `RANGE`. The following `CREATE TABLE` statement creates a table partitioned by `RANGE COLUMNS` using 1 partitioning column:

```
CREATE TABLE rx (
    a INT,
    b INT
)
PARTITION BY RANGE COLUMNS (a)  (
    PARTITION p0 VALUES LESS THAN (5),
    PARTITION p1 VALUES LESS THAN (MAXVALUE)
);
```

If we insert the rows `(5,10)`, `(5,11)`, and `(5,12)` into this table, we can see that their placement is the same as it is for the table `r` we created and populated earlier:

```
mysql> INSERT INTO rx VALUES (5,10), (5,11), (5,12);
Query OK, 3 rows affected (0.00 sec)
Records: 3  Duplicates: 0  Warnings: 0

mysql> SELECT PARTITION_NAME,TABLE_ROWS
    ->     FROM INFORMATION_SCHEMA.PARTITIONS
    ->     WHERE TABLE_NAME = 'rx';
+--------------+----------------+------------+
| TABLE_SCHEMA | PARTITION_NAME | TABLE_ROWS |
+--------------+----------------+------------+
| p            | p0             |          0 |
| p            | p1             |          3 |
+--------------+----------------+------------+
2 rows in set (0.00 sec)
```

It is also possible to create tables partitioned by `RANGE COLUMNS` where limiting values for one or more columns are repeated in successive partition definitions. You can do this as long as the tuples of column values used to define the partitions are strictly increasing. For example, each of the following `CREATE TABLE` statements is valid:

```
CREATE TABLE rc2 (
    a INT,
    b INT
)
PARTITION BY RANGE COLUMNS(a,b) (
    PARTITION p0 VALUES LESS THAN (0,10),
    PARTITION p1 VALUES LESS THAN (10,20),
    PARTITION p2 VALUES LESS THAN (10,30),
```

```
    PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE)
 );

CREATE TABLE rc3 (
    a INT,
    b INT
)
PARTITION BY RANGE COLUMNS(a,b) (
    PARTITION p0 VALUES LESS THAN (0,10),
    PARTITION p1 VALUES LESS THAN (10,20),
    PARTITION p2 VALUES LESS THAN (10,30),
    PARTITION p3 VALUES LESS THAN (10,35),
    PARTITION p4 VALUES LESS THAN (20,40),
    PARTITION p5 VALUES LESS THAN (MAXVALUE,MAXVALUE)
 );
```

The following statement also succeeds, even though it might appear at first glance that it would not, since the limiting value of column `b` is 25 for partition `p0` and 20 for partition `p1`, and the limiting value of column `c` is 100 for partition `p1` and 50 for partition `p2`:

```
CREATE TABLE rc4 (
    a INT,
    b INT,
    c INT
)
PARTITION BY RANGE COLUMNS(a,b,c) (
    PARTITION p0 VALUES LESS THAN (0,25,50),
    PARTITION p1 VALUES LESS THAN (10,20,100),
    PARTITION p2 VALUES LESS THAN (10,30,50)
    PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE,MAXVALUE)
 );
```

When designing tables partitioned by `RANGE COLUMNS`, you can always test successive partition definitions by comparing the desired tuples using the `mysql` client, like this:

```
mysql> SELECT (0,25,50) < (10,20,100), (10,20,100) < (10,30,50);
+-------------------------+-------------------------+
| (0,25,50) < (10,20,100) | (10,20,100) < (10,30,50) |
+-------------------------+-------------------------+
|                       1 |                       1 |
+-------------------------+-------------------------+
1 row in set (0.00 sec)
```

If a `CREATE TABLE` statement contains partition definitions that are not in strictly increasing order, it fails with an error, as shown in this example:

```
mysql> CREATE TABLE rcf (
    ->     a INT,
    ->     b INT,
    ->     c INT
    -> )
    -> PARTITION BY RANGE COLUMNS(a,b,c) (
    ->     PARTITION p0 VALUES LESS THAN (0,25,50),
    ->     PARTITION p1 VALUES LESS THAN (20,20,100),
    ->     PARTITION p2 VALUES LESS THAN (10,30,50),
    ->     PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE,MAXVALUE)
    ->  );
ERROR 1493 (HY000): VALUES LESS THAN value must be strictly increasing for each partition
```

When you get such an error, you can deduce which partition definitions are invalid by making “less than” comparisons between their column lists. In this case, the problem is with the definition of partition `p2` because the tuple used to define it is not less than the tuple used to define partition `p3`, as shown here:

```
mysql> SELECT (0,25,50) < (20,20,100), (20,20,100) < (10,30,50);
+-------------------------+-------------------------+
```

```
| (0,25,50) < (20,20,100) | (20,20,100) < (10,30,50) |
+-------------------------+--------------------------+
|                       1 |                        0 |
+-------------------------+--------------------------+
1 row in set (0.00 sec)
```

It is also possible for `MAXVALUE` to appear for the same column in more than one `VALUES LESS THAN` clause when using `RANGE COLUMNS`. However, the limiting values for individual columns in successive partition definitions should otherwise be increasing, there should be no more than one partition defined where `MAXVALUE` is used as the upper limit for all column values, and this partition definition should appear last in the list of `PARTITION ... VALUES LESS THAN` clauses. In addition, you cannot use `MAXVALUE` as the limiting value for the first column in more than one partition definition.

As stated previously, it is also possible with `RANGE COLUMNS` partitioning to use non-integer columns as partitioning columns. (See Section 19.2.3, “COLUMNS Partitioning”, for a complete listing of these.) Consider a table named `employees` (which is not partitioned), created using the following statement:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
);
```

Using `RANGE COLUMNS` partitioning, you can create a version of this table that stores each row in one of four partitions based on the employee's last name, like this:

```
CREATE TABLE employees_by_lname (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT NOT NULL,
    store_id INT NOT NULL
)
PARTITION BY RANGE COLUMNS (lname)  (
    PARTITION p0 VALUES LESS THAN ('g'),
    PARTITION p1 VALUES LESS THAN ('m'),
    PARTITION p2 VALUES LESS THAN ('t'),
    PARTITION p3 VALUES LESS THAN (MAXVALUE)
);
```

Alternatively, you could cause the `employees` table as created previously to be partitioned using this scheme by executing the following `ALTER TABLE` statement:

```
ALTER TABLE employees PARTITION BY RANGE COLUMNS (lname)  (
    PARTITION p0 VALUES LESS THAN ('g'),
    PARTITION p1 VALUES LESS THAN ('m'),
    PARTITION p2 VALUES LESS THAN ('t'),
    PARTITION p3 VALUES LESS THAN (MAXVALUE)
);
```

Note

Because different character sets and collations have different sort orders, the character sets and collations in use may effect which partition of a table partitioned by `RANGE COLUMNS` a given row is stored in when using string columns as partitioning columns. In addition, changing the character set or collation for a given database, table, or column after such a table is created may cause changes in how rows are distributed. For example, when using a case-

> sensitive collation, `'and'` sorts before `'Andersen'`, but when using a collation that is case insensitive, the reverse is true.
>
> For information about how MySQL handles character sets and collations, see Section 10.1, “Character Set Support”.

Similarly, you can cause the `employees` table to be partitioned in such a way that each row is stored in one of several partitions based on the decade in which the corresponding employee was hired using the `ALTER TABLE` statement shown here:

```
ALTER TABLE employees PARTITION BY RANGE COLUMNS (hired)  (
    PARTITION p0 VALUES LESS THAN ('1970-01-01'),
    PARTITION p1 VALUES LESS THAN ('1980-01-01'),
    PARTITION p2 VALUES LESS THAN ('1990-01-01'),
    PARTITION p3 VALUES LESS THAN ('2000-01-01'),
    PARTITION p4 VALUES LESS THAN ('2010-01-01'),
    PARTITION p5 VALUES LESS THAN (MAXVALUE)
);
```

See Section 13.1.17, “CREATE TABLE Syntax”, for additional information about `PARTITION BY RANGE COLUMNS` syntax.

19.2.3.2 LIST COLUMNS partitioning

MySQL 5.5 provides support for `LIST COLUMNS` partitioning. This is a variant of `LIST` partitioning that enables the use of multiple columns as partition keys, and for columns of data types other than integer types to be used as partitioning columns; you can use string types, `DATE`, and `DATETIME` columns. (For more information about permitted data types for `COLUMNS` partitioning columns, see Section 19.2.3, “COLUMNS Partitioning”.)

Suppose that you have a business that has customers in 12 cities which, for sales and marketing purposes, you organize into 4 regions of 3 cities each as shown in the following table:

Region	Cities
1	Oskarshamn, Högsby, Mönsterås
2	Vimmerby, Hultsfred, Västervik
3	Nässjö, Eksjö, Vetlanda
4	Uppvidinge, Alvesta, Växjo

With `LIST COLUMNS` partitioning, you can create a table for customer data that assigns a row to any of 4 partitions corresponding to these regions based on the name of the city where a customer resides, as shown here:

```
CREATE TABLE customers_1 (
    first_name VARCHAR(25),
    last_name VARCHAR(25),
    street_1 VARCHAR(30),
    street_2 VARCHAR(30),
    city VARCHAR(15),
    renewal DATE
)
PARTITION BY LIST COLUMNS(city) (
    PARTITION pRegion_1 VALUES IN('Oskarshamn', 'Högsby', 'Mönsterås'),
    PARTITION pRegion_2 VALUES IN('Vimmerby', 'Hultsfred', 'Västervik'),
    PARTITION pRegion_3 VALUES IN('Nässjö', 'Eksjö', 'Vetlanda'),
    PARTITION pRegion_4 VALUES IN('Uppvidinge', 'Alvesta', 'Växjo')
);
```

As with partitioning by `RANGE COLUMNS`, you do not need to use expressions in the `COLUMNS()` clause to convert column values into integers. (In fact, the use of expressions other than column names is not permitted with `COLUMNS()`.)

It is also possible to use `DATE` and `DATETIME` columns, as shown in the following example that uses the same name and columns as the `customers_1` table shown previously, but employs `LIST COLUMNS` partitioning based on the `renewal` column to store rows in one of 4 partitions depending on the week in February 2010 the customer's account is scheduled to renew:

```
CREATE TABLE customers_2 (
    first_name VARCHAR(25),
    last_name VARCHAR(25),
    street_1 VARCHAR(30),
    street_2 VARCHAR(30),
    city VARCHAR(15),
    renewal DATE
)
PARTITION BY LIST COLUMNS(renewal) (
    PARTITION pWeek_1 VALUES IN('2010-02-01', '2010-02-02', '2010-02-03',
        '2010-02-04', '2010-02-05', '2010-02-06', '2010-02-07'),
    PARTITION pWeek_2 VALUES IN('2010-02-08', '2010-02-09', '2010-02-10',
        '2010-02-11', '2010-02-12', '2010-02-13', '2010-02-14'),
    PARTITION pWeek_3 VALUES IN('2010-02-15', '2010-02-16', '2010-02-17',
        '2010-02-18', '2010-02-19', '2010-02-20', '2010-02-21'),
    PARTITION pWeek_4 VALUES IN('2010-02-22', '2010-02-23', '2010-02-24',
        '2010-02-25', '2010-02-26', '2010-02-27', '2010-02-28')
);
```

This works, but becomes cumbersome to define and maintain if the number of dates involved grows very large; in such cases, it is usually more practical to employ `RANGE` or `RANGE COLUMNS` partitioning instead. In this case, since the column we wish to use as the partitioning key is a `DATE` column, we use `RANGE COLUMNS` partitioning, as shown here:

```
CREATE TABLE customers_3 (
    first_name VARCHAR(25),
    last_name VARCHAR(25),
    street_1 VARCHAR(30),
    street_2 VARCHAR(30),
    city VARCHAR(15),
    renewal DATE
)
PARTITION BY RANGE COLUMNS(renewal) (
    PARTITION pWeek_1 VALUES LESS THAN('2010-02-09'),
    PARTITION pWeek_2 VALUES LESS THAN('2010-02-15'),
    PARTITION pWeek_3 VALUES LESS THAN('2010-02-22'),
    PARTITION pWeek_4 VALUES LESS THAN('2010-03-01')
);
```

See Section 19.2.3.1, “RANGE COLUMNS partitioning”, for more information.

In addition (as with `RANGE COLUMNS` partitioning), you can use multiple columns in the `COLUMNS()` clause.

See Section 13.1.17, “CREATE TABLE Syntax”, for additional information about `PARTITION BY LIST COLUMNS()` syntax.

19.2.4 HASH Partitioning

Partitioning by `HASH` is used primarily to ensure an even distribution of data among a predetermined number of partitions. With range or list partitioning, you must specify explicitly into which partition a given column value or set of column values is to be stored; with hash partitioning, MySQL takes care of this for you, and you need only specify a column value or expression based on a column value to be hashed and the number of partitions into which the partitioned table is to be divided.

To partition a table using `HASH` partitioning, it is necessary to append to the `CREATE TABLE` statement a `PARTITION BY HASH (expr)` clause, where *`expr`* is an expression that returns an integer. This can simply be the name of a column whose type is one of MySQL's integer types. In addition, you most likely want to follow this with `PARTITIONS num`, where *`num`* is a positive integer representing the number of partitions into which the table is to be divided.

Note

For simplicity, the tables in the examples that follow do not use any keys. You should be aware that, if a table has any unique keys, every column used in the partitioning expression for this table must be part of every unique key, including the primary key. See Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”, for more information.

The following statement creates a table that uses hashing on the `store_id` column and is divided into 4 partitions:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY HASH(store_id)
PARTITIONS 4;
```

If you do not include a `PARTITIONS` clause, the number of partitions defaults to `1`.

Using the `PARTITIONS` keyword without a number following it results in a syntax error.

You can also use an SQL expression that returns an integer for *`expr`*. For instance, you might want to partition based on the year in which an employee was hired. This can be done as shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY HASH( YEAR(hired) )
PARTITIONS 4;
```

`expr` must return a nonconstant, nonrandom integer value (in other words, it should be varying but deterministic), and must not contain any prohibited constructs as described in Section 19.5, “Restrictions and Limitations on Partitioning”. You should also keep in mind that this expression is evaluated each time a row is inserted or updated (or possibly deleted); this means that very complex expressions may give rise to performance issues, particularly when performing operations (such as batch inserts) that affect a great many rows at one time.

The most efficient hashing function is one which operates upon a single table column and whose value increases or decreases consistently with the column value, as this allows for “pruning” on ranges of partitions. That is, the more closely that the expression varies with the value of the column on which it is based, the more efficiently MySQL can use the expression for hash partitioning.

For example, where `date_col` is a column of type `DATE`, then the expression `TO_DAYS(date_col)` is said to vary directly with the value of `date_col`, because for every change in the value of `date_col`, the value of the expression changes in a consistent manner. The variance of the expression `YEAR(date_col)` with respect to `date_col` is not quite as direct as that of `TO_DAYS(date_col)`, because not every possible change in `date_col` produces an equivalent change in `YEAR(date_col)`. Even so, `YEAR(date_col)` is a good candidate for a hashing function, because it varies directly with a portion of `date_col` and there is no possible change in `date_col` that produces a disproportionate change in `YEAR(date_col)`.

By way of contrast, suppose that you have a column named `int_col` whose type is `INT`. Now consider the expression `POW(5-int_col,3) + 6`. This would be a poor choice for a hashing function because a change in the value of `int_col` is not guaranteed to produce a proportional change in the value of the expression. Changing the value of `int_col` by a given amount can produce widely differing changes in the value of the expression. For example, changing `int_col` from `5` to `6` produces a change of `-1` in the value of the expression, but changing the value of `int_col` from `6` to `7` produces a change of `-7` in the expression value.

In other words, the more closely the graph of the column value versus the value of the expression follows a straight line as traced by the equation `y=cx` where *`c`* is some nonzero constant, the better the expression is suited to hashing. This has to do with the fact that the more nonlinear an expression is, the more uneven the distribution of data among the partitions it tends to produce.

In theory, pruning is also possible for expressions involving more than one column value, but determining which of such expressions are suitable can be quite difficult and time-consuming. For this reason, the use of hashing expressions involving multiple columns is not particularly recommended.

When `PARTITION BY HASH` is used, MySQL determines which partition of *`num`* partitions to use based on the modulus of the result of the expression. In other words, for a given expression *`expr`*, the partition in which the record is stored is partition number *`N`*, where *`N = MOD(expr, num)`*. Suppose that table `t1` is defined as follows, so that it has 4 partitions:

```
CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATE)
    PARTITION BY HASH( YEAR(col3) )
    PARTITIONS 4;
```

If you insert a record into `t1` whose `col3` value is `'2005-09-15'`, then the partition in which it is stored is determined as follows:

```
MOD(YEAR('2005-09-01'),4)
=  MOD(2005,4)
=  1
```

MySQL 5.5 also supports a variant of `HASH` partitioning known as *linear hashing* which employs a more complex algorithm for determining the placement of new rows inserted into the partitioned table. See Section 19.2.4.1, “LINEAR HASH Partitioning”, for a description of this algorithm.

The user-supplied expression is evaluated each time a record is inserted or updated. It may also—depending on the circumstances—be evaluated when records are deleted.

19.2.4.1 LINEAR HASH Partitioning

MySQL also supports linear hashing, which differs from regular hashing in that linear hashing utilizes a linear powers-of-two algorithm whereas regular hashing employs the modulus of the hashing function's value.

Syntactically, the only difference between linear-hash partitioning and regular hashing is the addition of the `LINEAR` keyword in the `PARTITION BY` clause, as shown here:

```
CREATE TABLE employees (
    id INT NOT NULL,
    fname VARCHAR(30),
    lname VARCHAR(30),
    hired DATE NOT NULL DEFAULT '1970-01-01',
    separated DATE NOT NULL DEFAULT '9999-12-31',
    job_code INT,
    store_id INT
)
PARTITION BY LINEAR HASH( YEAR(hired) )
PARTITIONS 4;
```

Given an expression *expr*, the partition in which the record is stored when linear hashing is used is partition number *N* from among *num* partitions, where *N* is derived according to the following algorithm:

1. Find the next power of 2 greater than *num*. We call this value *V*; it can be calculated as:

   ```
   V = POWER(2, CEILING(LOG(2, num)))
   ```

   (Suppose that *num* is 13. Then `LOG(2,13)` is 3.7004397181411. `CEILING(3.7004397181411)` is 4, and *V* = `POWER(2,4)`, which is 16.)

2. Set *N* = *F*(*column_list*) & (*V* - 1).

3. While *N* >= *num*:

   - Set *V* = *V* / 2
   - Set *N* = *N* & (*V* - 1)

Suppose that the table `t1`, using linear hash partitioning and having 6 partitions, is created using this statement:

```
CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATE)
    PARTITION BY LINEAR HASH( YEAR(col3) )
    PARTITIONS 6;
```

Now assume that you want to insert two records into `t1` having the `col3` column values `'2003-04-14'` and `'1998-10-19'`. The partition number for the first of these is determined as follows:

```
V = POWER(2, CEILING( LOG(2,6) )) = 8
N = YEAR('2003-04-14') & (8 - 1)
   = 2003 & 7
   = 3

(3 >= 6 is FALSE: record stored in partition #3)
```

The number of the partition where the second record is stored is calculated as shown here:

```
V = 8
N = YEAR('1998-10-19') & (8 - 1)
  = 1998 & 7
  = 6

(6 >= 6 is TRUE: additional step required)

N = 6 & ((8 / 2) - 1)
  = 6 & 3
  = 2

(2 >= 6 is FALSE: record stored in partition #2)
```

The advantage in partitioning by linear hash is that the adding, dropping, merging, and splitting of partitions is made much faster, which can be beneficial when dealing with tables containing extremely large amounts (terabytes) of data. The disadvantage is that data is less likely to be evenly distributed between partitions as compared with the distribution obtained using regular hash partitioning.

19.2.5 KEY Partitioning

Partitioning by key is similar to partitioning by hash, except that where hash partitioning employs a user-defined expression, the hashing function for key partitioning is supplied by the MySQL server. NDB Cluster uses `MD5()` for this purpose; for tables using other storage engines, the server employs its own internal hashing function which is based on the same algorithm as `PASSWORD()`.

The syntax rules for `CREATE TABLE ... PARTITION BY KEY` are similar to those for creating a table that is partitioned by hash. The major differences are listed here:

- `KEY` is used rather than `HASH`.
- `KEY` takes only a list of zero or more column names. Any columns used as the partitioning key must comprise part or all of the table's primary key, if the table has one. Where no column name is specified as the partitioning key, the table's primary key is used, if there is one. For example, the following `CREATE TABLE` statement is valid in MySQL 5.5:

```
CREATE TABLE k1 (
    id INT NOT NULL PRIMARY KEY,
    name VARCHAR(20)
)
PARTITION BY KEY()
PARTITIONS 2;
```

If there is no primary key but there is a unique key, then the unique key is used for the partitioning key:

```
CREATE TABLE k1 (
    id INT NOT NULL,
    name VARCHAR(20),
    UNIQUE KEY (id)
)
PARTITION BY KEY()
PARTITIONS 2;
```

However, if the unique key column were not defined as `NOT NULL`, then the previous statement would fail.

In both of these cases, the partitioning key is the `id` column, even though it is not shown in the output of `SHOW CREATE TABLE` or in the `PARTITION_EXPRESSION` column of the `INFORMATION_SCHEMA.PARTITIONS` table.

Unlike the case with other partitioning types, columns used for partitioning by `KEY` are not restricted to integer or `NULL` values. For example, the following `CREATE TABLE` statement is valid:

```
CREATE TABLE tm1 (
    s1 CHAR(32) PRIMARY KEY
)
PARTITION BY KEY(s1)
PARTITIONS 10;
```

The preceding statement would *not* be valid, were a different partitioning type to be specified. (In this case, simply using `PARTITION BY KEY()` would also be valid and have the same effect as `PARTITION BY KEY(s1)`, since `s1` is the table's primary key.)

For additional information about this issue, see Section 19.5, “Restrictions and Limitations on Partitioning”.

Note

Tables using the `NDBCLUSTER` storage engine are implicitly partitioned by `KEY`, again using the table's primary key as the partitioning key. In the event that the NDB Cluster table has no explicit primary key, the “hidden” primary key generated by the `NDBCLUSTER` storage engine for each NDB Cluster table is used as the partitioning key.

If you define an explicit partitioning scheme for an `NDBCLUSTER` table, the table must have an explicit primary key, and any columns used in the partitioning expression must be part of this key. However, if the table uses

an “empty” partitioning expression—that is, `PARTITION BY KEY()` with no column references—then no explicit primary key is required.

You can observe this partitioning using the `ndb_desc` utility (with the `-p` option).

Important

For a key-partitioned table, you cannot execute an `ALTER TABLE DROP PRIMARY KEY`, as doing so generates the error `ERROR 1466 (HY000): Field in list of fields for partition function not found in table`. This is not an issue for NDB Cluster tables which are partitioned by `KEY`; in such cases, the table is reorganized using the “hidden” primary key as the table's new partitioning key. See Chapter 18, *MySQL NDB Cluster 7.2*.

It is also possible to partition a table by linear key. Here is a simple example:

```
CREATE TABLE tk (
    col1 INT NOT NULL,
    col2 CHAR(5),
    col3 DATE
)
PARTITION BY LINEAR KEY (col1)
PARTITIONS 3;
```

Using `LINEAR` has the same effect on `KEY` partitioning as it does on `HASH` partitioning, with the partition number being derived using a powers-of-two algorithm rather than modulo arithmetic. See Section 19.2.4.1, “LINEAR HASH Partitioning”, for a description of this algorithm and its implications.

19.2.6 Subpartitioning

Subpartitioning—also known as *composite partitioning*—is the further division of each partition in a partitioned table. Consider the following `CREATE TABLE` statement:

```
CREATE TABLE ts (id INT, purchased DATE)
    PARTITION BY RANGE( YEAR(purchased) )
    SUBPARTITION BY HASH( TO_DAYS(purchased) )
    SUBPARTITIONS 2 (
        PARTITION p0 VALUES LESS THAN (1990),
        PARTITION p1 VALUES LESS THAN (2000),
        PARTITION p2 VALUES LESS THAN MAXVALUE
    );
```

Table `ts` has 3 `RANGE` partitions. Each of these partitions—`p0`, `p1`, and `p2`—is further divided into 2 subpartitions. In effect, the entire table is divided into `3 * 2 = 6` partitions. However, due to the action of the `PARTITION BY RANGE` clause, the first 2 of these store only those records with a value less than 1990 in the `purchased` column.

In MySQL 5.5, it is possible to subpartition tables that are partitioned by `RANGE` or `LIST`. Subpartitions may use either `HASH` or `KEY` partitioning. This is also known as *composite partitioning*.

Note

`SUBPARTITION BY HASH` and `SUBPARTITION BY KEY` generally follow the same syntax rules as `PARTITION BY HASH` and `PARTITION BY KEY`, respectively. An exception to this is that `SUBPARTITION BY KEY` (unlike `PARTITION BY KEY`) does not currently support a default column, so the column used for this purpose must be specified, even if the table has an explicit primary key. This is a known issue which we are working to address; see Issues with subpartitions, for more information and an example.

It is also possible to define subpartitions explicitly using `SUBPARTITION` clauses to specify options for individual subpartitions. For example, a more verbose fashion of creating the same table `ts` as shown in the previous example would be:

```
CREATE TABLE ts (id INT, purchased DATE)
    PARTITION BY RANGE( YEAR(purchased) )
    SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990) (
            SUBPARTITION s0,
            SUBPARTITION s1
        ),
        PARTITION p1 VALUES LESS THAN (2000) (
            SUBPARTITION s2,
            SUBPARTITION s3
        ),
        PARTITION p2 VALUES LESS THAN MAXVALUE (
            SUBPARTITION s4,
            SUBPARTITION s5
        )
    );
```

Some syntactical items of note are listed here:

- Each partition must have the same number of subpartitions.
- If you explicitly define any subpartitions using `SUBPARTITION` on any partition of a partitioned table, you must define them all. In other words, the following statement will fail:

  ```
  CREATE TABLE ts (id INT, purchased DATE)
      PARTITION BY RANGE( YEAR(purchased) )
      SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
          PARTITION p0 VALUES LESS THAN (1990) (
              SUBPARTITION s0,
              SUBPARTITION s1
          ),
          PARTITION p1 VALUES LESS THAN (2000),
          PARTITION p2 VALUES LESS THAN MAXVALUE (
              SUBPARTITION s2,
              SUBPARTITION s3
          )
      );
  ```

  This statement would still fail even if it included a `SUBPARTITIONS 2` clause.

- Each `SUBPARTITION` clause must include (at a minimum) a name for the subpartition. Otherwise, you may set any desired option for the subpartition or allow it to assume its default setting for that option.
- Subpartition names must be unique across the entire table. For example, the following `CREATE TABLE` statement is valid in MySQL 5.5:

  ```
  CREATE TABLE ts (id INT, purchased DATE)
      PARTITION BY RANGE( YEAR(purchased) )
      SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
          PARTITION p0 VALUES LESS THAN (1990) (
              SUBPARTITION s0,
              SUBPARTITION s1
          ),
          PARTITION p1 VALUES LESS THAN (2000) (
              SUBPARTITION s2,
              SUBPARTITION s3
          ),
          PARTITION p2 VALUES LESS THAN MAXVALUE (
              SUBPARTITION s4,
              SUBPARTITION s5
          )
      );
  ```

Subpartitions can be used with especially large `MyISAM` tables to distribute data and indexes across many disks. Suppose that you have 6 disks mounted as `/disk0`, `/disk1`, `/disk2`, and so on. Now consider the following example:

```
CREATE TABLE ts (id INT, purchased DATE)
    ENGINE = MYISAM
    PARTITION BY RANGE( YEAR(purchased) )
    SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990) (
            SUBPARTITION s0
                DATA DIRECTORY = '/disk0/data'
                INDEX DIRECTORY = '/disk0/idx',
            SUBPARTITION s1
                DATA DIRECTORY = '/disk1/data'
                INDEX DIRECTORY = '/disk1/idx'
        ),
        PARTITION p1 VALUES LESS THAN (2000) (
            SUBPARTITION s2
                DATA DIRECTORY = '/disk2/data'
                INDEX DIRECTORY = '/disk2/idx',
            SUBPARTITION s3
                DATA DIRECTORY = '/disk3/data'
                INDEX DIRECTORY = '/disk3/idx'
        ),
        PARTITION p2 VALUES LESS THAN MAXVALUE (
            SUBPARTITION s4
                DATA DIRECTORY = '/disk4/data'
                INDEX DIRECTORY = '/disk4/idx',
            SUBPARTITION s5
                DATA DIRECTORY = '/disk5/data'
                INDEX DIRECTORY = '/disk5/idx'
        )
    );
```

In this case, a separate disk is used for the data and for the indexes of each `RANGE`. Many other variations are possible; another example might be:

```
CREATE TABLE ts (id INT, purchased DATE)
    ENGINE = MYISAM
    PARTITION BY RANGE(YEAR(purchased))
    SUBPARTITION BY HASH( TO_DAYS(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990) (
            SUBPARTITION s0a
                DATA DIRECTORY = '/disk0'
                INDEX DIRECTORY = '/disk1',
            SUBPARTITION s0b
                DATA DIRECTORY = '/disk2'
                INDEX DIRECTORY = '/disk3'
        ),
        PARTITION p1 VALUES LESS THAN (2000) (
            SUBPARTITION s1a
                DATA DIRECTORY = '/disk4/data'
                INDEX DIRECTORY = '/disk4/idx',
            SUBPARTITION s1b
                DATA DIRECTORY = '/disk5/data'
                INDEX DIRECTORY = '/disk5/idx'
        ),
        PARTITION p2 VALUES LESS THAN MAXVALUE (
            SUBPARTITION s2a,
            SUBPARTITION s2b
        )
    );
```

Here, the storage is as follows:

- Rows with `purchased` dates from before 1990 take up a vast amount of space, so are split up 4 ways, with a separate disk dedicated to the data and to the indexes for each of the two subpartitions (`s0a` and `s0b`) making up partition `p0`. In other words:

  - The data for subpartition `s0a` is stored on `/disk0`.
  - The indexes for subpartition `s0a` are stored on `/disk1`.
  - The data for subpartition `s0b` is stored on `/disk2`.
  - The indexes for subpartition `s0b` are stored on `/disk3`.
- Rows containing dates ranging from 1990 to 1999 (partition `p1`) do not require as much room as those from before 1990. These are split between 2 disks (`/disk4` and `/disk5`) rather than 4 disks as with the legacy records stored in `p0`:
  - Data and indexes belonging to `p1`'s first subpartition (`s1a`) are stored on `/disk4`—the data in `/disk4/data`, and the indexes in `/disk4/idx`.
  - Data and indexes belonging to `p1`'s second subpartition (`s1b`) are stored on `/disk5`—the data in `/disk5/data`, and the indexes in `/disk5/idx`.
- Rows reflecting dates from the year 2000 to the present (partition `p2`) do not take up as much space as required by either of the two previous ranges. Currently, it is sufficient to store all of these in the default location.

  In future, when the number of purchases for the decade beginning with the year 2000 grows to a point where the default location no longer provides sufficient space, the corresponding rows can be moved using an `ALTER TABLE ... REORGANIZE PARTITION` statement. See Section 19.3, “Partition Management”, for an explanation of how this can be done.

The `DATA DIRECTORY` and `INDEX DIRECTORY` options are not permitted in partition definitions when the `NO_DIR_IN_CREATE` server SQL mode is in effect. Beginning with MySQL 5.5.5, these options are also not permitted when defining subpartitions (Bug #42954).

19.2.7 How MySQL Partitioning Handles NULL

Partitioning in MySQL does nothing to disallow `NULL` as the value of a partitioning expression, whether it is a column value or the value of a user-supplied expression. Even though it is permitted to use `NULL` as the value of an expression that must otherwise yield an integer, it is important to keep in mind that `NULL` is not a number. MySQL's partitioning implementation treats `NULL` as being less than any non-`NULL` value, just as `ORDER BY` does.

This means that treatment of `NULL` varies between partitioning of different types, and may produce behavior which you do not expect if you are not prepared for it. This being the case, we discuss in this section how each MySQL partitioning type handles `NULL` values when determining the partition in which a row should be stored, and provide examples for each.

Handling of NULL with RANGE partitioning. If you insert a row into a table partitioned by `RANGE` such that the column value used to determine the partition is `NULL`, the row is inserted into the lowest partition. Consider these two tables in a database named `p`, created as follows:

```
mysql> CREATE TABLE t1 (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
    -> )
    -> PARTITION BY RANGE(c1) (
    ->     PARTITION p0 VALUES LESS THAN (0),
    ->     PARTITION p1 VALUES LESS THAN (10),
    ->     PARTITION p2 VALUES LESS THAN MAXVALUE
    -> );
Query OK, 0 rows affected (0.09 sec)

mysql> CREATE TABLE t2 (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
```

```
    -> )
    -> PARTITION BY RANGE(c1) (
    ->     PARTITION p0 VALUES LESS THAN (-5),
    ->     PARTITION p1 VALUES LESS THAN (0),
    ->     PARTITION p2 VALUES LESS THAN (10),
    ->     PARTITION p3 VALUES LESS THAN MAXVALUE
    -> );
Query OK, 0 rows affected (0.09 sec)
```

You can see the partitions created by these two `CREATE TABLE` statements using the following query against the `PARTITIONS` table in the `INFORMATION_SCHEMA` database:

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
     >   FROM INFORMATION_SCHEMA.PARTITIONS
     >   WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME LIKE 't_';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
+------------+----------------+------------+----------------+-------------+
| t1         | p0             |          0 |              0 |           0 |
| t1         | p1             |          0 |              0 |           0 |
| t1         | p2             |          0 |              0 |           0 |
| t2         | p0             |          0 |              0 |           0 |
| t2         | p1             |          0 |              0 |           0 |
| t2         | p2             |          0 |              0 |           0 |
| t2         | p3             |          0 |              0 |           0 |
+------------+----------------+------------+----------------+-------------+
7 rows in set (0.00 sec)
```

(For more information about this table, see Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”.) Now let us populate each of these tables with a single row containing a `NULL` in the column used as the partitioning key, and verify that the rows were inserted using a pair of `SELECT` statements:

```
mysql> INSERT INTO t1 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO t2 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM t1;
+------+--------+
| id   | name   |
+------+--------+
| NULL | mothra |
+------+--------+
1 row in set (0.00 sec)

mysql> SELECT * FROM t2;
+------+--------+
| id   | name   |
+------+--------+
| NULL | mothra |
+------+--------+
1 row in set (0.00 sec)
```

You can see which partitions are used to store the inserted rows by rerunning the previous query against `INFORMATION_SCHEMA.PARTITIONS` and inspecting the output:

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
     >   FROM INFORMATION_SCHEMA.PARTITIONS
     >   WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME LIKE 't_';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
+------------+----------------+------------+----------------+-------------+
| t1         | p0             |          1 |             20 |          20 |
| t1         | p1             |          0 |              0 |           0 |
| t1         | p2             |          0 |              0 |           0 |
| t2         | p0             |          1 |             20 |          20 |
```

```
| t2         | p1             |           0 |               0 |           0 |
| t2         | p2             |           0 |               0 |           0 |
| t2         | p3             |           0 |               0 |           0 |
+------------+----------------+-------------+-----------------+-------------+
7 rows in set (0.01 sec)
```

You can also demonstrate that these rows were stored in the lowest partition of each table by dropping these partitions, and then re-running the `SELECT` statements:

```
mysql> ALTER TABLE t1 DROP PARTITION p0;
Query OK, 0 rows affected (0.16 sec)

mysql> ALTER TABLE t2 DROP PARTITION p0;
Query OK, 0 rows affected (0.16 sec)

mysql> SELECT * FROM t1;
Empty set (0.00 sec)

mysql> SELECT * FROM t2;
Empty set (0.00 sec)
```

(For more information on `ALTER TABLE ... DROP PARTITION`, see Section 13.1.7, “ALTER TABLE Syntax”.)

`NULL` is also treated in this way for partitioning expressions that use SQL functions. Suppose that we define a table using a `CREATE TABLE` statement such as this one:

```
CREATE TABLE tndate (
    id INT,
    dt DATE
)
PARTITION BY RANGE( YEAR(dt) ) (
    PARTITION p0 VALUES LESS THAN (1990),
    PARTITION p1 VALUES LESS THAN (2000),
    PARTITION p2 VALUES LESS THAN MAXVALUE
);
```

As with other MySQL functions, `YEAR(NULL)` returns `NULL`. A row with a `dt` column value of `NULL` is treated as though the partitioning expression evaluated to a value less than any other value, and so is inserted into partition `p0`.

Handling of NULL with LIST partitioning. A table that is partitioned by `LIST` admits `NULL` values if and only if one of its partitions is defined using that value-list that contains `NULL`. The converse of this is that a table partitioned by `LIST` which does not explicitly use `NULL` in a value list rejects rows resulting in a `NULL` value for the partitioning expression, as shown in this example:

```
mysql> CREATE TABLE ts1 (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
    -> )
    -> PARTITION BY LIST(c1) (
    ->     PARTITION p0 VALUES IN (0, 3, 6),
    ->     PARTITION p1 VALUES IN (1, 4, 7),
    ->     PARTITION p2 VALUES IN (2, 5, 8)
    -> );
Query OK, 0 rows affected (0.01 sec)

mysql> INSERT INTO ts1 VALUES (9, 'mothra');
ERROR 1504 (HY000): Table has no partition for value 9

mysql> INSERT INTO ts1 VALUES (NULL, 'mothra');
ERROR 1504 (HY000): Table has no partition for value NULL
```

Only rows having a `c1` value between `0` and `8` inclusive can be inserted into `ts1`. `NULL` falls outside this range, just like the number `9`. We can create tables `ts2` and `ts3` having value lists containing `NULL`, as shown here:

```
mysql> CREATE TABLE ts2 (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
    -> )
    -> PARTITION BY LIST(c1) (
    ->     PARTITION p0 VALUES IN (0, 3, 6),
    ->     PARTITION p1 VALUES IN (1, 4, 7),
    ->     PARTITION p2 VALUES IN (2, 5, 8),
    ->     PARTITION p3 VALUES IN (NULL)
    -> );
Query OK, 0 rows affected (0.01 sec)

mysql> CREATE TABLE ts3 (
    ->     c1 INT,
    ->     c2 VARCHAR(20)
    -> )
    -> PARTITION BY LIST(c1) (
    ->     PARTITION p0 VALUES IN (0, 3, 6),
    ->     PARTITION p1 VALUES IN (1, 4, 7, NULL),
    ->     PARTITION p2 VALUES IN (2, 5, 8)
    -> );
Query OK, 0 rows affected (0.01 sec)
```

When defining value lists for partitioning, you can (and should) treat `NULL` just as you would any other value. For example, both `VALUES IN (NULL)` and `VALUES IN (1, 4, 7, NULL)` are valid, as are `VALUES IN (1, NULL, 4, 7)`, `VALUES IN (NULL, 1, 4, 7)`, and so on. You can insert a row having `NULL` for column `c1` into each of the tables `ts2` and `ts3`:

```
mysql> INSERT INTO ts2 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)

mysql> INSERT INTO ts3 VALUES (NULL, 'mothra');
Query OK, 1 row affected (0.00 sec)
```

By issuing the appropriate query against `INFORMATION_SCHEMA.PARTITIONS`, you can determine which partitions were used to store the rows just inserted (we assume, as in the previous examples, that the partitioned tables were created in the `p` database):

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
     >   FROM INFORMATION_SCHEMA.PARTITIONS
     >   WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME LIKE 'ts_';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
+------------+----------------+------------+----------------+-------------+
| ts2        | p0             |          0 |              0 |           0 |
| ts2        | p1             |          0 |              0 |           0 |
| ts2        | p2             |          0 |              0 |           0 |
| ts2        | p3             |          1 |             20 |          20 |
| ts3        | p0             |          0 |              0 |           0 |
| ts3        | p1             |          1 |             20 |          20 |
| ts3        | p2             |          0 |              0 |           0 |
+------------+----------------+------------+----------------+-------------+
7 rows in set (0.01 sec)
```

As shown earlier in this section, you can also verify which partitions were used for storing the rows by deleting these partitions and then performing a `SELECT`.

Handling of NULL with HASH and KEY partitioning. `NULL` is handled somewhat differently for tables partitioned by `HASH` or `KEY`. In these cases, any partition expression that yields a `NULL` value is treated as though its return value were zero. We can verify this behavior by examining the effects on the file system of creating a table partitioned by `HASH` and populating it with a record containing appropriate values. Suppose that you have a table `th` (also in the `p` database) created using the following statement:

```
mysql> CREATE TABLE th (
```

```
    ->     c1 INT,
    ->     c2 VARCHAR(20)
    -> )
    -> PARTITION BY HASH(c1)
    -> PARTITIONS 2;
Query OK, 0 rows affected (0.00 sec)
```

The partitions belonging to this table can be viewed using the query shown here:

```
mysql> SELECT TABLE_NAME,PARTITION_NAME,TABLE_ROWS,AVG_ROW_LENGTH,DATA_LENGTH
     >   FROM INFORMATION_SCHEMA.PARTITIONS
     >   WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME ='th';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
+------------+----------------+------------+----------------+-------------+
| th         | p0             |          0 |              0 |           0 |
| th         | p1             |          0 |              0 |           0 |
+------------+----------------+------------+----------------+-------------+
2 rows in set (0.00 sec)
```

`TABLE_ROWS` for each partition is 0. Now insert two rows into `th` whose `c1` column values are `NULL` and 0, and verify that these rows were inserted, as shown here:

```
mysql> INSERT INTO th VALUES (NULL, 'mothra'), (0, 'gigan');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM th;
+------+---------+
| c1   | c2      |
+------+---------+
| NULL | mothra  |
+------+---------+
|    0 | gigan   |
+------+---------+
2 rows in set (0.01 sec)
```

Recall that for any integer *`N`*, the value of `NULL MOD N` is always `NULL`. For tables that are partitioned by `HASH` or `KEY`, this result is treated for determining the correct partition as `0`. Checking the `INFORMATION_SCHEMA.PARTITIONS` table once again, we can see that both rows were inserted into partition `p0`:

```
mysql> SELECT TABLE_NAME, PARTITION_NAME, TABLE_ROWS, AVG_ROW_LENGTH, DATA_LENGTH
     >   FROM INFORMATION_SCHEMA.PARTITIONS
     >   WHERE TABLE_SCHEMA = 'p' AND TABLE_NAME ='th';
+------------+----------------+------------+----------------+-------------+
| TABLE_NAME | PARTITION_NAME | TABLE_ROWS | AVG_ROW_LENGTH | DATA_LENGTH |
+------------+----------------+------------+----------------+-------------+
| th         | p0             |          2 |             20 |          20 |
| th         | p1             |          0 |              0 |           0 |
+------------+----------------+------------+----------------+-------------+
2 rows in set (0.00 sec)
```

If you repeat this example using `PARTITION BY KEY` in place of `PARTITION BY HASH` in the definition of the table, you can verify easily that `NULL` is also treated like 0 for this type of partitioning.

19.3 Partition Management

MySQL 5.5 provides a number of ways to modify partitioned tables. It is possible to add, drop, redefine, merge, or split existing partitions. All of these actions can be carried out using the partitioning extensions to the `ALTER TABLE` statement. There are also ways to obtain information about partitioned tables and partitions. We discuss these topics in the sections that follow.

- For information about partition management in tables partitioned by `RANGE` or `LIST`, see Section 19.3.1, “Management of RANGE and LIST Partitions”.

- For a discussion of managing HASH and KEY partitions, see Section 19.3.2, “Management of HASH and KEY Partitions”.
- See Section 19.3.4, “Obtaining Information About Partitions”, for a discussion of mechanisms provided in MySQL 5.5 for obtaining information about partitioned tables and partitions.
- For a discussion of performing maintenance operations on partitions, see Section 19.3.3, “Maintenance of Partitions”.

Note

In MySQL 5.5, all partitions of a partitioned table must have the same number of subpartitions, and it is not possible to change the subpartitioning once the table has been created.

To change a table's partitioning scheme, it is necessary only to use the ALTER TABLE statement with a *partition_options* clause. This clause has the same syntax as that as used with CREATE TABLE for creating a partitioned table, and always begins with the keywords PARTITION BY. Suppose that you have a table partitioned by range using the following CREATE TABLE statement:

```
CREATE TABLE trb3 (id INT, name VARCHAR(50), purchased DATE)
    PARTITION BY RANGE( YEAR(purchased) ) (
        PARTITION p0 VALUES LESS THAN (1990),
        PARTITION p1 VALUES LESS THAN (1995),
        PARTITION p2 VALUES LESS THAN (2000),
        PARTITION p3 VALUES LESS THAN (2005)
    );
```

To repartition this table so that it is partitioned by key into two partitions using the id column value as the basis for the key, you can use this statement:

```
ALTER TABLE trb3 PARTITION BY KEY(id) PARTITIONS 2;
```

This has the same effect on the structure of the table as dropping the table and re-creating it using CREATE TABLE trb3 PARTITION BY KEY(id) PARTITIONS 2;.

ALTER TABLE ... ENGINE = ... changes only the storage engine used by the table, and leaves the table's partitioning scheme intact. Use ALTER TABLE ... REMOVE PARTITIONING to remove a table's partitioning. See Section 13.1.7, “ALTER TABLE Syntax”.

Important

Only a single PARTITION BY, ADD PARTITION, DROP PARTITION, REORGANIZE PARTITION, or COALESCE PARTITION clause can be used in a given ALTER TABLE statement. If you (for example) wish to drop a partition and reorganize a table's remaining partitions, you must do so in two separate ALTER TABLE statements (one using DROP PARTITION and then a second one using REORGANIZE PARTITION).

Beginning with MySQL 5.5.0, it is possible to delete all rows from one or more selected partitions using ALTER TABLE ... TRUNCATE PARTITION.

19.3.1 Management of RANGE and LIST Partitions

Adding and dropping of range and list partitions are handled in a similar fashion, so we discuss the management of both sorts of partitioning in this section. For information about working with tables that are partitioned by hash or key, see Section 19.3.2, “Management of HASH and KEY Partitions”.

Dropping a partition from a table that is partitioned by either RANGE or by LIST can be accomplished using the ALTER TABLE statement with the DROP PARTITION option. Suppose that you have created a table that is partitioned by range and then populated with 10 records using the following CREATE TABLE and INSERT statements:

```
mysql> CREATE TABLE tr (id INT, name VARCHAR(50), purchased DATE)
    ->     PARTITION BY RANGE( YEAR(purchased) ) (
    ->         PARTITION p0 VALUES LESS THAN (1990),
    ->         PARTITION p1 VALUES LESS THAN (1995),
    ->         PARTITION p2 VALUES LESS THAN (2000),
    ->         PARTITION p3 VALUES LESS THAN (2005),
    ->         PARTITION p4 VALUES LESS THAN (2010),
    ->         PARTITION p5 VALUES LESS THAN (2015)
    ->     );
Query OK, 0 rows affected (0.28 sec)

mysql> INSERT INTO tr VALUES
    ->     (1, 'desk organiser', '2003-10-15'),
    ->     (2, 'alarm clock', '1997-11-05'),
    ->     (3, 'chair', '2009-03-10'),
    ->     (4, 'bookcase', '1989-01-10'),
    ->     (5, 'exercise bike', '2014-05-09'),
    ->     (6, 'sofa', '1987-06-05'),
    ->     (7, 'espresso maker', '2011-11-22'),
    ->     (8, 'aquarium', '1992-08-04'),
    ->     (9, 'study desk', '2006-09-16'),
    ->     (10, 'lava lamp', '1998-12-25');
Query OK, 10 rows affected (0.05 sec)
Records: 10  Duplicates: 0  Warnings: 0
```

You can see which items should have been inserted into partition `p2` as shown here:

```
mysql> SELECT * FROM tr
    ->     WHERE purchased BETWEEN '1995-01-01' AND '1999-12-31';
+------+-------------+------------+
| id   | name        | purchased  |
+------+-------------+------------+
|    2 | alarm clock | 1997-11-05 |
|   10 | lava lamp   | 1998-12-25 |
+------+-------------+------------+
2 rows in set (0.00 sec)
```

To drop the partition named `p2`, execute the following command:

```
mysql> ALTER TABLE tr DROP PARTITION p2;
Query OK, 0 rows affected (0.03 sec)
```

Note

The `NDBCLUSTER` storage engine does not support `ALTER TABLE ... DROP PARTITION`. It does, however, support the other partitioning-related extensions to `ALTER TABLE` that are described in this chapter.

It is very important to remember that, *when you drop a partition, you also delete all the data that was stored in that partition*. You can see that this is the case by re-running the previous `SELECT` query:

```
mysql> SELECT * FROM tr WHERE purchased
    -> BETWEEN '1995-01-01' AND '1999-12-31';
Empty set (0.00 sec)
```

Because of this, you must have the `DROP` privilege for a table before you can execute `ALTER TABLE ... DROP PARTITION` on that table.

If you wish to drop all data from all partitions while preserving the table definition and its partitioning scheme, use the `TRUNCATE TABLE` statement. (See Section 13.1.33, “TRUNCATE TABLE Syntax”.)

If you intend to change the partitioning of a table *without* losing data, use `ALTER TABLE ... REORGANIZE PARTITION` instead. See below or in Section 13.1.7, “ALTER TABLE Syntax”, for information about `REORGANIZE PARTITION`.

If you now execute a `SHOW CREATE TABLE` statement, you can see how the partitioning makeup of the table has been changed:

```
mysql> SHOW CREATE TABLE tr\G
*************************** 1. row ***************************
       Table: tr
Create Table: CREATE TABLE `tr` (
  `id` int(11) DEFAULT NULL,
  `name` varchar(50) DEFAULT NULL,
  `purchased` date DEFAULT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1
/*!50100 PARTITION BY RANGE ( YEAR(purchased))
(PARTITION p0 VALUES LESS THAN (1990) ENGINE = InnoDB,
 PARTITION p1 VALUES LESS THAN (1995) ENGINE = InnoDB,
 PARTITION p3 VALUES LESS THAN (2005) ENGINE = InnoDB,
 PARTITION p4 VALUES LESS THAN (2010) ENGINE = InnoDB,
 PARTITION p5 VALUES LESS THAN (2015) ENGINE = InnoDB) */
1 row in set (0.00 sec)
```

When you insert new rows into the changed table with `purchased` column values between `'1995-01-01'` and `'2004-12-31'` inclusive, those rows will be stored in partition `p3`. You can verify this as follows:

```
mysql> INSERT INTO tr VALUES (11, 'pencil holder', '1995-07-12');
Query OK, 1 row affected (0.00 sec)

mysql> SELECT * FROM tr WHERE purchased
    -> BETWEEN '1995-01-01' AND '2004-12-31';
+------+----------------+------------+
| id   | name           | purchased  |
+------+----------------+------------+
|    1 | desk organiser | 2003-10-15 |
|   11 | pencil holder  | 1995-07-12 |
+------+----------------+------------+
2 rows in set (0.00 sec)

mysql> ALTER TABLE tr DROP PARTITION p3;
Query OK, 0 rows affected (0.03 sec)

mysql> SELECT * FROM tr WHERE purchased
    -> BETWEEN '1995-01-01' AND '2004-12-31';
Empty set (0.00 sec)
```

The number of rows dropped from the table as a result of `ALTER TABLE ... DROP PARTITION` is not reported by the server as it would be by the equivalent `DELETE` query.

Dropping `LIST` partitions uses exactly the same `ALTER TABLE ... DROP PARTITION` syntax as used for dropping `RANGE` partitions. However, there is one important difference in the effect this has on your use of the table afterward: You can no longer insert into the table any rows having any of the values that were included in the value list defining the deleted partition. (See Section 19.2.2, “LIST Partitioning”, for an example.)

To add a new range or list partition to a previously partitioned table, use the `ALTER TABLE ... ADD PARTITION` statement. For tables which are partitioned by `RANGE`, this can be used to add a new range to the end of the list of existing partitions. Suppose that you have a partitioned table containing membership data for your organization, which is defined as follows:

```
CREATE TABLE members (
    id INT,
    fname VARCHAR(25),
    lname VARCHAR(25),
    dob DATE
)
PARTITION BY RANGE( YEAR(dob) ) (
    PARTITION p0 VALUES LESS THAN (1980),
```

```
    PARTITION p1 VALUES LESS THAN (1990),
    PARTITION p2 VALUES LESS THAN (2000)
);
```

Suppose further that the minimum age for members is 16. As the calendar approaches the end of 2015, you realize that you will soon be admitting members who were born in 2000 (and later). You can modify the `members` table to accommodate new members born in the years 2000 to 2010 as shown here:

```
ALTER TABLE members ADD PARTITION (PARTITION p3 VALUES LESS THAN (2010));
```

With tables that are partitioned by range, you can use `ADD PARTITION` to add new partitions to the high end of the partitions list only. Trying to add a new partition in this manner between or before existing partitions results in an error as shown here:

```
mysql> ALTER TABLE members
    >     ADD PARTITION (
    >     PARTITION n VALUES LESS THAN (1970));
ERROR 1463 (HY000): VALUES LESS THAN value must be strictly »
   increasing for each partition
```

You can work around this problem by reorganizing the first partition into two new ones that split the range between them, like this:

```
ALTER TABLE members
    REORGANIZE PARTITION p0 INTO (
        PARTITION n0 VALUES LESS THAN (1970),
        PARTITION n1 VALUES LESS THAN (1980)
);
```

Using `SHOW CREATE TABLE` you can see that the `ALTER TABLE` statement has had the desired effect:

```
mysql> SHOW CREATE TABLE members\G
*************************** 1. row ***************************
       Table: members
Create Table: CREATE TABLE `members` (
  `id` int(11) DEFAULT NULL,
  `fname` varchar(25) DEFAULT NULL,
  `lname` varchar(25) DEFAULT NULL,
  `dob` date DEFAULT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1
/*!50100 PARTITION BY RANGE ( YEAR(dob))
(PARTITION n0 VALUES LESS THAN (1970) ENGINE = InnoDB,
 PARTITION n1 VALUES LESS THAN (1980) ENGINE = InnoDB,
 PARTITION p1 VALUES LESS THAN (1990) ENGINE = InnoDB,
 PARTITION p2 VALUES LESS THAN (2000) ENGINE = InnoDB,
 PARTITION p3 VALUES LESS THAN (2010) ENGINE = InnoDB) */
1 row in set (0.00 sec)
```

See also Section 13.1.7.1, “ALTER TABLE Partition Operations”.

You can also use `ALTER TABLE ... ADD PARTITION` to add new partitions to a table that is partitioned by `LIST`. Suppose a table `tt` is defined using the following `CREATE TABLE` statement:

```
CREATE TABLE tt (
    id INT,
    data INT
)
PARTITION BY LIST(data) (
    PARTITION p0 VALUES IN (5, 10, 15),
    PARTITION p1 VALUES IN (6, 12, 18)
);
```

You can add a new partition in which to store rows having the `data` column values `7`, `14`, and `21` as shown:

```
ALTER TABLE tt ADD PARTITION (PARTITION p2 VALUES IN (7, 14, 21));
```

Keep in mind that you *cannot* add a new `LIST` partition encompassing any values that are already included in the value list of an existing partition. If you attempt to do so, an error will result:

```
mysql> ALTER TABLE tt ADD PARTITION
    >     (PARTITION np VALUES IN (4, 8, 12));
ERROR 1465 (HY000): Multiple definition of same constant »
                    in list partitioning
```

Because any rows with the `data` column value `12` have already been assigned to partition `p1`, you cannot create a new partition on table `tt` that includes `12` in its value list. To accomplish this, you could drop `p1`, and add `np` and then a new `p1` with a modified definition. However, as discussed earlier, this would result in the loss of all data stored in `p1`—and it is often the case that this is not what you really want to do. Another solution might appear to be to make a copy of the table with the new partitioning and to copy the data into it using `CREATE TABLE ... SELECT ...`, then drop the old table and rename the new one, but this could be very time-consuming when dealing with a large amounts of data. This also might not be feasible in situations where high availability is a requirement.

You can add multiple partitions in a single `ALTER TABLE ... ADD PARTITION` statement as shown here:

```
CREATE TABLE employees (
  id INT NOT NULL,
  fname VARCHAR(50) NOT NULL,
  lname VARCHAR(50) NOT NULL,
  hired DATE NOT NULL
)
PARTITION BY RANGE( YEAR(hired) ) (
  PARTITION p1 VALUES LESS THAN (1991),
  PARTITION p2 VALUES LESS THAN (1996),
  PARTITION p3 VALUES LESS THAN (2001),
  PARTITION p4 VALUES LESS THAN (2005)
);

ALTER TABLE employees ADD PARTITION (
    PARTITION p5 VALUES LESS THAN (2010),
    PARTITION p6 VALUES LESS THAN MAXVALUE
);
```

Fortunately, MySQL's partitioning implementation provides ways to redefine partitions without losing data. Let us look first at a couple of simple examples involving `RANGE` partitioning. Recall the `members` table which is now defined as shown here:

```
mysql> SHOW CREATE TABLE members\G
*************************** 1. row ***************************
       Table: members
Create Table: CREATE TABLE `members` (
  `id` int(11) DEFAULT NULL,
  `fname` varchar(25) DEFAULT NULL,
  `lname` varchar(25) DEFAULT NULL,
  `dob` date DEFAULT NULL
) ENGINE=InnoDB DEFAULT CHARSET=latin1
/*!50100 PARTITION BY RANGE ( YEAR(dob))
(PARTITION n0 VALUES LESS THAN (1970) ENGINE = InnoDB,
 PARTITION n1 VALUES LESS THAN (1980) ENGINE = InnoDB,
 PARTITION p1 VALUES LESS THAN (1990) ENGINE = InnoDB,
 PARTITION p2 VALUES LESS THAN (2000) ENGINE = InnoDB,
 PARTITION p3 VALUES LESS THAN (2010) ENGINE = InnoDB) */
1 row in set (0.00 sec)
```

Suppose that you would like to move all rows representing members born before 1960 into a separate partition. As we have already seen, this cannot be done using `ALTER TABLE ... ADD PARTITION`. However, you can use another partition-related extension to `ALTER TABLE` to accomplish this:

```
ALTER TABLE members REORGANIZE PARTITION n0 INTO (
    PARTITION s0 VALUES LESS THAN (1960),
    PARTITION s1 VALUES LESS THAN (1970)
);
```

In effect, this command splits partition `p0` into two new partitions `s0` and `s1`. It also moves the data that was stored in `p0` into the new partitions according to the rules embodied in the two `PARTITION ... VALUES ...` clauses, so that `s0` contains only those records for which `YEAR(dob)` is less than 1960 and `s1` contains those rows in which `YEAR(dob)` is greater than or equal to 1960 but less than 1970.

A `REORGANIZE PARTITION` clause may also be used for merging adjacent partitions. You can reverse the effect of the previous statement on the `members` table as shown here:

```
ALTER TABLE members REORGANIZE PARTITION s0,s1 INTO (
    PARTITION p0 VALUES LESS THAN (1970)
);
```

No data is lost in splitting or merging partitions using `REORGANIZE PARTITION`. In executing the above statement, MySQL moves all of the records that were stored in partitions `s0` and `s1` into partition `p0`.

The general syntax for `REORGANIZE PARTITION` is shown here:

```
ALTER TABLE tbl_name
    REORGANIZE PARTITION partition_list
    INTO (partition_definitions);
```

Here, *`tbl_name`* is the name of the partitioned table, and *`partition_list`* is a comma-separated list of names of one or more existing partitions to be changed. *`partition_definitions`* is a comma-separated list of new partition definitions, which follow the same rules as for the *`partition_definitions`* list used in `CREATE TABLE`. You are not limited to merging several partitions into one, or to splitting one partition into many, when using `REORGANIZE PARTITION`. For example, you can reorganize all four partitions of the `members` table into two, like this:

```
ALTER TABLE members REORGANIZE PARTITION p0,p1,p2,p3 INTO (
    PARTITION m0 VALUES LESS THAN (1980),
    PARTITION m1 VALUES LESS THAN (2000)
);
```

You can also use `REORGANIZE PARTITION` with tables that are partitioned by `LIST`. Let us return to the problem of adding a new partition to the list-partitioned `tt` table and failing because the new partition had a value that was already present in the value-list of one of the existing partitions. We can handle this by adding a partition that contains only nonconflicting values, and then reorganizing the new partition and the existing one so that the value which was stored in the existing one is now moved to the new one:

```
ALTER TABLE tt ADD PARTITION (PARTITION np VALUES IN (4, 8));
ALTER TABLE tt REORGANIZE PARTITION p1,np INTO (
    PARTITION p1 VALUES IN (6, 18),
    PARTITION np VALUES in (4, 8, 12)
);
```

Here are some key points to keep in mind when using `ALTER TABLE ... REORGANIZE PARTITION` to repartition tables that are partitioned by `RANGE` or `LIST`:

- The `PARTITION` options used to determine the new partitioning scheme are subject to the same rules as those used with a `CREATE TABLE` statement.

A new RANGE partitioning scheme cannot have any overlapping ranges; a new LIST partitioning scheme cannot have any overlapping sets of values.

- The combination of partitions in the *partition_definitions* list should account for the same range or set of values overall as the combined partitions named in the *partition_list*.

  For example, partitions p1 and p2 together cover the years 1980 through 1999 in the members table used as an example in this section. Any reorganization of these two partitions should cover the same range of years overall.

- For tables partitioned by RANGE, you can reorganize only adjacent partitions; you cannot skip over range partitions.

  For instance, you could not reorganize the example members table using a statement beginning with ALTER TABLE members REORGANIZE PARTITION p0,p2 INTO ... because p0 covers the years prior to 1970 and p2 the years from 1990 through 1999 inclusive, so these are not adjacent partitions. (You cannot skip partition p1 in this case.)

- You cannot use REORGANIZE PARTITION to change the type of partitioning used by the table; for example, you cannot change RANGE partitions to HASH partitions or the reverse. You also cannot use this statement to change the partitioning expression or column. To accomplish either of these tasks without dropping and re-creating the table, you can use ALTER TABLE ... PARTITION BY ..., as shown here:

```
ALTER TABLE members
    PARTITION BY HASH( YEAR(dob) )
    PARTITIONS 8;
```

19.3.2 Management of HASH and KEY Partitions

Tables which are partitioned by hash or by key are very similar to one another with regard to making changes in a partitioning setup, and both differ in a number of ways from tables which have been partitioned by range or list. For that reason, this section addresses the modification of tables partitioned by hash or by key only. For a discussion of adding and dropping of partitions of tables that are partitioned by range or list, see Section 19.3.1, “Management of RANGE and LIST Partitions”.

You cannot drop partitions from tables that are partitioned by HASH or KEY in the same way that you can from tables that are partitioned by RANGE or LIST. However, you can merge HASH or KEY partitions using the ALTER TABLE ... COALESCE PARTITION statement. Suppose that you have a table containing data about clients, which is divided into twelve partitions. The clients table is defined as shown here:

```
CREATE TABLE clients (
    id INT,
    fname VARCHAR(30),
    lname VARCHAR(30),
    signed DATE
)
PARTITION BY HASH( MONTH(signed) )
PARTITIONS 12;
```

To reduce the number of partitions from twelve to eight, execute the following ALTER TABLE command:

```
mysql> ALTER TABLE clients COALESCE PARTITION 4;
Query OK, 0 rows affected (0.02 sec)
```

COALESCE works equally well with tables that are partitioned by HASH, KEY, LINEAR HASH, or LINEAR KEY. Here is an example similar to the previous one, differing only in that the table is partitioned by LINEAR KEY:

```
mysql> CREATE TABLE clients_lk (
    ->     id INT,
    ->     fname VARCHAR(30),
    ->     lname VARCHAR(30),
    ->     signed DATE
    -> )
    -> PARTITION BY LINEAR KEY(signed)
    -> PARTITIONS 12;
Query OK, 0 rows affected (0.03 sec)

mysql> ALTER TABLE clients_lk COALESCE PARTITION 4;
Query OK, 0 rows affected (0.06 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

The number following `COALESCE PARTITION` is the number of partitions to merge into the remainder —in other words, it is the number of partitions to remove from the table.

If you attempt to remove more partitions than the table has, the result is an error like the one shown:

```
mysql> ALTER TABLE clients COALESCE PARTITION 18;
ERROR 1478 (HY000): Cannot remove all partitions, use DROP TABLE instead
```

To increase the number of partitions for the `clients` table from 12 to 18. use `ALTER TABLE ... ADD PARTITION` as shown here:

```
ALTER TABLE clients ADD PARTITION PARTITIONS 6;
```

19.3.3 Maintenance of Partitions

A number of table and partition maintenance tasks can be carried out using SQL statements intended for such purposes on partitioned tables in MySQL 5.5.

Table maintenance of partitioned tables can be accomplished using the statements `CHECK TABLE`, `OPTIMIZE TABLE`, `ANALYZE TABLE`, and `REPAIR TABLE`, which are supported for partitioned tables.

You can use a number of extensions to `ALTER TABLE` for performing operations of this type on one or more partitions directly, as described in the following list:

- **Rebuilding partitions.** Rebuilds the partition; this has the same effect as dropping all records stored in the partition, then reinserting them. This can be useful for purposes of defragmentation.

  Example:

  ```
  ALTER TABLE t1 REBUILD PARTITION p0, p1;
  ```

- **Optimizing partitions.** If you have deleted a large number of rows from a partition or if you have made many changes to a partitioned table with variable-length rows (that is, having `VARCHAR`, `BLOB`, or `TEXT` columns), you can use `ALTER TABLE ... OPTIMIZE PARTITION` to reclaim any unused space and to defragment the partition data file.

  Example:

  ```
  ALTER TABLE t1 OPTIMIZE PARTITION p0, p1;
  ```

  Using `OPTIMIZE PARTITION` on a given partition is equivalent to running `CHECK PARTITION`, `ANALYZE PARTITION`, and `REPAIR PARTITION` on that partition.

  Some MySQL storage engines, including `InnoDB`, do not support per-partition optimization; in these cases, `ALTER TABLE ... OPTIMIZE PARTITION` rebuilds the entire table. In MySQL 5.5.30 and later, running this statement on such a table causes the entire table to rebuilt and analyzed,

and an appropriate warning to be issued. (Bug #11751825, Bug #42822) Use `ALTER TABLE ... REBUILD PARTITION` and `ALTER TABLE ... ANALYZE PARTITION` instead, to avoid this issue.

- **Analyzing partitions.** This reads and stores the key distributions for partitions.

  Example:

  ```
  ALTER TABLE t1 ANALYZE PARTITION p3;
  ```

- **Repairing partitions.** This repairs corrupted partitions.

  Example:

  ```
  ALTER TABLE t1 REPAIR PARTITION p0,p1;
  ```

- **Checking partitions.** You can check partitions for errors in much the same way that you can use `CHECK TABLE` with nonpartitioned tables.

  Example:

  ```
  ALTER TABLE trb3 CHECK PARTITION p1;
  ```

  This command will tell you if the data or indexes in partition `p1` of table `t1` are corrupted. If this is the case, use `ALTER TABLE ... REPAIR PARTITION` to repair the partition.

Each of the statements in the list just shown also supports the keyword `ALL` in place of the list of partition names. Using `ALL` causes the statement to act on all partitions in the table.

The use of `mysqlcheck` and `myisamchk` is not supported with partitioned tables.

Beginning with MySQL 5.5.0, you can also truncate partitions using `ALTER TABLE ... TRUNCATE PARTITION`. This statement can be used to delete all rows from one or more partitions in much the same way that `TRUNCATE TABLE` deletes all rows from a table.

`ALTER TABLE ... TRUNCATE PARTITION ALL` truncates all partitions in the table.

`ANALYZE`, `CHECK`, `OPTIMIZE`, `REBUILD`, `REPAIR`, and `TRUNCATE` operations are not supported for subpartitions.

19.3.4 Obtaining Information About Partitions

This section discusses obtaining information about existing partitions, which can be done in a number of ways. Methods of obtaining such information include the following:

- Using the `SHOW CREATE TABLE` statement to view the partitioning clauses used in creating a partitioned table.
- Using the `SHOW TABLE STATUS` statement to determine whether a table is partitioned.
- Querying the `INFORMATION_SCHEMA.PARTITIONS` table.
- Using the statement `EXPLAIN PARTITIONS SELECT` to see which partitions are used by a given `SELECT`.

As discussed elsewhere in this chapter, `SHOW CREATE TABLE` includes in its output the `PARTITION BY` clause used to create a partitioned table. For example:

```
mysql> SHOW CREATE TABLE trb3\G
*************************** 1. row ***************************
       Table: trb3
```

```
Create Table: CREATE TABLE `trb3` (
  `id` int(11) default NULL,
  `name` varchar(50) default NULL,
  `purchased` date default NULL
) ENGINE=MyISAM DEFAULT CHARSET=latin1
PARTITION BY RANGE (YEAR(purchased)) (
  PARTITION p0 VALUES LESS THAN (1990) ENGINE = MyISAM,
  PARTITION p1 VALUES LESS THAN (1995) ENGINE = MyISAM,
  PARTITION p2 VALUES LESS THAN (2000) ENGINE = MyISAM,
  PARTITION p3 VALUES LESS THAN (2005) ENGINE = MyISAM
)
1 row in set (0.00 sec)
```

The output from `SHOW TABLE STATUS` for partitioned tables is the same as that for nonpartitioned tables, except that the `Create_options` column contains the string `partitioned`. The `Engine` column contains the name of the storage engine used by all partitions of the table. (See Section 13.7.5.37, “SHOW TABLE STATUS Syntax”, for more information about this statement.)

You can also obtain information about partitions from `INFORMATION_SCHEMA`, which contains a `PARTITIONS` table. See Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”.

It is possible to determine which partitions of a partitioned table are involved in a given `SELECT` query using `EXPLAIN PARTITIONS`. The `PARTITIONS` keyword adds a `partitions` column to the output of `EXPLAIN` listing the partitions from which records would be matched by the query.

Suppose that you have a table `trb1` created and populated as follows:

```
CREATE TABLE trb1 (id INT, name VARCHAR(50), purchased DATE)
    PARTITION BY RANGE(id)
    (
        PARTITION p0 VALUES LESS THAN (3),
        PARTITION p1 VALUES LESS THAN (7),
        PARTITION p2 VALUES LESS THAN (9),
        PARTITION p3 VALUES LESS THAN (11)
    );

INSERT INTO trb1 VALUES
    (1, 'desk organiser', '2003-10-15'),
    (2, 'CD player', '1993-11-05'),
    (3, 'TV set', '1996-03-10'),
    (4, 'bookcase', '1982-01-10'),
    (5, 'exercise bike', '2004-05-09'),
    (6, 'sofa', '1987-06-05'),
    (7, 'popcorn maker', '2001-11-22'),
    (8, 'aquarium', '1992-08-04'),
    (9, 'study desk', '1984-09-16'),
    (10, 'lava lamp', '1998-12-25');
```

You can see which partitions are used in a query such as `SELECT * FROM trb1;`, as shown here:

```
mysql> EXPLAIN PARTITIONS SELECT * FROM trb1\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: trb1
   partitions: p0,p1,p2,p3
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 10
        Extra: Using filesort
```

In this case, all four partitions are searched. However, when a limiting condition making use of the partitioning key is added to the query, you can see that only those partitions containing matching values are scanned, as shown here:

```
mysql> EXPLAIN PARTITIONS SELECT * FROM trb1 WHERE id < 5\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: trb1
   partitions: p0,p1
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 10
        Extra: Using where
```

`EXPLAIN PARTITIONS` provides information about keys used and possible keys, just as with the standard `EXPLAIN SELECT` statement:

```
mysql> ALTER TABLE trb1 ADD PRIMARY KEY (id);
Query OK, 10 rows affected (0.03 sec)
Records: 10  Duplicates: 0  Warnings: 0

mysql> EXPLAIN PARTITIONS SELECT * FROM trb1 WHERE id < 5\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: trb1
   partitions: p0,p1
         type: range
possible_keys: PRIMARY
          key: PRIMARY
      key_len: 4
          ref: NULL
         rows: 7
        Extra: Using where
```

You should take note of the following restrictions and limitations on `EXPLAIN PARTITIONS`:

- You cannot use the `PARTITIONS` and `EXTENDED` keywords together in the same `EXPLAIN ... SELECT` statement. Attempting to do so produces a syntax error.
- If `EXPLAIN PARTITIONS` is used to examine a query against a nonpartitioned table, no error is produced, but the value of the `partitions` column is always `NULL`.

The `rows` column of `EXPLAIN PARTITIONS` output displays the total number of rows in the table.

See also Section 13.8.2, “EXPLAIN Syntax”.

19.4 Partition Pruning

This section discusses an optimization known as *partition pruning*. The core concept behind partition pruning is relatively simple, and can be described as “Do not scan partitions where there can be no matching values”. Suppose that you have a partitioned table `t1` defined by this statement:

```
CREATE TABLE t1 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
)
PARTITION BY RANGE( region_code ) (
    PARTITION p0 VALUES LESS THAN (64),
    PARTITION p1 VALUES LESS THAN (128),
    PARTITION p2 VALUES LESS THAN (192),
    PARTITION p3 VALUES LESS THAN MAXVALUE
);
```

Consider the case where you wish to obtain results from a `SELECT` statement such as this one:

```
SELECT fname, lname, region_code, dob
    FROM t1
    WHERE region_code > 125 AND region_code < 130;
```

It is easy to see that none of the rows which ought to be returned will be in either of the partitions `p0` or `p3`; that is, we need to search only in partitions `p1` and `p2` to find matching rows. By doing so, it is possible to expend much less time and effort in finding matching rows than would be required to scan all partitions in the table. This “cutting away” of unneeded partitions is known as *pruning*. When the optimizer can make use of partition pruning in performing this query, execution of the query can be an order of magnitude faster than the same query against a nonpartitioned table containing the same column definitions and data.

Note

When pruning is performed on a partitioned `MyISAM` table, all partitions are opened, whether or not they are examined, due to the design of the `MyISAM` storage engine. This means that you must have a sufficient number of file descriptors available to cover all partitions of the table. See MyISAM and partition file descriptor usage.

This limitation does not apply to partitioned tables using other MySQL storage engines such as `InnoDB`.

The optimizer can perform pruning whenever a `WHERE` condition can be reduced to either one of the following two cases:

- *`partition_column = constant`*
- *`partition_column`* `IN (`*`constant1, constant2, ..., constantN`*`)`

In the first case, the optimizer simply evaluates the partitioning expression for the value given, determines which partition contains that value, and scans only this partition. In many cases, the equal sign can be replaced with another arithmetic comparison, including `<`, `>`, `<=`, `>=`, and `<>`. Some queries using `BETWEEN` in the `WHERE` clause can also take advantage of partition pruning. See the examples later in this section.

In the second case, the optimizer evaluates the partitioning expression for each value in the list, creates a list of matching partitions, and then scans only the partitions in this partition list.

MySQL 5.5 and later can apply partition pruning to `SELECT`, `DELETE`, and `UPDATE` statements. `INSERT` statements currently cannot be pruned.

Pruning can also be applied to short ranges, which the optimizer can convert into equivalent lists of values. For instance, in the previous example, the `WHERE` clause can be converted to `WHERE region_code IN (126, 127, 128, 129)`. Then the optimizer can determine that the first two values in the list are found in partition `p1`, the remaining two values in partition `p2`, and that the other partitions contain no relevant values and so do not need to be searched for matching rows.

Beginning with MySQL 5.5.0, the optimizer can also perform pruning for `WHERE` conditions that involve comparisons of the preceding types on multiple columns for tables that use `RANGE COLUMNS` or `LIST COLUMNS` partitioning.

This type of optimization can be applied whenever the partitioning expression consists of an equality or a range which can be reduced to a set of equalities, or when the partitioning expression represents an increasing or decreasing relationship. Pruning can also be applied for tables partitioned on a `DATE` or `DATETIME` column when the partitioning expression uses the `YEAR()` or `TO_DAYS()` function. In addition, in MySQL 5.5, pruning can be applied for such tables when the partitioning expression uses the `TO_SECONDS()` function.

Suppose that table `t2`, defined as shown here, is partitioned on a `DATE` column:

```
CREATE TABLE t2 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
)
PARTITION BY RANGE( YEAR(dob) ) (
    PARTITION d0 VALUES LESS THAN (1970),
    PARTITION d1 VALUES LESS THAN (1975),
    PARTITION d2 VALUES LESS THAN (1980),
    PARTITION d3 VALUES LESS THAN (1985),
    PARTITION d4 VALUES LESS THAN (1990),
    PARTITION d5 VALUES LESS THAN (2000),
    PARTITION d6 VALUES LESS THAN (2005),
    PARTITION d7 VALUES LESS THAN MAXVALUE
);
```

The following statements using `t2` can make of use partition pruning:

```
SELECT * FROM t2 WHERE dob = '1982-06-23';

UPDATE t2 SET region_code = 8 WHERE dob BETWEEN '1991-02-15' AND '1997-04-25';

DELETE FROM t2 WHERE dob >= '1984-06-21' AND dob <= '1999-06-21'
```

In the case of the last statement, the optimizer can also act as follows:

1. *Find the partition containing the low end of the range*.

   `YEAR('1984-06-21')` yields the value `1984`, which is found in partition `d3`.

2. *Find the partition containing the high end of the range*.

   `YEAR('1999-06-21')` evaluates to `1999`, which is found in partition `d5`.

3. *Scan only these two partitions and any partitions that may lie between them*.

   In this case, this means that only partitions `d3`, `d4`, and `d5` are scanned. The remaining partitions may be safely ignored (and are ignored).

Important

Invalid `DATE` and `DATETIME` values referenced in the `WHERE` condition of a statement against a partitioned table are treated as `NULL`. This means that a query such as `SELECT * FROM partitioned_table WHERE date_column < '2008-12-00'` does not return any values (see Bug #40972).

So far, we have looked only at examples using `RANGE` partitioning, but pruning can be applied with other partitioning types as well.

Consider a table that is partitioned by `LIST`, where the partitioning expression is increasing or decreasing, such as the table `t3` shown here. (In this example, we assume for the sake of brevity that the `region_code` column is limited to values between 1 and 10 inclusive.)

```
CREATE TABLE t3 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
)
PARTITION BY LIST(region_code) (
```

```
    PARTITION r0 VALUES IN (1, 3),
    PARTITION r1 VALUES IN (2, 5, 8),
    PARTITION r2 VALUES IN (4, 9),
    PARTITION r3 VALUES IN (6, 7, 10)
);
```

For a statement such as `SELECT * FROM t3 WHERE region_code BETWEEN 1 AND 3`, the optimizer determines in which partitions the values 1, 2, and 3 are found (`r0` and `r1`) and skips the remaining ones (`r2` and `r3`).

For tables that are partitioned by `HASH` or `[LINEAR] KEY`, partition pruning is also possible in cases in which the `WHERE` clause uses a simple `=` relation against a column used in the partitioning expression. Consider a table created like this:

```
CREATE TABLE t4 (
    fname VARCHAR(50) NOT NULL,
    lname VARCHAR(50) NOT NULL,
    region_code TINYINT UNSIGNED NOT NULL,
    dob DATE NOT NULL
)
PARTITION BY KEY(region_code)
PARTITIONS 8;
```

A statement that compares a column value with a constant can be pruned:

```
UPDATE t4 WHERE region_code = 7;
```

Pruning can also be employed for short ranges, because the optimizer can turn such conditions into `IN` relations. For example, using the same table `t4` as defined previously, queries such as these can be pruned:

```
SELECT * FROM t4 WHERE region_code > 2 AND region_code < 6;

SELECT * FROM t4 WHERE region_code BETWEEN 3 AND 5;
```

In both these cases, the `WHERE` clause is transformed by the optimizer into `WHERE region_code IN (3, 4, 5)`.

Important

This optimization is used only if the range size is smaller than the number of partitions. Consider this statement:

```
DELETE FROM t4 WHERE region_code BETWEEN 4 AND 12;
```

The range in the `WHERE` clause covers 9 values (4, 5, 6, 7, 8, 9, 10, 11, 12), but `t4` has only 8 partitions. This means that the `DELETE` cannot be pruned.

When a table is partitioned by `HASH` or `[LINEAR] KEY`, pruning can be used only on integer columns. For example, this statement cannot use pruning because `dob` is a `DATE` column:

```
SELECT * FROM t4 WHERE dob >= '2001-04-14' AND dob <= '2005-10-15';
```

However, if the table stores year values in an `INT` column, then a query having `WHERE year_col >= 2001 AND year_col <= 2005` can be pruned.

Note

In MySQL 5.1, a query against a table partitioned by `KEY` and having a composite partitioning key could be pruned only if the query's `WHERE` clause compared every column in the key to a constant. In MySQL 5.5, it is possible to

prune queries against such tables even if the `WHERE` clause does not reference every column in the partitioning key.

19.5 Restrictions and Limitations on Partitioning

This section discusses current restrictions and limitations on MySQL partitioning support.

Prohibited constructs. The following constructs are not permitted in partitioning expressions:

- Stored procedures, stored functions, UDFs, or plugins.
- Declared variables or user variables.

For a list of SQL functions which are permitted in partitioning expressions, see Section 19.5.3, "Partitioning Limitations Relating to Functions".

Arithmetic and logical operators. Use of the arithmetic operators `+`, `-`, and `*` is permitted in partitioning expressions. However, the result must be an integer value or `NULL` (except in the case of `[LINEAR] KEY` partitioning, as discussed elsewhere in this chapter; see Section 19.2, "Partitioning Types", for more information).

The `DIV` operator is also supported, and the `/` operator is not permitted. (Bug #30188, Bug #33182)

The bit operators `|`, `&`, `^`, `<<`, `>>`, and `~` are not permitted in partitioning expressions.

HANDLER statements. In MySQL 5.5, the `HANDLER` statement is not supported with partitioned tables.

Server SQL mode. Tables employing user-defined partitioning do not preserve the SQL mode in effect at the time that they were created. As discussed in Section 5.1.8, "Server SQL Modes", the results of many MySQL functions and operators may change according to the server SQL mode. Therefore, a change in the SQL mode at any time after the creation of partitioned tables may lead to major changes in the behavior of such tables, and could easily lead to corruption or loss of data. For these reasons, *it is strongly recommended that you never change the server SQL mode after creating partitioned tables*.

Examples. The following examples illustrate some changes in behavior of partitioned tables due to a change in the server SQL mode:

1. **Error handling.** Suppose that you create a partitioned table whose partitioning expression is one such as *`column`* `DIV 0` or *`column`* `MOD 0`, as shown here:

```
mysql> CREATE TABLE tn (c1 INT)
    ->     PARTITION BY LIST(1 DIV c1) (
    ->       PARTITION p0 VALUES IN (NULL),
    ->       PARTITION p1 VALUES IN (1)
    -> );
Query OK, 0 rows affected (0.05 sec)
```

   The default behavior for MySQL is to return `NULL` for the result of a division by zero, without producing any errors:

```
mysql> SELECT @@sql_mode;
+------------+
| @@sql_mode |
+------------+
|            |
+------------+
1 row in set (0.00 sec)


mysql> INSERT INTO tn VALUES (NULL), (0), (1);
Query OK, 3 rows affected (0.00 sec)
```

```
Records: 3  Duplicates: 0  Warnings: 0
```

However, changing the server SQL mode to treat division by zero as an error and to enforce strict error handling causes the same `INSERT` statement to fail, as shown here:

```
mysql> SET sql_mode='STRICT_ALL_TABLES,ERROR_FOR_DIVISION_BY_ZERO';
Query OK, 0 rows affected (0.00 sec)

mysql> INSERT INTO tn VALUES (NULL), (0), (1);
ERROR 1365 (22012): Division by 0
```

2. **Table accessibility.** Sometimes a change in the server SQL mode can make partitioned tables unusable. The following `CREATE TABLE` statement can be executed successfully only if the `NO_UNSIGNED_SUBTRACTION` mode is in effect:

```
mysql> SELECT @@sql_mode;
+------------+
| @@sql_mode |
+------------+
|            |
+------------+
1 row in set (0.00 sec)

mysql> CREATE TABLE tu (c1 BIGINT UNSIGNED)
    ->   PARTITION BY RANGE(c1 - 10) (
    ->     PARTITION p0 VALUES LESS THAN (-5),
    ->     PARTITION p1 VALUES LESS THAN (0),
    ->     PARTITION p2 VALUES LESS THAN (5),
    ->     PARTITION p3 VALUES LESS THAN (10),
    ->     PARTITION p4 VALUES LESS THAN (MAXVALUE)
    -> );
ERROR 1563 (HY000): Partition constant is out of partition function domain

mysql> SET sql_mode='NO_UNSIGNED_SUBTRACTION';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @@sql_mode;
+------------------------+
| @@sql_mode             |
+------------------------+
| NO_UNSIGNED_SUBTRACTION |
+------------------------+
1 row in set (0.00 sec)

mysql> CREATE TABLE tu (c1 BIGINT UNSIGNED)
    ->   PARTITION BY RANGE(c1 - 10) (
    ->     PARTITION p0 VALUES LESS THAN (-5),
    ->     PARTITION p1 VALUES LESS THAN (0),
    ->     PARTITION p2 VALUES LESS THAN (5),
    ->     PARTITION p3 VALUES LESS THAN (10),
    ->     PARTITION p4 VALUES LESS THAN (MAXVALUE)
    -> );
Query OK, 0 rows affected (0.05 sec)
```

If you remove the `NO_UNSIGNED_SUBTRACTION` server SQL mode after creating `tu`, you may no longer be able to access this table:

```
mysql> SET sql_mode='';
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT * FROM tu;
ERROR 1563 (HY000): Partition constant is out of partition function domain
mysql> INSERT INTO tu VALUES (20);
ERROR 1563 (HY000): Partition constant is out of partition function domain
```

Server SQL modes also impact replication of partitioned tables. Differing SQL modes on master and slave can lead to partitioning expressions being evaluated differently; this can cause the distribution of

data among partitions to be different in the master's and slave's copies of a given table, and may even cause inserts into partitioned tables that succeed on the master to fail on the slave. For best results, you should always use the same server SQL mode on the master and on the slave.

Performance considerations. Some effects of partitioning operations on performance are given in the following list:

- **File system operations.** Partitioning and repartitioning operations (such as `ALTER TABLE` with `PARTITION BY ...`, `REORGANIZE PARTITION`, or `REMOVE PARTITIONING`) depend on file system operations for their implementation. This means that the speed of these operations is affected by such factors as file system type and characteristics, disk speed, swap space, file handling efficiency of the operating system, and MySQL server options and variables that relate to file handling. In particular, you should make sure that `large_files_support` is enabled and that `open_files_limit` is set properly. For partitioned tables using the `MyISAM` storage engine, increasing `myisam_max_sort_file_size` may improve performance; partitioning and repartitioning operations involving `InnoDB` tables may be made more efficient by enabling `innodb_file_per_table`.

  See also Maximum number of partitions.

- **MyISAM and partition file descriptor usage.** For a partitioned `MyISAM` table, MySQL uses 2 file descriptors for each partition, for each such table that is open. This means that you need many more file descriptors to perform operations on a partitioned `MyISAM` table than on a table which is identical to it except that the latter table is not partitioned, particularly when performing `ALTER TABLE` operations.

  Assume a `MyISAM` table `t` with 100 partitions, such as the table created by this SQL statement:

  ```
  CREATE TABLE t (c1 VARCHAR(50))
  PARTITION BY KEY (c1) PARTITIONS 100
  ENGINE=MYISAM;
  ```

  Note

  For brevity, we use `KEY` partitioning for the table shown in this example, but file descriptor usage as described here applies to all partitioned `MyISAM` tables, regardless of the type of partitioning that is employed. Partitioned tables using other storage engines such as `InnoDB` are not affected by this issue.

  Now assume that you wish to repartition `t` so that it has 101 partitions, using the statement shown here:

  ```
  ALTER TABLE t PARTITION BY KEY (c1) PARTITIONS 101;
  ```

  To process this `ALTER TABLE` statement, MySQL uses 402 file descriptors—that is, two for each of the 100 original partitions, plus two for each of the 101 new partitions. This is because all partitions (old and new) must be opened concurrently during the reorganization of the table data. It is recommended that, if you expect to perform such operations, you should make sure that `--open-files-limit` is not set too low to accommodate them.

- **Table locks.** The process executing a partitioning operation on a table takes a write lock on the table. Reads from such tables are relatively unaffected; pending `INSERT` and `UPDATE` operations are performed as soon as the partitioning operation has completed.

- **Storage engine.** Partitioning operations, queries, and update operations generally tend to be faster with `MyISAM` tables than with `InnoDB` or `NDB` tables.

- **Indexes; partition pruning.** As with nonpartitioned tables, proper use of indexes can speed up queries on partitioned tables significantly. In addition, designing partitioned tables and statements

using these tables to take advantage of *partition pruning* can improve performance dramatically. See Section 19.4, “Partition Pruning”, for more information.

- **Performance with LOAD DATA.** In MySQL 5.5, `LOAD DATA` uses buffering to improve performance. You should be aware that the buffer uses 130 KB memory per partition to achieve this.

Maximum number of partitions.
The maximum possible number of partitions for a given table (that does not use the `NDB` storage engine) is 1024. This number includes subpartitions.

The maximum possible number of user-defined partitions for a table using the `NDBCLUSTER` storage engine is determined according to the version of the NDB Cluster software being used, the number of data nodes, and other factors. See NDB and user-defined partitioning, for more information.

If, when creating tables with a large number of partitions (but less than the maximum), you encounter an error message such as `Got error ... from storage engine: Out of resources when opening file`, you may be able to address the issue by increasing the value of the `open_files_limit` system variable. However, this is dependent on the operating system, and may not be possible or advisable on all platforms; see Section B.5.2.18, “File Not Found and Similar Errors”, for more information. In some cases, using large numbers (hundreds) of partitions may also not be advisable due to other concerns, so using more partitions does not automatically lead to better results.

See also File system operations.

Query cache not supported.
The query cache is not supported for partitioned tables. Beginning with MySQL 5.5.23, the query cache is automatically disabled for queries involving partitioned tables, and cannot be enabled for such queries. (Bug #53775)

Per-partition key caches.
In MySQL 5.5, key caches are supported for partitioned `MyISAM` tables, using the `CACHE INDEX` and `LOAD INDEX INTO CACHE` statements. Key caches may be defined for one, several, or all partitions, and indexes for one, several, or all partitions may be preloaded into key caches.

Foreign keys not supported for partitioned InnoDB tables.
Partitioned tables using the `InnoDB` storage engine do not support foreign keys. More specifically, this means that the following two statements are true:

1. No definition of an `InnoDB` table employing user-defined partitioning may contain foreign key references; no `InnoDB` table whose definition contains foreign key references may be partitioned.

2. No `InnoDB` table definition may contain a foreign key reference to a user-partitioned table; no `InnoDB` table with user-defined partitioning may contain columns referenced by foreign keys.

The scope of the restrictions just listed includes all tables that use the `InnoDB` storage engine. `CREATE TABLE` and `ALTER TABLE` statements that would result in tables violating these restrictions are not allowed.

ALTER TABLE ... ORDER BY. An `ALTER TABLE ... ORDER BY *column*` statement run against a partitioned table causes ordering of rows only within each partition.

Effects on REPLACE statements by modification of primary keys. It can be desirable in some cases (see Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”) to modify a table's primary key. Be aware that, if your application uses `REPLACE` statements and you do this, the results of these statements can be drastically altered. See Section 13.2.8, “REPLACE Syntax”, for more information and an example.

FULLTEXT indexes.
Partitioned tables do not support `FULLTEXT` indexes or searches. This includes partitioned tables employing the `MyISAM` storage engine.

Spatial columns. Columns with spatial data types such as `POINT` or `GEOMETRY` cannot be used in partitioned tables.

Temporary tables.
Temporary tables cannot be partitioned. (Bug #17497)

Log tables. It is not possible to partition the log tables; an `ALTER TABLE ... PARTITION BY ...` statement on such a table fails with an error.

Data type of partitioning key.
A partitioning key must be either an integer column or an expression that resolves to an integer. Expressions employing `ENUM` columns cannot be used. The column or expression value may also be `NULL`. (See Section 19.2.7, “How MySQL Partitioning Handles NULL”.)

There are two exceptions to this restriction:

1. When partitioning by `[LINEAR] KEY`, it is possible to use columns of any valid MySQL data type other than `TEXT` or `BLOB` as partitioning keys, because MySQL's internal key-hashing functions produce the correct data type from these types. For example, the following two `CREATE TABLE` statements are valid:

```
CREATE TABLE tkc (c1 CHAR)
PARTITION BY KEY(c1)
PARTITIONS 4;

CREATE TABLE tke
    ( c1 ENUM('red', 'orange', 'yellow', 'green', 'blue', 'indigo', 'violet') )
PARTITION BY LINEAR KEY(c1)
PARTITIONS 6;
```

2. When partitioning by `RANGE COLUMNS` or `LIST COLUMNS`, it is possible to use string, `DATE`, and `DATETIME` columns. For example, each of the following `CREATE TABLE` statements is valid:

```
CREATE TABLE rc (c1 INT, c2 DATE)
PARTITION BY RANGE COLUMNS(c2) (
    PARTITION p0 VALUES LESS THAN('1990-01-01'),
    PARTITION p1 VALUES LESS THAN('1995-01-01'),
    PARTITION p2 VALUES LESS THAN('2000-01-01'),
    PARTITION p3 VALUES LESS THAN('2005-01-01'),
    PARTITION p4 VALUES LESS THAN(MAXVALUE)
);

CREATE TABLE lc (c1 INT, c2 CHAR(1))
PARTITION BY LIST COLUMNS(c2) (
    PARTITION p0 VALUES IN('a', 'd', 'g', 'j', 'm', 'p', 's', 'v', 'y'),
    PARTITION p1 VALUES IN('b', 'e', 'h', 'k', 'n', 'q', 't', 'w', 'z'),
    PARTITION p2 VALUES IN('c', 'f', 'i', 'l', 'o', 'r', 'u', 'x', NULL)
);
```

Neither of the preceding exceptions applies to `BLOB` or `TEXT` column types.

Subqueries.
A partitioning key may not be a subquery, even if that subquery resolves to an integer value or `NULL`.

Issues with subpartitions.
Subpartitions must use `HASH` or `KEY` partitioning. Only `RANGE` and `LIST` partitions may be subpartitioned; `HASH` and `KEY` partitions cannot be subpartitioned.

`SUBPARTITION BY KEY` requires that the subpartitioning column or columns be specified explicitly, unlike the case with `PARTITION BY KEY`, where it can be omitted (in which case the table's primary key column is used by default). Consider the table created by this statement:

```
CREATE TABLE ts (
```

```
    id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    name VARCHAR(30)
);
```

You can create a table having the same columns, partitioned by KEY, using a statement such as this one:

```
CREATE TABLE ts (
    id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    name VARCHAR(30)
)
PARTITION BY KEY()
PARTITIONS 4;
```

The previous statement is treated as though it had been written like this, with the table's primary key column used as the partitioning column:

```
CREATE TABLE ts (
    id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    name VARCHAR(30)
)
PARTITION BY KEY(id)
PARTITIONS 4;
```

However, the following statement that attempts to create a subpartitioned table using the default column as the subpartitioning column fails, and the column must be specified for the statement to succeed, as shown here:

```
mysql> CREATE TABLE ts (
    ->     id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    ->     name VARCHAR(30)
    -> )
    -> PARTITION BY RANGE(id)
    -> SUBPARTITION BY KEY()
    -> SUBPARTITIONS 4
    -> (
    ->     PARTITION p0 VALUES LESS THAN (100),
    ->     PARTITION p1 VALUES LESS THAN (MAXVALUE)
    -> );
ERROR 1064 (42000): You have an error in your SQL syntax; check the manual that
corresponds to your MySQL server version for the right syntax to use near ')

mysql> CREATE TABLE ts (
    ->     id INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
    ->     name VARCHAR(30)
    -> )
    -> PARTITION BY RANGE(id)
    -> SUBPARTITION BY KEY(id)
    -> SUBPARTITIONS 4
    -> (
    ->     PARTITION p0 VALUES LESS THAN (100),
    ->     PARTITION p1 VALUES LESS THAN (MAXVALUE)
    -> );
Query OK, 0 rows affected (0.07 sec)
```

This is a known issue (see Bug #51470).

DELAYED option not supported. Use of INSERT DELAYED to insert rows into a partitioned table is not supported. Attempting to do so fails with an error.

DATA DIRECTORY and INDEX DIRECTORY options. DATA DIRECTORY and INDEX DIRECTORY are subject to the following restrictions when used with partitioned tables:

- Table-level DATA DIRECTORY and INDEX DIRECTORY options are ignored (see Bug #32091).

- On Windows, the `DATA DIRECTORY` and `INDEX DIRECTORY` options are not supported for individual partitions or subpartitions (Bug #30459).

Repairing and rebuilding partitioned tables. The statements `CHECK TABLE`, `OPTIMIZE TABLE`, `ANALYZE TABLE`, and `REPAIR TABLE` are supported for partitioned tables.

In addition, you can use `ALTER TABLE ... REBUILD PARTITION` to rebuild one or more partitions of a partitioned table; `ALTER TABLE ... REORGANIZE PARTITION` also causes partitions to be rebuilt. See Section 13.1.7, “ALTER TABLE Syntax”, for more information about these two statements.

`mysqlcheck`, `myisamchk`, and `myisampack` are not supported with partitioned tables.

19.5.1 Partitioning Keys, Primary Keys, and Unique Keys

This section discusses the relationship of partitioning keys with primary keys and unique keys. The rule governing this relationship can be expressed as follows: All columns used in the partitioning expression for a partitioned table must be part of every unique key that the table may have.

In other words, *every unique key on the table must use every column in the table's partitioning expression*. (This also includes the table's primary key, since it is by definition a unique key. This particular case is discussed later in this section.) For example, each of the following table creation statements is invalid:

```
CREATE TABLE t1 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1, col2)
)
PARTITION BY HASH(col3)
PARTITIONS 4;

CREATE TABLE t2 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1),
    UNIQUE KEY (col3)
)
PARTITION BY HASH(col1 + col3)
PARTITIONS 4;
```

In each case, the proposed table would have at least one unique key that does not include all columns used in the partitioning expression.

Each of the following statements is valid, and represents one way in which the corresponding invalid table creation statement could be made to work:

```
CREATE TABLE t1 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1, col2, col3)
)
PARTITION BY HASH(col3)
PARTITIONS 4;

CREATE TABLE t2 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
```

```
    UNIQUE KEY (col1, col3)
)
PARTITION BY HASH(col1 + col3)
PARTITIONS 4;
```

This example shows the error produced in such cases:

```
mysql> CREATE TABLE t3 (
    ->     col1 INT NOT NULL,
    ->     col2 DATE NOT NULL,
    ->     col3 INT NOT NULL,
    ->     col4 INT NOT NULL,
    ->     UNIQUE KEY (col1, col2),
    ->     UNIQUE KEY (col3)
    -> )
    -> PARTITION BY HASH(col1 + col3)
    -> PARTITIONS 4;
ERROR 1491 (HY000): A PRIMARY KEY must include all columns in the table's partitioning function
```

The `CREATE TABLE` statement fails because both `col1` and `col3` are included in the proposed partitioning key, but neither of these columns is part of both of unique keys on the table. This shows one possible fix for the invalid table definition:

```
mysql> CREATE TABLE t3 (
    ->     col1 INT NOT NULL,
    ->     col2 DATE NOT NULL,
    ->     col3 INT NOT NULL,
    ->     col4 INT NOT NULL,
    ->     UNIQUE KEY (col1, col2, col3),
    ->     UNIQUE KEY (col3)
    -> )
    -> PARTITION BY HASH(col3)
    -> PARTITIONS 4;
Query OK, 0 rows affected (0.05 sec)
```

In this case, the proposed partitioning key `col3` is part of both unique keys, and the table creation statement succeeds.

The following table cannot be partitioned at all, because there is no way to include in a partitioning key any columns that belong to both unique keys:

```
CREATE TABLE t4 (
    col1 INT NOT NULL,
    col2 INT NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1, col3),
    UNIQUE KEY (col2, col4)
);
```

Since every primary key is by definition a unique key, this restriction also includes the table's primary key, if it has one. For example, the next two statements are invalid:

```
CREATE TABLE t5 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col2)
)
PARTITION BY HASH(col3)
PARTITIONS 4;

CREATE TABLE t6 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
```

```
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col3),
    UNIQUE KEY(col2)
)
PARTITION BY HASH( YEAR(col2) )
PARTITIONS 4;
```

In both cases, the primary key does not include all columns referenced in the partitioning expression. However, both of the next two statements are valid:

```
CREATE TABLE t7 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col2)
)
PARTITION BY HASH(col1 + YEAR(col2))
PARTITIONS 4;

CREATE TABLE t8 (
    col1 INT NOT NULL,
    col2 DATE NOT NULL,
    col3 INT NOT NULL,
    col4 INT NOT NULL,
    PRIMARY KEY(col1, col2, col4),
    UNIQUE KEY(col2, col1)
)
PARTITION BY HASH(col1 + YEAR(col2))
PARTITIONS 4;
```

If a table has no unique keys—this includes having no primary key—then this restriction does not apply, and you may use any column or columns in the partitioning expression as long as the column type is compatible with the partitioning type.

For the same reason, you cannot later add a unique key to a partitioned table unless the key includes all columns used by the table's partitioning expression. Consider the partitioned table created as shown here:

```
mysql> CREATE TABLE t_no_pk (c1 INT, c2 INT)
    ->     PARTITION BY RANGE(c1) (
    ->         PARTITION p0 VALUES LESS THAN (10),
    ->         PARTITION p1 VALUES LESS THAN (20),
    ->         PARTITION p2 VALUES LESS THAN (30),
    ->         PARTITION p3 VALUES LESS THAN (40)
    ->     );
Query OK, 0 rows affected (0.12 sec)
```

It is possible to add a primary key to `t_no_pk` using either of these `ALTER TABLE` statements:

```
#  possible PK
mysql> ALTER TABLE t_no_pk ADD PRIMARY KEY(c1);
Query OK, 0 rows affected (0.13 sec)
Records: 0  Duplicates: 0  Warnings: 0

# drop this PK
mysql> ALTER TABLE t_no_pk DROP PRIMARY KEY;
Query OK, 0 rows affected (0.10 sec)
Records: 0  Duplicates: 0  Warnings: 0

#  use another possible PK
mysql> ALTER TABLE t_no_pk ADD PRIMARY KEY(c1, c2);
Query OK, 0 rows affected (0.12 sec)
Records: 0  Duplicates: 0  Warnings: 0

# drop this PK
```

```
mysql> ALTER TABLE t_no_pk DROP PRIMARY KEY;
Query OK, 0 rows affected (0.09 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

However, the next statement fails, because `c1` is part of the partitioning key, but is not part of the proposed primary key:

```
#  fails with error 1503
mysql> ALTER TABLE t_no_pk ADD PRIMARY KEY(c2);
ERROR 1503 (HY000): A PRIMARY KEY must include all columns in the table's partitioning function
```

Since `t_no_pk` has only `c1` in its partitioning expression, attempting to adding a unique key on `c2` alone fails. However, you can add a unique key that uses both `c1` and `c2`.

These rules also apply to existing nonpartitioned tables that you wish to partition using `ALTER TABLE ... PARTITION BY`. Consider a table `np_pk` created as shown here:

```
mysql> CREATE TABLE np_pk (
    ->     id INT NOT NULL AUTO_INCREMENT,
    ->     name VARCHAR(50),
    ->     added DATE,
    ->     PRIMARY KEY (id)
    -> );
Query OK, 0 rows affected (0.08 sec)
```

The following `ALTER TABLE` statement fails with an error, because the `added` column is not part of any unique key in the table:

```
mysql> ALTER TABLE np_pk
    ->     PARTITION BY HASH( TO_DAYS(added) )
    ->     PARTITIONS 4;
ERROR 1503 (HY000): A PRIMARY KEY must include all columns in the table's partitioning function
```

However, this statement using the `id` column for the partitioning column is valid, as shown here:

```
mysql> ALTER TABLE np_pk
    ->     PARTITION BY HASH(id)
    ->     PARTITIONS 4;
Query OK, 0 rows affected (0.11 sec)
Records: 0  Duplicates: 0  Warnings: 0
```

In the case of `np_pk`, the only column that may be used as part of a partitioning expression is `id`; if you wish to partition this table using any other column or columns in the partitioning expression, you must first modify the table, either by adding the desired column or columns to the primary key, or by dropping the primary key altogether.

19.5.2 Partitioning Limitations Relating to Storage Engines

The following limitations apply to the use of storage engines with user-defined partitioning of tables.

MERGE storage engine. User-defined partitioning and the `MERGE` storage engine are not compatible. Tables using the `MERGE` storage engine cannot be partitioned. Partitioned tables cannot be merged.

FEDERATED storage engine. Partitioning of `FEDERATED` tables is not supported; it is not possible to create partitioned `FEDERATED` tables.

CSV storage engine. Partitioned tables using the `CSV` storage engine are not supported; it is not possible to create partitioned `CSV` tables.

InnoDB storage engine. `InnoDB` foreign keys and MySQL partitioning are not compatible. Partitioned `InnoDB` tables cannot have foreign key references, nor can they have columns referenced

by foreign keys. `InnoDB` tables which have or which are referenced by foreign keys cannot be partitioned.

`InnoDB` does not support the use of multiple disks for subpartitions. (This is currently supported only by `MyISAM`.)

In addition, `ALTER TABLE ... OPTIMIZE PARTITION` does not work correctly with partitioned tables that use the `InnoDB` storage engine. Use `ALTER TABLE ... REBUILD PARTITION` and `ALTER TABLE ... ANALYZE PARTITION`, instead, for such tables. For more information, see Section 13.1.7.1, “ALTER TABLE Partition Operations”.

User-defined partitioning and the NDB storage engine (NDB Cluster). Partitioning by `KEY` (including `LINEAR KEY`) is the only type of partitioning supported for the `NDB` storage engine. It is not possible under normal circumstances in MySQL NDB Cluster 7.2 or MySQL NDB Cluster 7.3 to create an NDB Cluster table using any partitioning type other than [`LINEAR`] `KEY`, and attempting to do so fails with an error.

Exception (not for production): It is possible to override this restriction by setting the `new` system variable on NDB Cluster SQL nodes to `ON`. If you choose to do this, you should be aware that tables using partitioning types other than `[LINEAR] KEY` are not supported in production. *In such cases, you can create and use tables with partitioning types other than `KEY` or `LINEAR KEY`, but you do this entirely at your own risk*.

The maximum number of partitions that can be defined for an `NDB` table depends on the number of data nodes and node groups in the cluster, the version of the NDB Cluster software in use, and other factors. See NDB and user-defined partitioning, for more information.

The maximum amount of fixed-size data that can be stored per partition in an `NDB` table is 16 GB.

`CREATE TABLE` and `ALTER TABLE` statements that would cause a user-partitioned `NDB` table not to meet either or both of the following two requirements are not permitted, and fail with an error:

1. The table must have an explicit primary key.

2. All columns listed in the table's partitioning expression must be part of the primary key.

Exception. If a user-partitioned `NDB` table is created using an empty column-list (that is, using `PARTITION BY KEY()` or `PARTITION BY LINEAR KEY()`), then no explicit primary key is required.

Upgrading partitioned tables. When performing an upgrade, tables which are partitioned by `KEY` and which use any storage engine other than `NDB` must be dumped and reloaded.

Same storage engine for all partitions. All partitions of a partitioned table must use the same storage engine and it must be the same storage engine used by the table as a whole. In addition, if one does not specify an engine on the table level, then one must do either of the following when creating or altering a partitioned table:

- Do *not* specify any engine for *any* partition or subpartition
- Specify the engine for *all* partitions or subpartitions

19.5.3 Partitioning Limitations Relating to Functions

This section discusses limitations in MySQL Partitioning relating specifically to functions used in partitioning expressions.

Only the MySQL functions shown in the following table are allowed in partitioning expressions.

`ABS()`	`CEILING()` (see CEILING() and FLOOR())	`DAY()`

DAYOFMONTH()	DAYOFWEEK()	DAYOFYEAR()
DATEDIFF()	EXTRACT() (see EXTRACT() function with WEEK specifier)	FLOOR() (see CEILING() and FLOOR())
HOUR()	MICROSECOND()	MINUTE()
MOD()	MONTH()	QUARTER()
SECOND()	TIME_TO_SEC()	TO_DAYS()
TO_SECONDS() (implemented in MySQL 5.5.0)	UNIX_TIMESTAMP() (permitted beginning with MySQL 5.5.1 and fully supported beginning with MySQL 5.5.15, with TIMESTAMP columns)	WEEKDAY()
YEAR()		YEARWEEK()

In MySQL 5.5, range optimization can be used for the TO_DAYS(), TO_SECONDS(), and YEAR() functions. In addition, beginning with MySQL 5.5.15, UNIX_TIMESTAMP() is treated as monotonic in partitioning expressions. See Section 19.4, “Partition Pruning”, for more information.

CEILING() and FLOOR(). Each of these functions returns an integer only if it is passed an argument of an exact numeric type, such as one of the INT types or DECIMAL. This means, for example, that the following CREATE TABLE statement fails with an error, as shown here:

```
mysql> CREATE TABLE t (c FLOAT) PARTITION BY LIST( FLOOR(c) )(
    ->     PARTITION p0 VALUES IN (1,3,5),
    ->     PARTITION p1 VALUES IN (2,4,6)
    -> );
ERROR 1490 (HY000): The PARTITION function returns the wrong type
```

EXTRACT() function with WEEK specifier. The value returned by the EXTRACT() function, when used as EXTRACT(WEEK FROM *col*), depends on the value of the default_week_format system variable. For this reason, beginning with MySQL 5.5.9, EXTRACT() is no longer permitted as a partitioning function when it specifies the unit as WEEK. (Bug #54483)

See Section 12.6.2, “Mathematical Functions”, for more information about the return types of these functions, as well as Section 11.2, “Numeric Types”.

19.5.4 Partitioning and Table-Level Locking

For storage engines such as MyISAM that actually execute table-level locks when executing DML or DDL statements, such a statement affecting a partitioned table imposes a lock on the table as a whole; that is, all partitions are locked until the statement was finished. For example, a SELECT from a partitioned MyISAM table causes a lock on the entire table.

In practical terms, what this means is that the statements discussed later in this section tend to execute more slowly as the number of partitions increases. This limitation is greatly reduced in MySQL 5.6, with the introduction of *partition lock pruning* in MySQL 5.6.6.

This is not true for statements affecting partitioned tables using storage engines such as InnoDB, that employ row-level locking and do not actually perform (or need to perform) the locks prior to partition pruning.

The next few paragraphs discuss the effects of MySQL statements on partitioned tables using storage engines that employ table-level locks.

DML statements

SELECT statements lock the entire table. SELECT statements containing unions or joins lock all tables named in the union or join.

`UPDATE` also locks the entire table.

`REPLACE` and `INSERT` (including `INSERT ... ON DUPLICATE KEY UPDATE`) lock the entire table.

`INSERT ... SELECT` locks both the source table and the target table.

Note

`INSERT DELAYED` is not supported for partitioned tables.

A `LOAD DATA` statement on a partitioned table locks the entire table.

A trigger on a partitioned table, once activated, locks the entire table.

DDL statements

`CREATE VIEW` causes a lock on any partitioned table from which it reads.

`ALTER TABLE` locks the affected partitioned table.

Other statements

`LOCK TABLES` locks all partitions of a partioned table.

Evaluating the *`expr`* in a `CALL stored_procedure(`*`expr`*`)` statement locks all partitions of any partitioned table referenced by *`expr`*.

`ALTER TABLE` also takes a metadata lock on the table level.

Chapter 20 Stored Programs and Views

Table of Contents

20.1 Defining Stored Programs 2516
20.2 Using Stored Routines (Procedures and Functions) 2517
20.2.1 Stored Routine Syntax 2517
20.2.2 Stored Routines and MySQL Privileges 2518
20.2.3 Stored Routine Metadata 2518
20.2.4 Stored Procedures, Functions, Triggers, and LAST_INSERT_ID() 2519
20.3 Using Triggers 2519
20.3.1 Trigger Syntax and Examples 2520
20.3.2 Trigger Metadata 2523
20.4 Using the Event Scheduler 2523
20.4.1 Event Scheduler Overview 2524
20.4.2 Event Scheduler Configuration 2525
20.4.3 Event Syntax 2527
20.4.4 Event Metadata 2527
20.4.5 Event Scheduler Status 2528
20.4.6 The Event Scheduler and MySQL Privileges 2528
20.5 Using Views 2531
20.5.1 View Syntax 2531
20.5.2 View Processing Algorithms 2532
20.5.3 Updatable and Insertable Views 2533
20.5.4 The View WITH CHECK OPTION Clause 2535
20.5.5 View Metadata 2535
20.6 Access Control for Stored Programs and Views 2536
20.7 Binary Logging of Stored Programs 2537

This chapter discusses stored programs and views, which are database objects defined in terms of SQL code that is stored on the server for later execution.

Stored programs include these objects:

- Stored routines, that is, stored procedures and functions. A stored procedure is invoked using the `CALL` statement. A procedure does not have a return value but can modify its parameters for later inspection by the caller. It can also generate result sets to be returned to the client program. A stored function is used much like a built-in function. you invoke it in an expression and it returns a value during expression evaluation.
- Triggers. A trigger is a named database object that is associated with a table and that is activated when a particular event occurs for the table, such as an insert or update.
- Events. An event is a task that the server runs according to schedule.

Views are stored queries that when referenced produce a result set. A view acts as a virtual table.

This chapter describes how to use stored programs and views. The following sections provide additional information about SQL syntax for statements related to these objects:

- For each object type, there are `CREATE`, `ALTER`, and `DROP` statements that control which objects exist and how they are defined. See Section 13.1, “Data Definition Statements”.
- The `CALL` statement is used to invoke stored procedures. See Section 13.2.1, “CALL Syntax”.
- Stored program definitions include a body that may use compound statements, loops, conditionals, and declared variables. See Section 13.6, “Compound-Statement Syntax”.

20.1 Defining Stored Programs

Each stored program contains a body that consists of an SQL statement. This statement may be a compound statement made up of several statements separated by semicolon (`;`) characters. For example, the following stored procedure has a body made up of a `BEGIN ... END` block that contains a `SET` statement and a `REPEAT` loop that itself contains another `SET` statement:

```
CREATE PROCEDURE dorepeat(p1 INT)
BEGIN
  SET @x = 0;
  REPEAT SET @x = @x + 1; UNTIL @x > p1 END REPEAT;
END;
```

If you use the `mysql` client program to define a stored program containing semicolon characters, a problem arises. By default, `mysql` itself recognizes the semicolon as a statement delimiter, so you must redefine the delimiter temporarily to cause `mysql` to pass the entire stored program definition to the server.

To redefine the `mysql` delimiter, use the `delimiter` command. The following example shows how to do this for the `dorepeat()` procedure just shown. The delimiter is changed to `//` to enable the entire definition to be passed to the server as a single statement, and then restored to `;` before invoking the procedure. This enables the `;` delimiter used in the procedure body to be passed through to the server rather than being interpreted by `mysql` itself.

```
mysql> delimiter //

mysql> CREATE PROCEDURE dorepeat(p1 INT)
    -> BEGIN
    ->   SET @x = 0;
    ->   REPEAT SET @x = @x + 1; UNTIL @x > p1 END REPEAT;
    -> END
    -> //
Query OK, 0 rows affected (0.00 sec)

mysql> delimiter ;

mysql> CALL dorepeat(1000);
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT @x;
+------+
| @x   |
+------+
| 1001 |
+------+
1 row in set (0.00 sec)
```

You can redefine the delimiter to a string other than `//`, and the delimiter can consist of a single character or multiple characters. You should avoid the use of the backslash (`\`) character because that is the escape character for MySQL.

The following is an example of a function that takes a parameter, performs an operation using an SQL function, and returns the result. In this case, it is unnecessary to use `delimiter` because the function definition contains no internal `;` statement delimiters:

```
mysql> CREATE FUNCTION hello (s CHAR(20))
mysql> RETURNS CHAR(50) DETERMINISTIC
    -> RETURN CONCAT('Hello, ',s,'!');
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT hello('world');
+----------------+
| hello('world') |
+----------------+
```

```
| Hello, world!  |
+----------------+
1 row in set (0.00 sec)
```

20.2 Using Stored Routines (Procedures and Functions)

MySQL supports stored routines (procedures and functions). A stored routine is a set of SQL statements that can be stored in the server. Once this has been done, clients don't need to keep reissuing the individual statements but can refer to the stored routine instead.

Stored routines require the `proc` table in the `mysql` database. This table is created during the MySQL installation procedure. If you are upgrading to MySQL 5.5 from an earlier version, be sure to update your grant tables to make sure that the `proc` table exists. See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

Stored routines can be particularly useful in certain situations:

- When multiple client applications are written in different languages or work on different platforms, but need to perform the same database operations.
- When security is paramount. Banks, for example, use stored procedures and functions for all common operations. This provides a consistent and secure environment, and routines can ensure that each operation is properly logged. In such a setup, applications and users would have no access to the database tables directly, but can only execute specific stored routines.

Stored routines can provide improved performance because less information needs to be sent between the server and the client. The tradeoff is that this does increase the load on the database server because more of the work is done on the server side and less is done on the client (application) side. Consider this if many client machines (such as Web servers) are serviced by only one or a few database servers.

Stored routines also enable you to have libraries of functions in the database server. This is a feature shared by modern application languages that enable such design internally (for example, by using classes). Using these client application language features is beneficial for the programmer even outside the scope of database use.

MySQL follows the SQL:2003 syntax for stored routines, which is also used by IBM's DB2. All syntax described here is supported and any limitations and extensions are documented where appropriate.

Additional Resources

- You may find the Stored Procedures User Forum of use when working with stored procedures and functions.
- For answers to some commonly asked questions regarding stored routines in MySQL, see Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”.
- There are some restrictions on the use of stored routines. See Section C.1, “Restrictions on Stored Programs”.
- Binary logging for stored routines takes place as described in Section 20.7, “Binary Logging of Stored Programs”.

20.2.1 Stored Routine Syntax

A stored routine is either a procedure or a function. Stored routines are created with the `CREATE PROCEDURE` and `CREATE FUNCTION` statements (see Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”). A procedure is invoked using a `CALL` statement (see Section 13.2.1, “CALL Syntax”), and can only pass back values using output variables. A function can be called from inside a statement just like any other function (that is, by invoking the function's name), and can return a scalar value. The body of a stored routine can use compound statements (see Section 13.6, “Compound-Statement Syntax”).

Stored routines can be dropped with the `DROP PROCEDURE` and `DROP FUNCTION` statements (see Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Syntax”), and altered with the `ALTER PROCEDURE` and `ALTER FUNCTION` statements (see Section 13.1.5, “ALTER PROCEDURE Syntax”).

A stored procedure or function is associated with a particular database. This has several implications:

- When the routine is invoked, an implicit `USE` *`db_name`* is performed (and undone when the routine terminates). `USE` statements within stored routines are not permitted.
- You can qualify routine names with the database name. This can be used to refer to a routine that is not in the current database. For example, to invoke a stored procedure `p` or function `f` that is associated with the `test` database, you can say `CALL test.p()` or `test.f()`.
- When a database is dropped, all stored routines associated with it are dropped as well.

Stored functions cannot be recursive.

Recursion in stored procedures is permitted but disabled by default. To enable recursion, set the `max_sp_recursion_depth` server system variable to a value greater than zero. Stored procedure recursion increases the demand on thread stack space. If you increase the value of `max_sp_recursion_depth`, it may be necessary to increase thread stack size by increasing the value of `thread_stack` at server startup. See Section 5.1.5, “Server System Variables”, for more information.

MySQL supports a very useful extension that enables the use of regular `SELECT` statements (that is, without using cursors or local variables) inside a stored procedure. The result set of such a query is simply sent directly to the client. Multiple `SELECT` statements generate multiple result sets, so the client must use a MySQL client library that supports multiple result sets. This means the client must use a client library from a version of MySQL at least as recent as 4.1. The client should also specify the `CLIENT_MULTI_RESULTS` option when it connects. For C programs, this can be done with the `mysql_real_connect()` C API function. See Section 23.8.7.52, “mysql_real_connect()”, and Section 23.8.16, “C API Multiple Statement Execution Support”.

20.2.2 Stored Routines and MySQL Privileges

The MySQL grant system takes stored routines into account as follows:

- The `CREATE ROUTINE` privilege is needed to create stored routines.
- The `ALTER ROUTINE` privilege is needed to alter or drop stored routines. This privilege is granted automatically to the creator of a routine if necessary, and dropped from the creator when the routine is dropped.
- The `EXECUTE` privilege is required to execute stored routines. However, this privilege is granted automatically to the creator of a routine if necessary (and dropped from the creator when the routine is dropped). Also, the default `SQL SECURITY` characteristic for a routine is `DEFINER`, which enables users who have access to the database with which the routine is associated to execute the routine.
- If the `automatic_sp_privileges` system variable is 0, the `EXECUTE` and `ALTER ROUTINE` privileges are not automatically granted to and dropped from the routine creator.
- The creator of a routine is the account used to execute the `CREATE` statement for it. This might not be the same as the account named as the `DEFINER` in the routine definition.

The server manipulates the `mysql.proc` table in response to statements that create, alter, or drop stored routines. It is not supported that the server will notice manual manipulation of this table.

20.2.3 Stored Routine Metadata

Metadata about stored routines can be obtained as follows:

- Query the `ROUTINES` table of the `INFORMATION_SCHEMA` database. See Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”.
- Use the `SHOW CREATE PROCEDURE` and `SHOW CREATE FUNCTION` statements to see routine definitions. See Section 13.7.5.11, “SHOW CREATE PROCEDURE Syntax”.
- Use the `SHOW PROCEDURE STATUS` and `SHOW FUNCTION STATUS` statements to see routine characteristics. See Section 13.7.5.29, “SHOW PROCEDURE STATUS Syntax”.

20.2.4 Stored Procedures, Functions, Triggers, and LAST_INSERT_ID()

Within the body of a stored routine (procedure or function) or a trigger, the value of `LAST_INSERT_ID()` changes the same way as for statements executed outside the body of these kinds of objects (see Section 12.14, “Information Functions”). The effect of a stored routine or trigger upon the value of `LAST_INSERT_ID()` that is seen by following statements depends on the kind of routine:

- If a stored procedure executes statements that change the value of `LAST_INSERT_ID()`, the changed value is seen by statements that follow the procedure call.
- For stored functions and triggers that change the value, the value is restored when the function or trigger ends, so following statements do not see a changed value.

20.3 Using Triggers

A trigger is a named database object that is associated with a table, and that activates when a particular event occurs for the table. Some uses for triggers are to perform checks of values to be inserted into a table or to perform calculations on values involved in an update.

A trigger is defined to activate when a statement inserts, updates, or deletes rows in the associated table. These row operations are trigger events. For example, rows can be inserted by `INSERT` or `LOAD DATA` statements, and an insert trigger activates for each inserted row. A trigger can be set to activate either before or after the trigger event. For example, you can have a trigger activate before each row that is inserted into a table or after each row that is updated.

Important

MySQL triggers activate only for changes made to tables by SQL statements. This includes changes to base tables that underlie updatable views. Triggers do not activate for changes to tables made by APIs that do not transmit SQL statements to the MySQL Server. This means that triggers are not activated by updates made using the `NDB` API.

Triggers are not activated by changes in `INFORMATION_SCHEMA` or `performance_schema` tables. Those tables are actually views and triggers are not permitted on views.

To use triggers if you have upgraded to MySQL 5.5 from an older release that did not support triggers, you should upgrade your grant tables so that they contain the trigger-related privileges. See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

The following sections describe the syntax for creating and dropping triggers, show some examples of how to use them, and indicate how to obtain trigger metadata.

Additional Resources

- You may find the Triggers User Forum of use when working with triggers.
- For answers to commonly asked questions regarding triggers in MySQL, see Section A.5, “MySQL 5.5 FAQ: Triggers”.

- There are some restrictions on the use of triggers; see Section C.1, “Restrictions on Stored Programs”.
- Binary logging for triggers takes place as described in Section 20.7, “Binary Logging of Stored Programs”.

20.3.1 Trigger Syntax and Examples

To create a trigger or drop a trigger, use the `CREATE TRIGGER` or `DROP TRIGGER` statement, described in Section 13.1.19, “CREATE TRIGGER Syntax”, and Section 13.1.30, “DROP TRIGGER Syntax”.

Here is a simple example that associates a trigger with a table, to activate for `INSERT` operations. The trigger acts as an accumulator, summing the values inserted into one of the columns of the table.

```
mysql> CREATE TABLE account (acct_num INT, amount DECIMAL(10,2));
Query OK, 0 rows affected (0.03 sec)

mysql> CREATE TRIGGER ins_sum BEFORE INSERT ON account
       FOR EACH ROW SET @sum = @sum + NEW.amount;
Query OK, 0 rows affected (0.01 sec)
```

The `CREATE TRIGGER` statement creates a trigger named `ins_sum` that is associated with the `account` table. It also includes clauses that specify the trigger action time, the triggering event, and what to do when the trigger activates:

- The keyword `BEFORE` indicates the trigger action time. In this case, the trigger activates before each row inserted into the table. The other permitted keyword here is `AFTER`.
- The keyword `INSERT` indicates the trigger event; that is, the type of operation that activates the trigger. In the example, `INSERT` operations cause trigger activation. You can also create triggers for `DELETE` and `UPDATE` operations.
- The statement following `FOR EACH ROW` defines the trigger body; that is, the statement to execute each time the trigger activates, which occurs once for each row affected by the triggering event. In the example, the trigger body is a simple `SET` that accumulates into a user variable the values inserted into the `amount` column. The statement refers to the column as `NEW.amount` which means “the value of the `amount` column to be inserted into the new row.”

To use the trigger, set the accumulator variable to zero, execute an `INSERT` statement, and then see what value the variable has afterward:

```
mysql> SET @sum = 0;
mysql> INSERT INTO account VALUES(137,14.98),(141,1937.50),(97,-100.00);
mysql> SELECT @sum AS 'Total amount inserted';
+-----------------------+
| Total amount inserted |
+-----------------------+
|               1852.48 |
+-----------------------+
```

In this case, the value of `@sum` after the `INSERT` statement has executed is `14.98 + 1937.50 - 100`, or `1852.48`.

To destroy the trigger, use a `DROP TRIGGER` statement. You must specify the schema name if the trigger is not in the default schema:

```
mysql> DROP TRIGGER test.ins_sum;
```

If you drop a table, any triggers for the table are also dropped.

Trigger names exist in the schema namespace, meaning that all triggers must have unique names within a schema. Triggers in different schemas can have the same name.

In addition to the requirement that trigger names be unique for a schema, there are other limitations on the types of triggers you can create. In particular, there cannot be multiple triggers for a given table that have the same trigger event and action time. For example, you cannot have two `BEFORE UPDATE` triggers for a table. To work around this, you can define a trigger that executes multiple statements by using the `BEGIN ... END` compound statement construct after `FOR EACH ROW`. (An example appears later in this section.)

Within the trigger body, the `OLD` and `NEW` keywords enable you to access columns in the rows affected by a trigger. `OLD` and `NEW` are MySQL extensions to triggers; they are not case sensitive.

In an `INSERT` trigger, only `NEW.col_name` can be used; there is no old row. In a `DELETE` trigger, only `OLD.col_name` can be used; there is no new row. In an `UPDATE` trigger, you can use `OLD.col_name` to refer to the columns of a row before it is updated and `NEW.col_name` to refer to the columns of the row after it is updated.

A column named with `OLD` is read only. You can refer to it (if you have the `SELECT` privilege), but not modify it. You can refer to a column named with `NEW` if you have the `SELECT` privilege for it. In a `BEFORE` trigger, you can also change its value with `SET NEW.col_name = value` if you have the `UPDATE` privilege for it. This means you can use a trigger to modify the values to be inserted into a new row or used to update a row. (Such a `SET` statement has no effect in an `AFTER` trigger because the row change will have already occurred.)

In a `BEFORE` trigger, the `NEW` value for an `AUTO_INCREMENT` column is 0, not the sequence number that is generated automatically when the new row actually is inserted.

By using the `BEGIN ... END` construct, you can define a trigger that executes multiple statements. Within the `BEGIN` block, you also can use other syntax that is permitted within stored routines such as conditionals and loops. However, just as for stored routines, if you use the `mysql` program to define a trigger that executes multiple statements, it is necessary to redefine the `mysql` statement delimiter so that you can use the `;` statement delimiter within the trigger definition. The following example illustrates these points. It defines an `UPDATE` trigger that checks the new value to be used for updating each row, and modifies the value to be within the range from 0 to 100. This must be a `BEFORE` trigger because the value must be checked before it is used to update the row:

```
mysql> delimiter //
mysql> CREATE TRIGGER upd_check BEFORE UPDATE ON account
    -> FOR EACH ROW
    -> BEGIN
    ->     IF NEW.amount < 0 THEN
    ->         SET NEW.amount = 0;
    ->     ELSEIF NEW.amount > 100 THEN
    ->         SET NEW.amount = 100;
    ->     END IF;
    -> END;//
mysql> delimiter ;
```

It can be easier to define a stored procedure separately and then invoke it from the trigger using a simple `CALL` statement. This is also advantageous if you want to execute the same code from within several triggers.

There are limitations on what can appear in statements that a trigger executes when activated:

- The trigger cannot use the `CALL` statement to invoke stored procedures that return data to the client or that use dynamic SQL. (Stored procedures are permitted to return data to the trigger through `OUT` or `INOUT` parameters.)
- The trigger cannot use statements that explicitly or implicitly begin or end a transaction, such as `START TRANSACTION`, `COMMIT`, or `ROLLBACK`. (`ROLLBACK to SAVEPOINT` is permitted because it does not end a transaction.).

See also Section C.1, “Restrictions on Stored Programs”.

MySQL handles errors during trigger execution as follows:

- If a BEFORE trigger fails, the operation on the corresponding row is not performed.
- A BEFORE trigger is activated by the *attempt* to insert or modify the row, regardless of whether the attempt subsequently succeeds.
- An AFTER trigger is executed only if any BEFORE triggers and the row operation execute successfully.
- An error during either a BEFORE or AFTER trigger results in failure of the entire statement that caused trigger invocation.
- For transactional tables, failure of a statement should cause rollback of all changes performed by the statement. Failure of a trigger causes the statement to fail, so trigger failure also causes rollback. For nontransactional tables, such rollback cannot be done, so although the statement fails, any changes performed prior to the point of the error remain in effect.

In MySQL 5.5, triggers can contain direct references to tables by name, such as the trigger named testref shown in this example:

```
CREATE TABLE test1(a1 INT);
CREATE TABLE test2(a2 INT);
CREATE TABLE test3(a3 INT NOT NULL AUTO_INCREMENT PRIMARY KEY);
CREATE TABLE test4(
  a4 INT NOT NULL AUTO_INCREMENT PRIMARY KEY,
  b4 INT DEFAULT 0
);

delimiter |

CREATE TRIGGER testref BEFORE INSERT ON test1
  FOR EACH ROW
  BEGIN
    INSERT INTO test2 SET a2 = NEW.a1;
    DELETE FROM test3 WHERE a3 = NEW.a1;
    UPDATE test4 SET b4 = b4 + 1 WHERE a4 = NEW.a1;
  END;
|

delimiter ;

INSERT INTO test3 (a3) VALUES
  (NULL), (NULL), (NULL), (NULL), (NULL),
  (NULL), (NULL), (NULL), (NULL), (NULL);

INSERT INTO test4 (a4) VALUES
  (0), (0), (0), (0), (0), (0), (0), (0), (0), (0);
```

Suppose that you insert the following values into table test1 as shown here:

```
mysql> INSERT INTO test1 VALUES
       (1), (3), (1), (7), (1), (8), (4), (4);
Query OK, 8 rows affected (0.01 sec)
Records: 8  Duplicates: 0  Warnings: 0
```

As a result, the four tables contain the following data:

```
mysql> SELECT * FROM test1;
+------+
| a1   |
+------+
|    1 |
|    3 |
|    1 |
|    7 |
|    1 |
|    8 |
|    4 |
```

```
|    4 |
+------+
8 rows in set (0.00 sec)

mysql> SELECT * FROM test2;
+------+
| a2   |
+------+
|    1 |
|    3 |
|    1 |
|    7 |
|    1 |
|    8 |
|    4 |
|    4 |
+------+
8 rows in set (0.00 sec)

mysql> SELECT * FROM test3;
+----+
| a3 |
+----+
|  2 |
|  5 |
|  6 |
|  9 |
| 10 |
+----+
5 rows in set (0.00 sec)

mysql> SELECT * FROM test4;
+----+------+
| a4 | b4   |
+----+------+
|  1 |    3 |
|  2 |    0 |
|  3 |    1 |
|  4 |    2 |
|  5 |    0 |
|  6 |    0 |
|  7 |    1 |
|  8 |    1 |
|  9 |    0 |
| 10 |    0 |
+----+------+
10 rows in set (0.00 sec)
```

20.3.2 Trigger Metadata

Metadata about triggers can be obtained as follows:

- Query the `TRIGGERS` table of the `INFORMATION_SCHEMA` database. See Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”.
- Use the `SHOW CREATE TRIGGER` statement. See Section 13.7.5.13, “SHOW CREATE TRIGGER Syntax”.
- Use the `SHOW TRIGGERS` statement. See Section 13.7.5.39, “SHOW TRIGGERS Syntax”.

20.4 Using the Event Scheduler

The *MySQL Event Scheduler* manages the scheduling and execution of events, that is, tasks that run according to a schedule. The following discussion covers the Event Scheduler and is divided into the following sections:

- Section 20.4.1, “Event Scheduler Overview”, provides an introduction to and conceptual overview of MySQL Events.

- Section 20.4.3, “Event Syntax”, discusses the SQL statements for creating, altering, and dropping MySQL Events.
- Section 20.4.4, “Event Metadata”, shows how to obtain information about events and how this information is stored by the MySQL Server.
- Section 20.4.6, “The Event Scheduler and MySQL Privileges”, discusses the privileges required to work with events and the ramifications that events have with regard to privileges when executing.

Stored routines require the `event` table in the `mysql` database. This table is created during the MySQL 5.5 installation procedure. If you are upgrading to MySQL 5.5 from an earlier version, be sure to update your grant tables to make sure that the `event` table exists. See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

Additional Resources

- You may find the MySQL Event Scheduler User Forum of use when working with scheduled events.
- There are some restrictions on the use of events; see Section C.1, “Restrictions on Stored Programs”.
- Binary logging for events takes place as described in Section 20.7, “Binary Logging of Stored Programs”.

20.4.1 Event Scheduler Overview

MySQL Events are tasks that run according to a schedule. Therefore, we sometimes refer to them as *scheduled* events. When you create an event, you are creating a named database object containing one or more SQL statements to be executed at one or more regular intervals, beginning and ending at a specific date and time. Conceptually, this is similar to the idea of the Unix `crontab` (also known as a “cron job”) or the Windows Task Scheduler.

Scheduled tasks of this type are also sometimes known as “temporal triggers”, implying that these are objects that are triggered by the passage of time. While this is essentially correct, we prefer to use the term *events* to avoid confusion with triggers of the type discussed in Section 20.3, “Using Triggers”. Events should more specifically not be confused with “temporary triggers”. Whereas a trigger is a database object whose statements are executed in response to a specific type of event that occurs on a given table, a (scheduled) event is an object whose statements are executed in response to the passage of a specified time interval.

While there is no provision in the SQL Standard for event scheduling, there are precedents in other database systems, and you may notice some similarities between these implementations and that found in the MySQL Server.

MySQL Events have the following major features and properties:

- In MySQL, an event is uniquely identified by its name and the schema to which it is assigned.
- An event performs a specific action according to a schedule. This action consists of an SQL statement, which can be a compound statement in a `BEGIN ... END` block if desired (see Section 13.6, “Compound-Statement Syntax”). An event's timing can be either *one-time* or *recurrent*. A one-time event executes one time only. A recurrent event repeats its action at a regular interval, and the schedule for a recurring event can be assigned a specific start day and time, end day and time, both, or neither. (By default, a recurring event's schedule begins as soon as it is created, and continues indefinitely, until it is disabled or dropped.)

  If a repeating event does not terminate within its scheduling interval, the result may be multiple instances of the event executing simultaneously. If this is undesirable, you should institute a mechanism to prevent simultaneous instances. For example, you could use the `GET_LOCK()` function, or row or table locking.

- Users can create, modify, and drop scheduled events using SQL statements intended for these purposes. Syntactically invalid event creation and modification statements fail with an appropriate error message. *A user may include statements in an event's action which require privileges that the user does not actually have*. The event creation or modification statement succeeds but the event's action fails. See Section 20.4.6, “The Event Scheduler and MySQL Privileges” for details.

- Many of the properties of an event can be set or modified using SQL statements. These properties include the event's name, timing, persistence (that is, whether it is preserved following the expiration of its schedule), status (enabled or disabled), action to be performed, and the schema to which it is assigned. See Section 13.1.2, “ALTER EVENT Syntax”.

  The default definer of an event is the user who created the event, unless the event has been altered, in which case the definer is the user who issued the last `ALTER EVENT` statement affecting that event. An event can be modified by any user having the `EVENT` privilege on the database for which the event is defined. See Section 20.4.6, “The Event Scheduler and MySQL Privileges”.

- An event's action statement may include most SQL statements permitted within stored routines. For restrictions, see Section C.1, “Restrictions on Stored Programs”.

20.4.2 Event Scheduler Configuration

Events are executed by a special *event scheduler thread*; when we refer to the Event Scheduler, we actually refer to this thread. When running, the event scheduler thread and its current state can be seen by users having the `PROCESS` privilege in the output of `SHOW PROCESSLIST`, as shown in the discussion that follows.

The global `event_scheduler` system variable determines whether the Event Scheduler is enabled and running on the server. It has one of these 3 values, which affect event scheduling as described here:

- `OFF`: The Event Scheduler is stopped. The event scheduler thread does not run, is not shown in the output of `SHOW PROCESSLIST`, and no scheduled events are executed. `OFF` is the default value for `event_scheduler`.

  When the Event Scheduler is stopped (`event_scheduler` is `OFF`), it can be started by setting the value of `event_scheduler` to `ON`. (See next item.)

- `ON`: The Event Scheduler is started; the event scheduler thread runs and executes all scheduled events.

  When the Event Scheduler is `ON`, the event scheduler thread is listed in the output of `SHOW PROCESSLIST` as a daemon process, and its state is represented as shown here:

```
mysql> SHOW PROCESSLIST\G
*************************** 1. row ***************************
     Id: 1
   User: root
   Host: localhost
     db: NULL
Command: Query
   Time: 0
  State: NULL
   Info: show processlist
*************************** 2. row ***************************
     Id: 2
   User: event_scheduler
   Host: localhost
     db: NULL
Command: Daemon
   Time: 3
  State: Waiting for next activation
   Info: NULL
2 rows in set (0.00 sec)
```

Event scheduling can be stopped by setting the value of `event_scheduler` to `OFF`.

- `DISABLED`: This value renders the Event Scheduler nonoperational. When the Event Scheduler is `DISABLED`, the event scheduler thread does not run (and so does not appear in the output of `SHOW PROCESSLIST`). In addition, the Event Scheduler state cannot be changed at runtime.

If the Event Scheduler status has not been set to `DISABLED`, `event_scheduler` can be toggled between `ON` and `OFF` (using `SET`). It is also possible to use `0` for `OFF`, and `1` for `ON` when setting this variable. Thus, any of the following 4 statements can be used in the `mysql` client to turn on the Event Scheduler:

```
SET GLOBAL event_scheduler = ON;
SET @@global.event_scheduler = ON;
SET GLOBAL event_scheduler = 1;
SET @@global.event_scheduler = 1;
```

Similarly, any of these 4 statements can be used to turn off the Event Scheduler:

```
SET GLOBAL event_scheduler = OFF;
SET @@global.event_scheduler = OFF;
SET GLOBAL event_scheduler = 0;
SET @@global.event_scheduler = 0;
```

Although `ON` and `OFF` have numeric equivalents, the value displayed for `event_scheduler` by `SELECT` or `SHOW VARIABLES` is always one of `OFF`, `ON`, or `DISABLED`. *`DISABLED` has no numeric equivalent*. For this reason, `ON` and `OFF` are usually preferred over `1` and `0` when setting this variable.

Note that attempting to set `event_scheduler` without specifying it as a global variable causes an error:

```
mysql< SET @@event_scheduler = OFF;
ERROR 1229 (HY000): Variable 'event_scheduler' is a GLOBAL
variable and should be set with SET GLOBAL
```

Important

It is possible to set the Event Scheduler to `DISABLED` only at server startup. If `event_scheduler` is `ON` or `OFF`, you cannot set it to `DISABLED` at runtime. Also, if the Event Scheduler is set to `DISABLED` at startup, you cannot change the value of `event_scheduler` at runtime.

To disable the event scheduler, use one of the following two methods:

- As a command-line option when starting the server:

  ```
  --event-scheduler=DISABLED
  ```

- In the server configuration file (`my.cnf`, or `my.ini` on Windows systems), include the line where it will be read by the server (for example, in a `[mysqld]` section):

  ```
  event_scheduler=DISABLED
  ```

To enable the Event Scheduler, restart the server without the `--event-scheduler=DISABLED` command-line option, or after removing or commenting out the line containing `event-scheduler=DISABLED` in the server configuration file, as appropriate. Alternatively, you can use `ON` (or `1`) or `OFF` (or `0`) in place of the `DISABLED` value when starting the server.

Note

You can issue event-manipulation statements when `event_scheduler` is set to `DISABLED`. No warnings or errors are generated in such cases (provided

> that the statements are themselves valid). However, scheduled events cannot execute until this variable is set to `ON` (or `1`). Once this has been done, the event scheduler thread executes all events whose scheduling conditions are satisfied.

Starting the MySQL server with the `--skip-grant-tables` option causes `event_scheduler` to be set to `DISABLED`, overriding any other value set either on the command line or in the `my.cnf` or `my.ini` file (Bug #26807).

For SQL statements used to create, alter, and drop events, see Section 20.4.3, “Event Syntax”.

MySQL provides an `EVENTS` table in the `INFORMATION_SCHEMA` database. This table can be queried to obtain information about scheduled events which have been defined on the server. See Section 20.4.4, “Event Metadata”, and Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”, for more information.

For information regarding event scheduling and the MySQL privilege system, see Section 20.4.6, “The Event Scheduler and MySQL Privileges”.

20.4.3 Event Syntax

MySQL provides several SQL statements for working with scheduled events:

- New events are defined using the `CREATE EVENT` statement. See Section 13.1.11, “CREATE EVENT Syntax”.
- The definition of an existing event can be changed by means of the `ALTER EVENT` statement. See Section 13.1.2, “ALTER EVENT Syntax”.
- When a scheduled event is no longer wanted or needed, it can be deleted from the server by its definer using the `DROP EVENT` statement. See Section 13.1.22, “DROP EVENT Syntax”. Whether an event persists past the end of its schedule also depends on its `ON COMPLETION` clause, if it has one. See Section 13.1.11, “CREATE EVENT Syntax”.

  An event can be dropped by any user having the `EVENT` privilege for the database on which the event is defined. See Section 20.4.6, “The Event Scheduler and MySQL Privileges”.

20.4.4 Event Metadata

Metadata about events can be obtained as follows:

- Query the `event` table of the `mysql` database.
- Query the `EVENTS` table of the `INFORMATION_SCHEMA` database. See Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”.
- Use the `SHOW CREATE EVENT` statement. See Section 13.7.5.9, “SHOW CREATE EVENT Syntax”.
- Use the `SHOW EVENTS` statement. See Section 13.7.5.19, “SHOW EVENTS Syntax”.

Event Scheduler Time Representation

Each session in MySQL has a session time zone (STZ). This is the session `time_zone` value that is initialized from the server's global `time_zone` value when the session begins but may be changed during the session.

The session time zone that is current when a `CREATE EVENT` or `ALTER EVENT` statement executes is used to interpret times specified in the event definition. This becomes the event time zone (ETZ); that is, the time zone that is used for event scheduling and is in effect within the event as it executes.

For representation of event information in the `mysql.event` table, the `execute_at`, `starts`, and `ends` times are converted to UTC and stored along with the event time zone. This enables event execution to proceed as defined regardless of any subsequent changes to the server time zone or daylight saving time effects. The `last_executed` time is also stored in UTC.

If you select information from `mysql.event`, the times just mentioned are retrieved as UTC values. These times can also be obtained by selecting from the `INFORMATION_SCHEMA.EVENTS` table or from `SHOW EVENTS`, but they are reported as ETZ values. Other times available from these sources indicate when an event was created or last altered; these are displayed as STZ values. The following table summarizes representation of event times.

Value	`mysql.event`	`INFORMATION_SCHEMA.EVENTS`	`SHOW EVENTS`
Execute at	UTC	ETZ	ETZ
Starts	UTC	ETZ	ETZ
Ends	UTC	ETZ	ETZ
Last executed	UTC	ETZ	n/a
Created	STZ	STZ	n/a
Last altered	STZ	STZ	n/a

20.4.5 Event Scheduler Status

The Event Scheduler writes information about event execution that terminates with an error or warning to the MySQL Server's error log. See Section 20.4.6, “The Event Scheduler and MySQL Privileges” for an example.

Information about the state of the Event Scheduler for debugging and troubleshooting purposes can be obtained by running `mysqladmin debug` (see Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”); after running this command, the server's error log contains output relating to the Event Scheduler, similar to what is shown here:

```
Events status:
LLA = Last Locked At  LUA = Last Unlocked At
WOC = Waiting On Condition  DL = Data Locked

Event scheduler status:
State      : INITIALIZED
Thread id  : 0
LLA        : init_scheduler:313
LUA        : init_scheduler:318
WOC        : NO
Workers    : 0
Executed   : 0
Data locked: NO

Event queue status:
Element count   : 1
Data locked     : NO
Attempting lock : NO
LLA             : init_queue:148
LUA             : init_queue:168
WOC             : NO
Next activation : 0000-00-00 00:00:00
```

In statements that occur as part of events executed by the Event Scheduler, diagnostics messages (not only errors, but also warnings) are written to the error log, and, on Windows, to the application event log. For frequently executed events, it is possible for this to result in many logged messages. For example, for `SELECT ... INTO var_list` statements, if the query returns no rows, a warning with error code 1329 occurs (`No data`), and the variable values remain unchanged. If the query returns multiple rows, error 1172 occurs (`Result consisted of more than one row`). For either condition, you can avoid having the warnings be logged by declaring a condition handler; see Section 13.6.7.2, “DECLARE ... HANDLER Syntax”. For statements that may retrieve multiple rows, another strategy is to use `LIMIT 1` to limit the result set to a single row.

20.4.6 The Event Scheduler and MySQL Privileges

To enable or disable the execution of scheduled events, it is necessary to set the value of the global `event_scheduler` system variable. This requires the `SUPER` privilege.

The `EVENT` privilege governs the creation, modification, and deletion of events. This privilege can be bestowed using `GRANT`. For example, this `GRANT` statement confers the `EVENT` privilege for the schema named `myschema` on the user `jon@ghidora`:

```
GRANT EVENT ON myschema.* TO jon@ghidora;
```

(We assume that this user account already exists, and that we wish for it to remain unchanged otherwise.)

To grant this same user the `EVENT` privilege on all schemas, use the following statement:

```
GRANT EVENT ON *.* TO jon@ghidora;
```

The `EVENT` privilege has global or schema-level scope. Therefore, trying to grant it on a single table results in an error as shown:

```
mysql> GRANT EVENT ON myschema.mytable TO jon@ghidora;
ERROR 1144 (42000): Illegal GRANT/REVOKE command; please
consult the manual to see which privileges can be used
```

It is important to understand that an event is executed with the privileges of its definer, and that it cannot perform any actions for which its definer does not have the requisite privileges. For example, suppose that `jon@ghidora` has the `EVENT` privilege for `myschema`. Suppose also that this user has the `SELECT` privilege for `myschema`, but no other privileges for this schema. It is possible for `jon@ghidora` to create a new event such as this one:

```
CREATE EVENT e_store_ts
    ON SCHEDULE
      EVERY 10 SECOND
    DO
      INSERT INTO myschema.mytable VALUES (UNIX_TIMESTAMP());
```

The user waits for a minute or so, and then performs a `SELECT * FROM mytable;` query, expecting to see several new rows in the table. Instead, the table is empty. Since the user does not have the `INSERT` privilege for the table in question, the event has no effect.

If you inspect the MySQL error log (*`hostname`*`.err`), you can see that the event is executing, but the action it is attempting to perform fails, as indicated by `RetCode=0`:

```
060209 22:39:44 [Note]     EVEX EXECUTING event newdb.e [EXPR:10]
060209 22:39:44 [Note]     EVEX EXECUTED event newdb.e  [EXPR:10]. RetCode=0
060209 22:39:54 [Note]     EVEX EXECUTING event newdb.e [EXPR:10]
060209 22:39:54 [Note]     EVEX EXECUTED event newdb.e  [EXPR:10]. RetCode=0
060209 22:40:04 [Note]     EVEX EXECUTING event newdb.e [EXPR:10]
060209 22:40:04 [Note]     EVEX EXECUTED event newdb.e  [EXPR:10]. RetCode=0
```

Since this user very likely does not have access to the error log, it is possible to verify whether the event's action statement is valid by executing it directly:

```
mysql> INSERT INTO myschema.mytable VALUES (UNIX_TIMESTAMP());
ERROR 1142 (42000): INSERT command denied to user
'jon'@'ghidora' for table 'mytable'
```

Inspection of the `INFORMATION_SCHEMA.EVENTS` table shows that `e_store_ts` exists and is enabled, but its `LAST_EXECUTED` column is `NULL`:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.EVENTS
```

```
     >     WHERE EVENT_NAME='e_store_ts'
     >     AND EVENT_SCHEMA='myschema'\G
*************************** 1. row ***************************
   EVENT_CATALOG: NULL
    EVENT_SCHEMA: myschema
      EVENT_NAME: e_store_ts
         DEFINER: jon@ghidora
      EVENT_BODY: SQL
EVENT_DEFINITION: INSERT INTO myschema.mytable VALUES (UNIX_TIMESTAMP())
      EVENT_TYPE: RECURRING
      EXECUTE_AT: NULL
  INTERVAL_VALUE: 5
  INTERVAL_FIELD: SECOND
        SQL_MODE: NULL
          STARTS: 0000-00-00 00:00:00
            ENDS: 0000-00-00 00:00:00
          STATUS: ENABLED
   ON_COMPLETION: NOT PRESERVE
         CREATED: 2006-02-09 22:36:06
    LAST_ALTERED: 2006-02-09 22:36:06
   LAST_EXECUTED: NULL
   EVENT_COMMENT:
1 row in set (0.00 sec)
```

To rescind the `EVENT` privilege, use the `REVOKE` statement. In this example, the `EVENT` privilege on the schema `myschema` is removed from the `jon@ghidora` user account:

```
REVOKE EVENT ON myschema.* FROM jon@ghidora;
```

Important

Revoking the `EVENT` privilege from a user does not delete or disable any events that may have been created by that user.

An event is not migrated or dropped as a result of renaming or dropping the user who created it.

Suppose that the user `jon@ghidora` has been granted the `EVENT` and `INSERT` privileges on the `myschema` schema. This user then creates the following event:

```
CREATE EVENT e_insert
    ON SCHEDULE
      EVERY 7 SECOND
    DO
      INSERT INTO myschema.mytable;
```

After this event has been created, `root` revokes the `EVENT` privilege for `jon@ghidora`. However, `e_insert` continues to execute, inserting a new row into `mytable` each seven seconds. The same would be true if `root` had issued either of these statements:

- `DROP USER jon@ghidora;`
- `RENAME USER jon@ghidora TO someotherguy@ghidora;`

You can verify that this is true by examining the `mysql.event` table (discussed later in this section) or the `INFORMATION_SCHEMA.EVENTS` table (see Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”) before and after issuing a `DROP USER` or `RENAME USER` statement.

Event definitions are stored in the `mysql.event` table. To drop an event created by another user account, the MySQL `root` user (or another user with the necessary privileges) can delete rows from this table. For example, to remove the event `e_insert` shown previously, `root` can use the following statement:

```
DELETE FROM mysql.event
    WHERE db = 'myschema'
```

```
      AND definer = 'jon@ghidora'
      AND name = 'e_insert';
```

It is very important to match the event name, database schema name, and user account when deleting rows from the `mysql.event` table. This is because the same user can create different events of the same name in different schemas.

Users' `EVENT` privileges are stored in the `Event_priv` columns of the `mysql.user` and `mysql.db` tables. In both cases, this column holds one of the values '`Y`' or '`N`'. '`N`' is the default. `mysql.user.Event_priv` is set to '`Y`' for a given user only if that user has the global `EVENT` privilege (that is, if the privilege was bestowed using `GRANT EVENT ON *.*`). For a schema-level `EVENT` privilege, `GRANT` creates a row in `mysql.db` and sets that row's `Db` column to the name of the schema, the `User` column to the name of the user, and the `Event_priv` column to '`Y`'. There should never be any need to manipulate these tables directly, since the `GRANT EVENT` and `REVOKE EVENT` statements perform the required operations on them.

Five status variables provide counts of event-related operations (but *not* of statements executed by events; see Section C.1, “Restrictions on Stored Programs”). These are:

- `Com_create_event`: The number of `CREATE EVENT` statements executed since the last server restart.
- `Com_alter_event`: The number of `ALTER EVENT` statements executed since the last server restart.
- `Com_drop_event`: The number of `DROP EVENT` statements executed since the last server restart.
- `Com_show_create_event`: The number of `SHOW CREATE EVENT` statements executed since the last server restart.
- `Com_show_events`: The number of `SHOW EVENTS` statements executed since the last server restart.

You can view current values for all of these at one time by running the statement `SHOW STATUS LIKE '%event%';`.

20.5 Using Views

MySQL supports views, including updatable views. Views are stored queries that when invoked produce a result set. A view acts as a virtual table.

To use views if you have upgraded to MySQL 5.5 from an older release that did not support views, you should upgrade your grant tables so that they contain the view-related privileges. See Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”.

The following discussion describes the syntax for creating and dropping views, and shows some examples of how to use them.

Additional Resources

- You may find the Views User Forum of use when working with views.
- For answers to some commonly asked questions regarding views in MySQL, see Section A.6, “MySQL 5.5 FAQ: Views”.
- There are some restrictions on the use of views; see Section C.5, “Restrictions on Views”.

20.5.1 View Syntax

The `CREATE VIEW` statement creates a new view (see Section 13.1.20, “CREATE VIEW Syntax”). To alter the definition of a view or drop a view, use `ALTER VIEW` (see Section 13.1.9, “ALTER VIEW Syntax”), or `DROP VIEW` (see Section 13.1.31, “DROP VIEW Syntax”).

A view can be created from many kinds of `SELECT` statements. It can refer to base tables or other views. It can use joins, `UNION`, and subqueries. The `SELECT` need not even refer to any tables. The following example defines a view that selects two columns from another table, as well as an expression calculated from those columns:

```
mysql> CREATE TABLE t (qty INT, price INT);
mysql> INSERT INTO t VALUES(3, 50), (5, 60);
mysql> CREATE VIEW v AS SELECT qty, price, qty*price AS value FROM t;
mysql> SELECT * FROM v;
+------+-------+-------+
| qty  | price | value |
+------+-------+-------+
|    3 |    50 |   150 |
|    5 |    60 |   300 |
+------+-------+-------+
mysql> SELECT * FROM v WHERE qty = 5;
+------+-------+-------+
| qty  | price | value |
+------+-------+-------+
|    5 |    60 |   300 |
+------+-------+-------+
```

20.5.2 View Processing Algorithms

The optional `ALGORITHM` clause for `CREATE VIEW` or `ALTER VIEW` is a MySQL extension to standard SQL. It affects how MySQL processes the view. `ALGORITHM` takes three values: `MERGE`, `TEMPTABLE`, or `UNDEFINED`.

- For `MERGE`, the text of a statement that refers to the view and the view definition are merged such that parts of the view definition replace corresponding parts of the statement.
- For `TEMPTABLE`, the results from the view are retrieved into a temporary table, which then is used to execute the statement.
- For `UNDEFINED`, MySQL chooses which algorithm to use. It prefers `MERGE` over `TEMPTABLE` if possible, because `MERGE` is usually more efficient and because a view cannot be updatable if a temporary table is used.
- If no `ALGORITHM` clause is present, `UNDEFINED` is the default algorithm.

A reason to specify `TEMPTABLE` explicitly is that locks can be released on underlying tables after the temporary table has been created and before it is used to finish processing the statement. This might result in quicker lock release than the `MERGE` algorithm so that other clients that use the view are not blocked as long.

A view algorithm can be `UNDEFINED` for three reasons:

- No `ALGORITHM` clause is present in the `CREATE VIEW` statement.
- The `CREATE VIEW` statement has an explicit `ALGORITHM = UNDEFINED` clause.
- `ALGORITHM = MERGE` is specified for a view that can be processed only with a temporary table. In this case, MySQL generates a warning and sets the algorithm to `UNDEFINED`.

As mentioned earlier, `MERGE` is handled by merging corresponding parts of a view definition into the statement that refers to the view. The following examples briefly illustrate how the `MERGE` algorithm works. The examples assume that there is a view `v_merge` that has this definition:

```
CREATE ALGORITHM = MERGE VIEW v_merge (vc1, vc2) AS
SELECT c1, c2 FROM t WHERE c3 > 100;
```

Example 1: Suppose that we issue this statement:

```
SELECT * FROM v_merge;
```

MySQL handles the statement as follows:

- `v_merge` becomes `t`
- `*` becomes `vc1, vc2`, which corresponds to `c1, c2`
- The view `WHERE` clause is added

The resulting statement to be executed becomes:

```
SELECT c1, c2 FROM t WHERE c3 > 100;
```

Example 2: Suppose that we issue this statement:

```
SELECT * FROM v_merge WHERE vc1 < 100;
```

This statement is handled similarly to the previous one, except that `vc1 < 100` becomes `c1 < 100` and the view `WHERE` clause is added to the statement `WHERE` clause using an `AND` connective (and parentheses are added to make sure the parts of the clause are executed with correct precedence). The resulting statement to be executed becomes:

```
SELECT c1, c2 FROM t WHERE (c3 > 100) AND (c1 < 100);
```

Effectively, the statement to be executed has a `WHERE` clause of this form:

```
WHERE (select WHERE) AND (view WHERE)
```

If the `MERGE` algorithm cannot be used, a temporary table must be used instead. `MERGE` cannot be used if the view contains any of the following constructs:

- Aggregate functions (`SUM()`, `MIN()`, `MAX()`, `COUNT()`, and so forth)
- `DISTINCT`
- `GROUP BY`
- `HAVING`
- `LIMIT`
- `UNION` or `UNION ALL`
- Subquery in the select list
- Assignment to user variables
- Refers only to literal values (in this case, there is no underlying table)

20.5.3 Updatable and Insertable Views

Some views are updatable and references to them can be used to specify tables to be updated in data change statements. That is, you can use them in statements such as `UPDATE`, `DELETE`, or `INSERT` to update the contents of the underlying table.

For a view to be updatable, there must be a one-to-one relationship between the rows in the view and the rows in the underlying table. There are also certain other constructs that make a view nonupdatable. To be more specific, a view is not updatable if it contains any of the following:

- Aggregate functions (`SUM()`, `MIN()`, `MAX()`, `COUNT()`, and so forth)

- `DISTINCT`
- `GROUP BY`
- `HAVING`
- `UNION` or `UNION ALL`
- Subquery in the select list
- Certain joins (see additional join discussion later in this section)
- Reference to nonupdatable view in the `FROM` clause
- Subquery in the `WHERE` clause that refers to a table in the `FROM` clause
- Refers only to literal values (in this case, there is no underlying table to update)
- `ALGORITHM = TEMPTABLE` (use of a temporary table always makes a view nonupdatable)
- Multiple references to any column of a base table

It is sometimes possible for a multiple-table view to be updatable, assuming that it can be processed with the `MERGE` algorithm. For this to work, the view must use an inner join (not an outer join or a `UNION`). Also, only a single table in the view definition can be updated, so the `SET` clause must name only columns from one of the tables in the view. Views that use `UNION ALL` are not permitted even though they might be theoretically updatable.

With respect to insertability (being updatable with `INSERT` statements), an updatable view is insertable if it also satisfies these additional requirements for the view columns:

- There must be no duplicate view column names.
- The view must contain all columns in the base table that do not have a default value.
- The view columns must be simple column references. They must not be expressions or composite expressions, such as these:

```
3.14159
col1 + 3
UPPER(col2)
col3 / col4
(subquery)
```

MySQL sets a flag, called the view updatability flag, at `CREATE VIEW` time. The flag is set to `YES` (true) if `UPDATE` and `DELETE` (and similar operations) are legal for the view. Otherwise, the flag is set to `NO` (false). The `IS_UPDATABLE` column in the `INFORMATION_SCHEMA.VIEWS` table displays the status of this flag. It means that the server always knows whether a view is updatable.

If a view is not updatable, statements such `UPDATE`, `DELETE`, and `INSERT` are illegal and are rejected. (Note that even if a view is updatable, it might not be possible to insert into it, as described elsewhere in this section.)

The updatability of views may be affected by the value of the `updatable_views_with_limit` system variable. See Section 5.1.5, “Server System Variables”.

Earlier discussion in this section pointed out that a view is not insertable if not all columns are simple column references (for example, if it contains columns that are expressions or composite expressions). Although such a view is not insertable, it can be updatable if you update only columns that are not expressions. Consider this view:

```
CREATE VIEW v AS SELECT col1, 1 AS col2 FROM t;
```

This view is not insertable because `col2` is an expression. But it is updatable if the update does not try to update `col2`. This update is permissible:

```
UPDATE v SET col1 = 0;
```

This update is not permissible because it attempts to update an expression column:

```
UPDATE v SET col2 = 0;
```

For a multiple-table updatable view, `INSERT` can work if it inserts into a single table. `DELETE` is not supported.

`INSERT DELAYED` is not supported for views.

If a table contains an `AUTO_INCREMENT` column, inserting into an insertable view on the table that does not include the `AUTO_INCREMENT` column does not change the value of `LAST_INSERT_ID()`, because the side effects of inserting default values into columns not part of the view should not be visible.

20.5.4 The View WITH CHECK OPTION Clause

The `WITH CHECK OPTION` clause can be given for an updatable view to prevent inserts to rows for which the `WHERE` clause in the *`select_statement`* is not true. It also prevents updates to rows for which the `WHERE` clause is true but the update would cause it to be not true (in other words, it prevents visible rows from being updated to nonvisible rows).

In a `WITH CHECK OPTION` clause for an updatable view, the `LOCAL` and `CASCADED` keywords determine the scope of check testing when the view is defined in terms of another view. When neither keyword is given, the default is `CASCADED`. The `LOCAL` keyword restricts the `CHECK OPTION` only to the view being defined. `CASCADED` causes the checks for underlying views to be evaluated as well.

Consider the definitions for the following table and set of views:

```
CREATE TABLE t1 (a INT);
CREATE VIEW v1 AS SELECT * FROM t1 WHERE a < 2
WITH CHECK OPTION;
CREATE VIEW v2 AS SELECT * FROM v1 WHERE a > 0
WITH LOCAL CHECK OPTION;
CREATE VIEW v3 AS SELECT * FROM v1 WHERE a > 0
WITH CASCADED CHECK OPTION;
```

Here the `v2` and `v3` views are defined in terms of another view, `v1`. `v2` has a `LOCAL` check option, so inserts are tested only against the `v2` check. `v3` has a `CASCADED` check option, so inserts are tested not only against its own check, but against those of underlying views. The following statements illustrate these differences:

```
mysql> INSERT INTO v2 VALUES (2);
Query OK, 1 row affected (0.00 sec)
mysql> INSERT INTO v3 VALUES (2);
ERROR 1369 (HY000): CHECK OPTION failed 'test.v3'
```

20.5.5 View Metadata

Metadata about views can be obtained as follows:

- Query the `VIEWS` table of the `INFORMATION_SCHEMA` database. See Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”.
- Use the `SHOW CREATE VIEW` statement. See Section 13.7.5.14, “SHOW CREATE VIEW Syntax”.

20.6 Access Control for Stored Programs and Views

Stored programs and views are defined prior to use and, when referenced, execute within a security context that determines their privileges. These privileges are controlled by their `DEFINER` attribute, and, if there is one, their `SQL SECURITY` characteristic.

All stored programs (procedures, functions, triggers, and events) and views can have a `DEFINER` attribute that names a MySQL account. If the `DEFINER` attribute is omitted from a stored program or view definition, the default account is the user who creates the object.

In addition, stored routines (procedures and functions) and views can have an `SQL SECURITY` characteristic with a value of `DEFINER` or `INVOKER` to specify whether the object executes in definer or invoker context. If the `SQL SECURITY` characteristic is omitted, the default is definer context.

Triggers and events have no `SQL SECURITY` characteristic and always execute in definer context. The server invokes these objects automatically as necessary, so there is no invoking user.

Definer and invoker security contexts differ as follows:

- A stored program or view that executes in definer security context executes with the privileges of the account named by its `DEFINER` attribute. These privileges may be entirely different from those of the invoking user. The invoker must have appropriate privileges to reference the object (for example, `EXECUTE` to call a stored procedure or `SELECT` to select from a view), but when the object executes, the invoker's privileges are ignored and only the `DEFINER` account privileges matter. If this account has few privileges, the object is correspondingly limited in the operations it can perform. If the `DEFINER` account is highly privileged (such as a `root` account), the object can perform powerful operations *no matter who invokes it.*
- A stored routine or view that executes in invoker security context can perform only operations for which the invoker has privileges. The `DEFINER` attribute can be specified but has no effect for objects that execute in invoker context.

Consider the following stored procedure:

```
CREATE DEFINER = 'admin'@'localhost' PROCEDURE p1()
SQL SECURITY DEFINER
BEGIN
  UPDATE t1 SET counter = counter + 1;
END;
```

Any user who has the `EXECUTE` privilege for `p1` can invoke it with a `CALL` statement. However, when `p1` executes, it does so in definer security context and thus executes with the privileges of `'admin'@'localhost'`, the account named in the `DEFINER` attribute. This account must have the `EXECUTE` privilege for `p1` as well as the `UPDATE` privilege for the table `t1`. Otherwise, the procedure fails.

Now consider this stored procedure, which is identical to `p1` except that its `SQL SECURITY` characteristic is `INVOKER`:

```
CREATE DEFINER = 'admin'@'localhost' PROCEDURE p2()
SQL SECURITY INVOKER
BEGIN
  UPDATE t1 SET counter = counter + 1;
END;
```

`p2`, unlike `p1`, executes in invoker security context. The `DEFINER` attribute is irrelevant and `p2` executes with the privileges of the invoking user. `p2` fails if the invoker lacks the `EXECUTE` privilege for `p2` or the `UPDATE` privilege for the table `t1`.

MySQL uses the following rules to control which accounts a user can specify in an object `DEFINER` attribute:

- You can specify a `DEFINER` value other than your own account only if you have the `SUPER` privilege.
- If you do not have the `SUPER` privilege, the only legal user value is your own account, either specified literally or by using `CURRENT_USER`. You cannot set the definer to some other account.

To minimize the risk potential for stored program and view creation and use, follow these guidelines:

- For a stored routine or view, use `SQL SECURITY INVOKER` in the object definition when possible so that it can be used only by users with permissions appropriate for the operations performed by the object.
- If you create definer-context stored programs or views while using an account that has the `SUPER` privilege, specify an explicit `DEFINER` attribute that names an account possessing only the privileges required for the operations performed by the object. Specify a highly privileged `DEFINER` account only when absolutely necessary.
- Administrators can prevent users from specifying highly privileged `DEFINER` accounts by not granting them the `SUPER` privilege.
- Definer-context objects should be written keeping in mind that they may be able to access data for which the invoking user has no privileges. In some cases, you can prevent reference to these objects by not granting unauthorized users particular privileges:
  - A stored procedure or function cannot be referenced by a user who does not have the `EXECUTE` privilege for it.
  - A view cannot be referenced by a user who does not have the appropriate privilege for it (`SELECT` to select from it, `INSERT` to insert into it, and so forth).

  However, no such control exists for triggers because users do not reference them directly. A trigger always executes in definer context and is activated by access to the table with which it is associated, even ordinary table accesses by users with no special privileges. If the `DEFINER` account is highly privileged, the trigger can perform sensitive or dangerous operations. This remains true if the `SUPER` and `TRIGGER` privileges needed to create the trigger are revoked from the account of the user who created it. Administrators should be especially careful about granting users that combination of privileges.

20.7 Binary Logging of Stored Programs

The binary log contains information about SQL statements that modify database contents. This information is stored in the form of “events” that describe the modifications. The binary log has two important purposes:

- For replication, the binary log is used on master replication servers as a record of the statements to be sent to slave servers. The master server sends the events contained in its binary log to its slaves, which execute those events to make the same data changes that were made on the master. See Section 17.2, “Replication Implementation”.
- Certain data recovery operations require use of the binary log. After a backup file has been restored, the events in the binary log that were recorded after the backup was made are re-executed. These events bring databases up to date from the point of the backup. See Section 7.3.2, “Using Backups for Recovery”.

However, if logging occurs at the statement level, there are certain binary logging issues with respect to stored programs (stored procedures and functions, triggers, and events):

- In some cases, a statement might affect different sets of rows on master and slave.
- Replicated statements executed on a slave are processed by the slave SQL thread, which has full privileges. It is possible for a procedure to follow different execution paths on master and slave

servers, so a user can write a routine containing a dangerous statement that will execute only on the slave where it is processed by a thread that has full privileges.

- If a stored program that modifies data is nondeterministic, it is not repeatable. This can result in different data on master and slave, or cause restored data to differ from the original data.

This section describes how MySQL handles binary logging for stored programs. It states the current conditions that the implementation places on the use of stored programs, and what you can do to avoid logging problems. It also provides additional information about the reasons for these conditions.

In general, the issues described here result when binary logging occurs at the SQL statement level. If you use row-based binary logging, the log contains changes made to individual rows as a result of executing SQL statements. When routines or triggers execute, row changes are logged, not the statements that make the changes. For stored procedures, this means that the `CALL` statement is not logged. For stored functions, row changes made within the function are logged, not the function invocation. For triggers, row changes made by the trigger are logged. On the slave side, only the row changes are seen, not the stored program invocation. For general information about row-based logging, see Section 17.1.2, “Replication Formats”.

Unless noted otherwise, the remarks here assume that you have enabled binary logging by starting the server with the `--log-bin` option. (See Section 5.4.4, “The Binary Log”.) If the binary log is not enabled, replication is not possible, nor is the binary log available for data recovery.

The conditions on the use of stored functions in MySQL can be summarized as follows. These conditions do not apply to stored procedures or Event Scheduler events and they do not apply unless binary logging is enabled.

- To create or alter a stored function, you must have the `SUPER` privilege, in addition to the `CREATE ROUTINE` or `ALTER ROUTINE` privilege that is normally required. (Depending on the `DEFINER` value in the function definition, `SUPER` might be required regardless of whether binary logging is enabled. See Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”.)

- When you create a stored function, you must declare either that it is deterministic or that it does not modify data. Otherwise, it may be unsafe for data recovery or replication.

  By default, for a `CREATE FUNCTION` statement to be accepted, at least one of `DETERMINISTIC`, `NO SQL`, or `READS SQL DATA` must be specified explicitly. Otherwise an error occurs:

```
ERROR 1418 (HY000): This function has none of DETERMINISTIC, NO SQL,
or READS SQL DATA in its declaration and binary logging is enabled
(you *might* want to use the less safe log_bin_trust_function_creators
variable)
```

  This function is deterministic (and does not modify data), so it is safe:

```
CREATE FUNCTION f1(i INT)
RETURNS INT
DETERMINISTIC
READS SQL DATA
BEGIN
  RETURN i;
END;
```

  This function uses `UUID()`, which is not deterministic, so the function also is not deterministic and is not safe:

```
CREATE FUNCTION f2()
RETURNS CHAR(36) CHARACTER SET utf8
BEGIN
  RETURN UUID();
END;
```

This function modifies data, so it may not be safe:

```
CREATE FUNCTION f3(p_id INT)
RETURNS INT
BEGIN
  UPDATE t SET modtime = NOW() WHERE id = p_id;
  RETURN ROW_COUNT();
END;
```

Assessment of the nature of a function is based on the "honesty" of the creator: MySQL does not check that a function declared `DETERMINISTIC` is free of statements that produce nondeterministic results.

- Although it is possible to create a deterministic stored function without specifying `DETERMINISTIC`, you cannot execute this function using statement-based binary logging. To execute such a function, you must use row-based or mixed binary logging. Alternatively, if you explicitly specify `DETERMINISTIC` in the function definition, you can use any kind of logging, including statement-based logging.

- To relax the preceding conditions on function creation (that you must have the `SUPER` privilege and that a function must be declared deterministic or to not modify data), set the global `log_bin_trust_function_creators` system variable to 1. By default, this variable has a value of 0, but you can change it like this:

```
mysql> SET GLOBAL log_bin_trust_function_creators = 1;
```

  You can also set this variable by using the `--log-bin-trust-function-creators=1` option when starting the server.

  If binary logging is not enabled, `log_bin_trust_function_creators` does not apply. `SUPER` is not required for function creation unless, as described previously, the `DEFINER` value in the function definition requires it.

- For information about built-in functions that may be unsafe for replication (and thus cause stored functions that use them to be unsafe as well), see Section 17.4.1, "Replication Features and Issues".

Triggers are similar to stored functions, so the preceding remarks regarding functions also apply to triggers with the following exception: `CREATE TRIGGER` does not have an optional `DETERMINISTIC` characteristic, so triggers are assumed to be always deterministic. However, this assumption might be invalid in some cases. For example, the `UUID()` function is nondeterministic (and does not replicate). Be careful about using such functions in triggers.

Triggers can update tables, so error messages similar to those for stored functions occur with `CREATE TRIGGER` if you do not have the required privileges. On the slave side, the slave uses the trigger `DEFINER` attribute to determine which user is considered to be the creator of the trigger.

The rest of this section provides additional detail about the logging implementation and its implications. You need not read it unless you are interested in the background on the rationale for the current logging-related conditions on stored routine use. This discussion applies only for statement-based logging, and not for row-based logging, with the exception of the first item: `CREATE` and `DROP` statements are logged as statements regardless of the logging mode.

- The server writes `CREATE EVENT`, `CREATE PROCEDURE`, `CREATE FUNCTION`, `ALTER EVENT`, `ALTER PROCEDURE`, `ALTER FUNCTION`, `DROP EVENT`, `DROP PROCEDURE`, and `DROP FUNCTION` statements to the binary log.

- A stored function invocation is logged as a `SELECT` statement if the function changes data and occurs within a statement that would not otherwise be logged. This prevents nonreplication of data changes that result from use of stored functions in nonlogged statements. For example, `SELECT` statements are not written to the binary log, but a `SELECT` might invoke a stored function that makes

changes. To handle this, a `SELECT func_name()` statement is written to the binary log when the given function makes a change. Suppose that the following statements are executed on the master:

```
CREATE FUNCTION f1(a INT) RETURNS INT
BEGIN
  IF (a < 3) THEN
    INSERT INTO t2 VALUES (a);
  END IF;
  RETURN 0;
END;

CREATE TABLE t1 (a INT);
INSERT INTO t1 VALUES (1),(2),(3);

SELECT f1(a) FROM t1;
```

When the `SELECT` statement executes, the function `f1()` is invoked three times. Two of those invocations insert a row, and MySQL logs a `SELECT` statement for each of them. That is, MySQL writes the following statements to the binary log:

```
SELECT f1(1);
SELECT f1(2);
```

The server also logs a `SELECT` statement for a stored function invocation when the function invokes a stored procedure that causes an error. In this case, the server writes the `SELECT` statement to the log along with the expected error code. On the slave, if the same error occurs, that is the expected result and replication continues. Otherwise, replication stops.

- Logging stored function invocations rather than the statements executed by a function has a security implication for replication, which arises from two factors:
  - It is possible for a function to follow different execution paths on master and slave servers.
  - Statements executed on a slave are processed by the slave SQL thread which has full privileges.

  The implication is that although a user must have the `CREATE ROUTINE` privilege to create a function, the user can write a function containing a dangerous statement that will execute only on the slave where it is processed by a thread that has full privileges. For example, if the master and slave servers have server ID values of 1 and 2, respectively, a user on the master server could create and invoke an unsafe function `unsafe_func()` as follows:

```
mysql> delimiter //
mysql> CREATE FUNCTION unsafe_func () RETURNS INT
    -> BEGIN
    ->   IF @@server_id=2 THEN dangerous_statement; END IF;
    ->   RETURN 1;
    -> END;
    -> //
mysql> delimiter ;
mysql> INSERT INTO t VALUES(unsafe_func());
```

The `CREATE FUNCTION` and `INSERT` statements are written to the binary log, so the slave will execute them. Because the slave SQL thread has full privileges, it will execute the dangerous statement. Thus, the function invocation has different effects on the master and slave and is not replication-safe.

To guard against this danger for servers that have binary logging enabled, stored function creators must have the `SUPER` privilege, in addition to the usual `CREATE ROUTINE` privilege that is required. Similarly, to use `ALTER FUNCTION`, you must have the `SUPER` privilege in addition to the `ALTER ROUTINE` privilege. Without the `SUPER` privilege, an error will occur:

```
ERROR 1419 (HY000): You do not have the SUPER privilege and
```

```
binary logging is enabled (you *might* want to use the less safe
log_bin_trust_function_creators variable)
```

If you do not want to require function creators to have the SUPER privilege (for example, if all users with the CREATE ROUTINE privilege on your system are experienced application developers), set the global log_bin_trust_function_creators system variable to 1. You can also set this variable by using the --log-bin-trust-function-creators=1 option when starting the server. If binary logging is not enabled, log_bin_trust_function_creators does not apply. SUPER is not required for function creation unless, as described previously, the DEFINER value in the function definition requires it.

- If a function that performs updates is nondeterministic, it is not repeatable. This can have two undesirable effects:
  - It will make a slave different from the master.
  - Restored data will be different from the original data.

  To deal with these problems, MySQL enforces the following requirement: On a master server, creation and alteration of a function is refused unless you declare the function to be deterministic or to not modify data. Two sets of function characteristics apply here:
  - The DETERMINISTIC and NOT DETERMINISTIC characteristics indicate whether a function always produces the same result for given inputs. The default is NOT DETERMINISTIC if neither characteristic is given. To declare that a function is deterministic, you must specify DETERMINISTIC explicitly.
  - The CONTAINS SQL, NO SQL, READS SQL DATA, and MODIFIES SQL DATA characteristics provide information about whether the function reads or writes data. Either NO SQL or READS SQL DATA indicates that a function does not change data, but you must specify one of these explicitly because the default is CONTAINS SQL if no characteristic is given.

  By default, for a CREATE FUNCTION statement to be accepted, at least one of DETERMINISTIC, NO SQL, or READS SQL DATA must be specified explicitly. Otherwise an error occurs:

```
ERROR 1418 (HY000): This function has none of DETERMINISTIC, NO SQL,
or READS SQL DATA in its declaration and binary logging is enabled
(you *might* want to use the less safe log_bin_trust_function_creators
variable)
```

  If you set log_bin_trust_function_creators to 1, the requirement that functions be deterministic or not modify data is dropped.

- Stored procedure calls are logged at the statement level rather than at the CALL level. That is, the server does not log the CALL statement, it logs those statements within the procedure that actually execute. As a result, the same changes that occur on the master will be observed on slave servers. This prevents problems that could result from a procedure having different execution paths on different machines.

  In general, statements executed within a stored procedure are written to the binary log using the same rules that would apply were the statements to be executed in standalone fashion. Some special care is taken when logging procedure statements because statement execution within procedures is not quite the same as in nonprocedure context:
  - A statement to be logged might contain references to local procedure variables. These variables do not exist outside of stored procedure context, so a statement that refers to such a variable cannot be logged literally. Instead, each reference to a local variable is replaced by this construct for logging purposes:

```
NAME_CONST(var_name, var_value)
```

var_name is the local variable name, and *var_value* is a constant indicating the value that the variable has at the time the statement is logged. NAME_CONST() has a value of *var_value*, and a “name” of *var_name*. Thus, if you invoke this function directly, you get a result like this:

```
mysql> SELECT NAME_CONST('myname', 14);
+--------+
| myname |
+--------+
|     14 |
+--------+
```

NAME_CONST() enables a logged standalone statement to be executed on a slave with the same effect as the original statement that was executed on the master within a stored procedure.

The use of NAME_CONST() can result in a problem for CREATE TABLE ... SELECT statements when the source column expressions refer to local variables. Converting these references to NAME_CONST() expressions can result in column names that are different on the master and slave servers, or names that are too long to be legal column identifiers. A workaround is to supply aliases for columns that refer to local variables. Consider this statement when myvar has a value of 1:

```
CREATE TABLE t1 SELECT myvar;
```

That will be rewritten as follows:

```
CREATE TABLE t1 SELECT NAME_CONST(myvar, 1);
```

To ensure that the master and slave tables have the same column names, write the statement like this:

```
CREATE TABLE t1 SELECT myvar AS myvar;
```

The rewritten statement becomes:

```
CREATE TABLE t1 SELECT NAME_CONST(myvar, 1) AS myvar;
```

- A statement to be logged might contain references to user-defined variables. To handle this, MySQL writes a SET statement to the binary log to make sure that the variable exists on the slave with the same value as on the master. For example, if a statement refers to a variable @my_var, that statement will be preceded in the binary log by the following statement, where *value* is the value of @my_var on the master:

  ```
  SET @my_var = value;
  ```

- Procedure calls can occur within a committed or rolled-back transaction. Transactional context is accounted for so that the transactional aspects of procedure execution are replicated correctly. That is, the server logs those statements within the procedure that actually execute and modify data, and also logs BEGIN, COMMIT, and ROLLBACK statements as necessary. For example, if a procedure updates only transactional tables and is executed within a transaction that is rolled back, those updates are not logged. If the procedure occurs within a committed transaction, BEGIN and COMMIT statements are logged with the updates. For a procedure that executes within a rolled-back transaction, its statements are logged using the same rules that would apply if the statements were executed in standalone fashion:

  - Updates to transactional tables are not logged.
  - Updates to nontransactional tables are logged because rollback does not cancel them.

    - Updates to a mix of transactional and nontransactional tables are logged surrounded by `BEGIN` and `ROLLBACK` so that slaves will make the same changes and rollbacks as on the master.

- A stored procedure call is *not* written to the binary log at the statement level if the procedure is invoked from within a stored function. In that case, the only thing logged is the statement that invokes the function (if it occurs within a statement that is logged) or a `DO` statement (if it occurs within a statement that is not logged). For this reason, care should be exercised in the use of stored functions that invoke a procedure, even if the procedure is otherwise safe in itself.

Chapter 21 INFORMATION_SCHEMA Tables

Table of Contents

21.1 The INFORMATION_SCHEMA CHARACTER_SETS Table 2548
21.2 The INFORMATION_SCHEMA COLLATIONS Table 2549
21.3 The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table ... 2549
21.4 The INFORMATION_SCHEMA COLUMNS Table 2550
21.5 The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table 2550
21.6 The INFORMATION_SCHEMA ENGINES Table 2551
21.7 The INFORMATION_SCHEMA EVENTS Table 2551
21.8 The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables 2555
21.9 The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables . 2555
21.10 The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table 2555
21.11 The INFORMATION_SCHEMA PARAMETERS Table 2556
21.12 The INFORMATION_SCHEMA PARTITIONS Table 2557
21.13 The INFORMATION_SCHEMA PLUGINS Table 2560
21.14 The INFORMATION_SCHEMA PROCESSLIST Table 2561
21.15 The INFORMATION_SCHEMA PROFILING Table 2562
21.16 The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table 2563
21.17 The INFORMATION_SCHEMA ROUTINES Table 2563
21.18 The INFORMATION_SCHEMA SCHEMATA Table 2565
21.19 The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table 2565
21.20 The INFORMATION_SCHEMA STATISTICS Table 2566
21.21 The INFORMATION_SCHEMA TABLES Table 2566
21.22 The INFORMATION_SCHEMA TABLESPACES Table 2568
21.23 The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table 2568
21.24 The INFORMATION_SCHEMA TABLE_PRIVILEGES Table 2569
21.25 The INFORMATION_SCHEMA TRIGGERS Table 2569
21.26 The INFORMATION_SCHEMA USER_PRIVILEGES Table 2571
21.27 The INFORMATION_SCHEMA VIEWS Table 2571
21.28 InnoDB INFORMATION_SCHEMA Tables 2573
21.28.1 The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table 2573
21.28.2 The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table 2575
21.28.3 The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table 2577
21.28.4 The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables 2579
21.28.5 The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables 2580
21.28.6 The INFORMATION_SCHEMA INNODB_LOCKS Table 2581
21.28.7 The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table 2582
21.28.8 The INFORMATION_SCHEMA INNODB_TRX Table 2583
21.29 NDB Cluster INFORMATION_SCHEMA Tables 2585
21.29.1 The INFORMATION_SCHEMA FILES Table 2586
21.29.2 The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table 2591
21.30 Thread Pool INFORMATION_SCHEMA Tables 2592
21.30.1 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table 2592
21.30.2 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table 2594
21.30.3 The INFORMATION_SCHEMA TP_THREAD_STATE Table 2596
21.31 Extensions to SHOW Statements 2596

`INFORMATION_SCHEMA` provides access to database *metadata*, information about the MySQL server such as the name of a database or table, the data type of a column, or access privileges. Other terms that are sometimes used for this information are *data dictionary* and *system catalog*.

INFORMATION_SCHEMA Usage Notes

`INFORMATION_SCHEMA` is a database within each MySQL instance, the place that stores information about all the other databases that the MySQL server maintains. The `INFORMATION_SCHEMA` database contains several read-only tables. They are actually views, not base tables, so there are no files associated with them, and you cannot set triggers on them. Also, there is no database directory with that name.

Although you can select `INFORMATION_SCHEMA` as the default database with a `USE` statement, you can only read the contents of tables, not perform `INSERT`, `UPDATE`, or `DELETE` operations on them.

Example

Here is an example of a statement that retrieves information from `INFORMATION_SCHEMA`:

```
mysql> SELECT table_name, table_type, engine
       FROM information_schema.tables
       WHERE table_schema = 'db5'
       ORDER BY table_name;
+------------+------------+--------+
| table_name | table_type | engine |
+------------+------------+--------+
| fk         | BASE TABLE | InnoDB |
| fk2        | BASE TABLE | InnoDB |
| goto       | BASE TABLE | MyISAM |
| into       | BASE TABLE | MyISAM |
| k          | BASE TABLE | MyISAM |
| kurs       | BASE TABLE | MyISAM |
| loop       | BASE TABLE | MyISAM |
| pk         | BASE TABLE | InnoDB |
| t          | BASE TABLE | MyISAM |
| t2         | BASE TABLE | MyISAM |
| t3         | BASE TABLE | MyISAM |
| t7         | BASE TABLE | MyISAM |
| tables     | BASE TABLE | MyISAM |
| v          | VIEW       | NULL   |
| v2         | VIEW       | NULL   |
| v3         | VIEW       | NULL   |
| v56        | VIEW       | NULL   |
+------------+------------+--------+
17 rows in set (0.01 sec)
```

Explanation: The statement requests a list of all the tables in database `db5`, showing just three pieces of information: the name of the table, its type, and its storage engine.

The definition for character columns (for example, `TABLES.TABLE_NAME`) is generally `VARCHAR(N) CHARACTER SET utf8` where *`N`* is at least 64. MySQL uses the default collation for this character set (`utf8_general_ci`) for all searches, sorts, comparisons, and other string operations on such columns. However, searches in `INFORMATION_SCHEMA` string columns are also affected by file system case sensitivity. For more information, see Section 10.1.8.7, “Using Collation in INFORMATION_SCHEMA Searches”.

Each MySQL user has the right to access these tables, but can see only the rows in the tables that correspond to objects for which the user has the proper access privileges. In some cases (for example, the `ROUTINE_DEFINITION` column in the `INFORMATION_SCHEMA.ROUTINES` table), users who have insufficient privileges will see `NULL`.

Character Set Considerations

The definition for character columns (for example, `TABLES.TABLE_NAME`) is generally `VARCHAR(N) CHARACTER SET utf8` where *`N`* is at least 64. MySQL uses the default collation for this character set (`utf8_general_ci`) for all searches, sorts, comparisons, and other string operations on such columns.

Because some MySQL objects are represented as files, searches in `INFORMATION_SCHEMA` string columns can be affected by file system case sensitivity. For more information, see Section 10.1.8.7, “Using Collation in INFORMATION_SCHEMA Searches”.

INFORMATION_SCHEMA as Alternative to SHOW Statements

The `SELECT ... FROM INFORMATION_SCHEMA` statement is intended as a more consistent way to provide access to the information provided by the various `SHOW` statements that MySQL supports (`SHOW DATABASES`, `SHOW TABLES`, and so forth). Using `SELECT` has these advantages, compared to `SHOW`:

- It conforms to Codd's rules, because all access is done on tables.
- You can use the familiar syntax of the `SELECT` statement, and only need to learn some table and column names.
- The implementor need not worry about adding keywords.
- You can filter, sort, concatenate, and transform the results from `INFORMATION_SCHEMA` queries into whatever format your application needs, such as a data structure or a text representation to parse.
- This technique is more interoperable with other database systems. For example, Oracle Database users are familiar with querying tables in the Oracle data dictionary.

Because `SHOW` is familiar and widely used, the `SHOW` statements remain as an alternative. In fact, along with the implementation of `INFORMATION_SCHEMA`, there are enhancements to `SHOW` as described in Section 21.31, “Extensions to SHOW Statements”.

Privileges

Each MySQL user has the right to access these tables, but can see only the rows in the tables that correspond to objects for which the user has the proper access privileges. In some cases (for example, the `ROUTINE_DEFINITION` column in the `INFORMATION_SCHEMA.ROUTINES` table), users who have insufficient privileges see `NULL`. These restrictions do not apply for `InnoDB` tables; you can see them with only the `PROCESS` privilege.

The same privileges apply to selecting information from `INFORMATION_SCHEMA` and viewing the same information through `SHOW` statements. In either case, you must have some privilege on an object to see information about it.

Performance Considerations

`INFORMATION_SCHEMA` queries that search for information from more than one database might take a long time and impact performance. To check the efficiency of a query, you can use `EXPLAIN`. For information about using `EXPLAIN` output to tune `INFORMATION_SCHEMA` queries, see Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”.

Standards Considerations

The implementation for the `INFORMATION_SCHEMA` table structures in MySQL follows the ANSI/ISO SQL:2003 standard Part 11 *Schemata*. Our intent is approximate compliance with SQL:2003 core feature F021 *Basic information schema*.

Users of SQL Server 2000 (which also follows the standard) may notice a strong similarity. However, MySQL has omitted many columns that are not relevant for our implementation, and added columns that are MySQL-specific. One such column is the `ENGINE` column in the `INFORMATION_SCHEMA.TABLES` table.

To avoid using any name that is reserved in the standard or in DB2, SQL Server, or Oracle, we changed the names of some columns marked “MySQL extension”. (For example, we changed `COLLATION` to `TABLE_COLLATION` in the `TABLES` table.) See the list of reserved words near the

end of this article: https://web.archive.org/web/20070428032454/http://www.dbazine.com/db2/db2-disarticles/gulutzan5.

Conventions in the INFORMATION_SCHEMA Reference Sections

The following sections describe each of the tables and columns in `INFORMATION_SCHEMA`. For each column, there are three pieces of information:

- "`INFORMATION_SCHEMA` Name" indicates the name for the column in the `INFORMATION_SCHEMA` table. This corresponds to the standard SQL name unless the "Remarks" field says "MySQL extension."
- "`SHOW` Name" indicates the equivalent field name in the closest `SHOW` statement, if there is one.
- "Remarks" provides additional information where applicable. If this field is `NULL`, it means that the value of the column is always `NULL`. If this field says "MySQL extension," the column is a MySQL extension to standard SQL.

Many sections indicate what `SHOW` statement is equivalent to a `SELECT` that retrieves information from `INFORMATION_SCHEMA`. For `SHOW` statements that display information for the default database if you omit a `FROM` *`db_name`* clause, you can often select information for the default database by adding an `AND TABLE_SCHEMA = SCHEMA()` condition to the `WHERE` clause of a query that retrieves information from an `INFORMATION_SCHEMA` table.

For information about `INFORMATION_SCHEMA` tables specific to the `InnoDB` storage engine, see Section 21.28, "InnoDB INFORMATION_SCHEMA Tables". For information about `INFORMATION_SCHEMA` tables specific to the `NDB` storage engine (NDB Cluster), see Section 21.29, "NDB Cluster INFORMATION_SCHEMA Tables". For information about `INFORMATION_SCHEMA` tables specific to the thread pool plugin, see Section 21.30, "Thread Pool INFORMATION_SCHEMA Tables".

For answers to questions that are often asked concerning the `INFORMATION_SCHEMA` database, see Section A.7, "MySQL 5.5 FAQ: INFORMATION_SCHEMA".

Related Information

These sections discuss additional `INFORMATION_SCHEMA`-related topics:

- information about `INFORMATION_SCHEMA` tables specific to the `InnoDB` storage engine: Section 21.28, "InnoDB INFORMATION_SCHEMA Tables"
- information about `INFORMATION_SCHEMA` tables specific to the `NDB` storage engine (NDB Cluster): Section 21.29, "NDB Cluster INFORMATION_SCHEMA Tables"
- information about `INFORMATION_SCHEMA` tables specific to the thread pool plugin: Section 21.30, "Thread Pool INFORMATION_SCHEMA Tables"
- Answers to questions that are often asked concerning the `INFORMATION_SCHEMA` database: Section A.7, "MySQL 5.5 FAQ: INFORMATION_SCHEMA"
- `INFORMATION_SCHEMA` queries and the optimizer: Section 8.2.3, "Optimizing INFORMATION_SCHEMA Queries"
- The effect of collation on `INFORMATION_SCHEMA` comparisons: Section 10.1.8.7, "Using Collation in INFORMATION_SCHEMA Searches"

21.1 The INFORMATION_SCHEMA CHARACTER_SETS Table

The `CHARACTER_SETS` table provides information about available character sets.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`CHARACTER_SET_NAME`	`Charset`	

INFORMATION_SCHEMA Name	SHOW Name	Remarks
DEFAULT_COLLATE_NAME	Default collation	
DESCRIPTION	Description	MySQL extension
MAXLEN	Maxlen	MySQL extension

The following statements are equivalent:

```
SELECT * FROM INFORMATION_SCHEMA.CHARACTER_SETS
  [WHERE CHARACTER_SET_NAME LIKE 'wild']

SHOW CHARACTER SET
  [LIKE 'wild']
```

21.2 The INFORMATION_SCHEMA COLLATIONS Table

The COLLATIONS table provides information about collations for each character set.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
COLLATION_NAME	Collation	
CHARACTER_SET_NAME	Charset	MySQL extension
ID	Id	MySQL extension
IS_DEFAULT	Default	MySQL extension
IS_COMPILED	Compiled	MySQL extension
SORTLEN	Sortlen	MySQL extension

- COLLATION_NAME is the collation name.
- CHARACTER_SET_NAME is the name of the character set with which the collation is associated.
- ID is the collation ID.
- IS_DEFAULT indicates whether the collation is the default for its character set.
- IS_COMPILED indicates whether the character set is compiled into the server.
- SORTLEN is related to the amount of memory required to sort strings expressed in the character set.

Collation information is also available from the SHOW COLLATION statement. The following statements are equivalent:

```
SELECT COLLATION_NAME FROM INFORMATION_SCHEMA.COLLATIONS
  [WHERE COLLATION_NAME LIKE 'wild']

SHOW COLLATION
  [LIKE 'wild']
```

21.3 The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table

The COLLATION_CHARACTER_SET_APPLICABILITY table indicates what character set is applicable for what collation. The columns are equivalent to the first two display fields that we get from SHOW COLLATION.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
COLLATION_NAME	Collation	
CHARACTER_SET_NAME	Charset	

21.4 The INFORMATION_SCHEMA COLUMNS Table

The `COLUMNS` table provides information about columns in tables.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`TABLE_CATALOG`		`def`
`TABLE_SCHEMA`		
`TABLE_NAME`		
`COLUMN_NAME`	`Field`	
`ORDINAL_POSITION`		see notes
`COLUMN_DEFAULT`	`Default`	
`IS_NULLABLE`	`Null`	
`DATA_TYPE`	`Type`	
`CHARACTER_MAXIMUM_LENGTH`	`Type`	
`CHARACTER_OCTET_LENGTH`		
`NUMERIC_PRECISION`	`Type`	
`NUMERIC_SCALE`	`Type`	
`CHARACTER_SET_NAME`		
`COLLATION_NAME`	`Collation`	
`COLUMN_TYPE`	`Type`	MySQL extension
`COLUMN_KEY`	`Key`	MySQL extension
`EXTRA`	`Extra`	MySQL extension
`PRIVILEGES`	`Privileges`	MySQL extension
`COLUMN_COMMENT`	`Comment`	MySQL extension

Notes:

- In `SHOW`, the `Type` display includes values from several different `COLUMNS` columns.
- `ORDINAL_POSITION` is necessary because you might want to say `ORDER BY ORDINAL_POSITION`. Unlike `SHOW`, `SELECT` does not have automatic ordering.
- `CHARACTER_OCTET_LENGTH` should be the same as `CHARACTER_MAXIMUM_LENGTH`, except for multibyte character sets.
- `CHARACTER_SET_NAME` can be derived from `Collation`. For example, if you say `SHOW FULL COLUMNS FROM t`, and you see in the `Collation` column a value of `latin1_swedish_ci`, the character set is what is before the first underscore: `latin1`.

The following statements are nearly equivalent:

```
SELECT COLUMN_NAME, DATA_TYPE, IS_NULLABLE, COLUMN_DEFAULT
  FROM INFORMATION_SCHEMA.COLUMNS
  WHERE table_name = 'tbl_name'
  [AND table_schema = 'db_name']
  [AND column_name LIKE 'wild']

SHOW COLUMNS
  FROM tbl_name
  [FROM db_name]
  [LIKE 'wild']
```

21.5 The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table

The COLUMN_PRIVILEGES table provides information about column privileges. This information comes from the mysql.columns_priv grant table.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
GRANTEE		*'user_name'@'host_name'* value
TABLE_CATALOG		def
TABLE_SCHEMA		
TABLE_NAME		
COLUMN_NAME		
PRIVILEGE_TYPE		
IS_GRANTABLE		

Notes:

- In the output from SHOW FULL COLUMNS, the privileges are all in one field and in lowercase, for example, select,insert,update,references. In COLUMN_PRIVILEGES, there is one privilege per row, in uppercase.
- PRIVILEGE_TYPE can contain one (and only one) of these values: SELECT, INSERT, UPDATE, REFERENCES.
- If the user has GRANT OPTION privilege, IS_GRANTABLE should be YES. Otherwise, IS_GRANTABLE should be NO. The output does not list GRANT OPTION as a separate privilege.

The following statements are *not* equivalent:

```
SELECT ... FROM INFORMATION_SCHEMA.COLUMN_PRIVILEGES

SHOW GRANTS ...
```

21.6 The INFORMATION_SCHEMA ENGINES Table

The ENGINES table provides information about storage engines.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
ENGINE	Engine	MySQL extension
SUPPORT	Support	MySQL extension
COMMENT	Comment	MySQL extension
TRANSACTIONS	Transactions	MySQL extension
XA	XA	MySQL extension
SAVEPOINTS	Savepoints	MySQL extension

Notes:

- The ENGINES table is a nonstandard table. Its contents correspond to the columns of the SHOW ENGINES statement. For descriptions of its columns, see Section 13.7.5.17, “SHOW ENGINES Syntax”.

See also Section 13.7.5.17, “SHOW ENGINES Syntax”.

21.7 The INFORMATION_SCHEMA EVENTS Table

The EVENTS table provides information about scheduled events, which are discussed in Section 20.4, "Using the Event Scheduler". The SHOW Name values correspond to column names of the SHOW EVENTS statement.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
EVENT_CATALOG		def, MySQL extension
EVENT_SCHEMA	Db	MySQL extension
EVENT_NAME	Name	MySQL extension
DEFINER	Definer	MySQL extension
TIME_ZONE	Time zone	MySQL extension
EVENT_BODY		MySQL extension
EVENT_DEFINITION		MySQL extension
EVENT_TYPE	Type	MySQL extension
EXECUTE_AT	Execute at	MySQL extension
INTERVAL_VALUE	Interval value	MySQL extension
INTERVAL_FIELD	Interval field	MySQL extension
SQL_MODE		MySQL extension
STARTS	Starts	MySQL extension
ENDS	Ends	MySQL extension
STATUS	Status	MySQL extension
ON_COMPLETION		MySQL extension
CREATED		MySQL extension
LAST_ALTERED		MySQL extension
LAST_EXECUTED		MySQL extension
EVENT_COMMENT		MySQL extension
ORIGINATOR	Originator	MySQL extension
CHARACTER_SET_CLIENT	character_set_client	MySQL extension
COLLATION_CONNECTION	collation_connection	MySQL extension
DATABASE_COLLATION	Database Collation	MySQL extension

Notes:

- The EVENTS table is a nonstandard table.
- EVENT_CATALOG: The value of this column is always def.
- EVENT_SCHEMA: The name of the schema (database) to which this event belongs.
- EVENT_NAME: The name of the event.
- DEFINER: The account of the user who created the event, in *'user_name'@'host_name'* format.
- TIME_ZONE: The event time zone, which is the time zone used for scheduling the event and that is in effect within the event as it executes. The default value is SYSTEM.
- EVENT_BODY: The language used for the statements in the event's DO clause; in MySQL 5.5, this is always SQL.

  This column is not to be confused with the column of the same name (now named EVENT_DEFINITION) that existed in earlier MySQL versions.

- `EVENT_DEFINITION`: The text of the SQL statement making up the event's `DO` clause; in other words, the statement executed by this event.
- `EVENT_TYPE`: The event repetition type, either `ONE TIME` (transient) or `RECURRING` (repeating).
- `EXECUTE_AT`: For a one-time event, this is the `DATETIME` value specified in the `AT` clause of the `CREATE EVENT` statement used to create the event, or of the last `ALTER EVENT` statement that modified the event. The value shown in this column reflects the addition or subtraction of any `INTERVAL` value included in the event's `AT` clause. For example, if an event is created using `ON SCHEDULE AT CURRENT_TIMESTAMP + '1:6' DAY_HOUR`, and the event was created at 2006-02-09 14:05:30, the value shown in this column would be `'2006-02-10 20:05:30'`.

  If the event's timing is determined by an `EVERY` clause instead of an `AT` clause (that is, if the event is recurring), the value of this column is `NULL`.
- `INTERVAL_VALUE`: For recurring events, this column contains the numeric portion of the event's `EVERY` clause.

  For a one-time event (that is, an event whose timing is determined by an `AT` clause), this column is `NULL`.
- `INTERVAL_FIELD`: For recurring events, this column contains the units portion of the `EVERY` clause governing the timing of the event. Thus, this column contains a value such as '`YEAR`', '`QUARTER`', '`DAY`', and so on.

  For a one-time event (that is, an event whose timing is determined by an `AT` clause), this column is `NULL`.
- `SQL_MODE`: The SQL mode in effect when the event was created or altered, and under which the event executes. For the permitted values, see Section 5.1.8, “Server SQL Modes”.
- `STARTS`: For a recurring event whose definition includes a `STARTS` clause, this column contains the corresponding `DATETIME` value. As with the `EXECUTE_AT` column, this value resolves any expressions used.

  If there is no `STARTS` clause affecting the timing of the event, this column is `NULL`
- `ENDS`: For a recurring event whose definition includes a `ENDS` clause, this column contains the corresponding `DATETIME` value. As with the `EXECUTE_AT` column, this value resolves any expressions used.

  If there is no `ENDS` clause affecting the timing of the event, this column is `NULL`.
- `STATUS`: One of the three values `ENABLED`, `DISABLED`, or `SLAVESIDE_DISABLED`.

  `SLAVESIDE_DISABLED` indicates that the creation of the event occurred on another MySQL server acting as a replication master and was replicated to the current MySQL server which is acting as a slave, but the event is not presently being executed on the slave. See Section 17.4.1.15, “Replication of Invoked Features”, for more information.
- `ON_COMPLETION`: One of the two values `PRESERVE` or `NOT PRESERVE`.
- `CREATED`: The date and time when the event was created. This is a `TIMESTAMP` value.
- `LAST_ALTERED`: The date and time when the event was last modified. This is a `TIMESTAMP` value. If the event has not been modified since its creation, this column holds the same value as the `CREATED` column.
- `LAST_EXECUTED`: The date and time when the event last executed. A `DATETIME` value. If the event has never executed, this column is `NULL`.

  `LAST_EXECUTED` indicates when the event started. As a result, the `ENDS` column is never less than `LAST_EXECUTED`.

- `EVENT_COMMENT`: The text of a comment, if the event has one. If not, the value of this column is an empty string.
- `ORIGINATOR`: The server ID of the MySQL server on which the event was created; used in replication. The default value is 0.
- `CHARACTER_SET_CLIENT`: The session value of the `character_set_client` system variable when the event was created.
- `COLLATION_CONNECTION`: The session value of the `collation_connection` system variable when the event was created.
- `DATABASE_COLLATION`: The collation of the database with which the event is associated.

Example: Suppose that the user `jon@ghidora` creates an event named `e_daily`, and then modifies it a few minutes later using an `ALTER EVENT` statement, as shown here:

```
DELIMITER |

CREATE EVENT e_daily
    ON SCHEDULE
      EVERY 1 DAY
    COMMENT 'Saves total number of sessions then clears the table each day'
    DO
      BEGIN
        INSERT INTO site_activity.totals (time, total)
          SELECT CURRENT_TIMESTAMP, COUNT(*)
            FROM site_activity.sessions;
        DELETE FROM site_activity.sessions;
      END |

DELIMITER ;

ALTER EVENT e_daily
    ENABLE;
```

(Note that comments can span multiple lines.)

This user can then run the following `SELECT` statement, and obtain the output shown:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.EVENTS
     > WHERE EVENT_NAME = 'e_daily'
     > AND EVENT_SCHEMA = 'myschema'\G
*************************** 1. row ***************************
       EVENT_CATALOG: def
        EVENT_SCHEMA: test
          EVENT_NAME: e_daily
             DEFINER: me@localhost
           TIME_ZONE: SYSTEM
          EVENT_BODY: SQL
    EVENT_DEFINITION: BEGIN
        INSERT INTO site_activity.totals (time, total)
          SELECT CURRENT_TIMESTAMP, COUNT(*)
            FROM site_activity.sessions;
        DELETE FROM site_activity.sessions;
      END
          EVENT_TYPE: RECURRING
          EXECUTE_AT: NULL
      INTERVAL_VALUE: 1
      INTERVAL_FIELD: DAY
            SQL_MODE:
              STARTS: 2008-09-03 12:13:39
                ENDS: NULL
              STATUS: ENABLED
       ON_COMPLETION: NOT PRESERVE
             CREATED: 2008-09-03 12:13:39
        LAST_ALTERED: 2008-09-03 12:13:39
       LAST_EXECUTED: NULL
```

```
       EVENT_COMMENT: Saves total number of sessions then clears the
                      table each day
          ORIGINATOR: 1
CHARACTER_SET_CLIENT: latin1
COLLATION_CONNECTION: latin1_swedish_ci
  DATABASE_COLLATION: latin1_swedish_ci
```

Times in the `EVENTS` table are displayed using the event time zone or the current session time zone, as described in Section 20.4.4, “Event Metadata”.

See also Section 13.7.5.19, “SHOW EVENTS Syntax”.

21.8 The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables

The `GLOBAL_STATUS` and `SESSION_STATUS` tables provide information about server status variables. Their contents correspond to the information produced by the `SHOW GLOBAL STATUS` and `SHOW SESSION STATUS` statements (see Section 13.7.5.36, “SHOW STATUS Syntax”).

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
VARIABLE_NAME	Variable_name	
VARIABLE_VALUE	Value	

Notes:

- The `VARIABLE_VALUE` column for each of these tables is defined as `VARCHAR(1024)`.

21.9 The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables

The `GLOBAL_VARIABLES` and `SESSION_VARIABLES` tables provide information about server status variables. Their contents correspond to the information produced by the `SHOW GLOBAL VARIABLES` and `SHOW SESSION VARIABLES` statements (see Section 13.7.5.40, “SHOW VARIABLES Syntax”).

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
VARIABLE_NAME	Variable_name	
VARIABLE_VALUE	Value	

Notes:

- The `VARIABLE_VALUE` column for each of these tables is defined as `VARCHAR(1024)`. For variables with very long values that are not completely displayed, use `SELECT` as a workaround. For example:

```
SELECT @@GLOBAL.innodb_data_file_path;
```

21.10 The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table

The `KEY_COLUMN_USAGE` table describes which key columns have constraints.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`CONSTRAINT_CATALOG`		`def`
`CONSTRAINT_SCHEMA`		
`CONSTRAINT_NAME`		
`TABLE_CATALOG`		`def`

INFORMATION_SCHEMA Name	SHOW Name	Remarks
TABLE_SCHEMA		
TABLE_NAME		
COLUMN_NAME		
ORDINAL_POSITION		
POSITION_IN_UNIQUE_CONSTRAINT		
REFERENCED_TABLE_SCHEMA		
REFERENCED_TABLE_NAME		
REFERENCED_COLUMN_NAME		

Notes:

- If the constraint is a foreign key, then this is the column of the foreign key, not the column that the foreign key references.
- The value of ORDINAL_POSITION is the column's position within the constraint, not the column's position within the table. Column positions are numbered beginning with 1.
- The value of POSITION_IN_UNIQUE_CONSTRAINT is NULL for unique and primary-key constraints. For foreign-key constraints, it is the ordinal position in key of the table that is being referenced.

  Suppose that there are two tables name t1 and t3 that have the following definitions:

```
CREATE TABLE t1
(
    s1 INT,
    s2 INT,
    s3 INT,
    PRIMARY KEY(s3)
) ENGINE=InnoDB;

CREATE TABLE t3
(
    s1 INT,
    s2 INT,
    s3 INT,
    KEY(s1),
    CONSTRAINT CO FOREIGN KEY (s2) REFERENCES t1(s3)
) ENGINE=InnoDB;
```

  For those two tables, the KEY_COLUMN_USAGE table has two rows:

  - One row with CONSTRAINT_NAME = 'PRIMARY', TABLE_NAME = 't1', COLUMN_NAME = 's3', ORDINAL_POSITION = 1, POSITION_IN_UNIQUE_CONSTRAINT = NULL.
  - One row with CONSTRAINT_NAME = 'CO', TABLE_NAME = 't3', COLUMN_NAME = 's2', ORDINAL_POSITION = 1, POSITION_IN_UNIQUE_CONSTRAINT = 1.

21.11 The INFORMATION_SCHEMA PARAMETERS Table

The PARAMETERS table provides information about stored procedure and function parameters, and about return values for stored functions. Parameter information is similar to the contents of the param_list column in the mysql.proc table.

INFORMATION_SCHEMA Name	mysql.proc Name	Remarks
SPECIFIC_CATALOG		def
SPECIFIC_SCHEMA	db	routine database

INFORMATION_SCHEMA Name	mysql.proc Name	Remarks
SPECIFIC_NAME	name	routine name
ORDINAL_POSITION		1, 2, 3, ... for parameters, 0 for function RETURNS clause
PARAMETER_MODE		IN, OUT, INOUT (NULL for RETURNS)
PARAMETER_NAME		parameter name (NULL for RETURNS)
DATA_TYPE		same as for COLUMNS table
CHARACTER_MAXIMUM_LENGTH		same as for COLUMNS table
CHARACTER_OCTET_LENGTH		same as for COLUMNS table
NUMERIC_PRECISION		same as for COLUMNS table
NUMERIC_SCALE		same as for COLUMNS table
CHARACTER_SET_NAME		same as for COLUMNS table
COLLATION_NAME		same as for COLUMNS table
DTD_IDENTIFIER		same as for COLUMNS table
ROUTINE_TYPE	type	same as for ROUTINES table

Notes:

- The PARAMETERS table was added in MySQL 5.5.3.
- For successive parameters of a stored procedure or function, the ORDINAL_POSITION values are 1, 2, 3, and so forth. For a stored function, there is also a row that describes the data type for the RETURNS clause. The return value is not a true parameter, so the row that describes it has these unique characteristics:
  - The ORDINAL_POSITION value is 0.
  - The PARAMETER_NAME and PARAMETER_MODE values are NULL because the return value has no name and the mode does not apply.

21.12 The INFORMATION_SCHEMA PARTITIONS Table

The PARTITIONS table provides information about table partitions. See Chapter 19, *Partitioning*, for more information about partitioning tables.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
TABLE_CATALOG		MySQL extension
TABLE_SCHEMA		MySQL extension
TABLE_NAME		MySQL extension
PARTITION_NAME		MySQL extension
SUBPARTITION_NAME		MySQL extension
PARTITION_ORDINAL_POSITION		MySQL extension
SUBPARTITION_ORDINAL_POSITION		MySQL extension
PARTITION_METHOD		MySQL extension
SUBPARTITION_METHOD		MySQL extension
PARTITION_EXPRESSION		MySQL extension
SUBPARTITION_EXPRESSION		MySQL extension

INFORMATION_SCHEMA Name	SHOW Name	Remarks
PARTITION_DESCRIPTION		MySQL extension
TABLE_ROWS		MySQL extension
AVG_ROW_LENGTH		MySQL extension
DATA_LENGTH		MySQL extension
MAX_DATA_LENGTH		MySQL extension
INDEX_LENGTH		MySQL extension
DATA_FREE		MySQL extension
CREATE_TIME		MySQL extension
UPDATE_TIME		MySQL extension
CHECK_TIME		MySQL extension
CHECKSUM		MySQL extension
PARTITION_COMMENT		MySQL extension
NODEGROUP		MySQL extension
TABLESPACE_NAME		MySQL extension

Notes:

- The PARTITIONS table is a nonstandard table.

  Each record in this table corresponds to an individual partition or subpartition of a partitioned table.

- TABLE_CATALOG: This column is always def.

- TABLE_SCHEMA: This column contains the name of the database to which the table belongs.

- TABLE_NAME: This column contains the name of the table containing the partition.

- PARTITION_NAME: The name of the partition.

- SUBPARTITION_NAME: If the PARTITIONS table record represents a subpartition, then this column contains the name of subpartition; otherwise it is NULL.

- PARTITION_ORDINAL_POSITION: All partitions are indexed in the same order as they are defined, with 1 being the number assigned to the first partition. The indexing can change as partitions are added, dropped, and reorganized; the number shown is this column reflects the current order, taking into account any indexing changes.

- SUBPARTITION_ORDINAL_POSITION: Subpartitions within a given partition are also indexed and reindexed in the same manner as partitions are indexed within a table.

- PARTITION_METHOD: One of the values RANGE, LIST, HASH, LINEAR HASH, KEY, or LINEAR KEY; that is, one of the available partitioning types as discussed in Section 19.2, “Partitioning Types”.

- SUBPARTITION_METHOD: One of the values HASH, LINEAR HASH, KEY, or LINEAR KEY; that is, one of the available subpartitioning types as discussed in Section 19.2.6, “Subpartitioning”.

- PARTITION_EXPRESSION: This is the expression for the partitioning function used in the CREATE TABLE or ALTER TABLE statement that created the table's current partitioning scheme.

  For example, consider a partitioned table created in the test database using this statement:

```
CREATE TABLE tp (
    c1 INT,
    c2 INT,
    c3 VARCHAR(25)
```

```
)
PARTITION BY HASH(c1 + c2)
PARTITIONS 4;
```

The PARTITION_EXPRESSION column in a PARTITIONS table record for a partition from this table displays c1 + c2, as shown here:

```
mysql> SELECT DISTINCT PARTITION_EXPRESSION
     >     FROM INFORMATION_SCHEMA.PARTITIONS
     >     WHERE TABLE_NAME='tp' AND TABLE_SCHEMA='test';
+----------------------+
| PARTITION_EXPRESSION |
+----------------------+
| c1 + c2              |
+----------------------+
1 row in set (0.09 sec)
```

- SUBPARTITION_EXPRESSION: This works in the same fashion for the subpartitioning expression that defines the subpartitioning for a table as PARTITION_EXPRESSION does for the partitioning expression used to define a table's partitioning.

  If the table has no subpartitions, then this column is NULL.

- PARTITION_DESCRIPTION: This column is used for RANGE and LIST partitions. For a RANGE partition, it contains the value set in the partition's VALUES LESS THAN clause, which can be either an integer or MAXVALUE. For a LIST partition, this column contains the values defined in the partition's VALUES IN clause, which is a comma-separated list of integer values.

  For partitions whose PARTITION_METHOD is other than RANGE or LIST, this column is always NULL.

- TABLE_ROWS: The number of table rows in the partition.

  For partitioned InnoDB tables, the row count given in the TABLE_ROWS column is only an estimated value used in SQL optimization, and may not always be exact.

  For NDB tables, you can also obtain this information using the ndb_desc utility.

- AVG_ROW_LENGTH: The average length of the rows stored in this partition or subpartition, in bytes.

  This is the same as DATA_LENGTH divided by TABLE_ROWS.

  You can also obtain equivalent information using the ndb_desc utility.

- DATA_LENGTH: The total length of all rows stored in this partition or subpartition, in bytes—that is, the total number of bytes stored in the partition or subpartition.

  For NDB tables, you can also obtain this information using the ndb_desc utility.

- MAX_DATA_LENGTH: The maximum number of bytes that can be stored in this partition or subpartition.

  For NDB tables, you can also obtain this information using the ndb_desc utility.

- INDEX_LENGTH: The length of the index file for this partition or subpartition, in bytes.

  For partitions of NDB tables, whether the tables use implicit or explicit partitioning, the INDEX_LENGTH column value is always 0. However, you can obtain equivalent information using the ndb_desc utility.

- DATA_FREE: The number of bytes allocated to the partition or subpartition but not used.

  For NDB tables, you can also obtain this information using the ndb_desc utility.

- CREATE_TIME: The time of the partition's or subpartition's creation.

Prior to MySQL 5.5.44, for partitioned `InnoDB` tables, this column was always `NULL`. The correct creation time is shown in MySQL 5.5.44 and later. (Bug #17299181, Bug #69990)

- `UPDATE_TIME`: The time that the partition or subpartition was last modified.

  For partitioned `InnoDB` tables, this column is always `NULL`.

- `CHECK_TIME`: The last time that the table to which this partition or subpartition belongs was checked.

  For partitioned `InnoDB` tables, this column is always `NULL`.

- `CHECKSUM`: The checksum value, if any; otherwise, this column is `NULL`.

- `PARTITION_COMMENT`: This column contains the text of any comment made for the partition.

  In MySQL 5.5, the display width of this column is 80 characters, and partition comments which exceed this length are truncated to fit. This issue is fixed in MySQL 5.6. (Bug #11748924, Bug #37728)

  The default value for this column is an empty string.

- `NODEGROUP`: This is the nodegroup to which the partition belongs. This is relevant only to NDB Cluster tables; otherwise the value of this column is always `0`.

- `TABLESPACE_NAME`: This column contains the name of the tablespace to which the partition belongs. The value of this column is always `DEFAULT`.

- A nonpartitioned table has one record in `INFORMATION_SCHEMA.PARTITIONS`; however, the values of the `PARTITION_NAME`, `SUBPARTITION_NAME`, `PARTITION_ORDINAL_POSITION`, `SUBPARTITION_ORDINAL_POSITION`, `PARTITION_METHOD`, `SUBPARTITION_METHOD`, `PARTITION_EXPRESSION`, `SUBPARTITION_EXPRESSION`, and `PARTITION_DESCRIPTION` columns are all `NULL`. (The `PARTITION_COMMENT` column in this case is blank.)

  In MySQL 5.5, there is also only one record in the `PARTITIONS` table for a table using the `NDBCLUSTER` storage engine. The same columns are also `NULL` (or empty) as for a nonpartitioned table.

21.13 The INFORMATION_SCHEMA PLUGINS Table

The `PLUGINS` table provides information about server plugins.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`PLUGIN_NAME`	`Name`	MySQL extension
`PLUGIN_VERSION`		MySQL extension
`PLUGIN_STATUS`	`Status`	MySQL extension
`PLUGIN_TYPE`	`Type`	MySQL extension
`PLUGIN_TYPE_VERSION`		MySQL extension
`PLUGIN_LIBRARY`	`Library`	MySQL extension
`PLUGIN_LIBRARY_VERSION`		MySQL extension
`PLUGIN_AUTHOR`		MySQL extension
`PLUGIN_DESCRIPTION`		MySQL extension
`PLUGIN_LICENSE`		MySQL extension
`LOAD_OPTION`		MySQL extension

Notes:

- The `PLUGINS` table is a nonstandard table.

- PLUGIN_NAME is the name used to refer to the plugin in statements such as INSTALL PLUGIN and UNINSTALL PLUGIN.
- PLUGIN_VERSION is the version from the plugin's general type descriptor.
- PLUGIN_STATUS indicates the plugin status, one of ACTIVE, INACTIVE, DISABLED, or DELETED.
- PLUGIN_TYPE indicates the type of plugin, such as STORAGE ENGINE, INFORMATION_SCHEMA, or AUTHENTICATION.
- PLUGIN_TYPE_VERSION is the version from the plugin's type-specific descriptor.
- PLUGIN_LIBRARY is the name of the plugin shared library file. This is the name used to refer to the plugin file in statements such as INSTALL PLUGIN and UNINSTALL PLUGIN. This file is located in the directory named by the plugin_dir system variable. If the library name is NULL, the plugin is compiled in and cannot be uninstalled with UNINSTALL PLUGIN.
- PLUGIN_LIBRARY_VERSION indicates the plugin API interface version.
- PLUGIN_AUTHOR names the plugin author.
- PLUGIN_DESCRIPTION provides a short description of the plugin.
- PLUGIN_LICENSE indicates how the plugin is licensed; for example, GPL.
- LOAD_OPTION indicates how the plugin was loaded. The value is OFF, ON, FORCE, or FORCE_PLUS_PERMANENT. See Section 5.5.1, “Installing and Uninstalling Plugins”. This column was added in MySQL 5.5.7.

For plugins installed with INSTALL PLUGIN, the PLUGIN_NAME and PLUGIN_LIBRARY values are also registered in the mysql.plugin table.

These statements are equivalent:

```
SELECT
  PLUGIN_NAME, PLUGIN_STATUS, PLUGIN_TYPE,
  PLUGIN_LIBRARY, PLUGIN_LICENSE
FROM INFORMATION_SCHEMA.PLUGINS;

SHOW PLUGINS;
```

For information about plugin data structures that form the basis of the information in the PLUGINS table, see Section 24.2, “The MySQL Plugin API”.

Plugin information is also available using the SHOW PLUGINS statement. See Section 13.7.5.26, “SHOW PLUGINS Syntax”.

21.14 The INFORMATION_SCHEMA PROCESSLIST Table

The PROCESSLIST table provides information about which threads are running.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
ID	Id	MySQL extension
USER	User	MySQL extension
HOST	Host	MySQL extension
DB	db	MySQL extension
COMMAND	Command	MySQL extension
TIME	Time	MySQL extension
STATE	State	MySQL extension
INFO	Info	MySQL extension

For an extensive description of the table columns, see Section 13.7.5.30, “SHOW PROCESSLIST Syntax”.

Notes:

- The `PROCESSLIST` table is a nonstandard table.
- Like the output from the corresponding `SHOW` statement, the `PROCESSLIST` table will only show information about your own threads, unless you have the `PROCESS` privilege, in which case you will see information about other threads, too. As an anonymous user, you cannot see any rows at all.
- If an SQL statement refers to `INFORMATION_SCHEMA.PROCESSLIST`, MySQL populates the entire table once, when statement execution begins, so there is read consistency during the statement. There is no read consistency for a multi-statement transaction, though.

The following statements are equivalent:

```
SELECT * FROM INFORMATION_SCHEMA.PROCESSLIST

SHOW FULL PROCESSLIST
```

21.15 The INFORMATION_SCHEMA PROFILING Table

The `PROFILING` table provides statement profiling information. Its contents correspond to the information produced by the `SHOW PROFILES` and `SHOW PROFILE` statements (see Section 13.7.5.32, “SHOW PROFILES Syntax”). The table is empty unless the `profiling` session variable is set to 1.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`QUERY_ID`	`Query_ID`	
`SEQ`		
`STATE`	`Status`	
`DURATION`	`Duration`	
`CPU_USER`	`CPU_user`	
`CPU_SYSTEM`	`CPU_system`	
`CONTEXT_VOLUNTARY`	`Context_voluntary`	
`CONTEXT_INVOLUNTARY`	`Context_involuntary`	
`BLOCK_OPS_IN`	`Block_ops_in`	
`BLOCK_OPS_OUT`	`Block_ops_out`	
`MESSAGES_SENT`	`Messages_sent`	
`MESSAGES_RECEIVED`	`Messages_received`	
`PAGE_FAULTS_MAJOR`	`Page_faults_major`	
`PAGE_FAULTS_MINOR`	`Page_faults_minor`	
`SWAPS`	`Swaps`	
`SOURCE_FUNCTION`	`Source_function`	
`SOURCE_FILE`	`Source_file`	
`SOURCE_LINE`	`Source_line`	

Notes:

- `QUERY_ID` is a numeric statement identifier.
- `SEQ` is a sequence number indicating the display order for rows with the same `QUERY_ID` value.

- `STATE` is the profiling state to which the row measurements apply.
- `DURATION` indicates how long statement execution remained in the given state, in seconds.
- `CPU_USER` and `CPU_SYSTEM` indicate user and system CPU use, in seconds.
- `CONTEXT_VOLUNTARY` and `CONTEXT_INVOLUNTARY` indicate how many voluntary and involuntary context switches occurred.
- `BLOCK_OPS_IN` and `BLOCK_OPS_OUT` indicate the number of block input and output operations.
- `MESSAGES_SENT` and `MESSAGES_RECEIVED` indicate the number of communication messages sent and received.
- `PAGE_FAULTS_MAJOR` and `PAGE_FAULTS_MINOR` indicate the number of major and minor page faults.
- `SWAPS` indicates how many swaps occurred.
- `SOURCE_FUNCTION`, `SOURCE_FILE`, and `SOURCE_LINE` provide information indicating where in the source code the profiled state executes.

21.16 The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table

The `REFERENTIAL_CONSTRAINTS` table provides information about foreign keys.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
CONSTRAINT_CATALOG		def
CONSTRAINT_SCHEMA		
CONSTRAINT_NAME		
UNIQUE_CONSTRAINT_CATALOG		def
UNIQUE_CONSTRAINT_SCHEMA		
UNIQUE_CONSTRAINT_NAME		
MATCH_OPTION		
UPDATE_RULE		
DELETE_RULE		
TABLE_NAME		
REFERENCED_TABLE_NAME		

Notes:

- `TABLE_NAME` has the same value as `TABLE_NAME` in `INFORMATION_SCHEMA.TABLE_CONSTRAINTS`.
- `CONSTRAINT_SCHEMA` and `CONSTRAINT_NAME` identify the foreign key.
- `UNIQUE_CONSTRAINT_SCHEMA`, `UNIQUE_CONSTRAINT_NAME`, and `REFERENCED_TABLE_NAME` identify the referenced key.
- The only valid value at this time for `MATCH_OPTION` is `NONE`.
- The possible values for `UPDATE_RULE` or `DELETE_RULE` are `CASCADE`, `SET NULL`, `SET DEFAULT`, `RESTRICT`, `NO ACTION`.

21.17 The INFORMATION_SCHEMA ROUTINES Table

The `ROUTINES` table provides information about stored routines (both procedures and functions). The `ROUTINES` table does not include user-defined functions (UDFs).

The column named "`mysql.proc` Name" indicates the `mysql.proc` table column that corresponds to the `INFORMATION_SCHEMA.ROUTINES` table column, if any.

`INFORMATION_SCHEMA` Name	**`mysql.proc` Name**	**Remarks**
`SPECIFIC_NAME`	`specific_name`	
`ROUTINE_CATALOG`		`def`
`ROUTINE_SCHEMA`	`db`	
`ROUTINE_NAME`	`name`	
`ROUTINE_TYPE`	`type`	`{PROCEDURE|FUNCTION}`
`DATA_TYPE`		same as for `COLUMNS` table
`CHARACTER_MAXIMUM_LENGTH`		same as for `COLUMNS` table
`CHARACTER_OCTET_LENGTH`		same as for `COLUMNS` table
`NUMERIC_PRECISION`		same as for `COLUMNS` table
`NUMERIC_SCALE`		same as for `COLUMNS` table
`CHARACTER_SET_NAME`		same as for `COLUMNS` table
`COLLATION_NAME`		same as for `COLUMNS` table
`DTD_IDENTIFIER`		data type descriptor
`ROUTINE_BODY`		`SQL`
`ROUTINE_DEFINITION`	`body_utf8`	
`EXTERNAL_NAME`		`NULL`
`EXTERNAL_LANGUAGE`	`language`	`NULL`
`PARAMETER_STYLE`		`SQL`
`IS_DETERMINISTIC`	`is_deterministic`	
`SQL_DATA_ACCESS`	`sql_data_access`	
`SQL_PATH`		`NULL`
`SECURITY_TYPE`	`security_type`	
`CREATED`	`created`	
`LAST_ALTERED`	`modified`	
`SQL_MODE`	`sql_mode`	MySQL extension
`ROUTINE_COMMENT`	`comment`	MySQL extension
`DEFINER`	`definer`	MySQL extension
`CHARACTER_SET_CLIENT`		MySQL extension
`COLLATION_CONNECTION`		MySQL extension
`DATABASE_COLLATION`		MySQL extension

Notes:

- MySQL calculates `EXTERNAL_LANGUAGE` thus:
  - If `mysql.proc.language='SQL'`, `EXTERNAL_LANGUAGE` is `NULL`
  - Otherwise, `EXTERNAL_LANGUAGE` is what is in `mysql.proc.language`. However, we do not have external languages yet, so it is always `NULL`.
- `CREATED`: The date and time when the routine was created. This is a `TIMESTAMP` value.

- LAST_ALTERED: The date and time when the routine was last modified. This is a TIMESTAMP value. If the routine has not been modified since its creation, this column holds the same value as the CREATED column.
- SQL_MODE: The SQL mode in effect when the routine was created or altered, and under which the routine executes. For the permitted values, see Section 5.1.8, “Server SQL Modes”.
- CHARACTER_SET_CLIENT: The session value of the character_set_client system variable when the routine was created.
- COLLATION_CONNECTION: The session value of the collation_connection system variable when the routine was created.
- DATABASE_COLLATION: The collation of the database with which the routine is associated.
- The DATA_TYPE, CHARACTER_MAXIMUM_LENGTH, CHARACTER_OCTET_LENGTH, NUMERIC_PRECISION, NUMERIC_SCALE, CHARACTER_SET_NAME, and COLLATION_NAME columns provide information about the data type for the RETURNS clause of stored functions. If a stored routine is a stored procedure, these columns all are NULL. These columns were added in MySQL 5.5.3.
- Information about stored function RETURNS data types is also available in the PARAMETERS table. The return value data type row for a function can be identified as the row that has an ORDINAL_POSITION value of 0.

21.18 The INFORMATION_SCHEMA SCHEMATA Table

A schema is a database, so the SCHEMATA table provides information about databases.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
CATALOG_NAME		def
SCHEMA_NAME	Database	
DEFAULT_CHARACTER_SET_NAME		
DEFAULT_COLLATION_NAME		
SQL_PATH		NULL

The following statements are equivalent:

```
SELECT SCHEMA_NAME AS `Database`
  FROM INFORMATION_SCHEMA.SCHEMATA
  [WHERE SCHEMA_NAME LIKE 'wild']

SHOW DATABASES
  [LIKE 'wild']
```

21.19 The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table

The SCHEMA_PRIVILEGES table provides information about schema (database) privileges. This information comes from the mysql.db grant table.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
GRANTEE		'user_name'@'host_name' value, MySQL extension
TABLE_CATALOG		def, MySQL extension
TABLE_SCHEMA		MySQL extension
PRIVILEGE_TYPE		MySQL extension
IS_GRANTABLE		MySQL extension

Notes:

- This is a nonstandard table. It takes its values from the `mysql.db` table.

21.20 The INFORMATION_SCHEMA STATISTICS Table

The `STATISTICS` table provides information about table indexes.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`TABLE_CATALOG`		`def`
`TABLE_SCHEMA`		= Database
`TABLE_NAME`	`Table`	
`NON_UNIQUE`	`Non_unique`	
`INDEX_SCHEMA`		= Database
`INDEX_NAME`	`Key_name`	
`SEQ_IN_INDEX`	`Seq_in_index`	
`COLUMN_NAME`	`Column_name`	
`COLLATION`	`Collation`	
`CARDINALITY`	`Cardinality`	
`SUB_PART`	`Sub_part`	MySQL extension
`PACKED`	`Packed`	MySQL extension
`NULLABLE`	`Null`	MySQL extension
`INDEX_TYPE`	`Index_type`	MySQL extension
`COMMENT`	`Comment`	MySQL extension

Notes:

- There is no standard table for indexes. The preceding list is similar to what SQL Server 2000 returns for `sp_statistics`, except that we replaced the name `QUALIFIER` with `CATALOG` and we replaced the name `OWNER` with `SCHEMA`.

  Clearly, the preceding table and the output from `SHOW INDEX` are derived from the same parent. So the correlation is already close.

The following statements are equivalent:

```
SELECT * FROM INFORMATION_SCHEMA.STATISTICS
  WHERE table_name = 'tbl_name'
  AND table_schema = 'db_name'

SHOW INDEX
  FROM tbl_name
  FROM db_name
```

21.21 The INFORMATION_SCHEMA TABLES Table

The `TABLES` table provides information about tables in databases.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`TABLE_CATALOG`		`def`
`TABLE_SCHEMA`	`Table_...`	
`TABLE_NAME`	`Table_...`	
`TABLE_TYPE`		

INFORMATION_SCHEMA Name	SHOW Name	Remarks
ENGINE	Engine	MySQL extension
VERSION	Version	The version number of the table's .frm file, MySQL extension
ROW_FORMAT	Row_format	MySQL extension
TABLE_ROWS	Rows	MySQL extension
AVG_ROW_LENGTH	Avg_row_length	MySQL extension
DATA_LENGTH	Data_length	MySQL extension
MAX_DATA_LENGTH	Max_data_length	MySQL extension
INDEX_LENGTH	Index_length	MySQL extension
DATA_FREE	Data_free	MySQL extension
AUTO_INCREMENT	Auto_increment	MySQL extension
CREATE_TIME	Create_time	MySQL extension
UPDATE_TIME	Update_time	MySQL extension
CHECK_TIME	Check_time	MySQL extension
TABLE_COLLATION	Collation	MySQL extension
CHECKSUM	Checksum	MySQL extension
CREATE_OPTIONS	Create_options	MySQL extension
TABLE_COMMENT	Comment	MySQL extension
INDEX_COMMENT	Index_comment	MySQL extension

Notes:

- Refer to SHOW TABLE STATUS for field descriptions.
- TABLE_SCHEMA and TABLE_NAME are a single field in a SHOW display, for example Table_in_db1.
- TABLE_TYPE should be BASE TABLE or VIEW. The TABLES table does not list TEMPORARY tables.
- For partitioned tables, the ENGINE column shows the name of the storage engine used by all partitions. (Previously, this column showed PARTITION for such tables.)
- The TABLE_ROWS column is NULL if the table is in the INFORMATION_SCHEMA database.

  For InnoDB tables, the row count is only a rough estimate used in SQL optimization. (This is also true if the InnoDB table is partitioned.)
- For NDB tables, DATA_LENGTH includes data stored in main memory only; the MAX_DATA_LENGTH and DATA_FREE columns apply to Disk Data.
- For NDB Cluster Disk Data tables, MAX_DATA_LENGTH shows the space allocated for the disk part of a Disk Data table or fragment. (In-memory data resource usage is reported by the DATA_LENGTH column.)
- The DATA_FREE column shows the free space in bytes for InnoDB tables.

  For NDB Cluster, DATA_FREE shows the space allocated on disk for, but not used by, a Disk Data table or fragment on disk. (In-memory data resource usage is reported by the DATA_LENGTH column.)
- Prior to MySQL 5.5.44, for partitioned InnoDB tables, the CREATE_TIME column showed NULL. This column shows the correct table creation time for such tables in MySQL 5.5.44 and later. (Bug #17299181, Bug #69990)

For partitioned InnoDB tables, the UPDATE_TIME and CHECK_TIME columns are always NULL.

- We have nothing for the table's default character set. TABLE_COLLATION is close, because collation names begin with a character set name.
- The CREATE_OPTIONS column shows partitioned if the table is partitioned.

The following statements are equivalent:

```
SELECT table_name FROM INFORMATION_SCHEMA.TABLES
  WHERE table_schema = 'db_name'
  [AND table_name LIKE 'wild']

SHOW TABLES
  FROM db_name
  [LIKE 'wild']
```

21.22 The INFORMATION_SCHEMA TABLESPACES Table

The TABLESPACES table provides information about active tablespaces. The table was added in MySQL 5.5.3.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
TABLESPACE_NAME		MySQL extension
ENGINE		MySQL extension
TABLESPACE_TYPE		MySQL extension
LOGFILE_GROUP_NAME		MySQL extension
EXTENT_SIZE		MySQL extension
AUTOEXTEND_SIZE		MySQL extension
MAXIMUM_SIZE		MySQL extension
NODEGROUP_ID		MySQL extension
TABLESPACE_COMMENT		MySQL extension

Notes:

The INFORMATION_SCHEMA.TABLESPACES table does not provide information about InnoDB tablespaces.

21.23 The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table

The TABLE_CONSTRAINTS table describes which tables have constraints.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
CONSTRAINT_CATALOG		def
CONSTRAINT_SCHEMA		
CONSTRAINT_NAME		
TABLE_SCHEMA		
TABLE_NAME		
CONSTRAINT_TYPE		

Notes:

- The CONSTRAINT_TYPE value can be UNIQUE, PRIMARY KEY, or FOREIGN KEY.
- The UNIQUE and PRIMARY KEY information is about the same as what you get from the Key_name field in the output from SHOW INDEX when the Non_unique field is 0.
- The CONSTRAINT_TYPE column can contain one of these values: UNIQUE, PRIMARY KEY, FOREIGN KEY, CHECK. This is a CHAR (not ENUM) column. The CHECK value is not available until we support CHECK.

21.24 The INFORMATION_SCHEMA TABLE_PRIVILEGES Table

The TABLE_PRIVILEGES table provides information about table privileges. This information comes from the mysql.tables_priv grant table.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
GRANTEE		*'user_name'@'host_name'* value
TABLE_CATALOG		def
TABLE_SCHEMA		
TABLE_NAME		
PRIVILEGE_TYPE		
IS_GRANTABLE		

Notes:

- PRIVILEGE_TYPE can contain one (and only one) of these values: SELECT, INSERT, UPDATE, REFERENCES, ALTER, INDEX, DROP, CREATE VIEW.

The following statements are *not* equivalent:

```
SELECT ... FROM INFORMATION_SCHEMA.TABLE_PRIVILEGES

SHOW GRANTS ...
```

21.25 The INFORMATION_SCHEMA TRIGGERS Table

The TRIGGERS table provides information about triggers. To see information about a table's triggers, you must have the TRIGGER privilege for the table.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
TRIGGER_CATALOG		def
TRIGGER_SCHEMA		
TRIGGER_NAME	Trigger	
EVENT_MANIPULATION	Event	
EVENT_OBJECT_CATALOG		def
EVENT_OBJECT_SCHEMA		
EVENT_OBJECT_TABLE	Table	
ACTION_ORDER		0
ACTION_CONDITION		NULL
ACTION_STATEMENT	Statement	
ACTION_ORIENTATION		ROW

INFORMATION_SCHEMA Name	SHOW Name	Remarks
ACTION_TIMING	Timing	
ACTION_REFERENCE_OLD_TABLE		NULL
ACTION_REFERENCE_NEW_TABLE		NULL
ACTION_REFERENCE_OLD_ROW		OLD
ACTION_REFERENCE_NEW_ROW		NEW
CREATED	Created	
SQL_MODE	sql_mode	MySQL extension
DEFINER	Definer	MySQL extension
CHARACTER_SET_CLIENT	character_set_client	MySQL extension
COLLATION_CONNECTION	collation_connection	MySQL extension
DATABASE_COLLATION	Database Collation	MySQL extension

Notes:

- The names in the "SHOW Name" column refer to the SHOW TRIGGERS statement, not SHOW CREATE TRIGGER. See Section 13.7.5.39, "SHOW TRIGGERS Syntax".
- TRIGGER_SCHEMA and TRIGGER_NAME: The name of the database in which the trigger occurs and the trigger name, respectively.
- EVENT_MANIPULATION: The trigger event. This is the type of operation on the associated table for which the trigger activates. The value is 'INSERT' (a row was inserted), 'DELETE' (a row was deleted), or 'UPDATE' (a row was modified).
- EVENT_OBJECT_SCHEMA and EVENT_OBJECT_TABLE: As noted in Section 20.3, "Using Triggers", every trigger is associated with exactly one table. These columns indicate the database in which this table occurs, and the table name, respectively.
- ACTION_ORDER: The ordinal position of the trigger's action within the list of all similar triggers on the same table. This value is always 0, because it is not possible to have more than one trigger with the same EVENT_MANIPULATION and ACTION_TIMING on the same table.
- ACTION_STATEMENT: The trigger body; that is, the statement executed when the trigger activates. This text uses UTF-8 encoding.
- ACTION_ORIENTATION: Always contains the value 'ROW'.
- ACTION_TIMING: Whether the trigger activates before or after the triggering event. The value is 'BEFORE' or 'AFTER'.
- ACTION_REFERENCE_OLD_ROW and ACTION_REFERENCE_NEW_ROW: The old and new column identifiers, respectively. This means that ACTION_REFERENCE_OLD_ROW always contains the value 'OLD' and ACTION_REFERENCE_NEW_ROW always contains the value 'NEW'.
- SQL_MODE: The SQL mode in effect when the trigger was created, and under which the trigger executes. For the permitted values, see Section 5.1.8, "Server SQL Modes".
- DEFINER: The account of the user who created the trigger, in '*user_name*'@'*host_name*' format.
- CHARACTER_SET_CLIENT: The session value of the character_set_client system variable when the trigger was created.
- COLLATION_CONNECTION: The session value of the collation_connection system variable when the trigger was created.
- DATABASE_COLLATION: The collation of the database with which the trigger is associated.

- The following columns currently always contain `NULL`: `ACTION_CONDITION`, `ACTION_REFERENCE_OLD_TABLE`, `ACTION_REFERENCE_NEW_TABLE`, and `CREATED`.

Example, using the `ins_sum` trigger defined in Section 20.3, "Using Triggers":

```
mysql> SELECT * FROM INFORMATION_SCHEMA.TRIGGERS
       WHERE TRIGGER_SCHEMA='test' AND TRIGGER_NAME='ins_sum'\G
*************************** 1. row ***************************
           TRIGGER_CATALOG: def
            TRIGGER_SCHEMA: test
              TRIGGER_NAME: ins_sum
        EVENT_MANIPULATION: INSERT
      EVENT_OBJECT_CATALOG: def
       EVENT_OBJECT_SCHEMA: test
        EVENT_OBJECT_TABLE: account
              ACTION_ORDER: 0
          ACTION_CONDITION: NULL
          ACTION_STATEMENT: SET @sum = @sum + NEW.amount
        ACTION_ORIENTATION: ROW
             ACTION_TIMING: BEFORE
ACTION_REFERENCE_OLD_TABLE: NULL
ACTION_REFERENCE_NEW_TABLE: NULL
  ACTION_REFERENCE_OLD_ROW: OLD
  ACTION_REFERENCE_NEW_ROW: NEW
                  CREATED: NULL
                SQL_MODE:
                 DEFINER: me@localhost
      CHARACTER_SET_CLIENT: utf8
      COLLATION_CONNECTION: utf8_general_ci
        DATABASE_COLLATION: latin1_swedish_ci
```

21.26 The INFORMATION_SCHEMA USER_PRIVILEGES Table

The `USER_PRIVILEGES` table provides information about global privileges. This information comes from the `mysql.user` grant table.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`GRANTEE`		`'user_name'@'host_name'` value, MySQL extension
`TABLE_CATALOG`		`def`, MySQL extension
`PRIVILEGE_TYPE`		MySQL extension
`IS_GRANTABLE`		MySQL extension

Notes:

- This is a nonstandard table. It takes its values from the `mysql.user` table.

21.27 The INFORMATION_SCHEMA VIEWS Table

The `VIEWS` table provides information about views in databases. You must have the `SHOW VIEW` privilege to access this table.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`TABLE_CATALOG`		`def`
`TABLE_SCHEMA`		
`TABLE_NAME`		
`VIEW_DEFINITION`		
`CHECK_OPTION`		
`IS_UPDATABLE`		

INFORMATION_SCHEMA Name	SHOW Name	Remarks
DEFINER		
SECURITY_TYPE		
CHARACTER_SET_CLIENT		MySQL extension
COLLATION_CONNECTION		MySQL extension

Notes:

- The VIEW_DEFINITION column has most of what you see in the Create Table field that SHOW CREATE VIEW produces. Skip the words before SELECT and skip the words WITH CHECK OPTION. Suppose that the original statement was:

  ```
  CREATE VIEW v AS
    SELECT s2,s1 FROM t
    WHERE s1 > 5
    ORDER BY s1
    WITH CHECK OPTION;
  ```

  Then the view definition looks like this:

  ```
  SELECT s2,s1 FROM t WHERE s1 > 5 ORDER BY s1
  ```

- The CHECK_OPTION column has a value of NONE, CASCADE, or LOCAL.

- MySQL sets a flag, called the view updatability flag, at CREATE VIEW time. The flag is set to YES (true) if UPDATE and DELETE (and similar operations) are legal for the view. Otherwise, the flag is set to NO (false). The IS_UPDATABLE column in the VIEWS table displays the status of this flag. It means that the server always knows whether a view is updatable.

  If a view is not updatable, statements such UPDATE, DELETE, and INSERT are illegal and will be rejected. (Note that even if a view is updatable, it might not be possible to insert into it; for details, refer to Section 20.5.3, “Updatable and Insertable Views”.)

- DEFINER: The account of the user who created the view, in *'user_name'@'host_name'* format. SECURITY_TYPE has a value of DEFINER or INVOKER.

- CHARACTER_SET_CLIENT: The session value of the character_set_client system variable when the view was created.

- COLLATION_CONNECTION: The session value of the collation_connection system variable when the view was created.

MySQL lets you use different sql_mode settings to tell the server the type of SQL syntax to support. For example, you might use the ANSI SQL mode to ensure MySQL correctly interprets the standard SQL concatenation operator, the double bar (||), in your queries. If you then create a view that concatenates items, you might worry that changing the sql_mode setting to a value different from ANSI could cause the view to become invalid. But this is not the case. No matter how you write out a view definition, MySQL always stores it the same way, in a canonical form. Here is an example that shows how the server changes a double bar concatenation operator to a CONCAT() function:

```
mysql> SET sql_mode = 'ANSI';
Query OK, 0 rows affected (0.00 sec)

mysql> CREATE VIEW test.v AS SELECT 'a' || 'b' as col1;
Query OK, 0 rows affected (0.00 sec)

mysql> SELECT VIEW_DEFINITION FROM INFORMATION_SCHEMA.VIEWS
       WHERE TABLE_SCHEMA = 'test' AND TABLE_NAME = 'v';
+---------------------------------+
```

```
| VIEW_DEFINITION                  |
+----------------------------------+
| select concat('a','b') AS `col1` |
+----------------------------------+
1 row in set (0.00 sec)
```

The advantage of storing a view definition in canonical form is that changes made later to the value of `sql_mode` will not affect the results from the view. However an additional consequence is that comments prior to `SELECT` are stripped from the definition by the server.

21.28 InnoDB INFORMATION_SCHEMA Tables

This section provides table definitions for `InnoDB INFORMATION_SCHEMA` tables. For related information and examples, see Section 14.18, "InnoDB INFORMATION_SCHEMA Tables".

`InnoDB INFORMATION_SCHEMA` tables can be used to monitor ongoing `InnoDB` activity, to detect inefficiencies before they turn into issues, or to troubleshoot performance and capacity issues. As your database becomes bigger and busier, running up against the limits of your hardware capacity, you monitor and tune these aspects to keep the database running smoothly.

21.28.1 The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table

The `INNODB_BUFFER_PAGE` table holds information about each page in the `InnoDB` buffer pool.

For related usage information and examples, see Section 14.18.3, "InnoDB INFORMATION_SCHEMA Buffer Pool Tables".

Warning

Querying the `INNODB_BUFFER_PAGE` table can introduce significant performance overhead. Do not query this table on a production system unless you are aware of the performance impact that your query may have, and have determined it to be acceptable. To avoid impacting performance, reproduce the issue you want to investigate on a test instance and query the `INNODB_BUFFER_PAGE` table on the test instance.

Table 21.1 INNODB_BUFFER_PAGE Columns

Column name	Description
`POOL_ID`	Buffer Pool ID. An identifier to distinguish between multiple buffer pool instances.
`BLOCK_ID`	Buffer Pool Block ID.
`SPACE`	Tablespace ID. Uses the same value as in `INNODB_SYS_TABLES.SPACE`.
`PAGE_NUMBER`	Page number.
`PAGE_TYPE`	Page type. Permitted values are `ALLOCATED` (Freshly allocated page), `INDEX` (B-tree node), `UNDO_LOG` (Undo log page), `INODE` (Index node), `IBUF_FREE_LIST` (Insert buffer free list), `IBUF_BITMAP` (Insert buffer bitmap), `SYSTEM` (System page), `TRX_SYSTEM` (Transaction system data), `FILE_SPACE_HEADER` (File space header), `EXTENT_DESCRIPTOR` (Extent descriptor page), `BLOB` (Uncompressed BLOB page), `COMPRESSED_BLOB` (First compressed BLOB page), `COMPRESSED_BLOB2` (Subsequent comp BLOB page), `IBUF_INDEX` (Insert buffer index), `UNKNOWN` (unknown).
`FLUSH_TYPE`	Flush type.
`FIX_COUNT`	Number of threads using this block within the buffer pool. When zero, the block is eligible to be evicted.

Column name	Description
IS_HASHED	Whether hash index has been built on this page.
NEWEST_MODIFICATION	Log Sequence Number of the youngest modification.
OLDEST_MODIFICATION	Log Sequence Number of the oldest modification.
ACCESS_TIME	An abstract number used to judge the first access time of the page.
TABLE_NAME	Name of the table the page belongs to. This column is only applicable to pages of type INDEX.
INDEX_NAME	Name of the index the page belongs to. It can be the name of a clustered index or a secondary index. This column is only applicable to pages of type INDEX.
NUMBER_RECORDS	Number of records within the page.
DATA_SIZE	Sum of the sizes of the records. This column is only applicable to pages of type INDEX.
COMPRESSED_SIZE	Compressed page size. Null for pages that are not compressed.
PAGE_STATE	Page state. Possible values include: NULL (clean compressed pages, compressed pages in the flush list, pages used as buffer pool watch sentinels), NOT_USED (in the free list), READY_FOR_USE (a free page), FILE_PAGE (a buffered file page), MEMORY (contains a main memory object), REMOVE_HASH (hash index should be removed before placing in the free list).
IO_FIX	Specifies whether any I/O is pending for this page: IO_NONE = no pending I/O, IO_READ = read pending, IO_WRITE = write pending.
IS_OLD	Specifies whether or not the block is in the sublist of old blocks in the LRU list.
FREE_PAGE_CLOCK	The value of the freed_page_clock counter when the block was the last placed at the head of the LRU list. The freed_page_clock counter tracks the number of blocks removed from the end of the LRU list.

Example:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE WHERE BLOCK_ID=9\G
*************************** 1. row ***************************
           POOL_ID: 0
          BLOCK_ID: 9
             SPACE: 0
       PAGE_NUMBER: 8019
         PAGE_TYPE: INDEX
        FLUSH_TYPE: 2
         FIX_COUNT: 0
         IS_HASHED: YES
NEWEST_MODIFICATION: 226918754
OLDEST_MODIFICATION: 0
       ACCESS_TIME: 3376847655
        TABLE_NAME: employees/salaries
        INDEX_NAME: PRIMARY
    NUMBER_RECORDS: 468
         DATA_SIZE: 14976
   COMPRESSED_SIZE: 0
        PAGE_STATE: FILE_PAGE
            IO_FIX: IO_NONE
            IS_OLD: YES
   FREE_PAGE_CLOCK: 8
```

Notes:

- This table is primarily useful for expert-level performance monitoring, or when developing performance-related extensions for MySQL.

- Use DESCRIBE or SHOW COLUMNS to view additional information about the columns of this table including data types and default values.
- You must have the PROCESS privilege to query this table.
- When tables, table rows, partitions, or indexes are deleted, associated pages remain in the buffer pool until space is required for other data. The INNODB_BUFFER_PAGE table reports information about these pages until they are evicted from the buffer pool. For more information about how the InnoDB manages buffer pool data, see Section 14.9.2.1, “The InnoDB Buffer Pool”.

21.28.2 The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table

The INNODB_BUFFER_PAGE_LRU table holds information about the pages in the InnoDB buffer pool, in particular how they are ordered that determines which pages to evict from the buffer pool when it becomes full.

The INNODB_BUFFER_PAGE_LRU table has the same columns as the INNODB_BUFFER_PAGE table, except that the INNODB_BUFFER_PAGE_LRU table has an LRU_POSITION column instead of a BLOCK_ID column.

For related usage information and examples, see Section 14.18.3, “InnoDB INFORMATION_SCHEMA Buffer Pool Tables”.

Warning

Querying the INNODB_BUFFER_PAGE_LRU table can introduce significant performance overhead. Do not query this table on a production system unless you are aware of the performance impact that your query may have, and have determined it to be acceptable. To avoid impacting performance, reproduce the issue you want to investigate on a test instance and query the INNODB_BUFFER_PAGE_LRU table on the test instance.

Table 21.2 INNODB_BUFFER_PAGE_LRU Columns

Column name	Description
POOL_ID	Buffer Pool ID. An identifier to distinguish between multiple buffer pool instances.
LRU_POSITION	The position of the page in the LRU list.
SPACE	Tablespace ID. Uses the same value as in INNODB_SYS_TABLES.SPACE.
PAGE_NUMBER	Page number.
PAGE_TYPE	Page type. Permitted values are ALLOCATED (Freshly allocated page), INDEX (B-tree node), UNDO_LOG (Undo log page), INODE (Index node), IBUF_FREE_LIST (Insert buffer free list), IBUF_BITMAP (Insert buffer bitmap), SYSTEM (System page), TRX_SYSTEM (Transaction system data), FILE_SPACE_HEADER (File space header), EXTENT_DESCRIPTOR (Extent descriptor page), BLOB (Uncompressed BLOB page), COMPRESSED_BLOB (First compressed BLOB page), COMPRESSED_BLOB2 (Subsequent comp BLOB page), IBUF_INDEX (Insert buffer index), UNKNOWN (unknown).
FLUSH_TYPE	Flush type.
FIX_COUNT	Number of threads using this block within the buffer pool. When zero, the block is eligible to be evicted.
IS_HASHED	Whether hash index has been built on this page.
NEWEST_MODIFICATION	Log Sequence Number of the youngest modification.
OLDEST_MODIFICATION	Log Sequence Number of the oldest modification.

Column name	Description
ACCESS_TIME	An abstract number used to judge the first access time of the page.
TABLE_NAME	Name of the table the page belongs to. This column is only applicable to pages of type INDEX.
INDEX_NAME	Name of the index the page belongs to. It can be the name of a clustered index or a secondary index. This column is only applicable to pages of type INDEX.
NUMBER_RECORDS	Number of records within the page.
DATA_SIZE	Sum of the sizes of the records. This column is only applicable to pages of type INDEX.
COMPRESSED_SIZE	Compressed page size. Null for pages that are not compressed.
PAGE_STATE	Page state. Possible values include: NULL (clean compressed pages, compressed pages in the flush list, pages used as buffer pool watch sentinels), NOT_USED (in the free list), READY_FOR_USE (a free page), FILE_PAGE (a buffered file page), MEMORY (contains a main memory object), REMOVE_HASH (hash index should be removed before placing in the free list).
IO_FIX	Specifies whether any I/O is pending for this page: IO_NONE = no pending I/O, IO_READ = read pending, IO_WRITE = write pending.
IS_OLD	Specifies whether or not the block is in the sublist of old blocks in the LRU list.
FREE_PAGE_CLOCK	The value of the freed_page_clock counter when the block was the last placed at the head of the LRU list. The freed_page_clock counter tracks the number of blocks removed from the end of the LRU list.

Example

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_BUFFER_PAGE_LRU LIMIT 1\G
*************************** 1. row ***************************
            POOL_ID: 0
       LRU_POSITION: 0
              SPACE: 0
        PAGE_NUMBER: 7485
          PAGE_TYPE: INDEX
         FLUSH_TYPE: 2
          FIX_COUNT: 0
          IS_HASHED: YES
NEWEST_MODIFICATION: 216319316
OLDEST_MODIFICATION: 0
        ACCESS_TIME: 3376846384
         TABLE_NAME: employees/salaries
         INDEX_NAME: emp_no
     NUMBER_RECORDS: 1300
          DATA_SIZE: 15600
    COMPRESSED_SIZE: 0
         COMPRESSED: NO
             IO_FIX: IO_NONE
             IS_OLD: YES
    FREE_PAGE_CLOCK: 0
```

Notes

- This table is primarily useful for expert-level performance monitoring, or when developing performance-related extensions for MySQL.
- You must have the PROCESS privilege to query this table.
- Use DESCRIBE or SHOW COLUMNS to view additional information about the columns of this table including data types and default values.

- Querying this table can require MySQL to allocate a large block of contiguous memory, more than 64 bytes time the number of active pages in the buffer pool. This allocation could potentially cause an out-of-memory error, especially for systems with multi-gigabyte buffer pools.
- Querying this table requires MySQL to lock the data structure representing the buffer pool while traversing the LRU list, which can reduce concurrency, especially for systems with multi-gigabyte buffer pools.
- When tables, table rows, partitions, or indexes are deleted, associated pages remain in the buffer pool until space is required for other data. The `INNODB_BUFFER_PAGE_LRU` table reports information about these pages until they are evicted from the buffer pool. For more information about how the `InnoDB` manages buffer pool data, see Section 14.9.2.1, "The InnoDB Buffer Pool".

21.28.3 The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table

The `INNODB_BUFFER_POOL_STATS` table provides much of the same buffer pool information provided in `SHOW ENGINE INNODB STATUS` output. Much of the same information may also be obtained using `InnoDB` buffer pool server status variables.

The idea of making pages in the buffer pool "young" or "not young" refers to transferring them between the sublists at the head and tail of the buffer pool data structure. Pages made "young" take longer to age out of the buffer pool, while pages made "not young" are moved much closer to the point of eviction.

For related usage information and examples, see Section 14.18.3, "InnoDB INFORMATION_SCHEMA Buffer Pool Tables".

Table 21.3 INNODB_BUFFER_POOL_STATS Columns

Column name	Description
`POOL_ID`	Buffer Pool ID. A unique identifier to distinguish between multiple buffer pool instances.
`POOL_SIZE`	The `InnoDB` buffer pool size in pages.
`FREE_BUFFERS`	The number of free pages in the `InnoDB` buffer pool
`DATABASE_PAGES`	The number of pages in the `InnoDB` buffer pool containing data. The number includes both dirty and clean pages.
`OLD_DATABASE_PAGES`	The number of pages in the `old` buffer pool sublist.
`MODIFIED_DATABASE_PAGES`	The number of modified (dirty) database pages
`PENDING_DECOMPRESS`	The number of pages pending decompression
`PENDING_READS`	The number of pending reads
`PENDING_FLUSH_LRU`	The number of pages pending flush in the LRU
`PENDING_FLUSH_LIST`	The number of pages pending flush in the flush list
`PAGES_MADE_YOUNG`	The number of pages made young
`PAGES_NOT_MADE_YOUNG`	The number of pages not made young
`PAGES_MADE_YOUNG_RATE`	The number of pages made young per second (pages made young since the last printout / time elapsed)
`PAGES_MADE_NOT_YOUNG_RATE`	The number of pages not made per second (pages not made young since the last printout / time elapsed)
`NUMBER_PAGES_READ`	The number of pages read
`NUMBER_PAGES_CREATED`	The number of pages created
`NUMBER_PAGES_WRITTEN`	The number of pages written

Column name	Description
PAGES_READ_RATE	The number of pages read per second (pages read since the last printout / time elapsed)
PAGES_CREATE_RATE	The number of pages created per second (pages created since the last printout / time elapsed)
PAGES_WRITTEN_RATE	The number of pages written per second (pages written since the last printout / time elapsed)
NUMBER_PAGES_GET	The number of logical read requests.
HIT_RATE	The buffer pool hit rate
YOUNG_MAKE_PER_THOUSAND_GETS	The number of pages made young per thousand gets
NOT_YOUNG_MAKE_PER_THOUSAND_GETS	The number of pages not made young per thousand gets
NUMBER_PAGES_READ_AHEAD	The number of pages read ahead
NUMBER_READ_AHEAD_EVICTED	The number of pages read into the InnoDB buffer pool by the read-ahead background thread that were subsequently evicted without having been accessed by queries.
READ_AHEAD_RATE	The read ahead rate per second (pages read ahead since the last printout / time elapsed)
READ_AHEAD_EVICTED_RATE	The number of read ahead pages evicted without access per second (read ahead pages not accessed since the last printout / time elapsed)
LRU_IO_TOTAL	LRU IO total
LRU_IO_CURRENT	LRU IO for the current interval
UNCOMPRESS_TOTAL	Total number of pages decompressed
UNCOMPRESS_CURRENT	The number of pages decompressed in the current interval

Example:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_BUFFER_POOL_STATS\G
*************************** 1. row ***************************
                     POOL_ID: 0
                   POOL_SIZE: 8192
                FREE_BUFFERS: 0
              DATABASE_PAGES: 8014
          OLD_DATABASE_PAGES: 2938
      MODIFIED_DATABASE_PAGES: 0
           PENDING_DECOMPRESS: 0
                PENDING_READS: 0
            PENDING_FLUSH_LRU: 0
           PENDING_FLUSH_LIST: 0
             PAGES_MADE_YOUNG: 7380
         PAGES_NOT_MADE_YOUNG: 0
        PAGES_MADE_YOUNG_RATE: 0
    PAGES_MADE_NOT_YOUNG_RATE: 0
            NUMBER_PAGES_READ: 2723
         NUMBER_PAGES_CREATED: 12657
         NUMBER_PAGES_WRITTEN: 16181
              PAGES_READ_RATE: 0
            PAGES_CREATE_RATE: 0
           PAGES_WRITTEN_RATE: 0
             NUMBER_PAGES_GET: 28952710
                     HIT_RATE: 1000
  YOUNG_MAKE_PER_THOUSAND_GETS: 0
NOT_YOUNG_MAKE_PER_THOUSAND_GETS: 0
       NUMBER_PAGES_READ_AHEAD: 2469
     NUMBER_READ_AHEAD_EVICTED: 0
           READ_AHEAD_RATE: 0
      READ_AHEAD_EVICTED_RATE: 0
                LRU_IO_TOTAL: 0
              LRU_IO_CURRENT: 0
            UNCOMPRESS_TOTAL: 0
```

```
             UNCOMPRESS_CURRENT: 0
1 row in set (0.00 sec)
```

Notes:

- This table is primarily useful for expert-level performance monitoring, or when developing performance-related extensions for MySQL.
- Use `DESCRIBE` or `SHOW COLUMNS` to view additional information about the columns of this table including data types and default values.
- You must have the `PROCESS` privilege to query this table.

21.28.4 The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables

The `INNODB_CMP` and `INNODB_CMP_RESET` tables contain status information on operations related to compressed `InnoDB` tables.

Table 21.4 Columns of INNODB_CMP and INNODB_CMP_RESET

Column name	Description
`PAGE_SIZE`	Compressed page size in bytes.
`COMPRESS_OPS`	Number of times a B-tree page of the size `PAGE_SIZE` has been compressed. Pages are compressed whenever an empty page is created or the space for the uncompressed modification log runs out.
`COMPRESS_OPS_OK`	Number of times a B-tree page of the size `PAGE_SIZE` has been successfully compressed. This count should never exceed `COMPRESS_OPS`.
`COMPRESS_TIME`	Total time in seconds spent in attempts to compress B-tree pages of the size `PAGE_SIZE`.
`UNCOMPRESS_OPS`	Number of times a B-tree page of the size `PAGE_SIZE` has been uncompressed. B-tree pages are uncompressed whenever compression fails or at first access when the uncompressed page does not exist in the buffer pool.
`UNCOMPRESS_TIME`	Total time in seconds spent in uncompressing B-tree pages of the size `PAGE_SIZE`.

Example:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_CMP\G
*************************** 1. row ***************************
      page_size: 1024
   compress_ops: 0
compress_ops_ok: 0
  compress_time: 0
 uncompress_ops: 0
uncompress_time: 0
*************************** 2. row ***************************
      page_size: 2048
   compress_ops: 0
compress_ops_ok: 0
  compress_time: 0
 uncompress_ops: 0
uncompress_time: 0
*************************** 3. row ***************************
      page_size: 4096
   compress_ops: 0
compress_ops_ok: 0
```

```
  compress_time: 0
 uncompress_ops: 0
uncompress_time: 0
*************************** 4. row ***************************
      page_size: 8192
   compress_ops: 199755
compress_ops_ok: 112015
  compress_time: 83
 uncompress_ops: 74253
uncompress_time: 13
*************************** 5. row ***************************
      page_size: 16384
   compress_ops: 0
compress_ops_ok: 0
  compress_time: 0
 uncompress_ops: 0
uncompress_time: 0
```

Notes:

- Use these tables to measure the effectiveness of `InnoDB` table compression in your database.
- Use `DESCRIBE` or `SHOW COLUMNS` to view additional information about the columns of these tables including data types and default values.
- You must have the `PROCESS` privilege to query this table.
- For usage information, see Section 14.18.1.3, “Using the Compression Information Schema Tables”.

21.28.5 The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables

The `INNODB_CMPMEM` and `INNODB_CMPMEM_RESET` tables contain status information on compressed pages within the `InnoDB` buffer pool.

Table 21.5 Columns of INNODB_CMPMEM and INNODB_CMPMEM_RESET

Column name	Description
`PAGE_SIZE`	Block size in bytes. Each record of this table describes blocks of this size.
`BUFFER_POOL_INSTANCE`	A unique identifier for the buffer pool instance.
`PAGES_USED`	Number of blocks of the size `PAGE_SIZE` that are currently in use.
`PAGES_FREE`	Number of blocks of the size `PAGE_SIZE` that are currently available for allocation. This column shows the external fragmentation in the memory pool. Ideally, these numbers should be at most 1.
`RELOCATION_OPS`	Number of times a block of the size `PAGE_SIZE` has been relocated. The buddy system can relocate the allocated “buddy neighbor” of a freed block when it tries to form a bigger freed block. Reading from the table `INNODB_CMPMEM_RESET` resets this count.
`RELOCATION_TIME`	Total time in microseconds spent in relocating blocks of the size `PAGE_SIZE`. Reading from the table `INNODB_CMPMEM_RESET` resets this count.

Example:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_CMPMEM\G
*************************** 1. row ***************************
          page_size: 1024
buffer_pool_instance: 0
         pages_used: 0
         pages_free: 0
```

```
      relocation_ops: 0
     relocation_time: 0
*************************** 2. row ***************************
           page_size: 2048
buffer_pool_instance: 0
          pages_used: 0
          pages_free: 0
      relocation_ops: 0
     relocation_time: 0
*************************** 3. row ***************************
           page_size: 4096
buffer_pool_instance: 0
          pages_used: 0
          pages_free: 0
      relocation_ops: 0
     relocation_time: 0
*************************** 4. row ***************************
           page_size: 8192
buffer_pool_instance: 0
          pages_used: 9043
          pages_free: 1
      relocation_ops: 2457
     relocation_time: 0
*************************** 5. row ***************************
           page_size: 16384
buffer_pool_instance: 0
          pages_used: 0
          pages_free: 0
      relocation_ops: 0
     relocation_time: 0
```

Notes:

- Use these tables to measure the effectiveness of `InnoDB` table compression in your database.
- Use `DESCRIBE` or `SHOW COLUMNS` to view additional information about the columns of these tables including data types and default values.
- You must have the `PROCESS` privilege to query this table.
- For usage information, see Section 14.18.1.3, “Using the Compression Information Schema Tables”.

21.28.6 The INFORMATION_SCHEMA INNODB_LOCKS Table

The `INNODB_LOCKS` table contains information about each lock that an `InnoDB` transaction has requested but not yet acquired, and each lock that a transaction holds that is blocking another transaction.

Table 21.6 INNODB_LOCKS Columns

Column name	Description
`LOCK_ID`	Unique lock ID number, internal to `InnoDB`. Treat it as an opaque string. Although `LOCK_ID` currently contains `TRX_ID`, the format of the data in `LOCK_ID` is subject to change at any time. Do not write applications that parse the `LOCK_ID` value.
`LOCK_TRX_ID`	ID of the transaction holding the lock. To obtain details about the transaction, join this column with the `TRX_ID` column of the `INNODB_TRX` table.
`LOCK_MODE`	How the lock is requested. Permitted values are `S[,GAP]`, `X[,GAP]`, `IS[,GAP]`, `IX[,GAP]`, `AUTO_INC`, and `UNKNOWN`. Lock modes other than `AUTO_INC` and `UNKNOWN` indicate gap locks, if present. For information about `S`, `X`, `IS`, `IX`, and gap locks, refer to Section 14.8.1, “InnoDB Locking”.
`LOCK_TYPE`	The type of lock. Permitted values are `RECORD` for a row-level lock, `TABLE` for a table-level lock.

Column name	Description
LOCK_TABLE	Name of the table that has been locked or contains locked records.
LOCK_INDEX	Name of the index, if LOCK_TYPE is RECORD; otherwise NULL.
LOCK_SPACE	Tablespace ID of the locked record, if LOCK_TYPE is RECORD; otherwise NULL.
LOCK_PAGE	Page number of the locked record, if LOCK_TYPE is RECORD; otherwise NULL.
LOCK_REC	Heap number of the locked record within the page, if LOCK_TYPE is RECORD; otherwise NULL.
LOCK_DATA	The data associated with the lock, if any. Values are primary key values of the locked record if LOCK_TYPE is RECORD, otherwise NULL. This column contains the values of the primary key columns in the locked row, formatted as a valid SQL string (ready to be copied to SQL statements). If there is no primary key, LOCK_DATA is the unique InnoDB internal row ID number. If a gap lock is taken for key values or ranges above the largest value in the index, LOCK_DATA reports supremum pseudo-record. When the page containing the locked record is not in the buffer pool (in the case that it was paged out to disk while the lock was held), InnoDB does not fetch the page from disk, to avoid unnecessary disk operations. Instead, LOCK_DATA is set to NULL.

Example:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_LOCKS\G
*************************** 1. row ***************************
    lock_id: 3723:72:3:2
lock_trx_id: 3723
  lock_mode: X
  lock_type: RECORD
 lock_table: `mysql`.`t`
 lock_index: PRIMARY
 lock_space: 72
  lock_page: 3
   lock_rec: 2
  lock_data: 1, 9
*************************** 2. row ***************************
    lock_id: 3722:72:3:2
lock_trx_id: 3722
  lock_mode: S
  lock_type: RECORD
 lock_table: `mysql`.`t`
 lock_index: PRIMARY
 lock_space: 72
  lock_page: 3
   lock_rec: 2
  lock_data: 1, 9
```

Notes:

- Use this table to help diagnose performance problems that occur during times of heavy concurrent load. Its contents are updated as described in Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”.
- Use DESCRIBE or SHOW COLUMNS to view additional information about the columns of this table including data types and default values.
- You must have the PROCESS privilege to query this table.
- For usage information, see Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”.

21.28.7 The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table

The INNODB_LOCK_WAITS table contains one or more rows for each blocked InnoDB transaction, indicating the lock it has requested and any locks that are blocking that request.

Table 21.7 INNODB_LOCK_WAITS Columns

Column name	Description
REQUESTING_TRX_ID	ID of the requesting (blocked) transaction.
REQUESTED_LOCK_ID	ID of the lock for which a transaction is waiting. To obtain details about the lock, join this column with the LOCK_ID column of the INNODB_LOCKS table.
BLOCKING_TRX_ID	ID of the blocking transaction.
BLOCKING_LOCK_ID	ID of a lock held by a transaction blocking another transaction from proceeding. To obtain details about the lock, join this column with the LOCK_ID column of the INNODB_LOCKS table.

Example:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_LOCK_WAITS\G
*************************** 1. row ***************************
requesting_trx_id: 3B7
requested_lock_id: 3B7:0:306:2
  blocking_trx_id: 3B6
 blocking_lock_id: 3B6:0:306:2
```

Notes:

- Use this table to help diagnose performance problems that occur during times of heavy concurrent load. Its contents are updated as described in Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”.
- Use DESCRIBE or SHOW COLUMNS to view additional information about the columns of this table including data types and default values.
- You must have the PROCESS privilege to query this table.
- For usage information, see Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”.

21.28.8 The INFORMATION_SCHEMA INNODB_TRX Table

The INNODB_TRX table contains information about every transaction currently executing inside InnoDB, including whether the transaction is waiting for a lock, when the transaction started, and the SQL statement the transaction is executing, if any.

Table 21.8 INNODB_TRX Columns

Column name	Description
TRX_ID	Unique transaction ID number, internal to InnoDB. (Starting in MySQL 5.6, these IDs are not created for transactions that are read only and nonlocking. See Optimizing InnoDB Read-Only Transactions for details.)
TRX_WEIGHT	The weight of a transaction, reflecting (but not necessarily the exact count of) the number of rows altered and the number of rows locked by the transaction. To resolve a deadlock, InnoDB selects the transaction with the smallest weight as the “victim” to roll back. Transactions that have changed non-transactional tables are considered heavier than others, regardless of the number of altered and locked rows.
TRX_STATE	Transaction execution state. Permitted values are RUNNING, LOCK WAIT, ROLLING BACK, and COMMITTING.
TRX_STARTED	Transaction start time.

Column name	Description
TRX_REQUESTED_LOCK_ID	ID of the lock the transaction is currently waiting for, if TRX_STATE is LOCK WAIT; otherwise NULL. To obtain details about the lock, join this column with the LOCK_ID column of the INNODB_LOCKS table.
TRX_WAIT_STARTED	Time when the transaction started waiting on the lock, if TRX_STATE is LOCK WAIT; otherwise NULL.
TRX_MYSQL_THREAD_ID	MySQL thread ID. To obtain details about the thread, join this column with the ID column of the INFORMATION_SCHEMA PROCESSLIST table, but see Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”.
TRX_QUERY	The SQL statement that is being executed by the transaction.
TRX_OPERATION_STATE	The transaction's current operation, if any; otherwise NULL.
TRX_TABLES_IN_USE	The number of InnoDB tables used while processing the current SQL statement of this transaction.
TRX_TABLES_LOCKED	Number of InnoDB tables that the current SQL statement has row locks on. (Because these are row locks, not table locks, the tables can usually still be read from and written to by multiple transactions, despite some rows being locked.)
TRX_LOCK_STRUCTS	The number of locks reserved by the transaction.
TRX_LOCK_MEMORY_BYTES	Total size taken up by the lock structures of this transaction in memory.
TRX_ROWS_LOCKED	Approximate number or rows locked by this transaction. The value might include delete-marked rows that are physically present but not visible to the transaction.
TRX_ROWS_MODIFIED	The number of modified and inserted rows in this transaction.
TRX_CONCURRENCY_TICKETS	A value indicating how much work the current transaction can do before being swapped out, as specified by the innodb_concurrency_tickets system variable.
TRX_ISOLATION_LEVEL	The isolation level of the current transaction.
TRX_UNIQUE_CHECKS	Whether unique checks are turned on or off for the current transaction. For example, they might be turned off during a bulk data load.
TRX_FOREIGN_KEY_CHECKS	Whether foreign key checks are turned on or off for the current transaction. For example, they might be turned off during a bulk data load.
TRX_LAST_FOREIGN_KEY_ERROR	Detailed error message for the last foreign key error, if any; otherwise NULL.
TRX_ADAPTIVE_HASH_LATCHED	Whether the adaptive hash index is locked by the current transaction. (Only a single transaction at a time can modify the adaptive hash index.)
TRX_ADAPTIVE_HASH_TIMEOUT	Whether to relinquish the search latch immediately for the adaptive hash index, or reserve it across calls from MySQL. When there is no adaptive hash index contention, this value remains zero and statements reserve the latch until they finish. During times of contention, it counts down to zero, and statements release the latch immediately after each row lookup.

Example:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.INNODB_TRX\G
```

```
*************************** 1. row ***************************
                    trx_id: 3B7
                 trx_state: RUNNING
               trx_started: 2014-11-19 14:33:45
     trx_requested_lock_id: NULL
          trx_wait_started: NULL
                trx_weight: 1
       trx_mysql_thread_id: 2
                 trx_query: SELECT * FROM INFORMATION_SCHEMA.INNODB_TRX
       trx_operation_state: NULL
         trx_tables_in_use: 0
         trx_tables_locked: 0
          trx_lock_structs: 1
     trx_lock_memory_bytes: 376
           trx_rows_locked: 0
         trx_rows_modified: 0
   trx_concurrency_tickets: 0
       trx_isolation_level: REPEATABLE READ
         trx_unique_checks: 1
    trx_foreign_key_checks: 1
trx_last_foreign_key_error: NULL
 trx_adaptive_hash_latched: 0
 trx_adaptive_hash_timeout: 10000
*************************** 2. row ***************************
                    trx_id: 3B6
                 trx_state: RUNNING
               trx_started: 2014-11-19 14:32:38
     trx_requested_lock_id: NULL
          trx_wait_started: NULL
                trx_weight: 94055
       trx_mysql_thread_id: 1
                 trx_query: DELETE FROM employees.salaries WHERE salary > 75000
       trx_operation_state: updating or deleting
         trx_tables_in_use: 1
         trx_tables_locked: 1
          trx_lock_structs: 841
     trx_lock_memory_bytes: 129464
           trx_rows_locked: 392752
         trx_rows_modified: 93214
   trx_concurrency_tickets: 0
       trx_isolation_level: REPEATABLE READ
         trx_unique_checks: 1
    trx_foreign_key_checks: 1
trx_last_foreign_key_error: NULL
 trx_adaptive_hash_latched: 0
 trx_adaptive_hash_timeout: 10000
```

Notes:

- Use this table to help diagnose performance problems that occur during times of heavy concurrent load. Its contents are updated as described in Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”.
- Use `DESCRIBE` or `SHOW COLUMNS` to view additional information about the columns of this table including data types and default values.
- You must have the `PROCESS` privilege to query this table.
- For usage information, see Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”.

21.29 NDB Cluster INFORMATION_SCHEMA Tables

The following sections provide information about `INFORMATION_SCHEMA` tables which are specific to NDB Cluster. The `FILES` table was added in MySQL Server 5.1.6 as part of NDB Cluster data-on-disk support (it is available in standard MySQL 5.5 but is not used there). The `ndb_transid_mysql_connection_map` table was added as part of additions made to NDB Cluster's `ndbinfo` information database in MySQL NDB Cluster 7.2.2; it is implemented as an `INFORMATION_SCHEMA` plugin available only in NDB Cluster binaries or source, and does not exist in MySQL Server 5.5.

Additional statistical and other data about NDB Cluster transactions, operations, threads, blocks, and other aspects of performance can be obtained from the tables in the `ndbinfo` database. Information about these tables, see Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”.

21.29.1 The INFORMATION_SCHEMA FILES Table

The `FILES` table provides information about the files in which MySQL `NDB` Disk Data tables are stored.

Note

This table provides information about Disk Data *files* only; you cannot use it for determining disk space allocation or availability for individual `NDB` tables. However, it is possible to see how much space is allocated for each `NDB` table having data stored on disk—as well as how much remains available for storage of data on disk for that table—using `ndb_desc`. For more information, see Section 18.4.10, “`ndb_desc` — Describe NDB Tables”.

`INFORMATION_SCHEMA` Name	`SHOW` Name	Remarks
`FILE_ID`		MySQL extension
`FILE_NAME`		MySQL extension
`FILE_TYPE`		MySQL extension
`TABLESPACE_NAME`		MySQL extension
`TABLE_CATALOG`		MySQL extension
`TABLE_SCHEMA`		MySQL extension
`TABLE_NAME`		MySQL extension
`LOGFILE_GROUP_NAME`		MySQL extension
`LOGFILE_GROUP_NUMBER`		MySQL extension
`ENGINE`		MySQL extension
`FULLTEXT_KEYS`		MySQL extension
`DELETED_ROWS`		MySQL extension
`UPDATE_COUNT`		MySQL extension
`FREE_EXTENTS`		MySQL extension
`TOTAL_EXTENTS`		MySQL extension
`EXTENT_SIZE`		MySQL extension
`INITIAL_SIZE`		MySQL extension
`MAXIMUM_SIZE`		MySQL extension
`AUTOEXTEND_SIZE`		MySQL extension
`CREATION_TIME`		MySQL extension
`LAST_UPDATE_TIME`		MySQL extension
`LAST_ACCESS_TIME`		MySQL extension
`RECOVER_TIME`		MySQL extension
`TRANSACTION_COUNTER`		MySQL extension
`VERSION`		MySQL extension
`ROW_FORMAT`		MySQL extension
`TABLE_ROWS`		MySQL extension
`AVG_ROW_LENGTH`		MySQL extension
`DATA_LENGTH`		MySQL extension

INFORMATION_SCHEMA Name	SHOW Name	Remarks
MAX_DATA_LENGTH		MySQL extension
INDEX_LENGTH		MySQL extension
DATA_FREE		MySQL extension
CREATE_TIME		MySQL extension
UPDATE_TIME		MySQL extension
CHECK_TIME		MySQL extension
CHECKSUM		MySQL extension
STATUS		MySQL extension
EXTRA		MySQL extension

Notes:

- FILE_ID column values are auto-generated.
- FILE_NAME is the name of an UNDO log file created by CREATE LOGFILE GROUP or ALTER LOGFILE GROUP, or of a data file created by CREATE TABLESPACE or ALTER TABLESPACE.
- FILE_TYPE is one of the values UNDOFILE, DATAFILE, or TABLESPACE.
- TABLESPACE_NAME is the name of the tablespace with which the file is associated.
- The value of the TABLESPACE_CATALOG column is always NULL.
- TABLE_NAME is the name of the Disk Data table with which the file is associated, if any.
- The LOGFILE_GROUP_NAME column gives the name of the log file group to which the log file or data file belongs.
- For an UNDO log file, the LOGFILE_GROUP_NUMBER contains the auto-generated ID number of the log file group to which the log file belongs.
- For an NDB Cluster Disk Data log file or data file, the value of the ENGINE column is always NDB or NDBCLUSTER.
- For an NDB Cluster Disk Data log file or data file, the value of the FULLTEXT_KEYS column is always empty.
- The FREE EXTENTS column displays the number of extents which have not yet been used by the file. The TOTAL EXTENTS column show the total number of extents allocated to the file.

  The difference between these two columns is the number of extents currently in use by the file:

```
SELECT TOTAL_EXTENTS - FREE_EXTENTS AS extents_used
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'myfile.dat';
```

  You can approximate the amount of disk space in use by the file by multiplying this difference by the value of the EXTENT_SIZE column, which gives the size of an extent for the file in bytes:

```
SELECT (TOTAL_EXTENTS - FREE_EXTENTS) * EXTENT_SIZE AS bytes_used
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'myfile.dat';
```

  Similarly, you can estimate the amount of space that remains available in a given file by multiplying FREE_EXTENTS by EXTENT_SIZE:

```
```

```
SELECT FREE_EXTENTS * EXTENT_SIZE AS bytes_free
    FROM INFORMATION_SCHEMA.FILES
    WHERE FILE_NAME = 'myfile.dat';
```

Important

The byte values produced by the preceding queries are approximations only, and their precision is inversely proportional to the value of `EXTENT_SIZE`. That is, the larger `EXTENT_SIZE` becomes, the less accurate the approximations are.

It is also important to remember that once an extent is used, it cannot be freed again without dropping the data file of which it is a part. This means that deletes from a Disk Data table do *not* release disk space.

The extent size can be set in a `CREATE TABLESPACE` statement. See Section 13.1.18, “CREATE TABLESPACE Syntax”, for more information.

- The `INITIAL_SIZE` column shows the size in bytes of the file. This is the same value that was used in the `INITIAL_SIZE` clause of the `CREATE LOGFILE GROUP`, `ALTER LOGFILE GROUP`, `CREATE TABLESPACE`, or `ALTER TABLESPACE` statement used to create the file.

  For NDB Cluster Disk Data files, the value of the `MAXIMUM_SIZE` column is always the same as `INITIAL_SIZE`, and the `AUTOEXTEND_SIZE` column is always empty.

- The `CREATION_TIME` column shows the date and time when the file was created. The `LAST_UPDATE_TIME` column displays the date and time when the file was last modified. The `LAST_ACCESSED` column provides the date and time when the file was last accessed by the server.

  The values of these columns are as reported by the operating system, and are not supplied by the `NDB` storage engine. Where no value is provided by the operating system, these columns display `0000-00-00 00:00:00`.

- For NDB Cluster Disk Data files, the value of the `RECOVER_TIME` and `TRANSACTION_COUNTER` columns is always `0`.

- For NDB Cluster Disk Data files, the following columns are always `NULL`:

  - `VERSION`
  - `ROW_FORMAT`
  - `TABLE_ROWS`
  - `AVG_ROW_LENGTH`
  - `DATA_LENGTH`
  - `MAX_DATA_LENGTH`
  - `INDEX_LENGTH`
  - `DATA_FREE`
  - `CREATE_TIME`
  - `UPDATE_TIME`
  - `CHECK_TIME`
  - `CHECKSUM`

- For NDB Cluster Disk Data files, the value of the `STATUS` column is always `NORMAL`.

- For NDB Cluster Disk Data files, the `EXTRA` column shows which data node the file belongs to, as each data node has its own copy of the file. Suppose that you use this statement on an NDB Cluster with four data nodes:

```
CREATE LOGFILE GROUP mygroup
    ADD UNDOFILE 'new_undo.dat'
    INITIAL_SIZE 2G
    ENGINE NDB;
```

  After running the `CREATE LOGFILE GROUP` statement successfully, you should see a result similar to the one shown here for this query against the `FILES` table:

```
mysql> SELECT LOGFILE_GROUP_NAME, FILE_TYPE, EXTRA
    ->     FROM INFORMATION_SCHEMA.FILES
    ->     WHERE FILE_NAME = 'new_undo.dat';
+--------------------+-------------+----------------+
| LOGFILE_GROUP_NAME | FILE_TYPE   | EXTRA          |
+--------------------+-------------+----------------+
| mygroup            | UNDO FILE   | CLUSTER_NODE=3 |
| mygroup            | UNDO FILE   | CLUSTER_NODE=4 |
| mygroup            | UNDO FILE   | CLUSTER_NODE=5 |
| mygroup            | UNDO FILE   | CLUSTER_NODE=6 |
+--------------------+-------------+----------------+
4 rows in set (0.01 sec)
```

- The `FILES` table is a nonstandard table.

- An additional row is present in the `FILES` table following the creation of a logfile group. This row has `NULL` for the value of the `FILE_NAME` column. For this row, the value of the `FILE_ID` column is always `0`, that of the `FILE_TYPE` column is always `UNDO FILE`, and that of the `STATUS` column is always `NORMAL`. The value of the `ENGINE` column is always `NDBCLUSTER`.

  The `FREE_EXTENTS` column in this row shows the total number of free extents available to all undo files belonging to a given log file group whose name and number are shown in the `LOGFILE_GROUP_NAME` and `LOGFILE_GROUP_NUMBER` columns, respectively.

  Suppose there are no existing log file groups on your NDB Cluster, and you create one using the following statement:

```
mysql> CREATE LOGFILE GROUP lg1
    ->   ADD UNDOFILE 'undofile.dat'
    ->   INITIAL_SIZE = 16M
    ->   UNDO_BUFFER_SIZE = 1M
    ->   ENGINE = NDB;
Query OK, 0 rows affected (3.81 sec)
```

  You can now see this `NULL` row when you query the `FILES` table:

```
mysql> SELECT DISTINCT
    ->   FILE_NAME AS File,
    ->   FREE_EXTENTS AS Free,
    ->   TOTAL_EXTENTS AS Total,
    ->   EXTENT_SIZE AS Size,
    ->   INITIAL_SIZE AS Initial
    ->   FROM INFORMATION_SCHEMA.FILES;
+--------------+---------+---------+------+----------+
| File         | Free    | Total   | Size | Initial  |
+--------------+---------+---------+------+----------+
| undofile.dat |    NULL | 4194304 |    4 | 16777216 |
| NULL         | 4184068 |    NULL |    4 |     NULL |
+--------------+---------+---------+------+----------+
2 rows in set (0.01 sec)
```

The total number of free extents available for undo logging is always somewhat less than the sum of the `TOTAL_EXTENTS` column values for all undo files in the log file group due to overhead required for maintaining the undo files. This can be seen by adding a second undo file to the log file group, then repeating the previous query against the `FILES` table:

```
mysql> ALTER LOGFILE GROUP lg1
    ->   ADD UNDOFILE 'undofile02.dat'
    ->   INITIAL_SIZE = 4M
    ->   ENGINE = NDB;
Query OK, 0 rows affected (1.02 sec)

mysql> SELECT DISTINCT
    ->   FILE_NAME AS File,
    ->   FREE_EXTENTS AS Free,
    ->   TOTAL_EXTENTS AS Total,
    ->   EXTENT_SIZE AS Size,
    ->   INITIAL_SIZE AS Initial
    ->   FROM INFORMATION_SCHEMA.FILES;
+---------------+---------+---------+------+----------+
| File          | Free    | Total   | Size | Initial  |
+---------------+---------+---------+------+----------+
| undofile.dat  |    NULL | 4194304 |    4 | 16777216 |
| undofile02.dat |    NULL | 1048576 |    4 |  4194304 |
| NULL          | 5223944 |    NULL |    4 |     NULL |
+---------------+---------+---------+------+----------+
3 rows in set (0.01 sec)
```

The amount of free space in bytes which is available for undo logging by Disk Data tables using this log file group can be approximated by multiplying the number of free extents by the initial size:

```
mysql> SELECT
    ->   FREE_EXTENTS AS 'Free Extents',
    ->   FREE_EXTENTS * EXTENT_SIZE AS 'Free Bytes'
    ->   FROM INFORMATION_SCHEMA.FILES
    ->   WHERE LOGFILE_GROUP_NAME = 'lg1'
    ->   AND FILE_NAME IS NULL;
+--------------+------------+
| Free Extents | Free Bytes |
+--------------+------------+
|      5223944 |   20895776 |
+--------------+------------+
1 row in set (0.02 sec)
```

If you create an NDB Cluster Disk Data table and then insert some rows into it, you can see approximately how much space remains for undo logging afterward, for example:

```
mysql> CREATE TABLESPACE ts1
    ->   ADD DATAFILE 'data1.dat'
    ->   USE LOGFILE GROUP lg1
    ->   INITIAL_SIZE 512M
    ->   ENGINE = NDB;
Query OK, 0 rows affected (8.71 sec)

mysql> CREATE TABLE dd (
    ->   c1 INT NOT NULL PRIMARY KEY,
    ->   c2 INT,
    ->   c3 DATE
    ->   )
    ->   TABLESPACE ts1 STORAGE DISK
    ->   ENGINE = NDB;
Query OK, 0 rows affected (2.11 sec)

mysql> INSERT INTO dd VALUES
    ->   (NULL, 1234567890, '2007-02-02'),
    ->   (NULL, 1126789005, '2007-02-03'),
    ->   (NULL, 1357924680, '2007-02-04'),
```

```
    ->   (NULL, 1642097531, '2007-02-05');
Query OK, 4 rows affected (0.01 sec)

mysql> SELECT
    ->   FREE_EXTENTS AS 'Free Extents',
    ->   FREE_EXTENTS * EXTENT_SIZE AS 'Free Bytes'
    ->   FROM INFORMATION_SCHEMA.FILES
    ->   WHERE LOGFILE_GROUP_NAME = 'lg1'
    ->   AND FILE_NAME IS NULL;
+--------------+------------+
| Free Extents | Free Bytes |
+--------------+------------+
|      5207565 |   20830260 |
+--------------+------------+
1 row in set (0.01 sec)
```

- An additional row is present in the FILES table for any NDB Cluster tablespace, whether or not any data files are associated with the tablespace. This row has NULL for the value of the FILE_NAME column. For this row, the value of the FILE_ID column is always 0, that of the FILE_TYPE column is always TABLESPACE, and that of the STATUS column is always NORMAL. The value of the ENGINE column is always NDBCLUSTER.
- There are no SHOW statements associated with the FILES table.
- For additional information, and examples of creating and dropping NDB Cluster Disk Data objects, see Section 18.5.12, “NDB Cluster Disk Data Tables”.

21.29.2 The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table

The ndb_transid_mysql_connection_map table provides a mapping between NDB transactions, NDB transaction coordinators, and MySQL Servers attached to an NDB Cluster as API nodes. This information is used when populating the server_operations and server_transactions tables of the ndbinfo NDB Cluster information database.

INFORMATION_SCHEMA Name	SHOW Name	Remarks
mysql_connection_id		MySQL Server connection ID
node_id		Transaction coordinator node ID
ndb_transid		NDB transaction ID

The mysql_connection_id is the same as the connection or session ID shown in the output of SHOW PROCESSLIST.

There are no SHOW statements associated with this table.

This is a nonstandard table, added in MySQL NDB Cluster 7.2.2. It is implemented as an INFORMATION_SCHEMA plugin; you can verify that it is supported by checking the output of SHOW PLUGINS. If ndb_transid_mysql_connection_map support is enabled, the output from this statement includes a plugin having this name, of type INFORMATION SCHEMA, and having status ACTIVE, as shown here (using emphasized text):

```
mysql> SHOW PLUGINS;
+----------------------------------+--------+--------------------+---------+---------+
| Name                             | Status | Type               | Library | License |
+----------------------------------+--------+--------------------+---------+---------+
| binlog                           | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| mysql_native_password            | ACTIVE | AUTHENTICATION     | NULL    | GPL     |
| mysql_old_password               | ACTIVE | AUTHENTICATION     | NULL    | GPL     |
| CSV                              | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
```

```
| MEMORY                             | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MRG_MYISAM                         | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| MyISAM                             | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| PERFORMANCE_SCHEMA                 | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| BLACKHOLE                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ARCHIVE                            | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndbcluster                         | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndbinfo                            | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| ndb_transid_mysql_connection_map   | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| InnoDB                             | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
| INNODB_TRX                         | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_LOCKS                       | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_LOCK_WAITS                  | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMP                         | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMP_RESET                   | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMPMEM                      | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| INNODB_CMPMEM_RESET                | ACTIVE | INFORMATION SCHEMA | NULL    | GPL     |
| partition                          | ACTIVE | STORAGE ENGINE     | NULL    | GPL     |
+------------------------------------+--------+--------------------+---------+---------+
22 rows in set (0.00 sec)
```

The plugin is enabled by default. You can disable it (or force the server not to run unless the plugin starts) by starting the server with the `--ndb-transid-mysql-connection-map` option. If the plugin is disabled, the status is shown by `SHOW PLUGINS` as `DISABLED`. The plugin cannot be enabled or disabled at runtime.

Although the names of this table and its columns are displayed using lowercase, you can use uppercase or lowercase when referring to them in SQL statements.

For this table to be created, the MySQL Server must be a binary supplied with the NDB Cluster distribution, or one built from the NDB Cluster sources with `NDB` storage engine support enabled. It is not available in the standard MySQL 5.5 Server.

21.30 Thread Pool INFORMATION_SCHEMA Tables

The following sections describe the `INFORMATION_SCHEMA` tables associated with the thread pool plugin. They provide information about thread pool operation:

- `TP_THREAD_GROUP_STATE`: Information about thread pool thread group states
- `TP_THREAD_GROUP_STATS`: Thread group statistics
- `TP_THREAD_STATE`: Information about thread pool thread states

Rows in these tables represent snapshots in time. In the case of `TP_THREAD_STATE`, all rows for a thread group comprise a snapshot in time. Thus, the MySQL server holds the mutex of the thread group while producing the snapshot. But it does not hold mutexes on all thread groups at the same time, to prevent a statement against `TP_THREAD_STATE` from blocking the entire MySQL server.

The thread pool `INFORMATION_SCHEMA` tables are implemented by individual plugins and the decision whether to load one can be made independently of the others (see Section 5.5.3.2, “Thread Pool Installation”). However, the content of all the tables depends on the thread pool plugin being enabled. If a table plugin is enabled but the thread pool plugin is not, the table becomes visible and can be accessed but will be empty.

21.30.1 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table

This table has one row per thread group in the thread pool. Each row provides information about the current state of a group. The table has these columns:

- `TP_GROUP_ID`

  The thread group ID. This is a unique key within the table.

- `CONSUMER_THREADS`

  The number of consumer threads. There is at most one thread ready to start executing if the active threads become stalled or blocked.

- `RESERVE_THREADS`

  The number of threads in the reserved state. This means that they will not be started until there is a need to wake a new thread and there is no consumer thread. This is where most threads end up when the thread group has created more threads than needed for normal operation. Often a thread group needs additional threads for a short while and then does not need them again for a while. In this case, they go into the reserved state and remain until needed again. They take up some extra memory resources, but no extra computing resources.

- `CONNECT_THREAD_COUNT`

  The number of threads that are processing or waiting to process connection initialization and authentication. There can be a maximum of four connection threads per thread group; these threads expire after a period of inactivity.

  This column was added in MySQL 5.5.55.

- `CONNECTION_COUNT`

  The number of connections using this thread group.

- `QUEUED_QUERIES`

  The number of statements waiting in the high-priority queue.

- `QUEUED_TRANSACTIONS`

  The number of statements waiting in the low-priority queue. These are the initial statements for transactions that have not started, so they also represent queued transactions.

- `STALL_LIMIT`

  The value of the `thread_pool_stall_limit` variable on the thread group. This is the same value for all thread groups.

- `PRIO_KICKUP_TIMER`

  The value of the `thread_pool_prio_kickup_timer` on the thread group. This is the same value for all thread groups.

- `ALGORITHM`

  The value of the `thread_pool_algorithm` on the thread group. This is the same value for all thread groups.

- `THREAD_COUNT`

  The number of threads started in the thread pool as part of this thread group.

- `ACTIVE_THREAD_COUNT`

  The number of threads active executing statements.

- `MAX_THREAD_IDS_IN_GROUP`

  The maximum thread ID of the threads in the group. This is the same as `MAX(TP_THREAD_NUMBER)` for the threads when selected from the `TP_THREAD_GROUP_STATE` table. That is, these two queries are equivalent:

```
SELECT TP_GROUP_ID, MAX_THREAD_IDS_IN_GROUP
FROM TP_THREAD_GROUP_STATE;

SELECT TP_GROUP_ID, MAX(TP_THREAD_NUMBER)
FROM TP_THREAD_STATE GROUP BY TP_GROUP_ID;
```

- `STALLED_THREAD_COUNT`

  The number of stalled statements in the thread group. A stalled statement could be executing, but from a thread pool perspective it is stalled and making no progress. A long-running statement quickly ends up in this category.

- `WAITING_THREAD_NUMBER`

  If there is a thread handling the polling of statements in the thread group, this specifies the thread number within this thread group. It is possible that this thread could be executing a statement.

- `OLDEST_QUEUED`

  How long in milliseconds the oldest queued statement has been waiting for execution.

21.30.2 The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table

This table reports statistics per thread group. There is one row per group. The table has these columns:

- `TP_GROUP_ID`

  The thread group ID. This is a unique key within the table.

- `CONNECTIONS_STARTED`

  The number of connections started.

- `CONNECTIONS_CLOSED`

  The number of connections closed.

- `QUERIES_EXECUTED`

  The number of statements executed. This number is incremented when a statement starts executing, not when it finishes.

- `QUERIES_QUEUED`

  The number of statements received that were queued for execution. This does not count statements that the thread group was able to begin executing immediately without queuing, which can happen under the conditions described in Section 5.5.3.3, “Thread Pool Operation”.

- `THREADS_STARTED`

  The number of threads started.

- `PRIO_KICKUPS`

  The number of statements that have been moved from low-priority queue to high-priority queue based on the value of the `thread_pool_prio_kickup_timer` system variable. If this number increases quickly, consider increasing the value of that variable. A quickly increasing counter means that the priority system is not keeping transactions from starting too early. For `InnoDB`, this most likely means deteriorating performance due to too many concurrent transactions..

- `STALLED_QUERIES_EXECUTED`

The number of statements that have become defined as stalled due to executing for a time longer than the value of the `thread_pool_stall_limit` system variable.

- `BECOME_CONSUMER_THREAD`

  The number of times thread have been assigned the consumer thread role.

- `BECOME_RESERVE_THREAD`

  The number of times threads have been assigned the reserve thread role.

- `BECOME_WAITING_THREAD`

  The number of times threads have been assigned the waiter thread role. When statements are queued, this happens very often, even in normal operation, so rapid increases in this value are normal in the case of a highly loaded system where statements are queued up.

- `WAKE_THREAD_STALL_CHECKER`

  The number of times the stall check thread decided to wake or create a thread to possibly handle some statements or take care of the waiter thread role.

- `SLEEP_WAITS`

  The number of `THD_WAIT_SLEEP` waits. These occur when threads go to sleep; for example, by calling the `SLEEP()` function.

- `DISK_IO_WAITS`

  The number of `THD_WAIT_DISKIO` waits. These occur when threads perform disk I/O that is likely to not hit the file system cache. Such waits occur when the buffer pool reads and writes data to disk, not for normal reads from and writes to files.

- `ROW_LOCK_WAITS`

  The number of `THD_WAIT_ROW_LOCK` waits for release of a row lock by another transaction.

- `GLOBAL_LOCK_WAITS`

  The number of `THD_WAIT_GLOBAL_LOCK` waits for a global lock to be released.

- `META_DATA_LOCK_WAITS`

  The number of `THD_WAIT_META_DATA_LOCK` waits for a metadata lock to be released.

- `TABLE_LOCK_WAITS`

  The number of `THD_WAIT_TABLE_LOCK` waits for a table to be unlocked that the statement needs to access.

- `USER_LOCK_WAITS`

  The number of `THD_WAIT_USER_LOCK` waits for a special lock constructed by the user thread.

- `BINLOG_WAITS`

  The number of `THD_WAIT_BINLOG_WAITS` waits for the binary log to become free.

- `GROUP_COMMIT_WAITS`

  The number of `THD_WAIT_GROUP_COMMIT` waits. These occur when a group commit must wait for the other parties to complete their part of a transaction.

- FSYNC_WAITS

  The number of THD_WAIT_SYNC waits for a file sync operation.

21.30.3 The INFORMATION_SCHEMA TP_THREAD_STATE Table

This table has one row per thread created by the thread pool to handle connections. The table has these columns:

- TP_GROUP_ID

  The thread group ID.

- TP_THREAD_NUMBER

  The ID of the thread within its thread group. TP_GROUP_ID and TP_THREAD_NUMBER together provide a unique key within the table.

- PROCESS_COUNT

  The 10ms interval in which the statement that uses this thread is currently executing. 0 means no statement is executing, 1 means it is in the first 10ms, and so forth.

- WAIT_TYPE

  The type of wait for the thread. NULL means the thread is not blocked. Otherwise, the thread is blocked by a call to thd_wait_begin() and the value specifies the type of wait. The *xxx*_WAIT columns of the TP_THREAD_GROUP_STATS table accumulate counts for each wait type.

  The WAIT_TYPE value is a string that describes the type of wait, as shown in the following table.

  Table 21.9 WAIT_TYPE Values

Wait Type	Meaning
THD_WAIT_SLEEP	Waiting for sleep
THD_WAIT_DISKIO	Waiting for Disk IO
THD_WAIT_ROW_LOCK	Waiting for row lock
THD_WAIT_GLOBAL_LOCK	Waiting for global lock
THD_WAIT_META_DATA_LOCK	Waiting for metadata lock
THD_WAIT_TABLE_LOCK	Waiting for table lock
THD_WAIT_USER_LOCK	Waiting for user lock
THD_WAIT_BINLOG	Waiting for binlog
THD_WAIT_GROUP_COMMIT	Waiting for group commit
THD_WAIT_SYNC	Waiting for fsync

21.31 Extensions to SHOW Statements

Some extensions to SHOW statements accompany the implementation of INFORMATION_SCHEMA:

- SHOW can be used to get information about the structure of INFORMATION_SCHEMA itself.
- Several SHOW statements accept a WHERE clause that provides more flexibility in specifying which rows to display.

INFORMATION_SCHEMA is an information database, so its name is included in the output from SHOW DATABASES. Similarly, SHOW TABLES can be used with INFORMATION_SCHEMA to obtain a list of its tables:

```
mysql> SHOW TABLES FROM INFORMATION_SCHEMA;
+---------------------------------------+
| Tables_in_INFORMATION_SCHEMA          |
+---------------------------------------+
| CHARACTER_SETS                        |
| COLLATIONS                            |
| COLLATION_CHARACTER_SET_APPLICABILITY |
| COLUMNS                               |
| COLUMN_PRIVILEGES                     |
| ENGINES                               |
| EVENTS                                |
| FILES                                 |
| GLOBAL_STATUS                         |
| GLOBAL_VARIABLES                      |
| KEY_COLUMN_USAGE                      |
| PARTITIONS                            |
| PLUGINS                               |
| PROCESSLIST                           |
| REFERENTIAL_CONSTRAINTS               |
| ROUTINES                              |
| SCHEMATA                              |
| SCHEMA_PRIVILEGES                     |
| SESSION_STATUS                        |
| SESSION_VARIABLES                     |
| STATISTICS                            |
| TABLES                                |
| TABLE_CONSTRAINTS                     |
| TABLE_PRIVILEGES                      |
| TRIGGERS                              |
| USER_PRIVILEGES                       |
| VIEWS                                 |
+---------------------------------------+
```

`SHOW COLUMNS` and `DESCRIBE` can display information about the columns in individual `INFORMATION_SCHEMA` tables.

`SHOW` statements that accept a `LIKE` clause to limit the rows displayed also permit a `WHERE` clause that specifies more general conditions that selected rows must satisfy:

```
SHOW CHARACTER SET
SHOW COLLATION
SHOW COLUMNS
SHOW DATABASES
SHOW FUNCTION STATUS
SHOW INDEX
SHOW OPEN TABLES
SHOW PROCEDURE STATUS
SHOW STATUS
SHOW TABLE STATUS
SHOW TABLES
SHOW TRIGGERS
SHOW VARIABLES
```

The `WHERE` clause, if present, is evaluated against the column names displayed by the `SHOW` statement. For example, the `SHOW CHARACTER SET` statement produces these output columns:

```
mysql> SHOW CHARACTER SET;
+----------+-----------------------------+---------------------+--------+
| Charset  | Description                 | Default collation   | Maxlen |
+----------+-----------------------------+---------------------+--------+
| big5     | Big5 Traditional Chinese    | big5_chinese_ci     |      2 |
| dec8     | DEC West European           | dec8_swedish_ci     |      1 |
| cp850    | DOS West European           | cp850_general_ci    |      1 |
| hp8      | HP West European            | hp8_english_ci      |      1 |
| koi8r    | KOI8-R Relcom Russian       | koi8r_general_ci    |      1 |
| latin1   | cp1252 West European        | latin1_swedish_ci   |      1 |
| latin2   | ISO 8859-2 Central European | latin2_general_ci   |      1 |
...
```

To use a `WHERE` clause with `SHOW CHARACTER SET`, you would refer to those column names. As an example, the following statement displays information about character sets for which the default collation contains the string `'japanese'`:

```
mysql> SHOW CHARACTER SET WHERE `Default collation` LIKE '%japanese%';
+---------+---------------------------+--------------------+--------+
| Charset | Description               | Default collation  | Maxlen |
+---------+---------------------------+--------------------+--------+
| ujis    | EUC-JP Japanese           | ujis_japanese_ci   |      3 |
| sjis    | Shift-JIS Japanese        | sjis_japanese_ci   |      2 |
| cp932   | SJIS for Windows Japanese | cp932_japanese_ci  |      2 |
| eucjpms | UJIS for Windows Japanese | eucjpms_japanese_ci |      3 |
+---------+---------------------------+--------------------+--------+
```

This statement displays the multibyte character sets:

```
mysql> SHOW CHARACTER SET WHERE Maxlen > 1;
+---------+---------------------------+--------------------+--------+
| Charset | Description               | Default collation  | Maxlen |
+---------+---------------------------+--------------------+--------+
| big5    | Big5 Traditional Chinese  | big5_chinese_ci    |      2 |
| ujis    | EUC-JP Japanese           | ujis_japanese_ci   |      3 |
| sjis    | Shift-JIS Japanese        | sjis_japanese_ci   |      2 |
| euckr   | EUC-KR Korean             | euckr_korean_ci    |      2 |
| gb2312  | GB2312 Simplified Chinese | gb2312_chinese_ci  |      2 |
| gbk     | GBK Simplified Chinese    | gbk_chinese_ci     |      2 |
| utf8    | UTF-8 Unicode             | utf8_general_ci    |      3 |
| ucs2    | UCS-2 Unicode             | ucs2_general_ci    |      2 |
| cp932   | SJIS for Windows Japanese | cp932_japanese_ci  |      2 |
| eucjpms | UJIS for Windows Japanese | eucjpms_japanese_ci |      3 |
+---------+---------------------------+--------------------+--------+
```

Chapter 22 MySQL Performance Schema

Table of Contents

22.1 Performance Schema Quick Start 2600
22.2 Performance Schema Build Configuration 2605
22.3 Performance Schema Startup Configuration 2606
22.4 Performance Schema Runtime Configuration 2607
22.4.1 Performance Schema Event Timing 2608
22.4.2 Performance Schema Event Filtering 2611
22.4.3 Event Pre-Filtering 2612
22.4.4 Naming Instruments or Consumers for Filtering Operations 2613
22.4.5 Determining What Is Instrumented 2614
22.5 Performance Schema Queries 2615
22.6 Performance Schema Instrument Naming Conventions 2615
22.7 Performance Schema Status Monitoring 2616
22.8 Performance Schema General Table Characteristics 2619
22.9 Performance Schema Table Descriptions 2620
22.9.1 Performance Schema Table Index 2620
22.9.2 Performance Schema Setup Tables 2621
22.9.3 Performance Schema Instance Tables 2623
22.9.4 Performance Schema Wait Event Tables 2626
22.9.5 Performance Schema Summary Tables 2630
22.9.6 Performance Schema Miscellaneous Tables 2632
22.10 Performance Schema Option and Variable Reference 2634
22.11 Performance Schema System Variables 2635
22.12 Performance Schema Status Variables 2640
22.13 Performance Schema and Plugins 2641
22.14 Using the Performance Schema to Diagnose Problems 2641

The MySQL Performance Schema is a feature for monitoring MySQL Server execution at a low level. The Performance Schema is available as of MySQL 5.5.3 and has these characteristics:

- The Performance Schema provides a way to inspect internal execution of the server at runtime. It is implemented using the `PERFORMANCE_SCHEMA` storage engine and the `performance_schema` database. The Performance Schema focuses primarily on performance data. This differs from `INFORMATION_SCHEMA`, which serves for inspection of metadata.
- The Performance Schema monitors server events. An “event” is anything the server does that takes time and has been instrumented so that timing information can be collected. In general, an event could be a function call, a wait for the operating system, a stage of an SQL statement execution such as parsing or sorting, or an entire statement or group of statements. Event collection provides access to information about synchronization calls (such as for mutexes) and file I/O calls for the server and for several storage engines.
- Performance Schema events are distinct from events written to the server's binary log (which describe data modifications) and Event Scheduler events (which are a type of stored program).
- Current events are available, as well as event histories and summaries. This enables you to determine how many times instrumented activities were performed and how much time they took. Event information is available to show the activities of specific threads, or activity associated with particular objects such as a mutex or file.
- The `PERFORMANCE_SCHEMA` storage engine collects event data using “instrumentation points” in server source code.
- Collected events are stored in tables in the `performance_schema` database. These tables can be queried using `SELECT` statements like other tables.

- Performance Schema configuration can be modified dynamically by updating tables in the `performance_schema` database through SQL statements. Configuration changes affect data collection immediately.
- Tables in the Performance Schema are in-memory tables that use no persistent on-disk storage. The contents are repopulated beginning at server startup and discarded at server shutdown.
- Monitoring is available on all platforms supported by MySQL.

  Some limitations might apply: The types of timers might vary per platform. Instruments that apply to storage engines might not be implemented for all storage engines. Instrumentation of each third-party engine is the responsibility of the engine maintainer. See also Section C.8, “Restrictions on Performance Schema”.
- Data collection is implemented by modifying the server source code to add instrumentation. There are no separate threads associated with the Performance Schema, unlike other features such as replication or the Event Scheduler.

The Performance Schema is intended to provide access to useful information about server execution while having minimal impact on server performance. The implementation follows these design goals:

- Activating the Performance Schema causes no changes in server behavior. For example, it does not cause thread scheduling to change, and it does not cause query execution plans (as shown by `EXPLAIN`) to change.
- No memory allocation is done beyond that which occurs during server startup. By using early allocation of structures with a fixed size, it is never necessary to resize or reallocate them, which is critical for achieving good runtime performance.
- Server monitoring occurs continuously and unobtrusively with very little overhead. Activating the Performance Schema does not make the server unusable.
- The parser is unchanged. There are no new keywords or statements.
- Execution of server code proceeds normally even if the Performance Schema fails internally.
- When there is a choice between performing processing during event collection initially or during event retrieval later, priority is given to making collection faster. This is because collection is ongoing whereas retrieval is on demand and might never happen at all.
- It is easy to add new instrumentation points.
- Instrumentation is versioned. If the instrumentation implementation changes, previously instrumented code will continue to work. This benefits developers of third-party plugins because it is not necessary to upgrade each plugin to stay synchronized with the latest Performance Schema changes.

22.1 Performance Schema Quick Start

This section briefly introduces the Performance Schema with examples that show how to use it. For additional examples, see Section 22.14, “Using the Performance Schema to Diagnose Problems”.

For the Performance Schema to be available, support for it must have been configured when MySQL was built. You can verify whether this is the case by checking the server's help output. If the Performance Schema is available, the output will mention several variables with names that begin with `performance_schema`:

```
shell> mysqld --verbose --help
...
  --performance_schema
                      Enable the performance schema.
  --performance_schema_events_waits_history_long_size=#
```

```
                      Number of rows in events_waits_history_long.
...
```

If such variables do not appear in the output, your server has not been built to support the Performance Schema. In this case, see Section 22.2, “Performance Schema Build Configuration”.

Assuming that the Performance Schema is available, it is disabled by default. To enable it, start the server with the `performance_schema` variable enabled. For example, use these lines in your `my.cnf` file:

```
[mysqld]
performance_schema
```

When the server starts, it sees `performance_schema` and attempts to initialize the Performance Schema. To verify successful initialization, use this statement:

```
mysql> SHOW VARIABLES LIKE 'performance_schema';
+--------------------+-------+
| Variable_name      | Value |
+--------------------+-------+
| performance_schema | ON    |
+--------------------+-------+
```

A value of `ON` means that the Performance Schema initialized successfully and is ready for use. A value of `OFF` means that some error occurred. Check the server error log for information about what went wrong.

The Performance Schema is implemented as a storage engine. If this engine is available (which you should already have checked earlier), you should see it listed with a `SUPPORT` value of `YES` in the output from the `INFORMATION_SCHEMA.ENGINES` table or the `SHOW ENGINES` statement:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.ENGINES
       WHERE ENGINE='PERFORMANCE_SCHEMA'\G
*************************** 1. row ***************************
      ENGINE: PERFORMANCE_SCHEMA
     SUPPORT: YES
     COMMENT: Performance Schema
TRANSACTIONS: NO
          XA: NO
  SAVEPOINTS: NO

mysql> SHOW ENGINES\G
...
      Engine: PERFORMANCE_SCHEMA
     Support: YES
     Comment: Performance Schema
Transactions: NO
          XA: NO
  Savepoints: NO
...
```

The `PERFORMANCE_SCHEMA` storage engine operates on tables in the `performance_schema` database. You can make `performance_schema` the default database so that references to its tables need not be qualified with the database name:

```
mysql> USE performance_schema;
```

Many examples in this chapter assume `performance_schema` as the default database.

Performance Schema tables are stored in the `performance_schema` database. Information about the structure of this database and its tables can be obtained, as for any other database, by selecting from the `INFORMATION_SCHEMA` database or by using `SHOW` statements. For example, use either of these statements to see what Performance Schema tables exist:

```
mysql> SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
       WHERE TABLE_SCHEMA = 'performance_schema';
+----------------------------------------------+
| TABLE_NAME                                   |
+----------------------------------------------+
| cond_instances                               |
| events_waits_current                         |
| events_waits_history                         |
| events_waits_history_long                    |
| events_waits_summary_by_instance             |
| events_waits_summary_by_thread_by_event_name |
| events_waits_summary_global_by_event_name    |
| file_instances                               |
| file_summary_by_event_name                   |
| file_summary_by_instance                     |
| mutex_instances                              |
| performance_timers                           |
| rwlock_instances                             |
| setup_consumers                              |
| setup_instruments                            |
| setup_timers                                 |
| threads                                      |
+----------------------------------------------+

mysql> SHOW TABLES FROM performance_schema;
+----------------------------------------------+
| Tables_in_performance_schema                 |
+----------------------------------------------+
| cond_instances                               |
| events_waits_current                         |
| events_waits_history                         |
...
```

The number of Performance Schema tables increases over time as implementation of additional instrumentation proceeds.

The name of the `performance_schema` database is lowercase, as are the names of tables within it. Queries should specify the names in lowercase.

Note

Before MySQL 5.5.8, the table names were uppercase, which caused problems on some systems for certain values of the `lower_case_table_names` system variable.

To see the structure of individual tables, use `SHOW CREATE TABLE`:

```
mysql> SHOW CREATE TABLE setup_consumers\G
*************************** 1. row ***************************
       Table: setup_consumers
Create Table: CREATE TABLE `setup_consumers` (
  `NAME` varchar(64) NOT NULL,
  `ENABLED` enum('YES','NO') NOT NULL,
  PRIMARY KEY (`NAME`)
) ENGINE=PERFORMANCE_SCHEMA DEFAULT CHARSET=utf8
```

Table structure is also available by selecting from tables such as `INFORMATION_SCHEMA.COLUMNS` or by using statements such as `SHOW COLUMNS`.

Tables in the `performance_schema` database can be grouped according to the type of information in them: Current events, event histories and summaries, object instances, and setup (configuration) information. The following examples illustrate a few uses for these tables. For detailed information about the tables in each group, see Section 22.9, “Performance Schema Table Descriptions”.

To see what the server is doing at the moment, examine the `events_waits_current` table. It contains one row per thread showing each thread's most recent monitored event:

```
mysql> SELECT * FROM events_waits_current\G
*************************** 1. row ***************************
            THREAD_ID: 0
             EVENT_ID: 5523
           EVENT_NAME: wait/synch/mutex/mysys/THR_LOCK::mutex
               SOURCE: thr_lock.c:525
          TIMER_START: 201660494489586
            TIMER_END: 201660494576112
           TIMER_WAIT: 86526
                SPINS: NULL
        OBJECT_SCHEMA: NULL
          OBJECT_NAME: NULL
          OBJECT_TYPE: NULL
OBJECT_INSTANCE_BEGIN: 142270668
     NESTING_EVENT_ID: NULL
           OPERATION: lock
      NUMBER_OF_BYTES: NULL
                FLAGS: 0
...
```

This event indicates that thread 0 was waiting for 86,526 picoseconds to acquire a lock on `THR_LOCK::mutex`, a mutex in the `mysys` subsystem. The first few columns provide the following information:

- The ID columns indicate which thread the event comes from and the event number.
- `EVENT_NAME` indicates what was instrumented and `SOURCE` indicates which source file contains the instrumented code.
- The timer columns show when the event started and stopped and how long it took. If an event is still in progress, the `TIMER_END` and `TIMER_WAIT` values are `NULL`. Timer values are approximate and expressed in picoseconds. For information about timers and event time collection, see Section 22.4.1, “Performance Schema Event Timing”.

The history tables contain the same kind of rows as the current-events table but have more rows and show what the server has been doing “recently” rather than “currently.” The `events_waits_history` and `events_waits_history_long` tables contain the most recent 10 events per thread and most recent 10,000 events, respectively. For example, to see information for recent events produced by thread 13, do this:

```
mysql> SELECT EVENT_ID, EVENT_NAME, TIMER_WAIT
       FROM events_waits_history WHERE THREAD_ID = 13
       ORDER BY EVENT_ID;
+----------+----------------------------------------+------------+
| EVENT_ID | EVENT_NAME                             | TIMER_WAIT |
+----------+----------------------------------------+------------+
|       86 | wait/synch/mutex/mysys/THR_LOCK::mutex |     686322 |
|       87 | wait/synch/mutex/mysys/THR_LOCK_malloc |     320535 |
|       88 | wait/synch/mutex/mysys/THR_LOCK_malloc |     339390 |
|       89 | wait/synch/mutex/mysys/THR_LOCK_malloc |     377100 |
|       90 | wait/synch/mutex/sql/LOCK_plugin       |     614673 |
|       91 | wait/synch/mutex/sql/LOCK_open         |     659925 |
|       92 | wait/synch/mutex/sql/THD::LOCK_thd_data |     494001 |
|       93 | wait/synch/mutex/mysys/THR_LOCK_malloc |     222489 |
|       94 | wait/synch/mutex/mysys/THR_LOCK_malloc |     214947 |
|       95 | wait/synch/mutex/mysys/LOCK_alarm      |     312993 |
+----------+----------------------------------------+------------+
```

As new events are added to a history table, older events are discarded if the table is full.

Summary tables provide aggregated information for all events over time. The tables in this group summarize event data in different ways. To see which instruments have been executed the most times or have taken the most wait time, sort the `events_waits_summary_global_by_event_name` table on the `COUNT_STAR` or `SUM_TIMER_WAIT` column, which correspond to a `COUNT(*)` or `SUM(TIMER_WAIT)` value, respectively, calculated over all events:

```
mysql> SELECT EVENT_NAME, COUNT_STAR
       FROM events_waits_summary_global_by_event_name
       ORDER BY COUNT_STAR DESC LIMIT 10;
+-----------------------------------------------------+------------+
| EVENT_NAME                                          | COUNT_STAR |
+-----------------------------------------------------+------------+
| wait/synch/mutex/mysys/THR_LOCK_malloc              |       6419 |
| wait/io/file/sql/FRM                                |        452 |
| wait/synch/mutex/sql/LOCK_plugin                    |        337 |
| wait/synch/mutex/mysys/THR_LOCK_open                |        187 |
| wait/synch/mutex/mysys/LOCK_alarm                   |        147 |
| wait/synch/mutex/sql/THD::LOCK_thd_data             |        115 |
| wait/io/file/myisam/kfile                           |        102 |
| wait/synch/mutex/sql/LOCK_global_system_variables   |         89 |
| wait/synch/mutex/mysys/THR_LOCK::mutex              |         89 |
| wait/synch/mutex/sql/LOCK_open                      |         88 |
+-----------------------------------------------------+------------+

mysql> SELECT EVENT_NAME, SUM_TIMER_WAIT
       FROM events_waits_summary_global_by_event_name
       ORDER BY SUM_TIMER_WAIT DESC LIMIT 10;
+---------------------------------------+----------------+
| EVENT_NAME                            | SUM_TIMER_WAIT |
+---------------------------------------+----------------+
| wait/io/file/sql/MYSQL_LOG            |     1599816582 |
| wait/synch/mutex/mysys/THR_LOCK_malloc |     1530083250 |
| wait/io/file/sql/binlog_index         |     1385291934 |
| wait/io/file/sql/FRM                  |     1292823243 |
| wait/io/file/myisam/kfile             |      411193611 |
| wait/io/file/myisam/dfile             |      322401645 |
| wait/synch/mutex/mysys/LOCK_alarm     |      145126935 |
| wait/io/file/sql/casetest             |      104324715 |
| wait/synch/mutex/sql/LOCK_plugin      |       86027823 |
| wait/io/file/sql/pid                  |       72591750 |
+---------------------------------------+----------------+
```

These results show that the `THR_LOCK_malloc` mutex is “hot,” both in terms of how often it is used and amount of time that threads wait attempting to acquire it.

Note

The `THR_LOCK_malloc` mutex is used only in debug builds. In production builds it is not hot because it is nonexistent.

Instance tables document what types of objects are instrumented. An instrumented object, when used by the server, produces an event. These tables provide event names and explanatory notes or status information. For example, the `file_instances` table lists instances of instruments for file I/O operations and their associated files:

```
mysql> SELECT * FROM file_instances\G
*************************** 1. row ***************************
 FILE_NAME: /opt/mysql-log/60500/binlog.000007
EVENT_NAME: wait/io/file/sql/binlog
OPEN_COUNT: 0
*************************** 2. row ***************************
 FILE_NAME: /opt/mysql/60500/data/mysql/tables_priv.MYI
EVENT_NAME: wait/io/file/myisam/kfile
OPEN_COUNT: 1
*************************** 3. row ***************************
 FILE_NAME: /opt/mysql/60500/data/mysql/columns_priv.MYI
EVENT_NAME: wait/io/file/myisam/kfile
OPEN_COUNT: 1
...
```

Setup tables are used to configure and display monitoring characteristics. For example, `setup_instruments` lists the set of instruments for which events can be collected and shows which of them are enabled:

```
mysql> SELECT * FROM setup_instruments;
+----------------------------------------------------+---------+-------+
| NAME                                               | ENABLED | TIMED |
+----------------------------------------------------+---------+-------+
...
| wait/synch/mutex/sql/LOCK_global_read_lock         | YES     | YES   |
| wait/synch/mutex/sql/LOCK_global_system_variables | YES     | YES   |
| wait/synch/mutex/sql/LOCK_lock_db                  | YES     | YES   |
| wait/synch/mutex/sql/LOCK_manager                  | YES     | YES   |
...
| wait/synch/rwlock/sql/LOCK_grant                   | YES     | YES   |
| wait/synch/rwlock/sql/LOGGER::LOCK_logger          | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_connect        | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_slave          | YES     | YES   |
...
| wait/io/file/sql/binlog                            | YES     | YES   |
| wait/io/file/sql/binlog_index                      | YES     | YES   |
| wait/io/file/sql/casetest                          | YES     | YES   |
| wait/io/file/sql/dbopt                             | YES     | YES   |
...
```

To understand how to interpret instrument names, see Section 22.6, “Performance Schema Instrument Naming Conventions”.

To control whether events are collected for an instrument, set its `ENABLED` value to `YES` or `NO`. For example:

```
mysql> UPDATE setup_instruments SET ENABLED = 'NO'
       WHERE NAME = 'wait/synch/mutex/sql/LOCK_mysql_create_db';
```

The Performance Schema uses collected events to update tables in the `performance_schema` database, which act as “consumers” of event information. The `setup_consumers` table lists the available consumers and shows which of them are enabled:

```
mysql> SELECT * FROM setup_consumers;
+----------------------------------------------+---------+
| NAME                                         | ENABLED |
+----------------------------------------------+---------+
| events_waits_current                         | YES     |
| events_waits_history                         | YES     |
| events_waits_history_long                    | YES     |
| events_waits_summary_by_thread_by_event_name | YES     |
| events_waits_summary_by_event_name           | YES     |
| events_waits_summary_by_instance             | YES     |
| file_summary_by_event_name                   | YES     |
| file_summary_by_instance                     | YES     |
+----------------------------------------------+---------+
```

To control whether the Performance Schema maintains a consumer as a destination for event information, set its `ENABLED` value.

For more information about the setup tables and how to use them to control event collection, see Section 22.4.2, “Performance Schema Event Filtering”.

There are some miscellaneous tables that do not fall into any of the previous groups. For example, `performance_timers` lists the available event timers and their characteristics. For information about timers, see Section 22.4.1, “Performance Schema Event Timing”.

22.2 Performance Schema Build Configuration

For the Performance Schema to be available, it must be configured into the MySQL server at build time. Binary MySQL distributions provided by Oracle Corporation are configured to support the Performance Schema. If you use a binary MySQL distribution from another provider, check with the provider whether the distribution has been appropriately configured.

If you build MySQL from a source distribution, enable the Performance Schema by running `CMake` with the `WITH_PERFSCHEMA_STORAGE_ENGINE` option enabled:

```
shell> cmake . -DWITH_PERFSCHEMA_STORAGE_ENGINE=1
```

Configuring MySQL with the `-DWITHOUT_PERFSCHEMA_STORAGE_ENGINE=1` option prevents inclusion of the Performance Schema, so if you want it included, do not use this option. See Section 2.9.4, “MySQL Source-Configuration Options”.

If you install MySQL over a previous installation that was configured without the Performance Schema (or with an older version of the Performance Schema that may not have all the current tables), run `mysql_upgrade` after starting the server to ensure that the `performance_schema` database exists with all current tables. Then restart the server. One indication that you need to do this is the presence of messages such as the following in the error log:

```
[ERROR] Native table 'performance_schema'.'events_waits_history'
has the wrong structure
[ERROR] Native table 'performance_schema'.'events_waits_history_long'
has the wrong structure
...
```

To verify whether a server was built with Performance Schema support, check its help output. If the Performance Schema is available, the output will mention several variables with names that begin with `performance_schema`:

```
shell> mysqld --verbose --help
...
  --performance_schema
                      Enable the performance schema.
  --performance_schema_events_waits_history_long_size=#
                      Number of rows in events_waits_history_long.
...
```

You can also connect to the server and look for a line that names the `PERFORMANCE_SCHEMA` storage engine in the output from `SHOW ENGINES`:

```
mysql> SHOW ENGINES\G
...
      Engine: PERFORMANCE_SCHEMA
     Support: YES
     Comment: Performance Schema
Transactions: NO
          XA: NO
  Savepoints: NO
...
```

If the Performance Schema was not configured into the server at build time, no row for `PERFORMANCE_SCHEMA` will appear in the output from `SHOW ENGINES`. You might see `performance_schema` listed in the output from `SHOW DATABASES`, but it will have no tables and you will not be able to use it.

A line for `PERFORMANCE_SCHEMA` in the `SHOW ENGINES` output means that the Performance Schema is available, not that it is enabled. To enable it, you must do so at server startup, as described in the next section.

22.3 Performance Schema Startup Configuration

To use the MySQL Performance Schema, it must be enabled at server startup to enable event collection to occur.

The Performance Schema is disabled by default. To enable it, start the server with the `performance_schema` variable enabled. For example, use these lines in your `my.cnf` file:

```
[mysqld]
performance_schema
```

If the server is unable to allocate any internal buffer during Performance Schema initialization, the Performance Schema disables itself and sets `performance_schema` to `OFF`, and the server runs without instrumentation.

The Performance Schema includes several system variables that provide configuration information:

```
mysql> SHOW VARIABLES LIKE 'perf%';
+----------------------------------------------------+---------+
| Variable_name                                      | Value   |
+----------------------------------------------------+---------+
| performance_schema                                 | ON      |
| performance_schema_events_waits_history_long_size | 10000   |
| performance_schema_events_waits_history_size       | 10      |
| performance_schema_max_cond_classes                | 80      |
| performance_schema_max_cond_instances              | 1000    |
| performance_schema_max_file_classes                | 50      |
| performance_schema_max_file_handles                | 32768   |
| performance_schema_max_file_instances              | 10000   |
| performance_schema_max_mutex_classes               | 200     |
| performance_schema_max_mutex_instances             | 1000000 |
| performance_schema_max_rwlock_classes              | 30      |
| performance_schema_max_rwlock_instances            | 1000000 |
| performance_schema_max_table_handles               | 100000  |
| performance_schema_max_table_instances             | 50000   |
| performance_schema_max_thread_classes              | 50      |
| performance_schema_max_thread_instances            | 1000    |
+----------------------------------------------------+---------+
```

The `performance_schema` variable is `ON` or `OFF` to indicate whether the Performance Schema is enabled or disabled. The other variables indicate table sizes (number of rows) or memory allocation values.

Note

With the Performance Schema enabled, the number of Performance Schema instances affects the server memory footprint, perhaps to a large extent. It may be necessary to tune the values of Performance Schema system variables to find the number of instances that balances insufficient instrumentation against excessive memory consumption.

To change the value of Performance Schema system variables, set them at server startup. For example, put the following lines in a `my.cnf` file to change the sizes of the history tables for wait events:

```
[mysqld]
performance_schema
performance_schema_events_waits_history_size=20
performance_schema_events_waits_history_long_size=15000
```

22.4 Performance Schema Runtime Configuration

Specific Performance Schema features can be enabled at runtime to control which types of event collection occur.

Performance Schema setup tables contain information about monitoring configuration:

```
mysql> SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
       WHERE TABLE_SCHEMA = 'performance_schema'
```

```
       AND TABLE_NAME LIKE 'setup%';
+-------------------+
| TABLE_NAME        |
+-------------------+
| setup_consumers   |
| setup_instruments |
| setup_timers      |
+-------------------+
```

You can examine the contents of these tables to obtain information about Performance Schema monitoring characteristics. If you have the `UPDATE` privilege, you can change Performance Schema operation by modifying setup tables to affect how monitoring occurs. For additional details about these tables, see Section 22.9.2, “Performance Schema Setup Tables”.

To see which event timer is selected, query the `setup_timers` tables:

```
mysql> SELECT * FROM setup_timers;
+------+------------+
| NAME | TIMER_NAME |
+------+------------+
| wait | CYCLE      |
+------+------------+
```

The `NAME` value indicates the type of instrument to which the timer applies, and `TIMER_NAME` indicates which timer applies to those instruments. The timer applies to instruments where their name begins with a component matching the `NAME` value. There are only “wait” instruments, so this table has only one row and the timer applies to all instruments.

To change the timer, update the `NAME` value. For example, to use the `NANOSECOND` timer:

```
mysql> UPDATE setup_timers SET TIMER_NAME = 'NANOSECOND'
       WHERE NAME = 'wait';

mysql> SELECT * FROM setup_timers;
+------+------------+
| NAME | TIMER_NAME |
+------+------------+
| wait | NANOSECOND |
+------+------------+
```

For discussion of timers, see Section 22.4.1, “Performance Schema Event Timing”.

The `setup_instruments` and `setup_consumers` tables list the instruments for which events can be collected and the types of consumers for which event information actually is collected, respectively. Section 22.4.2, “Performance Schema Event Filtering”, discusses how you can modify these tables to affect event collection.

If there are Performance Schema configuration changes that must be made at runtime using SQL statements and you would like these changes to take effect each time the server starts, put the statements in a file and start the server with the `--init-file=`*`file_name`* option. This strategy can also be useful if you have multiple monitoring configurations, each tailored to produce a different kind of monitoring, such as casual server health monitoring, incident investigation, application behavior troubleshooting, and so forth. Put the statements for each monitoring configuration into their own file and specify the appropriate file as the `--init-file` argument when you start the server.

22.4.1 Performance Schema Event Timing

Events are collected by means of instrumentation added to the server source code. Instruments time events, which is how the Performance Schema provides an idea of how long events take. It is also possible to configure instruments not to collect timing information. This section discusses the available timers and their characteristics, and how timing values are represented in events.

Performance Schema Timers

Two Performance Schema tables provide timer information:

- `performance_timers` lists the available timers and their characteristics.
- `setup_timers` indicates which timers are used for which instruments.

Each timer row in `setup_timers` must refer to one of the timers listed in `performance_timers`.

Timers vary in precision and amount of overhead. To see what timers are available and their characteristics, check the `performance_timers` table:

```
mysql> SELECT * FROM performance_timers;
+-------------+-----------------+------------------+----------------+
| TIMER_NAME  | TIMER_FREQUENCY | TIMER_RESOLUTION | TIMER_OVERHEAD |
+-------------+-----------------+------------------+----------------+
| CYCLE       |      2389029850 |                1 |             72 |
| NANOSECOND  |      1000000000 |                1 |            112 |
| MICROSECOND |         1000000 |                1 |            136 |
| MILLISECOND |            1036 |                1 |            168 |
| TICK        |             105 |                1 |           2416 |
+-------------+-----------------+------------------+----------------+
```

If the values associated with a given timer name are `NULL`, that timer is not supported on your platform. The rows that do not contain `NULL` indicate which timers you can use in `setup_timers`.

The columns have these meanings:

- The `TIMER_NAME` column shows the names of the available timers. `CYCLE` refers to the timer that is based on the CPU (processor) cycle counter. The timers in `setup_timers` that you can use are those that do not have `NULL` in the other columns. If the values associated with a given timer name are `NULL`, that timer is not supported on your platform.
- `TIMER_FREQUENCY` indicates the number of timer units per second. For a cycle timer, the frequency is generally related to the CPU speed. The value shown was obtained on a system with a 2.4GHz processor. The other timers are based on fixed fractions of seconds. For `TICK`, the frequency may vary by platform (for example, some use 100 ticks/second, others 1000 ticks/second).
- `TIMER_RESOLUTION` indicates the number of timer units by which timer values increase at a time. If a timer has a resolution of 10, its value increases by 10 each time.
- `TIMER_OVERHEAD` is the minimal number of cycles of overhead to obtain one timing with the given timer. The overhead per event is twice the value displayed because the timer is invoked at the beginning and end of the event.

To see which timer is in effect or to change the timer, access the `setup_timers` table:

```
mysql> SELECT * FROM setup_timers;
+------+------------+
| NAME | TIMER_NAME |
+------+------------+
| wait | CYCLE      |
+------+------------+

mysql> UPDATE setup_timers SET TIMER_NAME = 'MICROSECOND'
       WHERE NAME = 'wait';

mysql> SELECT * FROM setup_timers;
+------+-------------+
| NAME | TIMER_NAME  |
+------+-------------+
| wait | MICROSECOND |
```

```
+------+-------------+
```

By default, the Performance Schema uses the best timer available for each instrument type, but you can select a different one. Generally the best timer is `CYCLE`, which uses the CPU cycle counter whenever possible to provide high precision and low overhead.

The precision offered by the cycle counter depends on processor speed. If the processor runs at 1 GHz (one billion cycles/second) or higher, the cycle counter delivers sub-nanosecond precision. Using the cycle counter is much cheaper than getting the actual time of day. For example, the standard `gettimeofday()` function can take hundreds of cycles, which is an unacceptable overhead for data gathering that may occur thousands or millions of times per second.

Cycle counters also have disadvantages:

- End users expect to see timings in wall-clock units, such as fractions of a second. Converting from cycles to fractions of seconds can be expensive. For this reason, the conversion is a quick and fairly rough multiplication operation.
- Processor cycle rate might change, such as when a laptop goes into power-saving mode or when a CPU slows down to reduce heat generation. If a processor's cycle rate fluctuates, conversion from cycles to real-time units is subject to error.
- Cycle counters might be unreliable or unavailable depending on the processor or the operating system. For example, on Pentiums, the instruction is `RDTSC` (an assembly-language rather than a C instruction) and it is theoretically possible for the operating system to prevent user-mode programs from using it.
- Some processor details related to out-of-order execution or multiprocessor synchronization might cause the counter to seem fast or slow by up to 1000 cycles.

MySQL works with cycle counters on x386 (Windows, macOS, Linux, Solaris, and other Unix flavors), PowerPC, and IA-64.

Performance Schema Timer Representation in Events

Rows in Performance Schema tables that store current events and historical events have three columns to represent timing information: `TIMER_START` and `TIMER_END` indicate when the event started and finished, and `TIMER_WAIT` indicates the event duration.

The `setup_instruments` table has an `ENABLED` column to indicate the instruments for which to collect events. The table also has a `TIMED` column to indicate which instruments are timed. If an instrument is not enabled, it produces no events. If an enabled instrument is not timed, events produced by the instrument have `NULL` for the `TIMER_START`, `TIMER_END`, and `TIMER_WAIT` timer values. This in turn causes those values to be ignored when calculating aggregate time values in summary tables (sum, minimum, maximum, and average).

Within events, times are stored in picoseconds (trillionths of a second) to normalize them to a standard unit, regardless of which timer is selected. The timer used for an event is the one in effect when event timing begins. This timer is used to convert start and end values to picoseconds for storage in the event.

Modifications to the `setup_timers` table affect monitoring immediately. Events already measured are stored using the original timer unit, and events in progress may use the original timer for the begin time and the new timer for the end time. To avoid unpredictable results if you make timer changes, use `TRUNCATE TABLE` to reset Performance Schema statistics.

The timer baseline (“time zero”) occurs at Performance Schema initialization during server startup. `TIMER_START` and `TIMER_END` values in events represent picoseconds since the baseline. `TIMER_WAIT` values are durations in picoseconds.

Picosecond values in events are approximate. Their accuracy is subject to the usual forms of error associated with conversion from one unit to another. If the `CYCLE` timer is used and the processor rate varies, there might be drift. For these reasons, it is not reasonable to look at the `TIMER_START` value for an event as an accurate measure of time elapsed since server startup. On the other hand, it is reasonable to use `TIMER_START` or `TIMER_WAIT` values in `ORDER BY` clauses to order events by start time or duration.

The choice of picoseconds in events rather than a value such as microseconds has a performance basis. One implementation goal was to show results in a uniform time unit, regardless of the timer. In an ideal world this time unit would look like a wall-clock unit and be reasonably precise; in other words, microseconds. But to convert cycles or nanoseconds to microseconds, it would be necessary to perform a division for every instrumentation. Division is expensive on many platforms. Multiplication is not expensive, so that is what is used. Therefore, the time unit is an integer multiple of the highest possible `TIMER_FREQUENCY` value, using a multiplier large enough to ensure that there is no major precision loss. The result is that the time unit is “picoseconds.” This precision is spurious, but the decision enables overhead to be minimized.

22.4.2 Performance Schema Event Filtering

Events are processed in a producer/consumer fashion:

- Instrumented code is the source for events and produces events to be collected. The `setup_instruments` table lists the instruments for which events can be collected, whether they are enabled, and (for enabled instruments) whether to collect timing information:

```
mysql> SELECT * FROM setup_instruments;
+-----------------------------------------------------+---------+-------+
| NAME                                                | ENABLED | TIMED |
+-----------------------------------------------------+---------+-------+
...
| wait/synch/mutex/sql/LOCK_global_read_lock          | YES     | YES   |
| wait/synch/mutex/sql/LOCK_global_system_variables | YES     | YES   |
| wait/synch/mutex/sql/LOCK_lock_db                   | YES     | YES   |
| wait/synch/mutex/sql/LOCK_manager                   | YES     | YES   |
...
| wait/synch/rwlock/sql/LOCK_grant                    | YES     | YES   |
| wait/synch/rwlock/sql/LOGGER::LOCK_logger           | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_connect         | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_slave           | YES     | YES   |
...
| wait/io/file/sql/binlog                             | YES     | YES   |
| wait/io/file/sql/binlog_index                       | YES     | YES   |
| wait/io/file/sql/casetest                           | YES     | YES   |
| wait/io/file/sql/dbopt                              | YES     | YES   |
...
```

- Performance Schema tables are the destinations for events and consume events. The `setup_consumers` table lists the types of consumers to which event information can be sent:

```
mysql> SELECT * FROM setup_consumers;
+-------------------------------------------+---------+
| NAME                                      | ENABLED |
+-------------------------------------------+---------+
| events_waits_current                      | YES     |
| events_waits_history                      | YES     |
| events_waits_history_long                 | YES     |
| events_waits_summary_by_thread_by_event_name | YES     |
| events_waits_summary_by_event_name        | YES     |
| events_waits_summary_by_instance          | YES     |
| file_summary_by_event_name                | YES     |
| file_summary_by_instance                  | YES     |
+-------------------------------------------+---------+
```

Filtering can be done at different stages of performance monitoring:

- **Pre-filtering.** This is done by modifying Performance Schema configuration so that only certain types of events are collected from producers, and collected events update only certain consumers. To do this, enable or disable instruments or consumers. Pre-filtering is done by the Performance Schema and has a global effect that applies to all users.

  Reasons to use pre-filtering:

  - To reduce overhead. Performance Schema overhead should be minimal even with all instruments enabled, but perhaps you want to reduce it further. Or you do not care about timing events and want to disable the timing code to eliminate timing overhead.
  - To avoid filling the current-events or history tables with events in which you have no interest. Pre-filtering leaves more “room” in these tables for instances of rows for enabled instrument types. If you enable only file instruments with pre-filtering, no rows are collected for nonfile instruments. With post-filtering, nonfile events are collected, leaving fewer rows for file events.
  - To avoid maintaining some kinds of event tables. If you disable a consumer, the server does not spend time maintaining destinations for that consumer. For example, if you do not care about event histories, you can disable the history table consumers to improve performance.

- **Post-filtering.** This involves the use of `WHERE` clauses in queries that select information from Performance Schema tables, to specify which of the available events you want to see. Post-filtering is performed on a per-user basis because individual users select which of the available events are of interest.

  Reasons to use post-filtering:

  - To avoid making decisions for individual users about which event information is of interest.
  - To use the Performance Schema to investigate a performance issue when the restrictions to impose using pre-filtering are not known in advance.

The following sections provide more detail about pre-filtering and provide guidelines for naming instruments or consumers in filtering operations. For information about writing queries to retrieve information (post-filtering), see Section 22.5, “Performance Schema Queries”.

22.4.3 Event Pre-Filtering

Pre-filtering is done by modifying Performance Schema configuration so that only certain types of events are collected from producers, and collected events update only certain consumers. This type of filtering is done by the Performance Schema and has a global effect that applies to all users.

Pre-filtering can be applied to either the producer or consumer stage of event processing:

- To affect pre-filtering at the producer stage, modify the `setup_instruments` table. An instrument can be enabled or disabled by setting its `ENABLED` value to `YES` or `NO`. An instrument can be configured whether to collect timing information by setting its `TIMED` value to `YES` or `NO`.
- To affect pre-filtering at the consumer stage, modify the `setup_consumers` table. A consumer can be enabled or disabled by setting its `ENABLED` value to `YES` or `NO`.

Here are some examples that show the types of pre-filtering operations available:

- Disable all instruments:

  ```
  mysql> UPDATE setup_instruments SET ENABLED = 'NO';
  ```

  Now no events will be collected. This change, like other pre-filtering operations, affects other users as well, even if they want to see event information.

- Disable all file instruments, adding them to the current set of disabled instruments:

```
mysql> UPDATE setup_instruments SET ENABLED = 'NO'
       WHERE NAME LIKE 'wait/io/file/%';
```

- Disable only file instruments, enable all other instruments:

```
mysql> UPDATE setup_instruments
       SET ENABLED = IF(NAME LIKE 'wait/io/file/%', 'NO', 'YES');
```

  The preceding queries use the `LIKE` operator and the pattern `'wait/io/file/%'` to match all instrument names that begin with `'wait/io/file/`. For additional information about specifying patterns to select instruments, see Section 22.4.4, “Naming Instruments or Consumers for Filtering Operations”.

- Enable all but those instruments in the `mysys` library:

```
mysql> UPDATE setup_instruments
       SET ENABLED = CASE WHEN NAME LIKE '%/mysys/%' THEN 'YES' ELSE 'NO' END;
```

- Disable a specific instrument:

```
mysql> UPDATE setup_instruments SET ENABLED = 'NO'
       WHERE NAME = 'wait/synch/mutex/mysys/TMPDIR_mutex';
```

- To toggle the state of an instrument, “flip” its `ENABLED` value:

```
mysql> UPDATE setup_instruments
       SET ENABLED = IF(ENABLED = 'YES', 'NO', 'YES')
       WHERE NAME = 'wait/synch/mutex/mysys/TMPDIR_mutex';
```

- Disable timing for all events:

```
mysql> UPDATE setup_instruments SET TIMED = 'NO';
```

Setting the `TIMED` column for instruments affects Performance Schema table contents as described in Section 22.4.1, “Performance Schema Event Timing”.

When you change the monitoring configuration, the Performance Schema does not flush the history tables. Events already collected remain in the current-events and history tables until displaced by newer events. If you disable instruments, you might need to wait a while before events for them are displaced by newer events of interest. Alternatively, use `TRUNCATE TABLE` to empty the history tables.

After making instrumentation changes, you might want to truncate the summary tables to clear aggregate information for previously collected events. The effect of `TRUNCATE TABLE` for summary tables is to reset the summary columns to 0 or `NULL`, not to remove rows.

If you disable a consumer, the server does not spend time maintaining destinations for that consumer. For example, if you do not care about historical event information, disable the history consumers:

```
mysql> UPDATE setup_consumers
       SET ENABLED = 'NO' WHERE NAME LIKE '%history%';
```

22.4.4 Naming Instruments or Consumers for Filtering Operations

Names given for filtering operations can be as specific or general as required. To indicate a single instrument or consumer, specify its name in full:

```
mysql> UPDATE setup_instruments
       SET ENABLED = 'NO'
       WHERE NAME = 'wait/synch/mutex/myisammrg/MYRG_INFO::mutex';

mysql> UPDATE setup_consumers
       SET ENABLED = 'NO' WHERE NAME = 'file_summary_by_instance';
```

To specify a group of instruments or consumers, use a pattern that matches the group members:

```
mysql> UPDATE setup_instruments
       SET ENABLED = 'NO'
       WHERE NAME LIKE 'wait/synch/mutex/%';

mysql> UPDATE setup_consumers
       SET ENABLED = 'NO' WHERE NAME LIKE '%history%';
```

If you use a pattern, it should be chosen so that it matches all the items of interest and no others. For example, to select all file I/O instruments, it is better to use a pattern that includes the entire instrument name prefix:

```
... WHERE NAME LIKE 'wait/io/file/%';
```

A pattern of `'%/file/%'` will match other instruments that have a component of `'/file/'` anywhere in the name. Even less suitable is the pattern `'%file%'` because it will match instruments with `'file'` anywhere in the name, such as `wait/synch/mutex/sql/LOCK_des_key_file`.

To check which instrument or consumer names a pattern matches, perform a simple test:

```
mysql> SELECT NAME FROM setup_instruments WHERE NAME LIKE 'pattern';

mysql> SELECT NAME FROM setup_consumers WHERE NAME LIKE 'pattern';
```

For information about the types of names that are supported, see Section 22.6, “Performance Schema Instrument Naming Conventions”.

22.4.5 Determining What Is Instrumented

It is always possible to determine what instruments the Performance Schema includes by checking the `setup_instruments` table. For example, to see what file-related events are instrumented for the `InnoDB` storage engine, use this query:

```
mysql> SELECT * FROM setup_instruments WHERE NAME LIKE 'wait/io/file/innodb/%';
+----------------------------------------+---------+-------+
| NAME                                   | ENABLED | TIMED |
+----------------------------------------+---------+-------+
| wait/io/file/innodb/innodb_data_file   | YES     | YES   |
| wait/io/file/innodb/innodb_log_file    | YES     | YES   |
| wait/io/file/innodb/innodb_temp_file   | YES     | YES   |
+----------------------------------------+---------+-------+
```

An exhaustive description of precisely what is instrumented is not given in this documentation, for several reasons:

- What is instrumented is the server code. Changes to this code occur often, which also affects the set of instruments.
- It is not practical to list all the instruments because there are hundreds of them.
- As described earlier, it is possible to find out by querying the `setup_instruments` table. This information is always up to date for your version of MySQL, also includes instrumentation for

instrumented plugins you might have installed that are not part of the core server, and can be used by automated tools.

22.5 Performance Schema Queries

Pre-filtering limits which event information is collected and is independent of any particular user. By contrast, post-filtering is performed by individual users through the use of queries with appropriate `WHERE` clauses that restrict what event information to select from the events available after pre-filtering has been applied.

In Section 22.4.3, “Event Pre-Filtering”, an example showed how to pre-filter for file instruments. If the event tables contain both file and nonfile information, post-filtering is another way to see information only for file events. Add a `WHERE` clause to queries to restrict event selection appropriately:

```
mysql> SELECT THREAD_ID, NUMBER_OF_BYTES
       FROM events_waits_history
       WHERE EVENT_NAME LIKE 'wait/io/file/%'
       AND NUMBER_OF_BYTES IS NOT NULL;
+-----------+-----------------+
| THREAD_ID | NUMBER_OF_BYTES |
+-----------+-----------------+
|        11 |              66 |
|        11 |              47 |
|        11 |             139 |
|         5 |              24 |
|         5 |             834 |
+-----------+-----------------+
```

22.6 Performance Schema Instrument Naming Conventions

An instrument name consists of a sequence of components separated by `'/'` characters. Example names:

```
wait/io/file/myisam/log
wait/io/file/mysys/charset
wait/synch/cond/mysys/COND_alarm
wait/synch/cond/sql/BINLOG::update_cond
wait/synch/mutex/mysys/BITMAP_mutex
wait/synch/mutex/sql/LOCK_delete
wait/synch/rwlock/innodb/trx_sys_lock
wait/synch/rwlock/sql/Query_cache_query::lock
```

The instrument name space has a tree-like structure. The components of an instrument name from left to right provide a progression from more general to more specific. The number of components a name has depends on the type of instrument.

The interpretation of a given component in a name depends on the components to the left of it. For example, `myisam` appears in both of the following names, but `myisam` in the first name is related to file I/O, whereas in the second it is related to a synchronization instrument:

```
wait/io/file/myisam/log
wait/synch/cond/myisam/MI_SORT_INFO::cond
```

Instrument names consist of a prefix with a structure defined by the Performance Schema implementation and a suffix defined by the developer implementing the instrument code. The top-level component of an instrument prefix indicates the type of instrument. This component also determines which event timer in the `setup_timers` table applies to the instrument. For the prefix part of instrument names, the top level indicates the type of instrument.

The suffix part of instrument names comes from the code for the instruments themselves. Suffixes may include levels such as these:

- A name for the major component (a server module such as `myisam`, `innodb`, `mysys`, or `sql`) or a plugin name.
- The name of a variable in the code, in the form *`XXX`* (a global variable) or *`CCC`*`::`*`MMM`* (a member *`MMM`* in class *`CCC`*). Examples: `COND_thread_cache`, `THR_LOCK_myisam`, `BINLOG::LOCK_index`.

In MySQL 5.5, there is a single top-level component, `wait`, indicating a wait instrument. The naming tree for wait instruments has this structure:

- `wait/io`

  An instrumented I/O operation.

  - `wait/io/file`

    An instrumented file I/O operation. For files, the wait is the time waiting for the file operation to complete (for example, a call to `fwrite()`). Due to caching, the physical file I/O on the disk might not happen within this call.

- `wait/synch`

  An instrumented synchronization object. For synchronization objects, the `TIMER_WAIT` time includes the amount of time blocked while attempting to acquire a lock on the object, if any.

  - `wait/synch/cond`

    A condition is used by one thread to signal to other threads that something they were waiting for has happened. If a single thread was waiting for a condition, it can wake up and proceed with its execution. If several threads were waiting, they can all wake up and compete for the resource for which they were waiting.

  - `wait/synch/mutex`

    A mutual exclusion object used to permit access to a resource (such as a section of executable code) while preventing other threads from accessing the resource.

  - `wait/synch/rwlock`

    A read/write lock object used to lock a specific variable for access while preventing its use by other threads. A shared read lock can be acquired simultaneously by multiple threads. An exclusive write lock can be acquired by only one thread at a time.

22.7 Performance Schema Status Monitoring

There are several status variables associated with the Performance Schema:

```
mysql> SHOW STATUS LIKE 'perf%';
+-------------------------------------------+-------+
| Variable_name                             | Value |
+-------------------------------------------+-------+
| Performance_schema_cond_classes_lost      | 0     |
| Performance_schema_cond_instances_lost    | 0     |
| Performance_schema_file_classes_lost      | 0     |
| Performance_schema_file_handles_lost      | 0     |
| Performance_schema_file_instances_lost    | 0     |
| Performance_schema_locker_lost            | 0     |
| Performance_schema_mutex_classes_lost     | 0     |
| Performance_schema_mutex_instances_lost   | 0     |
| Performance_schema_rwlock_classes_lost    | 0     |
| Performance_schema_rwlock_instances_lost  | 0     |
| Performance_schema_table_handles_lost     | 0     |
| Performance_schema_table_instances_lost   | 0     |
| Performance_schema_thread_classes_lost    | 0     |
```

```
| Performance_schema_thread_instances_lost | 0     |
+------------------------------------------+-------+
```

The Performance Schema status variables provide information about instrumentation that could not be loaded or created due to memory constraints. Names for these variables have several forms:

- `Performance_schema_xxx_classes_lost` indicates how many instruments of type *`xxx`* could not be loaded.
- `Performance_schema_xxx_instances_lost` indicates how many instances of object type *`xxx`* could not be created.
- `Performance_schema_xxx_handles_lost` indicates how many instances of object type *`xxx`* could not be opened.
- `Performance_schema_locker_lost` indicates how many events are “lost” or not recorded.

For example, if a mutex is instrumented in the server source but the server cannot allocate memory for the instrumentation at runtime, it increments `Performance_schema_mutex_classes_lost`. The mutex still functions as a synchronization object (that is, the server continues to function normally), but performance data for it will not be collected. If the instrument can be allocated, it can be used for initializing instrumented mutex instances. For a singleton mutex such as a global mutex, there will be only one instance. Other mutexes have an instance per connection, or per page in various caches and data buffers, so the number of instances varies over time. Increasing the maximum number of connections or the maximum size of some buffers will increase the maximum number of instances that might be allocated at once. If the server cannot create a given instrumented mutex instance, it increments `Performance_schema_mutex_instances_lost`.

Suppose that the following conditions hold:

- The server was started with the `--performance_schema_max_mutex_classes=200` option and thus has room for 200 mutex instruments.
- 150 mutex instruments have been loaded already.
- The plugin named `plugin_a` contains 40 mutex instruments.
- The plugin named `plugin_b` contains 20 mutex instruments.

The server allocates mutex instruments for the plugins depending on how many they need and how many are available, as illustrated by the following sequence of statements:

```
INSTALL PLUGIN plugin_a
```

The server now has 150+40 = 190 mutex instruments.

```
UNINSTALL PLUGIN plugin_a;
```

The server still has 190 instruments. All the historical data generated by the plugin code is still available, but new events for the instruments are not collected.

```
INSTALL PLUGIN plugin_a;
```

The server detects that the 40 instruments are already defined, so no new instruments are created, and previously assigned internal memory buffers are reused. The server still has 190 instruments.

```
INSTALL PLUGIN plugin_b;
```

The server has room for 200-190 = 10 instruments (in this case, mutex classes), and sees that the plugin contains 20 new instruments. 10 instruments are loaded, and 10 are discarded or “lost.” The

`Performance_schema_mutex_classes_lost` indicates the number of instruments (mutex classes) lost:

```
mysql> SHOW STATUS LIKE "perf%mutex_classes_lost";
+---------------------------------------+-------+
| Variable_name                         | Value |
+---------------------------------------+-------+
| Performance_schema_mutex_classes_lost | 10    |
+---------------------------------------+-------+
1 row in set (0.10 sec)
```

The instrumentation still works and collects (partial) data for `plugin_b`.

When the server cannot create a mutex instrument, these results occur:

- No row for the instrument is inserted into the `setup_instruments` table.
- `Performance_schema_mutex_classes_lost` increases by 1.
- `Performance_schema_mutex_instances_lost` does not change. (When the mutex instrument is not created, it cannot be used to create instrumented mutex instances later.)

The pattern just described applies to all types of instruments, not just mutexes.

A value of `Performance_schema_mutex_classes_lost` greater than 0 can happen in two cases:

- To save a few bytes of memory, you start the server with `--performance_schema_max_mutex_classes=N`, where *N* is less than the default value. The default value is chosen to be sufficient to load all the plugins provided in the MySQL distribution, but this can be reduced if some plugins are never loaded. For example, you might choose not to load some of the storage engines in the distribution.
- You load a third-party plugin that is instrumented for the Performance Schema but do not allow for the plugin's instrumentation memory requirements when you start the server. Because it comes from a third party, the instrument memory consumption of this engine is not accounted for in the default value chosen for `performance_schema_max_mutex_classes`.

  If the server has insufficient resources for the plugin's instruments and you do not explicitly allocate more using `--performance_schema_max_mutex_classes=N`, loading the plugin leads to starvation of instruments.

If the value chosen for `performance_schema_max_mutex_classes` is too small, no error is reported in the error log and there is no failure at runtime. However, the content of the tables in the `performance_schema` database will miss events. The `Performance_schema_mutex_classes_lost` status variable is the only visible sign to indicate that some events were dropped internally due to failure to create instruments.

If an instrument is not lost, it is known to the Performance Schema, and is used when instrumenting instances. For example, `wait/synch/mutex/sql/LOCK_delete` is the name of a mutex instrument in the `setup_instruments` table. This single instrument is used when creating a mutex in the code (in `THD::LOCK_delete`) however many instances of the mutex are needed as the server runs. In this case, `LOCK_delete` is a mutex that is per connection (`THD`), so if a server has 1000 connections, there are 1000 threads, and 1000 instrumented `LOCK_delete` mutex instances (`THD::LOCK_delete`).

If the server does not have room for all these 1000 instrumented mutexes (instances), some mutexes are created with instrumentation, and some are created without instrumentation. If the server can create only 800 instances, 200 instances are lost. The server continues to run, but increments `Performance_schema_mutex_instances_lost` by 200 to indicate that instances could not be created.

A value of `Performance_schema_mutex_instances_lost` greater than 0 can happen when the code initializes more mutexes at runtime than were allocated for `--performance_schema_max_mutex_instances=N`.

The bottom line is that if `SHOW STATUS LIKE 'perf%'` says that nothing was lost (all values are zero), the Performance Schema data is accurate and can be relied upon. If something was lost, the data is incomplete, and the Performance Schema could not record everything given the insufficient amount of memory it was given to use. In this case, the specific `Performance_schema_xxx_lost` variable indicates the problem area.

It might be appropriate in some cases to cause deliberate instrument starvation. For example, if you do not care about performance data for file I/O, you can start the server with all Performance Schema parameters related to file I/O set to 0. No memory will be allocated for file-related classes, instances, or handles, and all file events will be lost.

Use `SHOW ENGINE PERFORMANCE_SCHEMA STATUS` to inspect the internal operation of the Performance Schema code:

```
mysql> SHOW ENGINE PERFORMANCE_SCHEMA STATUS\G
...
*************************** 3. row ***************************
  Type: performance_schema
  Name: events_waits_history.row_size
Status: 76
*************************** 4. row ***************************
  Type: performance_schema
  Name: events_waits_history.row_count
Status: 10000
*************************** 5. row ***************************
  Type: performance_schema
  Name: events_waits_history.memory
Status: 760000
...
*************************** 57. row ***************************
  Type: performance_schema
  Name: performance_schema.memory
Status: 26459600
...
```

This statement is intended to help the DBA understand the effects that different Performance Schema options have on memory requirements. For a description of the field meanings, see Section 13.7.5.16, “SHOW ENGINE Syntax”.

22.8 Performance Schema General Table Characteristics

The name of the `performance_schema` database is lowercase, as are the names of tables within it. Queries should specify the names in lowercase.

Many tables in the `performance_schema` database are read only and cannot be modified:

```
mysql> TRUNCATE TABLE setup_instruments;
ERROR 1683 (HY000): Invalid performance_schema usage.
```

Some of the setup tables have columns that can be modified to affect Performance Schema operation. Truncation is permitted to clear collected events, so `TRUNCATE TABLE` can be used on tables containing those kinds of information, such as tables named with a prefix of `events_waits_`.

Summary tables can be truncated with `TRUNCATE TABLE`. The effect is to reset the summary columns to 0 or `NULL`, not to remove rows. This enables you to clear collected values and restart aggregation. That might be useful, for example, after you have made a runtime configuration change.

Privileges are as for other databases and tables:

- To retrieve from `performance_schema` tables, you must have the `SELECT` privilege.
- To change those columns that can be modified, you must have the `UPDATE` privilege.
- To truncate tables that can be truncated, you must have the `DROP` privilege.

Because only a limited set of privileges apply to Performance Schema tables, attempts to use `GRANT ALL` as shorthand for granting privileges at the database or table leval fail with an error:

```
mysql> GRANT ALL ON performance_schema.*
       TO 'u1'@'localhost';
ERROR 1044 (42000): Access denied for user 'root'@'localhost'
to database 'performance_schema'
mysql> GRANT ALL ON performance_schema.setup_instruments
       TO 'u2'@'localhost';
ERROR 1044 (42000): Access denied for user 'root'@'localhost'
to database 'performance_schema'
```

Instead, grant exactly the desired privileges:

```
mysql> GRANT SELECT ON performance_schema.*
       TO 'u1'@'localhost';
Query OK, 0 rows affected (0.03 sec)

mysql> GRANT SELECT, UPDATE ON performance_schema.setup_instruments
       TO 'u2'@'localhost';
Query OK, 0 rows affected (0.02 sec)
```

22.9 Performance Schema Table Descriptions

Tables in the `performance_schema` database can be grouped as follows:

- Setup tables. These tables are used to configure and display monitoring characteristics.
- Current events table. The `events_waits_current` table contains the most recent event for each thread.
- History tables. These tables have the same structure as `events_waits_current` but contain more rows. The `events_waits_history` table contains the most recent 10 events per thread. `events_waits_history_long` contains the most recent 10,000 events.

  To change the sizes of these tables, set the `performance_schema_events_waits_history_size` and `performance_schema_events_waits_history_long_size` system variables at server startup.
- Summary tables. These tables contain information aggregated over groups of events, including those that have been discarded from the history tables.
- Instance tables. These tables document what types of objects are instrumented. An instrumented object, when used by the server, produces an event. These tables provide event names and explanatory notes or status information.
- Miscellaneous tables. These do not fall into any of the other table groups.

22.9.1 Performance Schema Table Index

The following table lists each Performance Schema table and provides a short description of each one.

Table 22.1 Performance Schema Tables

Table Name	Description
`cond_instances`	synchronization object instances

Table Name	Description
events_waits_current	Current wait events
events_waits_history	Most recent wait events for each thread
events_waits_history_long	Most recent wait events overall
events_waits_summary_by_instance	Wait events per instance
events_waits_summary_by_thread_by_event_name	Wait events per thread and event name
events_waits_summary_global_by_event_name	Wait events per event name
file_instances	File instances
file_summary_by_event_name	File events per event name
file_summary_by_instance	File events per file instance
mutex_instances	Mutex synchronization object instances
performance_timers	Which event timers are available
rwlock_instances	Lock synchronization object instances
setup_consumers	Consumers for which event information can be stored
setup_instruments	Classes of instrumented objects for which events can be collected
setup_timers	Current event timer
threads	Information about server threads

22.9.2 Performance Schema Setup Tables

The setup tables provide information about the current instrumentation and enable the monitoring configuration to be changed. For this reason, some columns in these tables can be changed if you have the UPDATE privilege.

The use of tables rather than individual variables for setup information provides a high degree of flexibility in modifying Performance Schema configuration. For example, you can use a single statement with standard SQL syntax to make multiple simultaneous configuration changes.

These setup tables are available:

- setup_consumers: The types of consumers for which event information can be stored
- setup_instruments: The classes of instrumented objects for which events can be collected
- setup_timers: The current event timer

22.9.2.1 The setup_consumers Table

The setup_consumers table lists the types of consumers for which event information can be stored:

```
mysql> SELECT * FROM setup_consumers;
+----------------------------------------------+---------+
| NAME                                         | ENABLED |
+----------------------------------------------+---------+
| events_waits_current                         | YES     |
| events_waits_history                         | YES     |
| events_waits_history_long                    | YES     |
| events_waits_summary_by_thread_by_event_name | YES     |
| events_waits_summary_by_event_name           | YES     |
| events_waits_summary_by_instance             | YES     |
| file_summary_by_event_name                   | YES     |
| file_summary_by_instance                     | YES     |
+----------------------------------------------+---------+
```

The `setup_consumers` table has these columns:

- `NAME`

  The consumer name.

- `ENABLED`

  Whether the consumer is enabled. The value is `YES` or `NO`. This column can be modified. If you disable a consumer, the server does not spend time adding event information to it.

`TRUNCATE TABLE` is not permitted for the `setup_consumers` table.

Disabling the `events_waits_current` consumer disables everything else that depends on waits, such as the `events_waits_history` and `events_waits_history_long` tables, and all summary tables.

22.9.2.2 The setup_instruments Table

The `setup_instruments` table lists classes of instrumented objects for which events can be collected:

```
mysql> SELECT * FROM setup_instruments;
+----------------------------------------------------+---------+-------+
| NAME                                               | ENABLED | TIMED |
+----------------------------------------------------+---------+-------+
...
| wait/synch/mutex/sql/LOCK_global_read_lock         | YES     | YES   |
| wait/synch/mutex/sql/LOCK_global_system_variables | YES     | YES   |
| wait/synch/mutex/sql/LOCK_lock_db                  | YES     | YES   |
| wait/synch/mutex/sql/LOCK_manager                  | YES     | YES   |
...
| wait/synch/rwlock/sql/LOCK_grant                   | YES     | YES   |
| wait/synch/rwlock/sql/LOGGER::LOCK_logger          | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_connect        | YES     | YES   |
| wait/synch/rwlock/sql/LOCK_sys_init_slave          | YES     | YES   |
...
| wait/io/file/sql/binlog                            | YES     | YES   |
| wait/io/file/sql/binlog_index                      | YES     | YES   |
| wait/io/file/sql/casetest                          | YES     | YES   |
| wait/io/file/sql/dbopt                             | YES     | YES   |
...
```

Each instrument added to the source code provides a row for the `setup_instruments` table, even when the instrumented code is not executed. When an instrument is enabled and executed, instrumented instances are created, which are visible in the *`xxx`*`_instances` tables, such as `file_instances` or `rwlock_instances`.

The `setup_instruments` table has these columns:

- `NAME`

  The instrument name. Instrument names may have multiple parts and form a hierarchy, as discussed in Section 22.6, “Performance Schema Instrument Naming Conventions”. Events produced from execution of an instrument have an `EVENT_NAME` value that is taken from the instrument `NAME` value. (Events do not really have a “name,” but this provides a way to associate events with instruments.)

- `ENABLED`

  Whether the instrument is enabled. The value is `YES` or `NO`. A disabled instrument produces no events. This column can be modified, although setting `ENABLED` has no effect for instruments that have already been created.

- `TIMED`

Whether the instrument is timed. The value is `YES` or `NO`. This column can be modified, although setting `TIMED` has no effect for instruments that have already been created.

If an enabled instrument is not timed, the instrument code is enabled, but the timer is not. Events produced by the instrument have `NULL` for the `TIMER_START`, `TIMER_END`, and `TIMER_WAIT` timer values. This in turn causes those values to be ignored when calculating the sum, minimum, maximum, and average time values in summary tables.

`TRUNCATE TABLE` is not permitted for the `setup_instruments` table.

22.9.2.3 The setup_timers Table

The `setup_timers` table shows the currently selected event timer:

```
mysql> SELECT * FROM setup_timers;
+------+------------+
| NAME | TIMER_NAME |
+------+------------+
| wait | CYCLE      |
+------+------------+
```

The `setup_timers.TIMER_NAME` value can be changed to select a different timer. The value can be any of the values in the `performance_timers.TIMER_NAME` column. For an explanation of how event timing occurs, see Section 22.4.1, “Performance Schema Event Timing”.

Modifications to the `setup_timers` table affect monitoring immediately. Events already in progress use the original timer for the begin time and the new timer for the end time, which leads to unpredictable results. If you make timer changes, you may want to use `TRUNCATE TABLE` to reset Performance Schema statistics.

The `setup_timers` table has these columns:

- `NAME`

  The type of instrument the timer is used for.

- `TIMER_NAME`

  The timer that applies to the instrument type. This column can be modified.

`TRUNCATE TABLE` is not permitted for the `setup_timers` table.

22.9.3 Performance Schema Instance Tables

Instance tables document what types of objects are instrumented. They provide event names and explanatory notes or status information:

- `cond_instances`: Condition synchronization object instances
- `file_instances`: File instances
- `mutex_instances`: Mutex synchronization object instances
- `rwlock_instances`: Lock synchronization object instances

These tables list instrumented synchronization objects and files. There are three types of synchronization objects: `cond`, `mutex`, and `rwlock`. Each instance table has an `EVENT_NAME` or `NAME` column to indicate the instrument associated with each row. Instrument names may have multiple parts and form a hierarchy, as discussed in Section 22.6, “Performance Schema Instrument Naming Conventions”.

The `mutex_instances.LOCKED_BY_THREAD_ID` and `rwlock_instances.WRITE_LOCKED_BY_THREAD_ID` columns are extremely important for investigating performance bottlenecks or deadlocks. For examples of how to use them for this purpose, see Section 22.14, “Using the Performance Schema to Diagnose Problems”

22.9.3.1 The cond_instances Table

The `cond_instances` table lists all the conditions seen by the Performance Schema while the server executes. A condition is a synchronization mechanism used in the code to signal that a specific event has happened, so that a thread waiting for this condition can resume work.

When a thread is waiting for something to happen, the condition name is an indication of what the thread is waiting for, but there is no immediate way to tell which other thread, or threads, will cause the condition to happen.

The `cond_instances` table has these columns:

- `NAME`

  The instrument name associated with the condition.

- `OBJECT_INSTANCE_BEGIN`

  The address in memory of the instrumented condition.

`TRUNCATE TABLE` is not permitted for the `cond_instances` table.

22.9.3.2 The file_instances Table

The `file_instances` table lists all the files seen by the Performance Schema when executing file I/O instrumentation. If a file on disk has never been opened, it will not be in `file_instances`. When a file is deleted from the disk, it is also removed from the `file_instances` table.

The `file_instances` table has these columns:

- `FILE_NAME`

  The file name.

- `EVENT_NAME`

  The instrument name associated with the file.

- `OPEN_COUNT`

  The count of open handles on the file. If a file was opened and then closed, it was opened 1 time, but `OPEN_COUNT` will be 0. To list all the files currently opened by the server, use `WHERE OPEN_COUNT > 0`.

`TRUNCATE TABLE` is not permitted for the `file_instances` table.

22.9.3.3 The mutex_instances Table

The `mutex_instances` table lists all the mutexes seen by the Performance Schema while the server executes. A mutex is a synchronization mechanism used in the code to enforce that only one thread at a given time can have access to some common resource. The resource is said to be “protected” by the mutex.

When two threads executing in the server (for example, two user sessions executing a query simultaneously) do need to access the same resource (a file, a buffer, or some piece of data), these

two threads will compete against each other, so that the first query to obtain a lock on the mutex will cause the other query to wait until the first is done and unlocks the mutex.

The work performed while holding a mutex is said to be in a “critical section,” and multiple queries do execute this critical section in a serialized way (one at a time), which is a potential bottleneck.

The `mutex_instances` table has these columns:

- `NAME`

  The instrument name associated with the mutex.

- `OBJECT_INSTANCE_BEGIN`

  The address in memory of the instrumented mutex.

- `LOCKED_BY_THREAD_ID`

  When a thread currently has a mutex locked, `LOCKED_BY_THREAD_ID` is the `THREAD_ID` of the locking thread, otherwise it is `NULL`.

`TRUNCATE TABLE` is not permitted for the `mutex_instances` table.

For every mutex instrumented in the code, the Performance Schema provides the following information.

- The `setup_instruments` table lists the name of the instrumentation point, with the prefix `wait/synch/mutex/`.
- When some code creates a mutex, a row is added to the `mutex_instances` table. The `OBJECT_INSTANCE_BEGIN` column is a property that uniquely identifies the mutex.
- When a thread attempts to lock a mutex, the `events_waits_current` table shows a row for that thread, indicating that it is waiting on a mutex (in the `EVENT_NAME` column), and indicating which mutex is waited on (in the `OBJECT_INSTANCE_BEGIN` column).
- When a thread succeeds in locking a mutex:
  - `events_waits_current` shows that the wait on the mutex is completed (in the `TIMER_END` and `TIMER_WAIT` columns)
  - The completed wait event is added to the `events_waits_history` and `events_waits_history_long` tables
  - `mutex_instances` shows that the mutex is now owned by the thread (in the `THREAD_ID` column).
- When a thread unlocks a mutex, `mutex_instances` shows that the mutex now has no owner (the `THREAD_ID` column is `NULL`).
- When a mutex object is destroyed, the corresponding row is removed from `mutex_instances`.

By performing queries on both of the following tables, a monitoring application or a DBA can detect bottlenecks or deadlocks between threads that involve mutexes:

- `events_waits_current`, to see what mutex a thread is waiting for
- `mutex_instances`, to see which other thread currently owns a mutex

22.9.3.4 The rwlock_instances Table

The `rwlock_instances` table lists all the `rwlock` instances (read write locks) seen by the Performance Schema while the server executes. An `rwlock` is a synchronization mechanism used in

the code to enforce that threads at a given time can have access to some common resource following certain rules. The resource is said to be “protected” by the `rwlock`. The access is either shared (many threads can have a read lock at the same time) or exclusive (only one thread can have a write lock at a given time).

Depending on how many threads are requesting a lock, and the nature of the locks requested, access can be either granted in shared mode, granted in exclusive mode, or not granted at all, waiting for other threads to finish first.

The `rwlock_instances` table has these columns:

- `NAME`

  The instrument name associated with the lock.

- `OBJECT_INSTANCE_BEGIN`

  The address in memory of the instrumented lock.

- `WRITE_LOCKED_BY_THREAD_ID`

  When a thread currently has an `rwlock` locked in exclusive (write) mode, `WRITE_LOCKED_BY_THREAD_ID` is the `THREAD_ID` of the locking thread, otherwise it is `NULL`.

- `READ_LOCKED_BY_COUNT`

  When a thread currently has an `rwlock` locked in shared (read) mode, `READ_LOCKED_BY_COUNT` is incremented by 1. This is a counter only, so it cannot be used directly to find which thread holds a read lock, but it can be used to see whether there is a read contention on an `rwlock`, and see how many readers are currently active.

`TRUNCATE TABLE` is not permitted for the `rwlock_instances` table.

By performing queries on both of the following tables, a monitoring application or a DBA may detect some bottlenecks or deadlocks between threads that involve locks:

- `events_waits_current`, to see what `rwlock` a thread is waiting for
- `rwlock_instances`, to see which other thread currently owns an `rwlock`

There is a limitation: The `rwlock_instances` can be used only to identify the thread holding a write lock, but not the threads holding a read lock.

22.9.4 Performance Schema Wait Event Tables

The Performance Schema instruments waits, which are events that take time.

These tables store wait events:

- `events_waits_current`: Current wait events
- `events_waits_history`: The most recent wait events per thread
- `events_waits_history_long`: The most recent wait events globally (across all threads)

The following sections describe the wait event tables. There are also summary tables that aggregate information about wait events; see Section 22.9.5.1, “Wait Event Summary Tables”.

Wait Event Configuration

To control collection of wait events, set the state of the relevant instruments and consumers:

- The `setup_instruments` table contains instruments with names that begin with `wait`. Use these instruments to enable or disable collection of wait events.
- The `setup_consumers` table contains consumer values with names corresponding to the current and recent wait event table names. Use these consumers to filter collection of wait events.

The wait instruments are enabled by default. For example:

```
mysql> SELECT * FROM setup_instruments
       WHERE NAME LIKE 'wait/io/file/innodb%';
+---------------------------------------+---------+-------+
| NAME                                  | ENABLED | TIMED |
+---------------------------------------+---------+-------+
| wait/io/file/innodb/innodb_data_file | YES     | YES   |
| wait/io/file/innodb/innodb_log_file  | YES     | YES   |
| wait/io/file/innodb/innodb_temp_file | YES     | YES   |
+---------------------------------------+---------+-------+
```

The wait consumers are enabled by default:

```
mysql> SELECT * FROM setup_consumers WHERE NAME LIKE '%waits%';
+----------------------------+---------+
| NAME                       | ENABLED |
+----------------------------+---------+
| events_waits_current       | YES     |
| events_waits_history       | YES     |
| events_waits_history_long | YES     |
+----------------------------+---------+
```

To control wait event collection, update the `setup_instruments` and `setup_consumers` tables:

- Enable:

```
UPDATE setup_instruments SET ENABLED = 'YES', TIMED = 'YES'
WHERE NAME = 'wait/%';
UPDATE setup_consumers SET ENABLED = 'YES'
WHERE NAME LIKE '%waits%';
```

- Disable:

```
UPDATE setup_instruments SET ENABLED = 'NO', TIMED = 'NO'
WHERE NAME = 'wait/%';
UPDATE setup_consumers SET ENABLED = 'NO'
WHERE NAME LIKE '%waits%';
```

To collect only specific wait events, enable only the corresponding wait instruments. To collect wait events only for specific wait event tables, enable the wait instruments but only the wait consumers corresponding to the desired tables.

The `setup_timers` table contains a row with a `NAME` value of `wait` that indicates the unit for wait event timing. The default unit is `CYCLE`:

```
mysql> SELECT * FROM setup_timers WHERE NAME = 'wait';
+------+------------+
| NAME | TIMER_NAME |
+------+------------+
| wait | CYCLE      |
+------+------------+
```

To change the timing unit, modify the `TIMER_NAME` value:

```
UPDATE setup_timers SET TIMER_NAME = 'NANOSECOND'
```

```
WHERE NAME = 'wait';
```

For additional information about configuring event collection, see Section 22.4, “Performance Schema Runtime Configuration”.

22.9.4.1 The events_waits_current Table

The `events_waits_current` table contains current wait events, one row per thread showing the current status of the thread's most recent monitored wait event.

Of the tables that contain wait event rows, `events_waits_current` is the most fundamental. Other tables that contain wait event rows are logically derived from the current events. For example, the `events_waits_history` and `events_waits_history_long` tables are collections of the most recent wait events, up to a fixed number of rows.

For information about configuration of wait event collection, see Section 22.9.4, “Performance Schema Wait Event Tables”.

The `events_waits_current` table has these columns:

- `THREAD_ID`, `EVENT_ID`

  The thread associated with the event and the thread current event number when the event starts. The `THREAD_ID` and `EVENT_ID` values taken together uniquely identify the row. No two rows have the same pair of values.

- `EVENT_NAME`

  The name of the instrument that produced the event. This is a `NAME` value from the `setup_instruments` table. Instrument names may have multiple parts and form a hierarchy, as discussed in Section 22.6, “Performance Schema Instrument Naming Conventions”.

- `SOURCE`

  The name of the source file containing the instrumented code that produced the event and the line number in the file at which the instrumentation occurs. This enables you to check the source to determine exactly what code is involved. For example, if a mutex or lock is being blocked, you can check the context in which this occurs.

- `TIMER_START`, `TIMER_END`, `TIMER_WAIT`

  Timing information for the event. The unit for these values is picoseconds (trillionths of a second). The `TIMER_START` and `TIMER_END` values indicate when event timing started and ended. `TIMER_WAIT` is the event elapsed time (duration).

  If an event has not finished, `TIMER_END` and `TIMER_WAIT` are `NULL`.

  If an event is produced from an instrument that has `TIMED = NO`, timing information is not collected, and `TIMER_START`, `TIMER_END`, and `TIMER_WAIT` are all `NULL`.

  For discussion of picoseconds as the unit for event times and factors that affect time values, see Section 22.4.1, “Performance Schema Event Timing”.

- `SPINS`

  For a mutex, the number of spin rounds. If the value is `NULL`, the code does not use spin rounds or spinning is not instrumented.

- `OBJECT_SCHEMA`, `OBJECT_NAME`, `OBJECT_TYPE`, `OBJECT_INSTANCE_BEGIN`

  These columns identify the object “being acted on.” What that means depends on the object type.

For a synchronization object (`cond`, `mutex`, `rwlock`):

- `OBJECT_SCHEMA`, `OBJECT_NAME`, and `OBJECT_TYPE` are `NULL`.
- `OBJECT_INSTANCE_BEGIN` is the address of the synchronization object in memory.

For a file I/O object:

- `OBJECT_SCHEMA` is `NULL`.
- `OBJECT_NAME` is the file name.
- `OBJECT_TYPE` is `FILE`.
- `OBJECT_INSTANCE_BEGIN` is an address in memory.

An `OBJECT_INSTANCE_BEGIN` value itself has no meaning, except that different values indicate different objects. `OBJECT_INSTANCE_BEGIN` can be used for debugging. For example, it can be used with `GROUP BY OBJECT_INSTANCE_BEGIN` to see whether the load on 1,000 mutexes (that protect, say, 1,000 pages or blocks of data) is spread evenly or just hitting a few bottlenecks. This can help you correlate with other sources of information if you see the same object address in a log file or another debugging or performance tool.

- `NESTING_EVENT_ID`

  Always `NULL`.

- `OPERATION`

  The type of operation performed, such as `lock`, `read`, or `write`.

- `NUMBER_OF_BYTES`

  The number of bytes read or written by the operation.

- `FLAGS`

  Reserved for future use.

`TRUNCATE TABLE` is permitted for the `events_waits_current` table. It removes the rows.

22.9.4.2 The events_waits_history Table

The `events_waits_history` table contains the most recent 10 wait events per thread. To change the table size, modify the `performance_schema_events_waits_history_size` system variable at server startup. Wait events are not added to the table until they have ended. As new events are added, older events are discarded if the table is full.

The `events_waits_history` table has the same structure as `events_waits_current`. See Section 22.9.4.1, “The events_waits_current Table”.

`TRUNCATE TABLE` is permitted for the `events_waits_history` table. It removes the rows.

For information about configuration of wait event collection, see Section 22.9.4, “Performance Schema Wait Event Tables”.

22.9.4.3 The events_waits_history_long Table

The `events_waits_history_long` table contains the most recent 10,000 wait events. To change the table size, modify the `performance_schema_events_waits_history_long_size` system variable at server startup. Wait events are not added to the table until they have ended. As new events

are added, older events are discarded if the table is full. When a thread ends, its rows are removed from the table.

The `events_waits_history_long` table has the same structure as `events_waits_current`. See Section 22.9.4.1, “The events_waits_current Table”.

`TRUNCATE TABLE` is permitted for the `events_waits_history_long` table. It removes the rows.

For information about configuration of wait event collection, see Section 22.9.4, “Performance Schema Wait Event Tables”.

22.9.5 Performance Schema Summary Tables

Summary tables provide aggregated information for terminated events over time. The tables in this group summarize event data in different ways.

Wait Event Summaries

- `events_waits_summary_by_instance`: Wait events per instance
- `events_waits_summary_by_thread_by_event_name`: Wait events per thread and event name
- `events_waits_summary_global_by_event_name`: Wait events per event name

File I/O Summaries

- `file_summary_by_event_name`: File events per event name
- `file_summary_by_instance`: File events per file instance

Each summary table has grouping columns that determine how to group the data to be aggregated, and summary columns that contain the aggregated values. Tables that summarize events in similar ways often have similar sets of summary columns and differ only in the grouping columns used to determine how events are aggregated.

Summary tables can be truncated with `TRUNCATE TABLE`. The effect is to reset the summary columns to 0 or `NULL`, not to remove rows. This enables you to clear collected values and restart aggregation. That might be useful, for example, after you have made a runtime configuration change.

22.9.5.1 Wait Event Summary Tables

The Performance Schema maintains tables for collecting current and recent wait events, and aggregates that information in summary tables. Section 22.9.4, “Performance Schema Wait Event Tables” describes the events on which wait summaries are based. See that discussion for information about the content of wait events, the current and recent wait event tables, and how to control wait event collection.

Example wait event summary information:

```
mysql> SELECT * FROM events_waits_summary_global_by_event_name\G
...
*************************** 6. row ***************************
    EVENT_NAME: wait/synch/mutex/sql/BINARY_LOG::LOCK_index
    COUNT_STAR: 8
SUM_TIMER_WAIT: 2119302
MIN_TIMER_WAIT: 196092
AVG_TIMER_WAIT: 264912
MAX_TIMER_WAIT: 569421
...
*************************** 9. row ***************************
    EVENT_NAME: wait/synch/mutex/sql/hash_filo::lock
    COUNT_STAR: 69
```

```
SUM_TIMER_WAIT: 16848828
MIN_TIMER_WAIT: 0
AVG_TIMER_WAIT: 244185
MAX_TIMER_WAIT: 735345
...
```

Each wait event summary table has one or more grouping columns to indicate how the table aggregates events. Event names refer to names of event instruments in the `setup_instruments` table:

- `events_waits_summary_by_instance` has `EVENT_NAME` and `OBJECT_INSTANCE_BEGIN` columns. Each row summarizes events for a given event name and object. If an instrument is used to create multiple instances, each instance has a unique `OBJECT_INSTANCE_BEGIN` value, so these instances are summarized separately in this table.
- `events_waits_summary_by_thread_by_event_name` has `THREAD_ID` and `EVENT_NAME` columns. Each row summarizes events for a given thread and event name.
- `events_waits_summary_global_by_event_name` has an `EVENT_NAME` column. Each row summarizes events for a given event name. An instrument might be used to create multiple instances of the instrumented object. For example, if there is an instrument for a mutex that is created for each connection, there are as many instances as there are connections. The summary row for the instrument summarizes over all these instances.

Each wait event summary table has these summary columns containing aggregated values:

- `COUNT_STAR`

  The number of summarized events. This value includes all events, whether timed or nontimed.

- `SUM_TIMER_WAIT`

  The total wait time of the summarized timed events. This value is calculated only for timed events because nontimed events have a wait time of `NULL`. The same is true for the other *`xxx`*`_TIMER_WAIT` values.

- `MIN_TIMER_WAIT`

  The minimum wait time of the summarized timed events.

- `AVG_TIMER_WAIT`

  The average wait time of the summarized timed events.

- `MAX_TIMER_WAIT`

  The maximum wait time of the summarized timed events.

`TRUNCATE TABLE` is permitted for wait summary tables. It resets the summary columns to zero rather than removing rows.

22.9.5.2 File I/O Summary Tables

The Performance Schema maintains file I/O summary tables that aggregate information about I/O operations.

Example file I/O event summary information:

```
mysql> SELECT * FROM file_summary_by_instance\G
...
*************************** 2. row ***************************
                FILE_NAME: /var/mysql/share/english/errmsg.sys
```

```
               EVENT_NAME: wait/io/file/sql/ERRMSG
               COUNT_READ: 3
              COUNT_WRITE: 0
 SUM_NUMBER_OF_BYTES_READ: 42211
SUM_NUMBER_OF_BYTES_WRITE: 0
...
*************************** 6. row ***************************
                FILE_NAME: /var/mysql/data/binlog.000001
               EVENT_NAME: wait/io/file/sql/binlog
               COUNT_READ: 0
              COUNT_WRITE: 0
 SUM_NUMBER_OF_BYTES_READ: 0
SUM_NUMBER_OF_BYTES_WRITE: 0
...
```

Each file I/O summary table has one or more grouping columns to indicate how the table aggregates events. Event names refer to names of event instruments in the `setup_instruments` table:

- `file_summary_by_event_name` has an `EVENT_NAME` column. Each row summarizes events for a given event name.
- `file_summary_by_instance` has `FILE_NAME` and `EVENT_NAME` columns. Each row summarizes events for a given file instrument instance.

Each file I/O summary table has these summary columns containing aggregated values:

- `COUNT_READ`

  The number of read operations in the summarized events.

- `COUNT_WRITE`

  The number of write operations in the summarized events.

- `SUM_NUMBER_OF_BYTES_READ`

  The number of bytes read in the summarized events.

- `SUM_NUMBER_OF_BYTES_WRITE`

  The number of bytes written in the summarized events.

`TRUNCATE TABLE` is permitted for file I/O summary tables. It resets the summary columns to zero rather than removing rows.

The MySQL server uses several techniques to avoid I/O operations by caching information read from files, so it is possible that statements you might expect to result in I/O events will not. You may be able to ensure that I/O does occur by flushing caches or restarting the server to reset its state.

22.9.6 Performance Schema Miscellaneous Tables

The following sections describe tables that do not fall into the table categories discussed in the preceding sections:

- `performance_timers`: Which event timers are available
- `threads`: Information about server threads

22.9.6.1 The performance_timers Table

The `performance_timers` table shows which event timers are available:

```
mysql> SELECT * FROM performance_timers;
```

```
+-------------+-----------------+------------------+----------------+
| TIMER_NAME  | TIMER_FREQUENCY | TIMER_RESOLUTION | TIMER_OVERHEAD |
+-------------+-----------------+------------------+----------------+
| CYCLE       |      2389029850 |                1 |             72 |
| NANOSECOND  |            NULL |             NULL |           NULL |
| MICROSECOND |         1000000 |                1 |            585 |
| MILLISECOND |            1035 |                1 |            738 |
| TICK        |             101 |                1 |            630 |
+-------------+-----------------+------------------+----------------+
```

If the values associated with a given timer name are `NULL`, that timer is not supported on your platform. The rows that do not contain `NULL` indicate which timers you can use in `setup_timers`. For an explanation of how event timing occurs, see Section 22.4.1, “Performance Schema Event Timing”.

The `performance_timers` table has these columns:

- `TIMER_NAME`

  The name by which to refer to the timer when configuring the `setup_timers` table.

- `TIMER_FREQUENCY`

  The number of timer units per second. For a cycle timer, the frequency is generally related to the CPU speed. For example, on a system with a 2.4GHz processor, the `CYCLE` may be close to 2400000000.

- `TIMER_RESOLUTION`

  Indicates the number of timer units by which timer values increase. If a timer has a resolution of 10, its value increases by 10 each time.

- `TIMER_OVERHEAD`

  The minimal number of cycles of overhead to obtain one timing with the given timer. The Performance Schema determines this value by invoking the timer 20 times during initialization and picking the smallest value. The total overhead really is twice this amount because the instrumentation invokes the timer at the start and end of each event. The timer code is called only for timed events, so this overhead does not apply for nontimed events.

`TRUNCATE TABLE` is not permitted for the `performance_timers` table.

22.9.6.2 The threads Table

The `threads` table contains a row for each server thread:

```
mysql> SELECT * FROM threads;
+-----------+----------------+----------------------------------------+
| THREAD_ID | PROCESSLIST_ID | NAME                                   |
+-----------+----------------+----------------------------------------+
|         0 |              0 | thread/sql/main                        |
|         1 |              0 | thread/innodb/io_handler_thread        |
|        16 |              0 | thread/sql/signal_handler              |
|        23 |              7 | thread/sql/one_connection              |
|         5 |              0 | thread/innodb/io_handler_thread        |
|        12 |              0 | thread/innodb/srv_lock_timeout_thread  |
|        22 |              6 | thread/sql/one_connection              |
...
```

Note

For `INFORMATION_SCHEMA.PROCESSLIST` and `SHOW PROCESSLIST`, information about threads for other users is shown only if the current user has the `PROCESS` privilege. That is not true of the `threads` table; all rows are shown to any user who has the `SELECT` privilege for the table. Users who

should not be able to see threads for other users should not be given that privilege.

The `threads` table has these columns:

- `THREAD_ID`

  This is the unique identifier of an instrumented thread.

- `PROCESSLIST_ID`

  For threads that are displayed in the `INFORMATION_SCHEMA.PROCESSLIST` table, this is the same value displayed in the `ID` column of that table. It is also the value displayed in the `Id` column of `SHOW PROCESSLIST` output, and the value that `CONNECTION_ID()` would return within that thread.

  For background threads (threads not associated with a user connection), `PROCESSLIST_ID` is 0, so the values are not unique.

  This column was named `ID` before MySQL 5.5.8.

- `NAME`

  `NAME` is the name associated with the instrumentation of the code in the server. For example, `thread/sql/one_connection` corresponds to the thread function in the code responsible for handling a user connection, and `thread/sql/main` stands for the `main()` function of the server.

`TRUNCATE TABLE` is not permitted for the `threads` table.

The `threads` table was named `PROCESSLIST` before MySQL 5.5.6.

22.10 Performance Schema Option and Variable Reference

Table 22.2 Performance Schema Variable Reference

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
performance_schema	Yes	Yes	Yes		Global	No
Performance_schema_cond_classes_lost				Yes	Global	No
Performance_schema_cond_instances_lost				Yes	Global	No
performance_schema_events_waits_history_long_size	Yes	Yes	Yes		Global	No
performance_schema_events_waits_history_size	Yes	Yes	Yes		Global	No
Performance_schema_file_classes_lost				Yes	Global	No
Performance_schema_file_handles_lost				Yes	Global	No
Performance_schema_file_instances_lost				Yes	Global	No
Performance_schema_locker_lost				Yes	Global	No
performance_schema_max_cond_classes	Yes	Yes	Yes		Global	No
performance_schema_max_cond_instances	Yes	Yes	Yes		Global	No
performance_schema_max_file_classes	Yes	Yes	Yes		Global	No
performance_schema_max_file_handles	Yes	Yes	Yes		Global	No
performance_schema_max_file_instances	Yes	Yes	Yes		Global	No
performance_schema_max_mutex_classes	Yes	Yes	Yes		Global	No
performance_schema_max_mutex_instances	Yes	Yes	Yes		Global	No
performance_schema_max_rwlock_classes	Yes	Yes	Yes		Global	No
performance_schema_max_rwlock_instances	Yes	Yes	Yes		Global	No

Name	Cmd-Line	Option File	System Var	Status Var	Var Scope	Dynamic
performance_schema_max_table_handles	Yes	Yes	Yes		Global	No
performance_schema_max_table_instances	Yes	Yes	Yes		Global	No
performance_schema_max_thread_classes	Yes	Yes	Yes		Global	No
performance_schema_max_thread_instances	Yes	Yes	Yes		Global	No
Performance_schema_mutex_classes_lost				Yes	Global	No
Performance_schema_mutex_instances_lost				Yes	Global	No
Performance_schema_rwlock_classes_lost				Yes	Global	No
Performance_schema_rwlock_instances_lost				Yes	Global	No
Performance_schema_table_handles_lost				Yes	Global	No
Performance_schema_table_instances_lost				Yes	Global	No
Performance_schema_thread_classes_lost				Yes	Global	No
Performance_schema_thread_instances_lost				Yes	Global	No

22.11 Performance Schema System Variables

The Performance Schema implements several system variables that provide configuration information:

```
mysql> SHOW VARIABLES LIKE 'perf%';
+----------------------------------------------------+---------+
| Variable_name                                      | Value   |
+----------------------------------------------------+---------+
| performance_schema                                 | ON      |
| performance_schema_events_waits_history_long_size  | 10000   |
| performance_schema_events_waits_history_size       | 10      |
| performance_schema_max_cond_classes                | 80      |
| performance_schema_max_cond_instances              | 1000    |
| performance_schema_max_file_classes                | 50      |
| performance_schema_max_file_handles                | 32768   |
| performance_schema_max_file_instances              | 10000   |
| performance_schema_max_mutex_classes               | 200     |
| performance_schema_max_mutex_instances             | 1000000 |
| performance_schema_max_rwlock_classes              | 30      |
| performance_schema_max_rwlock_instances            | 1000000 |
| performance_schema_max_table_handles               | 100000  |
| performance_schema_max_table_instances             | 50000   |
| performance_schema_max_thread_classes              | 50      |
| performance_schema_max_thread_instances            | 1000    |
+----------------------------------------------------+---------+
```

Performance Schema system variables can be set at server startup on the command line or in option files, and many can be set at runtime. See Section 22.10, “Performance Schema Option and Variable Reference”.

Performance Schema system variables have the following meanings:

- `performance_schema`

Introduced	5.5.3	
Command-Line Format	`--performance-schema=#`	
System Variable	**Name**	`performance_schema`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	boolean
	Default	`OFF`

The value of this variable is `ON` or `OFF` to indicate whether the Performance Schema is enabled. By default, the value is `OFF`. At server startup, you can specify this variable with no value or a value of 1 to enable it, or with a value of 0 to disable it.

- `performance_schema_events_waits_history_long_size`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-events-waits-history-long-size=#`	
System Variable	**Name**	`performance_schema_events_waits_history_long_size`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`10000`

The number of rows in the `events_waits_history_long` table.

- `performance_schema_events_waits_history_size`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-events-waits-history-size=#`	
System Variable	**Name**	`performance_schema_events_waits_history_size`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`10`

The number of rows per thread in the `events_waits_history` table.

- `performance_schema_max_cond_classes`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-cond-classes=#`	
System Variable	**Name**	`performance_schema_max_cond_classes`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`80`

The maximum number of condition instruments.

- `performance_schema_max_cond_instances`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-cond-instances=#`	
System Variable	**Name**	`performance_schema_max_cond_instances`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`1000`

The maximum number of instrumented condition objects.

- `performance_schema_max_file_classes`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-file-classes=#`	
System Variable	**Name**	`performance_schema_max_file_classes`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`50`

The maximum number of file instruments.

- `performance_schema_max_file_handles`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-file-handles=#`	
System Variable	**Name**	`performance_schema_max_file_handles`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`32768`

The maximum number of opened file objects.

The value of `performance_schema_max_file_handles` should be greater than the value of `open_files_limit`: `open_files_limit` affects the maximum number of open file handles the server can support and `performance_schema_max_file_handles` affects how many of these file handles can be instrumented.

- `performance_schema_max_file_instances`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-file-instances=#`	
System Variable	**Name**	`performance_schema_max_file_instances`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`10000`

The maximum number of instrumented file objects.

- `performance_schema_max_mutex_classes`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-mutex-classes=#`	
System Variable	**Name**	`performance_schema_max_mutex_classes`
	Scope	Global
	Dynamic	No

Permitted Values	**Type**	integer
	Default	`200`

The maximum number of mutex instruments.

- `performance_schema_max_mutex_instances`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-mutex-instances=#`	
System Variable	**Name**	`performance_schema_max_mutex_instances`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`1000`

The maximum number of instrumented mutex objects.

- `performance_schema_max_rwlock_classes`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-rwlock-classes=#`	
System Variable	**Name**	`performance_schema_max_rwlock_classes`
	Scope	Global
	Dynamic	No
Permitted Values (<= 5.5.6)	**Type**	integer
	Default	`20`
Permitted Values (>= 5.5.7)	**Type**	integer
	Default	`30`

The maximum number of rwlock instruments.

- `performance_schema_max_rwlock_instances`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-rwlock-instances=#`	
System Variable	**Name**	`performance_schema_max_rwlock_instances`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`1000`

The maximum number of instrumented rwlock objects.

- `performance_schema_max_table_handles`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-table-handles=#`	
System Variable	**Name**	`performance_schema_max_table_handles`
	Scope	Global

	Dynamic	No
Permitted Values	**Type**	integer
	Default	`100000`

The maximum number of opened table objects.

- `performance_schema_max_table_instances`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-table-instances=#`	
System Variable	**Name**	`performance_schema_max_table_instances`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`50000`

The maximum number of instrumented table objects.

- `performance_schema_max_thread_classes`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-thread-classes=#`	
System Variable	**Name**	`performance_schema_max_thread_classes`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`50`

The maximum number of thread instruments.

- `performance_schema_max_thread_instances`

Introduced	5.5.3	
Command-Line Format	`--performance-schema-max-thread-instances=#`	
System Variable	**Name**	`performance_schema_max_thread_instances`
	Scope	Global
	Dynamic	No
Permitted Values	**Type**	integer
	Default	`1000`

The maximum number of instrumented thread objects. The value controls the size of the `threads` table. If this maximum is exceeded such that a thread cannot be instrumented, the Performance Schema increments the `Performance_schema_thread_instances_lost` status variable.

The `max_connections` and `max_delayed_threads` system variables affect how many threads are run in the server. `performance_schema_max_thread_instances` affects how many of these running threads can be instrumented. If you increase `max_connections` or `max_delayed_threads`, you should consider increasing `performance_schema_max_thread_instances` so that `performance_schema_max_thread_instances` is greater than the sum of `max_connections` and `max_delayed_threads`.

22.12 Performance Schema Status Variables

The Performance Schema implements several status variables that provide information about instrumentation that could not be loaded or created due to memory constraints:

```
mysql> SHOW STATUS LIKE 'perf%';
+----------------------------------------+-------+
| Variable_name                          | Value |
+----------------------------------------+-------+
| Performance_schema_cond_classes_lost   | 0     |
| Performance_schema_cond_instances_lost | 0     |
| Performance_schema_file_classes_lost   | 0     |
| Performance_schema_file_handles_lost   | 0     |
| Performance_schema_file_instances_lost | 0     |
| Performance_schema_locker_lost         | 0     |
| Performance_schema_mutex_classes_lost  | 0     |
| Performance_schema_mutex_instances_lost | 0     |
| Performance_schema_rwlock_classes_lost | 0     |
| Performance_schema_rwlock_instances_lost | 0     |
| Performance_schema_table_handles_lost  | 0     |
| Performance_schema_table_instances_lost | 0     |
| Performance_schema_thread_classes_lost | 0     |
| Performance_schema_thread_instances_lost | 0     |
+----------------------------------------+-------+
```

Performance Schema status variables have the following meanings:

- `Performance_schema_cond_classes_lost`

  How many condition instruments could not be loaded.

- `Performance_schema_cond_instances_lost`

  How many condition instrument instances could not be created.

- `Performance_schema_file_classes_lost`

  How many file instruments could not be loaded.

- `Performance_schema_file_handles_lost`

  How many file instrument instances could not be opened.

- `Performance_schema_file_instances_lost`

  How many file instrument instances could not be created.

- `Performance_schema_locker_lost`

  How many events are “lost” or not recorded, due to the following conditions:

  - Events are recursive (for example, waiting for A caused a wait on B, which caused a wait on C).
  - The depth of the nested events stack is greater than the limit imposed by the implementation.

  Events recorded by the Performance Schema are not recursive, so this variable should always be 0.

- `Performance_schema_mutex_classes_lost`

  How many mutex instruments could not be loaded.

- `Performance_schema_mutex_instances_lost`

  How many mutex instrument instances could not be created.

- `Performance_schema_rwlock_classes_lost`

  How many rwlock instruments could not be loaded.

- `Performance_schema_rwlock_instances_lost`

  How many rwlock instrument instances could not be created.

- `Performance_schema_table_handles_lost`

  How many table instrument instances could not be opened.

- `Performance_schema_table_instances_lost`

  How many table instrument instances could not be created.

- `Performance_schema_thread_classes_lost`

  How many thread instruments could not be loaded.

- `Performance_schema_thread_instances_lost`

  The number of thread instances that could not be instrumented in the `threads` table. This can be nonzero if the value of `performance_schema_max_thread_instances` is too small.

For information on using these variables to check Performance Schema status, see Section 22.7, “Performance Schema Status Monitoring”.

22.13 Performance Schema and Plugins

Removing a plugin with `UNINSTALL PLUGIN` does not affect information already collected for code in that plugin. Time spent executing the code while the plugin was loaded was still spent even if the plugin is unloaded later. The associated event information, including aggregate information, remains readable in `performance_schema` database tables. For additional information about the effect of plugin installation and removal, see Section 22.7, “Performance Schema Status Monitoring”.

A plugin implementor who instruments plugin code should document its instrumentation characteristics to enable those who load the plugin to account for its requirements. For example, a third-party storage engine should include in its documentation how much memory the engine needs for mutex and other instruments.

22.14 Using the Performance Schema to Diagnose Problems

The Performance Schema is a tool to help a DBA do performance tuning by taking real measurements instead of “wild guesses.” This section demonstrates some ways to use the Performance Schema for this purpose. The discussion here relies on the use of event filtering, which is described in Section 22.4.2, “Performance Schema Event Filtering”.

The following example provides one methodology that you can use to analyze a repeatable problem, such as investigating a performance bottleneck. To begin, you should have a repeatable use case where performance is deemed “too slow” and needs optimization, and you should enable all instrumentation (no pre-filtering at all).

1. Run the use case.

2. Using the Performance Schema tables, analyze the root cause of the performance problem. This analysis will rely heavily on post-filtering.

3. For problem areas that are ruled out, disable the corresponding instruments. For example, if analysis shows that the issue is not related to file I/O in a particular storage engine, disable the file

I/O instruments for that engine. Then truncate the history and summary tables to remove previously collected events.

4. Repeat the process at step 1.

   At each iteration, the Performance Schema output, particularly the `events_waits_history_long` table, will contain less and less “noise” caused by nonsignificant instruments, and given that this table has a fixed size, will contain more and more data relevant to the analysis of the problem at hand.

   At each iteration, investigation should lead closer and closer to the root cause of the problem, as the “signal/noise” ratio will improve, making analysis easier.

5. Once a root cause of performance bottleneck is identified, take the appropriate corrective action, such as:

   - Tune the server parameters (cache sizes, memory, and so forth).
   - Tune a query by writing it differently,
   - Tune the database schema (tables, indexes, and so forth).
   - Tune the code (this applies to storage engine or server developers only).

6. Start again at step 1, to see the effects of the changes on performance.

The `mutex_instances.LOCKED_BY_THREAD_ID` and `rwlock_instances.WRITE_LOCKED_BY_THREAD_ID` columns are extremely important for investigating performance bottlenecks or deadlocks. This is made possible by Performance Schema instrumentation as follows:

1. Suppose that thread 1 is stuck waiting for a mutex.
2. You can determine what the thread is waiting for:

   ```
   SELECT * FROM events_waits_current WHERE THREAD_ID = thread_1;
   ```

   Say the query result identifies that the thread is waiting for mutex A, found in `events_waits_current.OBJECT_INSTANCE_BEGIN`.

3. You can determine which thread is holding mutex A:

   ```
   SELECT * FROM mutex_instances WHERE OBJECT_INSTANCE_BEGIN = mutex_A;
   ```

   Say the query result identifies that it is thread 2 holding mutex A, as found in `mutex_instances.LOCKED_BY_THREAD_ID`.

4. You can see what thread 2 is doing:

   ```
   SELECT * FROM events_waits_current WHERE THREAD_ID = thread_2;
   ```

Chapter 23 Connectors and APIs

Table of Contents

23.1 MySQL Connector/C 2646
23.2 MySQL Connector/C++ 2646
23.3 MySQL Connector/J 2646
23.4 MySQL Connector/Net 2647
23.5 MySQL Connector/ODBC 2647
23.6 MySQL Connector/Python 2647
23.7 libmysqld, the Embedded MySQL Server Library 2647
    23.7.1 Compiling Programs with libmysqld 2648
    23.7.2 Restrictions When Using the Embedded MySQL Server 2648
    23.7.3 Options with the Embedded Server 2649
    23.7.4 Embedded Server Examples 2649
23.8 MySQL C API 2652
    23.8.1 MySQL C API Implementations 2653
    23.8.2 Simultaneous MySQL Server and Connector/C Installations 2654
    23.8.3 Example C API Client Programs 2655
    23.8.4 Building and Running C API Client Programs 2655
    23.8.5 C API Data Structures 2659
    23.8.6 C API Function Overview 2664
    23.8.7 C API Function Descriptions 2669
    23.8.8 C API Prepared Statements 2718
    23.8.9 C API Prepared Statement Data Structures 2718
    23.8.10 C API Prepared Statement Function Overview 2724
    23.8.11 C API Prepared Statement Function Descriptions 2727
    23.8.12 C API Threaded Function Descriptions 2750
    23.8.13 C API Embedded Server Function Descriptions 2751
    23.8.14 C API Client Plugin Functions 2752
    23.8.15 C API Encrypted Connection Support 2755
    23.8.16 C API Multiple Statement Execution Support 2757
    23.8.17 C API Prepared Statement Handling of Date and Time Values 2759
    23.8.18 C API Prepared CALL Statement Support 2760
    23.8.19 C API Prepared Statement Problems 2763
    23.8.20 C API Automatic Reconnection Control 2764
    23.8.21 C API Common Issues 2765
23.9 MySQL PHP API 2766
23.10 MySQL Perl API 2766
23.11 MySQL Python API 2767
23.12 MySQL Ruby APIs 2767
    23.12.1 The MySQL/Ruby API 2768
    23.12.2 The Ruby/MySQL API 2768
23.13 MySQL Tcl API 2768
23.14 MySQL Eiffel Wrapper 2768

MySQL Connectors provide connectivity to the MySQL server for client programs. APIs provide low-level access to the MySQL protocol and MySQL resources. Both Connectors and the APIs enable you to connect and execute MySQL statements from another language or environment, including ODBC, Java (JDBC), Perl, Python, PHP, Ruby, and native C and embedded MySQL instances.

Note

Connector version numbers do not correlate with MySQL Server version numbers. See Table 23.2, “MySQL Connector Versions and MySQL Server Versions”.

MySQL Connectors

Oracle develops a number of connectors:

- Connector/C is a standalone replacement for the MySQL Client Library (`libmysqlclient`), to be used for C applications.
- Connector/C++ enables C++ applications to connect to MySQL.
- Connector/J provides driver support for connecting to MySQL from Java applications using the standard Java Database Connectivity (JDBC) API.
- Connector/Net enables developers to create .NET applications that connect to MySQL. Connector/Net implements a fully functional ADO.NET interface and provides support for use with ADO.NET aware tools. Applications that use Connector/Net can be written in any supported .NET language.

  MySQL for Visual Studio works with Connector/Net and Microsoft Visual Studio 2012, 2013, 2015, and 2017. MySQL for Visual Studio provides access to MySQL objects and data from Visual Studio. As a Visual Studio package, it integrates directly into Server Explorer providing the ability to create new connections and work with MySQL database objects.
- Connector/ODBC provides driver support for connecting to MySQL using the Open Database Connectivity (ODBC) API. Support is available for ODBC connectivity from Windows, Unix, and OS X platforms.
- Connector/Python provides driver support for connecting to MySQL from Python applications using an API that is compliant with the Python DB API version 2.0. No additional Python modules or MySQL client libraries are required.

The MySQL C API

For direct access to using MySQL natively within a C application, there are two methods:

- The C API provides low-level access to the MySQL client/server protocol through the `libmysqlclient` client library. This is the primary method used to connect to an instance of the MySQL server, and is used both by MySQL command-line clients and many of the MySQL Connectors and third-party APIs detailed here.

  `libmysqlclient` is included in MySQL distributions and in Connector/C distributions.
- `libmysqld` is an embedded MySQL server library that enables you to embed an instance of the MySQL server into your C applications.

  `libmysqld` is included in MySQL distributions, but not in Connector/C distributions.

See also Section 23.8.1, “MySQL C API Implementations”.

To access MySQL from a C application, or to build an interface to MySQL for a language not supported by the Connectors or APIs in this chapter, the C API is where to start. A number of programmer's utilities are available to help with the process; see Section 4.7, “MySQL Program Development Utilities”.

Third-Party MySQL APIs

The remaining APIs described in this chapter provide an interface to MySQL from specific application languages. These third-party solutions are not developed or supported by Oracle. Basic information on their usage and abilities is provided here for reference purposes only.

All the third-party language APIs are developed using one of two methods, using `libmysqlclient` or by implementing a *native driver*. The two solutions offer different benefits:

- Using *`libmysqlclient`* offers complete compatibility with MySQL because it uses the same libraries as the MySQL client applications. However, the feature set is limited to the implementation

and interfaces exposed through `libmysqlclient` and the performance may be lower as data is copied between the native language, and the MySQL API components.

- *Native drivers* are an implementation of the MySQL network protocol entirely within the host language or environment. Native drivers are fast, as there is less copying of data between components, and they can offer advanced functionality not available through the standard MySQL API. Native drivers are also easier for end users to build and deploy because no copy of the MySQL client libraries is needed to build the native driver components.

Table 23.1, "MySQL APIs and Interfaces" lists many of the libraries and interfaces available for MySQL. Table 23.2, "MySQL Connector Versions and MySQL Server Versions" shows which MySQL Server versions each connector supports.

Table 23.1 MySQL APIs and Interfaces

Environment	API	Type	Notes
Ada	GNU Ada MySQL Bindings	`libmysqlclient`	See MySQL Bindings for GNU Ada
C	C API	`libmysqlclient`	See Section 23.8, "MySQL C API".
C	Connector/C	Replacement for `libmysqlclient`	See MySQL Connector/C Developer Guide.
C++	Connector/C++	`libmysqlclient`	See MySQL Connector/C++ Developer Guide.
	MySQL++	`libmysqlclient`	See MySQL++ Web site.
	MySQL wrapped	`libmysqlclient`	See MySQL wrapped.
Cocoa	MySQL-Cocoa	`libmysqlclient`	Compatible with the Objective-C Cocoa environment. See http://mysql-cocoa.sourceforge.net/
D	MySQL for D	`libmysqlclient`	See MySQL for D.
Eiffel	Eiffel MySQL	`libmysqlclient`	See Section 23.14, "MySQL Eiffel Wrapper".
Erlang	`erlang-mysql-driver`	`libmysqlclient`	See `erlang-mysql-driver`.
Haskell	Haskell MySQL Bindings	Native Driver	See Brian O'Sullivan's pure Haskell MySQL bindings.
	`hsql-mysql`	`libmysqlclient`	See MySQL driver for Haskell .
Java/ JDBC	Connector/J	Native Driver	See MySQL Connector/J 5.1 Developer Guide.
Kaya	MyDB	`libmysqlclient`	See MyDB.
Lua	LuaSQL	`libmysqlclient`	See LuaSQL.
.NET/ Mono	Connector/Net	Native Driver	See MySQL Connector/Net Developer Guide.
Objective Caml	OBjective Caml MySQL Bindings	`libmysqlclient`	See MySQL Bindings for Objective Caml.
Octave	Database bindings for GNU Octave	`libmysqlclient`	See Database bindings for GNU Octave.
ODBC	Connector/ODBC	`libmysqlclient`	See MySQL Connector/ODBC Developer Guide.
Perl	`DBI`/`DBD::mysql`	`libmysqlclient`	See Section 23.10, "MySQL Perl API".
	`Net::MySQL`	Native Driver	See `Net::MySQL` at CPAN
PHP	`mysql`, `ext/mysql` interface (deprecated)	`libmysqlclient`	See Original MySQL API.

Environment	API	Type	Notes
	`mysqli`, `ext/mysqli` interface	`libmysqlclient`	See MySQL Improved Extension.
	`PDO_MYSQL`	`libmysqlclient`	See MySQL Functions (PDO_MYSQL).
	PDO mysqlnd	Native Driver	
Python	Connector/Python	Native Driver	See MySQL Connector/Python Developer Guide.
Python	Connector/Python C Extension	`libmysqlclient`	See MySQL Connector/Python Developer Guide.
	MySQLdb	`libmysqlclient`	See Section 23.11, “MySQL Python API”.
Ruby	MySQL/Ruby	`libmysqlclient`	Uses `libmysqlclient`. See Section 23.12.1, “The MySQL/Ruby API”.
	Ruby/MySQL	Native Driver	See Section 23.12.2, “The Ruby/MySQL API”.
Scheme	`Myscsh`	`libmysqlclient`	See `Myscsh`.
SPL	`sql_mysql`	`libmysqlclient`	See `sql_mysql` for SPL.
Tcl	MySQLtcl	`libmysqlclient`	See Section 23.13, “MySQL Tcl API”.

Table 23.2 MySQL Connector Versions and MySQL Server Versions

Connector	Connector version	MySQL Server version
Connector/C	6.1.0 GA	5.6, 5.5, 5.1, 5.0, 4.1
Connector/C++	1.0.5 GA	5.6, 5.5, 5.1
Connector/J	5.1.8	5.6, 5.5, 5.1, 5.0, 4.1
Connector/Net	6.9.9 GA	5.7, 5.6, 5.5, 5.1, 5.0
Connector/Net	6.8.8 GA	5.7, 5.6, 5.5, 5.1, 5.0
Connector/ODBC	5.1	5.6, 5.5, 5.1, 5.0, 4.1.1+
Connector/ODBC	3.51 (Unicode not supported)	5.6, 5.5, 5.1, 5.0, 4.1
Connector/Python	2.0	5.7, 5.6, 5.5
Connector/Python	1.2	5.7, 5.6, 5.5

23.1 MySQL Connector/C

The MySQL Connector/C manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/C Developer Guide
- Release notes: MySQL Connector/C Release Notes

23.2 MySQL Connector/C++

The MySQL Connector/C++ manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/C++ Developer Guide
- Release notes: MySQL Connector/C++ Release Notes

23.3 MySQL Connector/J

The MySQL Connector/J manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/J 5.1 Developer Guide
- Release notes: MySQL Connector/J Release Notes

23.4 MySQL Connector/Net

The MySQL Connector/Net manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/Net Developer Guide
- Release notes: MySQL Connector/Net Release Notes

23.5 MySQL Connector/ODBC

The MySQL Connector/ODBC manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/ODBC Developer Guide
- Release notes: MySQL Connector/ODBC Release Notes

23.6 MySQL Connector/Python

The MySQL Connector/Python manual is published in standalone form, not as part of the MySQL Reference Manual. For information, see these documents:

- Main manual: MySQL Connector/Python Developer Guide
- Release notes: MySQL Connector/Python Release Notes

23.7 libmysqld, the Embedded MySQL Server Library

The embedded MySQL server library makes it possible to run a full-featured MySQL server inside a client application. The main benefits are increased speed and more simple management for embedded applications.

The embedded server library is based on the client/server version of MySQL, which is written in C/C++. Consequently, the embedded server also is written in C/C++. There is no embedded server available in other languages.

The API is identical for the embedded MySQL version and the client/server version. To change an old threaded application to use the embedded library, you normally only have to add calls to the following functions.

Table 23.3 MySQL Embedded Server Library Functions

Function	When to Call
`mysql_library_init()`	Call it before any other MySQL function is called, preferably early in the `main()` function.
`mysql_library_end()`	Call it before your program exits.
`mysql_thread_init()`	Call it in each thread you create that accesses MySQL.
`mysql_thread_end()`	Call it before calling `pthread_exit()`.

Then you must link your code with `libmysqld.a` instead of `libmysqlclient.a`. To ensure binary compatibility between your application and the server library, be sure to compile your application against headers for the same series of MySQL that was used to compile the server library. For

example, if `libmysqld` was compiled against MySQL 5.1 headers, do not compile your application against MySQL 5.5 headers, or vice versa.

The `mysql_library_xxx()` functions are also included in `libmysqlclient.a` to enable you to change between the embedded and the client/server version by just linking your application with the right library. See Section 23.8.7.40, “mysql_library_init()”.

One difference between the embedded server and the standalone server is that for the embedded server, authentication for connections is disabled by default.

23.7.1 Compiling Programs with libmysqld

In precompiled binary MySQL distributions that include `libmysqld`, the embedded server library, MySQL builds the library using the appropriate vendor compiler if there is one.

To get a `libmysqld` library if you build MySQL from source yourself, you should configure MySQL with the `-DWITH_EMBEDDED_SERVER=1` option. See Section 2.9.4, “MySQL Source-Configuration Options”.

When you link your program with `libmysqld`, you must also include the system-specific `pthread` libraries and some libraries that the MySQL server uses. You can get the full list of libraries by executing `mysql_config --libmysqld-libs`.

The correct flags for compiling and linking a threaded program must be used, even if you do not directly call any thread functions in your code.

To compile a C program to include the necessary files to embed the MySQL server library into an executable version of a program, the compiler will need to know where to find various files and need instructions on how to compile the program. The following example shows how a program could be compiled from the command line, assuming that you are using `gcc`, use the GNU C compiler:

```
gcc mysql_test.c -o mysql_test \
`/usr/local/mysql/bin/mysql_config --include --libmysqld-libs`
```

Immediately following the `gcc` command is the name of the C program source file. After it, the `-o` option is given to indicate that the file name that follows is the name that the compiler is to give to the output file, the compiled program. The next line of code tells the compiler to obtain the location of the include files and libraries and other settings for the system on which it is compiled. The `mysql_config` command is contained in backticks, not single quotation marks.

On some non-`gcc` platforms, the embedded library depends on C++ runtime libraries and linking against the embedded library might result in missing-symbol errors. To solve this, link using a C++ compiler or explicitly list the required libraries on the link command line.

23.7.2 Restrictions When Using the Embedded MySQL Server

The embedded server has the following limitations:

- No user-defined functions (UDFs).
- No stack trace on core dump.
- You cannot set this up as a master or a slave (no replication).
- Very large result sets may be unusable on low memory systems.
- You cannot connect to an embedded server from an outside process with sockets or TCP/IP. However, you can connect to an intermediate application, which in turn can connect to an embedded server on the behalf of a remote client or outside process.
- `InnoDB` is not reentrant in the embedded server and cannot be used for multiple connections, either successively or simultaneously.

- The Event Scheduler is not available. Because of this, the `event_scheduler` system variable is disabled.
- The Performance Schema is not available.

Some of these limitations can be changed by editing the `mysql_embed.h` include file and recompiling MySQL.

23.7.3 Options with the Embedded Server

Any options that may be given with the `mysqld` server daemon, may be used with an embedded server library. Server options may be given in an array as an argument to the `mysql_library_init()`, which initializes the server. They also may be given in an option file like `my.cnf`. To specify an option file for a C program, use the `--defaults-file` option as one of the elements of the second argument of the `mysql_library_init()` function. See Section 23.8.7.40, “mysql_library_init()”, for more information on the `mysql_library_init()` function.

Using option files can make it easier to switch between a client/server application and one where MySQL is embedded. Put common options under the `[server]` group. These are read by both MySQL versions. Client/server-specific options should go under the `[mysqld]` section. Put options specific to the embedded MySQL server library in the `[embedded]` section. Options specific to applications go under section labeled `[ApplicationName_SERVER]`. See Section 4.2.6, “Using Option Files”.

23.7.4 Embedded Server Examples

These two example programs should work without any changes on a Linux or FreeBSD system. For other operating systems, minor changes are needed, mostly with file paths. These examples are designed to give enough details for you to understand the problem, without the clutter that is a necessary part of a real application. The first example is very straightforward. The second example is a little more advanced with some error checking. The first is followed by a command-line entry for compiling the program. The second is followed by a GNUmake file that may be used for compiling instead.

Example 1

`test1_libmysqld.c`

```
#include <stdio.h>
#include <stdlib.h>
#include <stdarg.h>
#include "mysql.h"

MYSQL *mysql;
MYSQL_RES *results;
MYSQL_ROW record;

static char *server_options[] = \
       { "mysql_test", "--defaults-file=my.cnf", NULL };
int num_elements = (sizeof(server_options) / sizeof(char *)) - 1;

static char *server_groups[] = { "libmysqld_server",
                                 "libmysqld_client", NULL };

int main(void)
{
   mysql_library_init(num_elements, server_options, server_groups);
   mysql = mysql_init(NULL);
   mysql_options(mysql, MYSQL_READ_DEFAULT_GROUP, "libmysqld_client");
   mysql_options(mysql, MYSQL_OPT_USE_EMBEDDED_CONNECTION, NULL);

   mysql_real_connect(mysql, NULL,NULL,NULL, "database1", 0,NULL,0);

   mysql_query(mysql, "SELECT column1, column2 FROM table1");
```

```
   results = mysql_store_result(mysql);

   while((record = mysql_fetch_row(results))) {
      printf("%s - %s \n", record[0], record[1]);
   }

   mysql_free_result(results);
   mysql_close(mysql);
   mysql_library_end();

   return 0;
}
```

Here is the command line for compiling the above program:

```
gcc test1_libmysqld.c -o test1_libmysqld \
 `/usr/local/mysql/bin/mysql_config --include --libmysqld-libs`
```

Example 2

To try the example, create an `test2_libmysqld` directory at the same level as the MySQL source directory. Save the `test2_libmysqld.c` source and the `GNUmakefile` in the directory, and run GNU `make` from inside the `test2_libmysqld` directory.

`test2_libmysqld.c`

```
/*
 * A simple example client, using the embedded MySQL server library
*/

#include <mysql.h>
#include <stdarg.h>
#include <stdio.h>
#include <stdlib.h>

MYSQL *db_connect(const char *dbname);
void db_disconnect(MYSQL *db);
void db_do_query(MYSQL *db, const char *query);

const char *server_groups[] = {
  "test2_libmysqld_SERVER", "embedded", "server", NULL
};

int
main(int argc, char **argv)
{
  MYSQL *one, *two;

  /* mysql_library_init() must be called before any other mysql
   * functions.
   *
   * You can use mysql_library_init(0, NULL, NULL), and it
   * initializes the server using groups = {
   *   "server", "embedded", NULL
   *  }.
   *
   * In your $HOME/.my.cnf file, you probably want to put:

[test2_libmysqld_SERVER]
language = /path/to/source/of/mysql/sql/share/english

   * You could, of course, modify argc and argv before passing
   * them to this function.  Or you could create new ones in any
   * way you like.  But all of the arguments in argv (except for
   * argv[0], which is the program name) should be valid options
   * for the MySQL server.
   *
   * If you link this client against the normal mysqlclient
   * library, this function is just a stub that does nothing.
   */
```

```
  mysql_library_init(argc, argv, (char **)server_groups);

  one = db_connect("test");
  two = db_connect(NULL);

  db_do_query(one, "SHOW TABLE STATUS");
  db_do_query(two, "SHOW DATABASES");

  mysql_close(two);
  mysql_close(one);

  /* This must be called after all other mysql functions */
  mysql_library_end();

  exit(EXIT_SUCCESS);
}

static void
die(MYSQL *db, char *fmt, ...)
{
  va_list ap;
  va_start(ap, fmt);
  vfprintf(stderr, fmt, ap);
  va_end(ap);
  (void)putc('\n', stderr);
  if (db)
    db_disconnect(db);
  exit(EXIT_FAILURE);
}

MYSQL *
db_connect(const char *dbname)
{
  MYSQL *db = mysql_init(NULL);
  if (!db)
    die(db, "mysql_init failed: no memory");
  /*
   * Notice that the client and server use separate group names.
   * This is critical, because the server does not accept the
   * client's options, and vice versa.
   */
  mysql_options(db, MYSQL_READ_DEFAULT_GROUP, "test2_libmysqld_CLIENT");
  if (!mysql_real_connect(db, NULL, NULL, NULL, dbname, 0, NULL, 0))
    die(db, "mysql_real_connect failed: %s", mysql_error(db));

  return db;
}

void
db_disconnect(MYSQL *db)
{
  mysql_close(db);
}

void
db_do_query(MYSQL *db, const char *query)
{
  if (mysql_query(db, query) != 0)
    goto err;

  if (mysql_field_count(db) > 0)
  {
    MYSQL_RES   *res;
    MYSQL_ROW    row, end_row;
    int num_fields;

    if (!(res = mysql_store_result(db)))
      goto err;
    num_fields = mysql_num_fields(res);
    while ((row = mysql_fetch_row(res)))
    {
      (void)fputs(">> ", stdout);
```

```
      for (end_row = row + num_fields; row < end_row; ++row)
        (void)printf("%s\t", row ? (char*)*row : "NULL");
      (void)fputc('\n', stdout);
    }
    (void)fputc('\n', stdout);
    mysql_free_result(res);
  }
  else
    (void)printf("Affected rows: %lld\n", mysql_affected_rows(db));

  return;

err:
  die(db, "db_do_query failed: %s [%s]", mysql_error(db), query);
}
```

`GNUmakefile`

```
# This assumes the MySQL software is installed in /usr/local/mysql
inc      := /usr/local/mysql/include/mysql
lib      := /usr/local/mysql/lib

# If you have not installed the MySQL software yet, try this instead
#inc      := $(HOME)/mysql-5.5/include
#lib      := $(HOME)/mysql-5.5/libmysqld

CC       := gcc
CPPFLAGS := -I$(inc) -D_THREAD_SAFE -D_REENTRANT
CFLAGS   := -g -W -Wall
LDFLAGS  := -static
# You can change -lmysqld to -lmysqlclient to use the
# client/server library
LDLIBS    = -L$(lib) -lmysqld -lm -ldl -lcrypt

ifneq (,$(shell grep FreeBSD /COPYRIGHT 2>/dev/null))
# FreeBSD
LDFLAGS += -pthread
else
# Assume Linux
LDLIBS += -lpthread
endif

# This works for simple one-file test programs
sources := $(wildcard *.c)
objects := $(patsubst %c,%o,$(sources))
targets := $(basename $(sources))

all: $(targets)

clean:
        rm -f $(targets) $(objects) *.core
```

23.8 MySQL C API

The C API provides low-level access to the MySQL client/server protocol and enables C programs to access database contents. The C API code is distributed with MySQL and implemented in the `libmysqlclient` library. See Section 23.8.1, “MySQL C API Implementations”.

Most other client APIs use the `libmysqlclient` library to communicate with the MySQL server. (Exceptions are Connector/J and Connector/Net.) This means that, for example, you can take advantage of many of the same environment variables that are used by other client programs because they are referenced from the library. For a list of these variables, see Section 4.1, “Overview of MySQL Programs”.

For instructions on building client programs using the C API, see Section 23.8.4.1, “Building C API Client Programs”. For programming with threads, see Section 23.8.4.2, “Writing C API Threaded Client Programs”. To create a standalone application which includes the "server" and "client" in the same

program (and does not communicate with an external MySQL server), see Section 23.7, “libmysqld, the Embedded MySQL Server Library”.

Note

If, after an upgrade, you experience problems with compiled client programs, such as `Commands out of sync` or unexpected core dumps, the programs were probably compiled using old header or library files. In this case, check the date of the `mysql.h` file and `libmysqlclient.a` library used for compilation to verify that they are from the new MySQL distribution. If not, recompile the programs with the new headers and libraries. Recompilation might also be necessary for programs compiled against the shared client library if the library major version number has changed (for example, from `libmysqlclient.so.17` to `libmysqlclient.so.18`). For additional compatibility information, see Section 23.8.4.3, “Running C API Client Programs”.

Clients have a maximum communication buffer size. The size of the buffer that is allocated initially (16KB) is automatically increased up to the maximum size (16MB by default). Because buffer sizes are increased only as demand warrants, simply increasing the maximum limit does not in itself cause more resources to be used. This size check is mostly a precaution against erroneous statements and communication packets.

The communication buffer must be large enough to contain a single SQL statement (for client-to-server traffic) and one row of returned data (for server-to-client traffic). Each session's communication buffer is dynamically enlarged to handle any query or row up to the maximum limit. For example, if you have `BLOB` values that contain up to 16MB of data, you must have a communication buffer limit of at least 16MB (in both server and client). The default maximum built into the client library is 1GB, but the default maximum in the server is 1MB. You can increase this by changing the value of the `max_allowed_packet` parameter at server startup. See Section 5.1.1, “Configuring the Server”.

The MySQL server shrinks each communication buffer to `net_buffer_length` bytes after each query. For clients, the size of the buffer associated with a connection is not decreased until the connection is closed, at which time client memory is reclaimed.

23.8.1 MySQL C API Implementations

The MySQL C API is a C-based API that client applications written in C can use to communicate with MySQL Server. Client programs refer to C API header files at compile time and link to a C API library file at link time. The library comes in two versions, depending on how the application is intended to communicate with the server:

- `libmysqlclient`: The client version of the library, used for applications that communicate over a network connection as a client of a standalone server process.
- `libmysqld`: The embedded server version of the library, used for applications intended to include an embedded MySQL server within the application itself. The application communicates with its own private server instance.

Both libraries have the same interface. In terms of C API calls, an application communicates with a standalone server the same way it communicates with an embedded server. A given client can be built to communicate with a standalone or embedded server, depending on whether it is linked against `libmysqlclient` or `libmysqld` at build time.

There are two ways to obtain the C API header and library files required to build C API client programs:

- Install a MySQL Server distribution. Server distributions include both `libmysqlclient` and `libmysqld`.
- Install a Connector/C distribution. Connector/C distributions include only `libmysqlclient`. They do not include `libmysqld`.

For both MySQL Server and Connector/C, you can install a binary distribution that contains the C API files pre-built, or you can use a source distribution and build the C API files yourself.

Normally, you install either a MySQL Server distribution or a Connector/C distribution, but not both. For information about issues involved with simultaneous MySQL Server and Connector/C installations, see Section 23.8.2, “Simultaneous MySQL Server and Connector/C Installations”.

The names of the library files to use when linking C API client applications depend on the library type and platform for which a distribution is built:

- On Unix (and Unix-like) sytems, the static library is `libmysqlclient.a`. The dynamic library is `libmysqlclient.so` on most Unix systems and `libmysqlclient.dylib` on OS X.

  For distributions that include embedded server libraries, the corresponding library names begin with `libmysqld` rather than `libmysqlclient`.

- On Windows, the static library is `mysqlclient.lib` and the dynamic library is `libmysql.dll`. Windows distributions also include `libmysql.lib`, a static import library needed for using the dynamic library.

  For distributions that include embedded server libraries, the corresponding library names are `mysqlserver.lib`, `libmysqld.dll`, and `libmysqld.lib`.

  Windows distributions also include a set of debug libraries. These have the same names as the nondebug libraries, but are located in the `lib/debug` library. You must use the debug libraries when compiling clients built using the debug C runtime.

On Unix, you may also see libraries that include `_r` in the names. Before MySQL 5.5, these were built as thread-safe (re-entrant) libraries separately from the non-`_r` libraries. As of 5.5, both libraries are the same and the `_r` names are symbolic links to the corresponding non-`_r` names. There is no need to use the `_r` libraries. For example, if you use `mysql_config` to obtain linker flags, you can use `mysql_config --libs` in all cases, even for threaded clients. There is no need to use `mysql_config --libs_r`.

23.8.2 Simultaneous MySQL Server and Connector/C Installations

MySQL Server and Connector/C installation packages both provide the files needed to build and run MySQL C API client programs. This section discusses when it is possible to install both products on the same system. For some packaging formats, this is possible without conflict. For others, both products cannot be installed at the same time.

This discussion assumes the use of similar package types for both products (for example, RPM packages for both products). It does not try to describe coexistence between packaging types (for example, use of RPM packages for one product and a `tar` file package for the other). Nor does it describe coexistence of packages provided by Oracle and those provided by third-party vendors.

If you install both products, it may be necessary to adjust your development tools or runtime environment to choose one set of header files and libraries over the other. See Section 23.8.4.1, “Building C API Client Programs”, and Section 23.8.4.3, “Running C API Client Programs”.

`tar` and Zip file packages install under the directory into which you unpack them. For example, you can unpack MySQL Server and Connector/C `tar` packages under `/usr/local` and they will unpack into distinct directory names without conflict.

Windows MSI installers use their own installation directory, so MySQL Server and Connector/C installers do not conflict.

OS X DMG packages install under the same parent directory but in a different subdirectory, so there is no conflict. For example:

```
/usr/local/mysql-5.6.11-osx10.7-x86_64/
```

```
/usr/local/mysql-connector-c-6.1.0-osx10.7-x86/
```

Solaris PKG packages install under the same parent directory but in a different subdirectory, so there is no conflict. For example:

```
/opt/mysql/mysql
/opt/mysql/connector-c
```

The Solaris Connector/C installer does not create any symlinks from system directories such as `/usr/bin` or `/usr/lib` into the installation directory. That must be done manually if desired after installation.

For RPM installations, there are several types of RPM packages. MySQL Server `shared` and `devel` RPM packages are similar to the corresponding Connector/C RPM packages. These RPM package types cannot coexist because the MySQL Server and Connector/C RPM packages use the same installation locations for the client library-related files. This means the following conditions hold:

- If MySQL Server `shared` and `devel` RPM packages are installed, they provide the C API headers and libraries, and there is no need to install the Connector/C RPM packages. To install the Connector/C packages anyway, you must first remove the corresponding MySQL Server packages.
- To install MySQL Server RPM packages if you already have Connector/C RPM packages installed, you must first remove the Connector/C RPM packages.

MySQL Server RPM packages other than `shared` and `devel` do not conflict with Connector/C packages and can be installed if Connector/C is installed. This includes the main server RPM that includes the `mysqld` server itself.

23.8.3 Example C API Client Programs

Many of the clients in MySQL source distributions are written in C, such as `mysql`, `mysqladmin`, and `mysqlshow`. If you are looking for examples that demonstrate how to use the C API, take a look at these clients: Obtain a source distribution and look in its `client` directory. See Section 2.1.2, “How to Get MySQL”.

23.8.4 Building and Running C API Client Programs

The following sections provide information on building client programs that use the C API. Topics include compiling and linking clients, writing threaded clients, and troubleshooting runtime problems.

23.8.4.1 Building C API Client Programs

This section provides guidelines for compiling C programs that use the MySQL C API.

Compiling MySQL Clients on Unix

The examples here use `gcc` as the compiler. A different compiler might be appropriate on some systems (for example, `clang` on OS X or FreeBSD, or Sun Studio on Solaris). Adjust the examples as necessary.

You may need to specify an `-I` option when you compile client programs that use MySQL header files, so that the compiler can find them. For example, if the header files are installed in `/usr/local/mysql/include`, use this option in the compile command:

```
-I/usr/local/mysql/include
```

MySQL clients must be linked using the `-lmysqlclient` option in the link command. You may also need to specify a `-L` option to tell the linker where to find the library. For example, if the library is installed in `/usr/local/mysql/lib`, use these options in the link command:

```
-L/usr/local/mysql/lib -lmysqlclient
```

The path names may differ on your system. Adjust the `-I` and `-L` options as necessary.

To make it simpler to compile MySQL programs on Unix, use the `mysql_config` script. See Section 4.7.2, “`mysql_config` — Display Options for Compiling Clients”.

`mysql_config` displays the options needed for compiling or linking:

```
shell> mysql_config --cflags
shell> mysql_config --libs
```

You can run those commands to get the proper options and add them manually to compilation or link commands. Alternatively, include the output from `mysql_config` directly within command lines using backticks:

```
shell> gcc -c `mysql_config --cflags` progname.c
shell> gcc -o progname progname.o `mysql_config --libs`
```

On Unix, linking uses dynamic libraries by default. To link to the static client library instead, add its path name to the link command. For example, if the library is located in `/usr/local/mysql/lib`, link like this:

```
shell> gcc -o progname progname.o /usr/local/mysql/lib/libmysqlclient.a
```

Or use `mysql_config` to provide the library name:

```
shell> gcc -o progname progname.o `mysql_config --variable=pkglibdir`/libmysqlclient.a
```

`mysql_config` does not currently provide a way to list all libraries needed for static linking, so it might be necessary to name additional libraries on the link command (for example, `-lnsl -lsocket` on Solaris). To get an idea which libraries to add, use `mysql_config --libs` and `ldd libmysqlclient.so` (or `otool -L libmysqlclient.dylib` on OS X).

Compiling MySQL Clients on Microsoft Windows

To specify header and library file locations, use the facilities provided by your development environment.

To build C API clients on Windows, you must link in the C client library, as well as the Windows ws2_32 sockets library and Secur32 security library.

You link your code with either the dynamic or static C client library. On Windows, the static library is named `mysqlclient.lib` and the dynamic library is named `libmysql.dll`. In addition, the `libmysql.lib` static import library is needed for using the dynamic library. If the static C client library is used, the client application must be compiled with the same version of Visual Studio used to compile the C client library (which is Visual Studio 2008 for the static C client library built by Oracle).

Note

The MySQL Connector/C is a standalone, drop-in replacement of the MySQL C client libraries that come with the MySQL server distribution. The Oracle-built MySQL Connector/C contains currently two versions of the static client library, one built with Visual Studio 2013 and the other one with Visual Studio 2015; use the one that matches the Visual Studio version you use to compile your application.

When using the Oracle-built MySQL C client library (or MySQL Connector/C), following these rules when it comes to linking the C runtime for your client application:

- For the Community version of the MySQL C client library (or the Community version of MySQL Connector/C):

- *For version 5.5.54 and before* (or MySQL Connector/C Community 6.1.9 and before):
  - If linking to the static C client library, link statically to the C runtime (use the `/MT` compiler option).
  - If linking to the dynamic C client library, link either statically or dynamically to the C runtime (use either `/MT` or `/MD` compiler option).
- *For version 5.5.55 and later* (or MySQL Connector/C Community 6.1.10 and later): Always link dynamically to the C runtime (use the `/MD` compiler option), whether you are linking to the static or dynamic C client library. Also, target hosts running the client application need to have the Visual C++ Redistributable for Visual Studio 2008 installed if you are using the C client libraries, or the Visual C++ Redistributable for Visual Studio 2015 installed if you are using MySQL Connector/C. The redistributable packages are available at the Microsoft Download Center.

- For the Commercial version of the MySQL C client library (or the Commercial version of MySQL Connector/C):
  - If linking to the static C client library, link statically to the C runtime (use the `/MT` compiler option).
  - If linking to the dynamic C client library, link either statically or dynamically to the C runtime (use either `/MT` or `/MD` compiler option).

In general, when linking to a static MySQL C client library, the client library and the client application must use the same compiler option when it comes to linking the C runtime—that is, if your C client library is compiled with the `/MT` option, your client application should also be compiled with the `/MT` option, and so on (see the MSDN page describing the C library linking options for more details). Follow this rule when you are building your own static MySQL C client library (or MySQL Connector/C) from source and linking you client application to it.

Note

Debug Mode: Because of the above-mentioned rule, you cannot build your application in debug mode (with the `/MTd` or `/MDd` compiler option) and link it to the static C client library built by Oracle, which is *not* built with the debug options; instead, you will have to build the static client library from source with the debug options.

Troubleshooting Problems Linking to the MySQL Client Library

If the linker cannot find the MySQL client library, you might get undefined-reference errors for symbols that start with `mysql_`, such as those shown here:

```
/tmp/ccFKsdPa.o: In function `main':
/tmp/ccFKsdPa.o(.text+0xb): undefined reference to `mysql_init'
/tmp/ccFKsdPa.o(.text+0x31): undefined reference to `mysql_real_connect'
/tmp/ccFKsdPa.o(.text+0x69): undefined reference to `mysql_error'
/tmp/ccFKsdPa.o(.text+0x9a): undefined reference to `mysql_close'
```

You should be able to solve this problem by adding `-L`*`dir_path`* `-lmysqlclient` at the end of your link command, where *`dir_path`* represents the path name of the directory where the client library is located. To determine the correct directory, try this command:

```
shell> mysql_config --libs
```

The output from `mysql_config` might indicate other libraries that should be specified on the link command as well. You can include `mysql_config` output directly in your compile or link command using backticks. For example:

```
shell> gcc -o progname progname.o `mysql_config --libs`
```

If an error occurs at link time that the `floor` symbol is undefined, link to the math library by adding `-lm` to the end of the compile/link line. Similarly, if you get undefined-reference errors for other functions that should exist on your system, such as `connect()`, check the manual page for the function in question to determine which libraries you should add to the link command.

If you get undefined-reference errors such as the following for functions that do not exist on your system, it usually means that your MySQL client library was compiled on a system that is not 100% compatible with yours:

```
mf_format.o(.text+0x201): undefined reference to `__lxstat'
```

In this case, you should download the latest MySQL or Connector/C source distribution and compile the MySQL client library yourself. See Section 2.9, “Installing MySQL from Source”, and MySQL Connector/C Developer Guide.

23.8.4.2 Writing C API Threaded Client Programs

The client library is almost thread-safe. The biggest problem is that the subroutines in `sql/net_serv.cc` that read from sockets are not interrupt-safe. This was done with the thought that you might want to have your own alarm that can break a long read to a server. If you install interrupt handlers for the `SIGPIPE` interrupt, socket handling should be thread-safe.

To avoid aborting the program when a connection terminates, MySQL blocks `SIGPIPE` on the first call to `mysql_library_init()`, `mysql_init()`, or `mysql_connect()`. To use your own `SIGPIPE` handler, first call `mysql_library_init()`, then install your handler.

If “undefined symbol” errors occur when linking against the `libmysqlclient` client library, in most cases this is because you have not included the thread libraries on the link/compile command.

The client library is thread-safe per connection. You can let two threads share the same connection with the following caveats:

- Multiple threads cannot send a query to the MySQL server at the same time on the same connection. In particular, you must ensure that between calls to `mysql_query()` and `mysql_store_result()` in one thread, no other thread uses the same connection. You must have a mutex lock around your pair of `mysql_query()` and `mysql_store_result()` calls. After `mysql_store_result()` returns, the lock can be released and other threads may query the same connection.

  If you use POSIX threads, you can use `pthread_mutex_lock()` and `pthread_mutex_unlock()` to establish and release a mutex lock.

- Many threads can access different result sets that are retrieved with `mysql_store_result()`.

- To use `mysql_use_result()`, you must ensure that no other thread is using the same connection until the result set is closed. However, it really is best for threaded clients that share the same connection to use `mysql_store_result()`.

You need to know the following if you have a thread that did not create the connection to the MySQL database but is calling MySQL functions:

When you call `mysql_init()`, MySQL creates a thread-specific variable for the thread that is used by the debug library (among other things). If you call a MySQL function before the thread has called `mysql_init()`, the thread does not have the necessary thread-specific variables in place and you are likely to end up with a core dump sooner or later. To avoid problems, you must do the following:

1. Call `mysql_library_init()` before any other MySQL functions. It is not thread-safe, so call it before threads are created, or protect the call with a mutex.

2. Arrange for `mysql_thread_init()` to be called early in the thread handler before calling any MySQL function. If you call `mysql_init()`, it will call `mysql_thread_init()` for you.

3. In the thread, call `mysql_thread_end()` before calling `pthread_exit()`. This frees the memory used by MySQL thread-specific variables.

The preceding notes regarding `mysql_init()` also apply to `mysql_connect()`, which calls `mysql_init()`.

23.8.4.3 Running C API Client Programs

If, after an upgrade, you experience problems with compiled client programs, such as `Commands out of sync` or unexpected core dumps, the programs were probably compiled using old header or library files. In this case, check the date of the `mysql.h` file and `libmysqlclient.a` library used for compilation to verify that they are from the new MySQL distribution. If not, recompile the programs with the new headers and libraries. Recompilation might also be necessary for programs compiled against the shared client library if the library major version number has changed (for example, from `libmysqlclient.so.17` to `libmysqlclient.so.18`).

The major client library version determines compatibility. (For example, for `libmysqlclient.so.18.1.0`, the major version is 18.) For this reason, the libraries shipped with newer versions of MySQL are drop-in replacements for older versions that have the same major number. As long as the major library version is the same, you can upgrade the library and old applications should continue to work with it.

Undefined-reference errors might occur at runtime when you try to execute a MySQL program. If these errors specify symbols that start with `mysql_` or indicate that the `libmysqlclient` library cannot be found, it means that your system cannot find the shared `libmysqlclient.so` library. The solution to this problem is to tell your system to search for shared libraries in the directory where that library is located. Use whichever of the following methods is appropriate for your system:

- Add the path of the directory where `libmysqlclient.so` is located to the `LD_LIBRARY_PATH` or `LD_LIBRARY` environment variable.
- On OS X, add the path of the directory where `libmysqlclient.dylib` is located to the `DYLD_LIBRARY_PATH` environment variable.
- Copy the shared-library files (such as `libmysqlclient.so`) to some directory that is searched by your system, such as `/lib`, and update the shared library information by executing `ldconfig`. Be sure to copy all related files. A shared library might exist under several names, using symlinks to provide the alternate names.

If the application is linked to the embedded server library, runtime error messages will indicate the `libmysqld` rather than `libmysqlclient` library, but the solution to the problem is the same as just described.

23.8.4.4 C API Server and Client Library Versions

The string and numeric forms of the MySQL server version are available at compile time as the values of the `MYSQL_SERVER_VERSION` and `MYSQL_VERSION_ID` macros, and at runtime as the values of the `mysql_get_server_info()` and `mysql_get_server_version()` functions.

The client library version is the MySQL version. For Connector/C, this is the MySQL version on which the Connector/C distribution is based. The string and numeric forms of this version are available at compile time as the values of the `MYSQL_SERVER_VERSION` and `MYSQL_VERSION_ID` macros, and at runtime as the values of the `mysql_get_client_info()` and `mysql_get_client_version()` functions.

23.8.5 C API Data Structures

This section describes C API data structures other than those used for prepared statements. For information about the latter, see Section 23.8.9, “C API Prepared Statement Data Structures”.

- `MYSQL`

This structure represents handler for one database connection. It is used for almost all MySQL functions. Do not try to make a copy of a `MYSQL` structure. There is no guarantee that such a copy will be usable.

- `MYSQL_RES`

  This structure represents the result of a query that returns rows (`SELECT`, `SHOW`, `DESCRIBE`, `EXPLAIN`). The information returned from a query is called the *result set* in the remainder of this section.

- `MYSQL_ROW`

  This is a type-safe representation of one row of data. It is currently implemented as an array of counted byte strings. (You cannot treat these as null-terminated strings if field values may contain binary data, because such values may contain null bytes internally.) Rows are obtained by calling `mysql_fetch_row()`.

- `MYSQL_FIELD`

  This structure contains metadata: information about a field, such as the field's name, type, and size. Its members are described in more detail later in this section. You may obtain the `MYSQL_FIELD` structures for each field by calling `mysql_fetch_field()` repeatedly. Field values are not part of this structure; they are contained in a `MYSQL_ROW` structure.

- `MYSQL_FIELD_OFFSET`

  This is a type-safe representation of an offset into a MySQL field list. (Used by `mysql_field_seek()`.) Offsets are field numbers within a row, beginning at zero.

- `my_ulonglong`

  The type used for the number of rows and for `mysql_affected_rows()`, `mysql_num_rows()`, and `mysql_insert_id()`. This type provides a range of `0` to `1.84e19`.

  Some functions that return a row count using this type return -1 as an unsigned value to indicate an error or exceptional condition. You can check for -1 by comparing the return value to `(my_ulonglong)-1` (or to `(my_ulonglong)~0`, which is equivalent).

  On some systems, attempting to print a value of type `my_ulonglong` does not work. To print such a value, convert it to `unsigned long` and use a `%lu` print format. Example:

```
printf ("Number of rows: %lu\n",
        (unsigned long) mysql_num_rows(result));
```

- `my_bool`

  A boolean type, for values that are true (nonzero) or false (zero).

The `MYSQL_FIELD` structure contains the members described in the following list. The definitions apply primarily for columns of result sets such as those produced by `SELECT` statements. `MYSQL_FIELD` structures are also used to provide metadata for `OUT` and `INOUT` parameters returned from stored procedures executed using prepared `CALL` statements. For such parameters, some of the structure members have a meaning different from the meaning for column values.

- `char * name`

  The name of the field, as a null-terminated string. If the field was given an alias with an `AS` clause, the value of `name` is the alias. For a procedure parameter, the parameter name.

- `char * org_name`

The name of the field, as a null-terminated string. Aliases are ignored. For expressions, the value is an empty string. For a procedure parameter, the parameter name.

- `char * table`

  The name of the table containing this field, if it is not a calculated field. For calculated fields, the `table` value is an empty string. If the column is selected from a view, `table` names the view. If the table or view was given an alias with an `AS` clause, the value of `table` is the alias. For a `UNION`, the value is the empty string. For a procedure parameter, the procedure name.

- `char * org_table`

  The name of the table, as a null-terminated string. Aliases are ignored. If the column is selected from a view, `org_table` names the view. For a `UNION`, the value is the empty string. For a procedure parameter, the procedure name.

- `char * db`

  The name of the database that the field comes from, as a null-terminated string. If the field is a calculated field, `db` is an empty string. For a `UNION`, the value is the empty string. For a procedure parameter, the name of the database containing the procedure.

- `char * catalog`

  The catalog name. This value is always `"def"`.

- `char * def`

  The default value of this field, as a null-terminated string. This is set only if you use `mysql_list_fields()`.

- `unsigned long length`

  The width of the field. This corresponds to the display length, in bytes.

  The server determines the `length` value before it generates the result set, so this is the minimum length required for a data type capable of holding the largest possible value from the result column, without knowing in advance the actual values that will be produced by the query for the result set.

- `unsigned long max_length`

  The maximum width of the field for the result set (the length in bytes of the longest field value for the rows actually in the result set). If you use `mysql_store_result()` or `mysql_list_fields()`, this contains the maximum length for the field. If you use `mysql_use_result()`, the value of this variable is zero.

  The value of `max_length` is the length of the string representation of the values in the result set. For example, if you retrieve a `FLOAT` column and the “widest” value is `-12.345`, `max_length` is 7 (the length of `'-12.345'`).

  If you are using prepared statements, `max_length` is not set by default because for the binary protocol the lengths of the values depend on the types of the values in the result set. (See Section 23.8.9, “C API Prepared Statement Data Structures”.) If you want the `max_length` values anyway, enable the `STMT_ATTR_UPDATE_MAX_LENGTH` option with `mysql_stmt_attr_set()` and the lengths will be set when you call `mysql_stmt_store_result()`. (See Section 23.8.11.3, “mysql_stmt_attr_set()”, and Section 23.8.11.28, “mysql_stmt_store_result()”.)

- `unsigned int name_length`

  The length of `name`.

- `unsigned int org_name_length`

The length of `org_name`.

- `unsigned int table_length`

  The length of `table`.

- `unsigned int org_table_length`

  The length of `org_table`.

- `unsigned int db_length`

  The length of `db`.

- `unsigned int catalog_length`

  The length of `catalog`.

- `unsigned int def_length`

  The length of `def`.

- `unsigned int flags`

  Bit-flags that describe the field. The `flags` value may have zero or more of the bits set that are shown in the following table.

Flag Value	Flag Description
`NOT_NULL_FLAG`	Field cannot be `NULL`
`PRI_KEY_FLAG`	Field is part of a primary key
`UNIQUE_KEY_FLAG`	Field is part of a unique key
`MULTIPLE_KEY_FLAG`	Field is part of a nonunique key
`UNSIGNED_FLAG`	Field has the `UNSIGNED` attribute
`ZEROFILL_FLAG`	Field has the `ZEROFILL` attribute
`BINARY_FLAG`	Field has the `BINARY` attribute
`AUTO_INCREMENT_FLAG`	Field has the `AUTO_INCREMENT` attribute
`ENUM_FLAG`	Field is an `ENUM`
`SET_FLAG`	Field is a `SET`
`BLOB_FLAG`	Field is a `BLOB` or `TEXT` (deprecated)
`TIMESTAMP_FLAG`	Field is a `TIMESTAMP` (deprecated)
`NUM_FLAG`	Field is numeric; see additional notes following table
`NO_DEFAULT_VALUE_FLAG`	Field has no default value; see additional notes following table

Some of these flags indicate data type information and are superseded by or used in conjunction with the `MYSQL_TYPE_`*`xxx`* value in the `field->type` member described later:

- To check for `BLOB` or `TIMESTAMP` values, check whether `type` is `MYSQL_TYPE_BLOB` or `MYSQL_TYPE_TIMESTAMP`. (The `BLOB_FLAG` and `TIMESTAMP_FLAG` flags are unneeded.)
- `ENUM` and `SET` values are returned as strings. For these, check that the `type` value is `MYSQL_TYPE_STRING` and that the `ENUM_FLAG` or `SET_FLAG` flag is set in the `flags` value.

`NUM_FLAG` indicates that a column is numeric. This includes columns with a type of `MYSQL_TYPE_DECIMAL`, `MYSQL_TYPE_NEWDECIMAL`, `MYSQL_TYPE_TINY`, `MYSQL_TYPE_SHORT`,

MYSQL_TYPE_LONG, MYSQL_TYPE_FLOAT, MYSQL_TYPE_DOUBLE, MYSQL_TYPE_NULL, MYSQL_TYPE_LONGLONG, MYSQL_TYPE_INT24, and MYSQL_TYPE_YEAR.

NO_DEFAULT_VALUE_FLAG indicates that a column has no DEFAULT clause in its definition. This does not apply to NULL columns (because such columns have a default of NULL), or to AUTO_INCREMENT columns (which have an implied default value).

The following example illustrates a typical use of the flags value:

```
if (field->flags & NOT_NULL_FLAG)
    printf("Field cannot be null\n");
```

You may use the convenience macros shown in the following table to determine the boolean status of the flags value.

Flag Status	Description
IS_NOT_NULL(flags)	True if this field is defined as NOT NULL
IS_PRI_KEY(flags)	True if this field is a primary key
IS_BLOB(flags)	True if this field is a BLOB or TEXT (deprecated; test field->type instead)

- unsigned int decimals

  The number of decimals for numeric fields.

- unsigned int charsetnr

  An ID number that indicates the character set/collation pair for the field.

  Normally, character values in result sets are converted to the character set indicated by the character_set_results system variable. In this case, charsetnr corresponds to the character set indicated by that variable. Character set conversion can be suppressed by setting character_set_results to NULL. In this case, charsetnr corresponds to the character set of the original table column or expression. See also Section 10.1.4, “Connection Character Sets and Collations”.

  To distinguish between binary and nonbinary data for string data types, check whether the charsetnr value is 63. If so, the character set is binary, which indicates binary rather than nonbinary data. This enables you to distinguish BINARY from CHAR, VARBINARY from VARCHAR, and the BLOB types from the TEXT types.

  charsetnr values are the same as those displayed in the Id column of the SHOW COLLATION statement or the ID column of the INFORMATION_SCHEMA COLLATIONS table. You can use those information sources to see which character set and collation specific charsetnr values indicate:

```
mysql> SHOW COLLATION WHERE Id = 63;
+----------+---------+----+---------+----------+---------+
| Collation | Charset | Id | Default | Compiled | Sortlen |
+----------+---------+----+---------+----------+---------+
| binary    | binary  | 63 | Yes     | Yes      |       1 |
+----------+---------+----+---------+----------+---------+

mysql> SELECT COLLATION_NAME, CHARACTER_SET_NAME
    -> FROM INFORMATION_SCHEMA.COLLATIONS WHERE ID = 33;
+----------------+--------------------+
| COLLATION_NAME  | CHARACTER_SET_NAME |
+----------------+--------------------+
| utf8_general_ci | utf8               |
+----------------+--------------------+
```

- enum enum_field_types type

The type of the field. The `type` value may be one of the `MYSQL_TYPE_` symbols shown in the following table.

Type Value	Type Description
`MYSQL_TYPE_TINY`	`TINYINT` field
`MYSQL_TYPE_SHORT`	`SMALLINT` field
`MYSQL_TYPE_LONG`	`INTEGER` field
`MYSQL_TYPE_INT24`	`MEDIUMINT` field
`MYSQL_TYPE_LONGLONG`	`BIGINT` field
`MYSQL_TYPE_DECIMAL`	`DECIMAL` or `NUMERIC` field
`MYSQL_TYPE_NEWDECIMAL`	Precision math `DECIMAL` or `NUMERIC`
`MYSQL_TYPE_FLOAT`	`FLOAT` field
`MYSQL_TYPE_DOUBLE`	`DOUBLE` or `REAL` field
`MYSQL_TYPE_BIT`	`BIT` field
`MYSQL_TYPE_TIMESTAMP`	`TIMESTAMP` field
`MYSQL_TYPE_DATE`	`DATE` field
`MYSQL_TYPE_TIME`	`TIME` field
`MYSQL_TYPE_DATETIME`	`DATETIME` field
`MYSQL_TYPE_YEAR`	`YEAR` field
`MYSQL_TYPE_STRING`	`CHAR` or `BINARY` field
`MYSQL_TYPE_VAR_STRING`	`VARCHAR` or `VARBINARY` field
`MYSQL_TYPE_BLOB`	`BLOB` or `TEXT` field (use `max_length` to determine the maximum length)
`MYSQL_TYPE_SET`	`SET` field
`MYSQL_TYPE_ENUM`	`ENUM` field
`MYSQL_TYPE_GEOMETRY`	Spatial field
`MYSQL_TYPE_NULL`	`NULL`-type field

You can use the `IS_NUM()` macro to test whether a field has a numeric type. Pass the `type` value to `IS_NUM()` and it evaluates to TRUE if the field is numeric:

```
if (IS_NUM(field->type))
    printf("Field is numeric\n");
```

`ENUM` and `SET` values are returned as strings. For these, check that the `type` value is `MYSQL_TYPE_STRING` and that the `ENUM_FLAG` or `SET_FLAG` flag is set in the `flags` value.

23.8.6 C API Function Overview

The following table summarizes the functions available in the C API. For greater detail, see the descriptions in Section 23.8.7, “C API Function Descriptions”.

Table 23.4 C API Function Names and Descriptions

Function	Description
`my_init()`	Initialize global variables, and thread handler in thread-safe programs
`mysql_affected_rows()`	Returns the number of rows changed/deleted/inserted by the last `UPDATE`, `DELETE`, or `INSERT` query

Function	Description
mysql_autocommit()	Toggles autocommit mode on/off
mysql_change_user()	Changes user and database on an open connection
mysql_character_set_name()	Return default character set name for current connection
mysql_client_find_plugin()	Return pointer to plugin
mysql_client_register_plugin()	Register a plugin
mysql_close()	Closes a server connection
mysql_commit()	Commits the transaction
mysql_connect()	Connects to a MySQL server (this function is deprecated; use mysql_real_connect() instead)
mysql_create_db()	Creates a database (this function is deprecated; use the SQL statement CREATE DATABASE instead)
mysql_data_seek()	Seeks to an arbitrary row number in a query result set
mysql_debug()	Does a DBUG_PUSH with the given string
mysql_drop_db()	Drops a database (this function is deprecated; use the SQL statement DROP DATABASE instead)
mysql_dump_debug_info()	Makes the server write debug information to the log
mysql_eof()	Determines whether the last row of a result set has been read (this function is deprecated; mysql_errno() or mysql_error() may be used instead)
mysql_errno()	Returns the error number for the most recently invoked MySQL function
mysql_error()	Returns the error message for the most recently invoked MySQL function
mysql_escape_string()	Escapes special characters in a string for use in an SQL statement
mysql_fetch_field()	Returns the type of the next table field
mysql_fetch_field_direct()	Returns the type of a table field, given a field number
mysql_fetch_fields()	Returns an array of all field structures
mysql_fetch_lengths()	Returns the lengths of all columns in the current row
mysql_fetch_row()	Fetches the next row from the result set
mysql_field_count()	Returns the number of result columns for the most recent statement
mysql_field_seek()	Puts the column cursor on a specified column
mysql_field_tell()	Returns the position of the field cursor used for the last mysql_fetch_field()
mysql_free_result()	Frees memory used by a result set
mysql_get_character_set_info()	Return information about default character set
mysql_get_client_info()	Returns client version information as a string
mysql_get_client_version()	Returns client version information as an integer
mysql_get_host_info()	Returns a string describing the connection
mysql_get_proto_info()	Returns the protocol version used by the connection
mysql_get_server_info()	Returns the server version number
mysql_get_server_version()	Returns version number of server as an integer
mysql_get_ssl_cipher()	Return current SSL cipher
mysql_hex_string()	Encode string in hexadecimal format

Function	Description
mysql_info()	Returns information about the most recently executed query
mysql_init()	Gets or initializes a MYSQL structure
mysql_insert_id()	Returns the ID generated for an AUTO_INCREMENT column by the previous query
mysql_kill()	Kills a given thread
mysql_library_end()	Finalize the MySQL C API library
mysql_library_init()	Initialize the MySQL C API library
mysql_list_dbs()	Returns database names matching a simple regular expression
mysql_list_fields()	Returns field names matching a simple regular expression
mysql_list_processes()	Returns a list of the current server threads
mysql_list_tables()	Returns table names matching a simple regular expression
mysql_load_plugin()	Load a plugin
mysql_load_plugin_v()	Load a plugin
mysql_more_results()	Checks whether any more results exist
mysql_next_result()	Returns/initiates the next result in multiple-result executions
mysql_num_fields()	Returns the number of columns in a result set
mysql_num_rows()	Returns the number of rows in a result set
mysql_options()	Sets connect options for mysql_real_connect()
mysql_ping()	Checks whether the connection to the server is working, reconnecting as necessary
mysql_plugin_options()	Set a plugin option
mysql_query()	Executes an SQL query specified as a null-terminated string
mysql_real_connect()	Connects to a MySQL server
mysql_real_escape_string()	Escapes special characters in a string for use in an SQL statement, taking into account the current character set of the connection
mysql_real_query()	Executes an SQL query specified as a counted string
mysql_refresh()	Flush or reset tables and caches
mysql_reload()	Tells the server to reload the grant tables
mysql_rollback()	Rolls back the transaction
mysql_row_seek()	Seeks to a row offset in a result set, using value returned from mysql_row_tell()
mysql_row_tell()	Returns the row cursor position
mysql_select_db()	Selects a database
mysql_server_end()	Finalize the MySQL C API library
mysql_server_init()	Initialize the MySQL C API library
mysql_set_character_set()	Set default character set for current connection
mysql_set_local_infile_default()	Set the LOAD DATA LOCAL INFILE handler callbacks to their default values
mysql_set_local_infile_handler()	Install application-specific LOAD DATA LOCAL INFILE handler callbacks
mysql_set_server_option()	Sets an option for the connection (like multi-statements)
mysql_sqlstate()	Returns the SQLSTATE error code for the last error

Function	Description
mysql_shutdown()	Shuts down the database server
mysql_ssl_set()	Prepare to establish SSL connection to server
mysql_stat()	Returns the server status as a string
mysql_store_result()	Retrieves a complete result set to the client
mysql_thread_end()	Finalize thread handler
mysql_thread_id()	Returns the current thread ID
mysql_thread_init()	Initialize thread handler
mysql_thread_safe()	Returns 1 if the clients are compiled as thread-safe
mysql_use_result()	Initiates a row-by-row result set retrieval
mysql_warning_count()	Returns the warning count for the previous SQL statement

Application programs should use this general outline for interacting with MySQL:

1. Initialize the MySQL library by calling mysql_library_init(). This function exists in both the libmysqlclient C client library and the libmysqld embedded server library, so it is used whether you build a regular client program by linking with the -libmysqlclient flag, or an embedded server application by linking with the -libmysqld flag.

2. Initialize a connection handler by calling mysql_init() and connect to the server by calling mysql_real_connect().

3. Issue SQL statements and process their results. (The following discussion provides more information about how to do this.)

4. Close the connection to the MySQL server by calling mysql_close().

5. End use of the MySQL library by calling mysql_library_end().

The purpose of calling mysql_library_init() and mysql_library_end() is to provide proper initialization and finalization of the MySQL library. For applications that are linked with the client library, they provide improved memory management. If you do not call mysql_library_end(), a block of memory remains allocated. (This does not increase the amount of memory used by the application, but some memory leak detectors will complain about it.) For applications that are linked with the embedded server, these calls start and stop the server.

In a nonmulti-threaded environment, the call to mysql_library_init() may be omitted, because mysql_init() will invoke it automatically as necessary. However, mysql_library_init() is not thread-safe in a multi-threaded environment, and thus neither is mysql_init(), which calls mysql_library_init(). You must either call mysql_library_init() prior to spawning any threads, or else use a mutex to protect the call, whether you invoke mysql_library_init() or indirectly through mysql_init(). This should be done prior to any other client library call.

To connect to the server, call mysql_init() to initialize a connection handler, then call mysql_real_connect() with that handler (along with other information such as the host name, user name, and password). Upon connection, mysql_real_connect() sets the reconnect flag (part of the MYSQL structure) to a value of 1 in versions of the API older than 5.0.3, or 0 in newer versions. A value of 1 for this flag indicates that if a statement cannot be performed because of a lost connection, to try reconnecting to the server before giving up. You can use the MYSQL_OPT_RECONNECT option to mysql_options() to control reconnection behavior. When you are done with the connection, call mysql_close() to terminate it.

While a connection is active, the client may send SQL statements to the server using mysql_query() or mysql_real_query(). The difference between the two is that mysql_query() expects the query to be specified as a null-terminated string whereas mysql_real_query() expects a counted string. If the string contains binary data (which may include null bytes), you must use mysql_real_query().

For each non-SELECT query (for example, INSERT, UPDATE, DELETE), you can find out how many rows were changed (affected) by calling mysql_affected_rows().

For SELECT queries, you retrieve the selected rows as a result set. (Note that some statements are SELECT-like in that they return rows. These include SHOW, DESCRIBE, and EXPLAIN. Treat these statements the same way as SELECT statements.)

There are two ways for a client to process result sets. One way is to retrieve the entire result set all at once by calling mysql_store_result(). This function acquires from the server all the rows returned by the query and stores them in the client. The second way is for the client to initiate a row-by-row result set retrieval by calling mysql_use_result(). This function initializes the retrieval, but does not actually get any rows from the server.

In both cases, you access rows by calling mysql_fetch_row(). With mysql_store_result(), mysql_fetch_row() accesses rows that have previously been fetched from the server. With mysql_use_result(), mysql_fetch_row() actually retrieves the row from the server. Information about the size of the data in each row is available by calling mysql_fetch_lengths().

After you are done with a result set, call mysql_free_result() to free the memory used for it.

The two retrieval mechanisms are complementary. Choose the approach that is most appropriate for each client application. In practice, clients tend to use mysql_store_result() more commonly.

An advantage of mysql_store_result() is that because the rows have all been fetched to the client, you not only can access rows sequentially, you can move back and forth in the result set using mysql_data_seek() or mysql_row_seek() to change the current row position within the result set. You can also find out how many rows there are by calling mysql_num_rows(). On the other hand, the memory requirements for mysql_store_result() may be very high for large result sets and you are more likely to encounter out-of-memory conditions.

An advantage of mysql_use_result() is that the client requires less memory for the result set because it maintains only one row at a time (and because there is less allocation overhead, mysql_use_result() can be faster). Disadvantages are that you must process each row quickly to avoid tying up the server, you do not have random access to rows within the result set (you can only access rows sequentially), and the number of rows in the result set is unknown until you have retrieved them all. Furthermore, you *must* retrieve all the rows even if you determine in mid-retrieval that you've found the information you were looking for.

The API makes it possible for clients to respond appropriately to statements (retrieving rows only as necessary) without knowing whether the statement is a SELECT. You can do this by calling mysql_store_result() after each mysql_query() (or mysql_real_query()). If the result set call succeeds, the statement was a SELECT and you can read the rows. If the result set call fails, call mysql_field_count() to determine whether a result was actually to be expected. If mysql_field_count() returns zero, the statement returned no data (indicating that it was an INSERT, UPDATE, DELETE, and so forth), and was not expected to return rows. If mysql_field_count() is nonzero, the statement should have returned rows, but did not. This indicates that the statement was a SELECT that failed. See the description for mysql_field_count() for an example of how this can be done.

Both mysql_store_result() and mysql_use_result() enable you to obtain information about the fields that make up the result set (the number of fields, their names and types, and so forth). You can access field information sequentially within the row by calling mysql_fetch_field() repeatedly, or by field number within the row by calling mysql_fetch_field_direct(). The current field cursor position may be changed by calling mysql_field_seek(). Setting the field cursor affects subsequent calls to mysql_fetch_field(). You can also get information for fields all at once by calling mysql_fetch_fields().

For detecting and reporting errors, MySQL provides access to error information by means of the mysql_errno() and mysql_error() functions. These return the error code or error message for

the most recently invoked function that can succeed or fail, enabling you to determine when an error occurred and what it was.

23.8.7 C API Function Descriptions

In the descriptions here, a parameter or return value of `NULL` means `NULL` in the sense of the C programming language, not a MySQL `NULL` value.

Functions that return a value generally return a pointer or an integer. Unless specified otherwise, functions returning a pointer return a non-`NULL` value to indicate success or a `NULL` value to indicate an error, and functions returning an integer return zero to indicate success or nonzero to indicate an error. Note that “nonzero” means just that. Unless the function description says otherwise, do not test against a value other than zero:

```
if (result)                  /* correct */
    ... error ...

if (result < 0)              /* incorrect */
    ... error ...

if (result == -1)            /* incorrect */
    ... error ...
```

When a function returns an error, the **Errors** subsection of the function description lists the possible types of errors. You can find out which of these occurred by calling `mysql_errno()`. A string representation of the error may be obtained by calling `mysql_error()`.

23.8.7.1 mysql_affected_rows()

```
my_ulonglong mysql_affected_rows(MYSQL *mysql)
```

Description

`mysql_affected_rows()` may be called immediately after executing a statement with `mysql_query()` or `mysql_real_query()`. It returns the number of rows changed, deleted, or inserted by the last statement if it was an `UPDATE`, `DELETE`, or `INSERT`. For `SELECT` statements, `mysql_affected_rows()` works like `mysql_num_rows()`.

For `UPDATE` statements, the affected-rows value by default is the number of rows actually changed. If you specify the `CLIENT_FOUND_ROWS` flag to `mysql_real_connect()` when connecting to `mysqld`, the affected-rows value is the number of rows “found”; that is, matched by the `WHERE` clause.

For `REPLACE` statements, the affected-rows value is 2 if the new row replaced an old row, because in this case, one row was inserted after the duplicate was deleted.

For `INSERT ... ON DUPLICATE KEY UPDATE` statements, the affected-rows value per row is 1 if the row is inserted as a new row, 2 if an existing row is updated, and 0 if an existing row is set to its current values. If you specify the `CLIENT_FOUND_ROWS` flag, the affected-rows value is 1 (not 0) if an existing row is set to its current values.

Following a `CALL` statement for a stored procedure, `mysql_affected_rows()` returns the value that it would return for the last statement executed within the procedure, or `0` if that statement would return `-1`. Within the procedure, you can use `ROW_COUNT()` at the SQL level to obtain the affected-rows value for individual statements.

`mysql_affected_rows()` returns a meaningful value for a wider range of statements. For details, see the description for `ROW_COUNT()` in Section 12.14, “Information Functions”.

Return Values

An integer greater than zero indicates the number of rows affected or retrieved. Zero indicates that no records were updated for an `UPDATE` statement, no rows matched the `WHERE` clause in the query or

that no query has yet been executed. -1 indicates that the query returned an error or that, for a `SELECT` query, `mysql_affected_rows()` was called prior to calling `mysql_store_result()`.

Because `mysql_affected_rows()` returns an unsigned value, you can check for -1 by comparing the return value to `(my_ulonglong)-1` (or to `(my_ulonglong)~0`, which is equivalent).

Errors

None.

Example

```
char *stmt = "UPDATE products SET cost=cost*1.25
              WHERE group=10";
mysql_query(&mysql,stmt);
printf("%ld products updated",
       (long) mysql_affected_rows(&mysql));
```

23.8.7.2 mysql_autocommit()

```
my_bool mysql_autocommit(MYSQL *mysql, my_bool mode)
```

Description

Sets autocommit mode on if `mode` is 1, off if `mode` is 0.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

None.

23.8.7.3 mysql_change_user()

```
my_bool mysql_change_user(MYSQL *mysql, const char *user, const char
*password, const char *db)
```

Description

Changes the user and causes the database specified by `db` to become the default (current) database on the connection specified by `mysql`. In subsequent queries, this database is the default for table references that include no explicit database specifier.

`mysql_change_user()` fails if the connected user cannot be authenticated or does not have permission to use the database. In this case, the user and database are not changed.

Pass a `db` parameter of `NULL` if you do not want to have a default database.

This function resets the session state as if one had done a new connect and reauthenticated. (See Section 23.8.20, “C API Automatic Reconnection Control”.) It always performs a `ROLLBACK` of any active transactions, closes and drops all temporary tables, and unlocks all locked tables. Session system variables are reset to the values of the corresponding global system variables. Prepared statements are released and `HANDLER` variables are closed. Locks acquired with `GET_LOCK()` are released. These effects occur even if the user did not change.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

The same that you can get from `mysql_real_connect()`, plus:

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

- `ER_UNKNOWN_COM_ERROR`

  The MySQL server does not implement this command (probably an old server).

- `ER_ACCESS_DENIED_ERROR`

  The user or password was wrong.

- `ER_BAD_DB_ERROR`

  The database did not exist.

- `ER_DBACCESS_DENIED_ERROR`

  The user did not have access rights to the database.

- `ER_WRONG_DB_NAME`

  The database name was too long.

Example

```
if (mysql_change_user(&mysql, "user", "password", "new_database"))
{
   fprintf(stderr, "Failed to change user.  Error: %s\n",
           mysql_error(&mysql));
}
```

23.8.7.4 mysql_character_set_name()

```
const char *mysql_character_set_name(MYSQL *mysql)
```

Description

Returns the default character set name for the current connection.

Return Values

The default character set name

Errors

None.

23.8.7.5 mysql_close()

```
void mysql_close(MYSQL *mysql)
```

Description

Closes a previously opened connection. `mysql_close()` also deallocates the connection handler pointed to by `mysql` if the handler was allocated automatically by `mysql_init()` or `mysql_connect()`.

Return Values

None.

Errors

None.

23.8.7.6 mysql_commit()

```
my_bool mysql_commit(MYSQL *mysql)
```

Description

Commits the current transaction.

The action of this function is subject to the value of the `completion_type` system variable. In particular, if the value of `completion_type` is `RELEASE` (or 2), the server performs a release after terminating a transaction and closes the client connection. Call `mysql_close()` from the client program to close the connection from the client side.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

None.

23.8.7.7 mysql_connect()

```
MYSQL *mysql_connect(MYSQL *mysql, const char *host, const char *user, const
char *passwd)
```

Description

This function is deprecated. Use `mysql_real_connect()` instead.

`mysql_connect()` attempts to establish a connection to a MySQL database engine running on `host`. `mysql_connect()` must complete successfully before you can execute any of the other API functions, with the exception of `mysql_get_client_info()`.

The meanings of the parameters are the same as for the corresponding parameters for `mysql_real_connect()` with the difference that the connection parameter may be `NULL`. In this case, the C API allocates memory for the connection structure automatically and frees it when you call `mysql_close()`. The disadvantage of this approach is that you cannot retrieve an error message if the connection fails. (To get error information from `mysql_errno()` or `mysql_error()`, you must provide a valid `MYSQL` pointer.)

Return Values

Same as for `mysql_real_connect()`.

Errors

Same as for `mysql_real_connect()`.

23.8.7.8 mysql_create_db()

```
int mysql_create_db(MYSQL *mysql, const char *db)
```

Description

Creates the database named by the `db` parameter.

This function is deprecated. Use `mysql_query()` to issue an SQL `CREATE DATABASE` statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

```
if(mysql_create_db(&mysql, "my_database"))
{
   fprintf(stderr, "Failed to create new database.  Error: %s\n",
           mysql_error(&mysql));
}
```

23.8.7.9 mysql_data_seek()

```
void mysql_data_seek(MYSQL_RES *result, my_ulonglong offset)
```

Description

Seeks to an arbitrary row in a query result set. The `offset` value is a row number. Specify a value in the range from `0` to `mysql_num_rows(result)-1`.

This function requires that the result set structure contains the entire result of the query, so `mysql_data_seek()` may be used only in conjunction with `mysql_store_result()`, not with `mysql_use_result()`.

Return Values

None.

Errors

None.

23.8.7.10 mysql_debug()

```
void mysql_debug(const char *debug)
```

Description

Does a `DBUG_PUSH` with the given string. `mysql_debug()` uses the Fred Fish debug library. To use this function, you must compile the client library to support debugging. See Section 24.5.3, “The DBUG Package”.

Return Values

None.

Errors

None.

Example

The call shown here causes the client library to generate a trace file in `/tmp/client.trace` on the client machine:

```
mysql_debug("d:t:O,/tmp/client.trace");
```

23.8.7.11 mysql_drop_db()

```
int mysql_drop_db(MYSQL *mysql, const char *db)
```

Description

Drops the database named by the `db` parameter.

This function is deprecated. Use `mysql_query()` to issue an SQL `DROP DATABASE` statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

```
if(mysql_drop_db(&mysql, "my_database"))
  fprintf(stderr, "Failed to drop the database: Error: %s\n",
          mysql_error(&mysql));
```

23.8.7.12 mysql_dump_debug_info()

```
int mysql_dump_debug_info(MYSQL *mysql)
```

Description

Instructs the server to write debugging information to the error log. The connected user must have the `SUPER` privilege.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.13 mysql_eof()

```
my_bool mysql_eof(MYSQL_RES *result)
```

Description

This function is deprecated. `mysql_errno()` or `mysql_error()` may be used instead.

`mysql_eof()` determines whether the last row of a result set has been read.

If you acquire a result set from a successful call to `mysql_store_result()`, the client receives the entire set in one operation. In this case, a `NULL` return from `mysql_fetch_row()` always means the end of the result set has been reached and it is unnecessary to call `mysql_eof()`. When used with `mysql_store_result()`, `mysql_eof()` always returns true.

On the other hand, if you use `mysql_use_result()` to initiate a result set retrieval, the rows of the set are obtained from the server one by one as you call `mysql_fetch_row()` repeatedly. Because an error may occur on the connection during this process, a `NULL` return value from `mysql_fetch_row()` does not necessarily mean the end of the result set was reached normally. In this case, you can use `mysql_eof()` to determine what happened. `mysql_eof()` returns a nonzero value if the end of the result set was reached and zero if an error occurred.

Historically, `mysql_eof()` predates the standard MySQL error functions `mysql_errno()` and `mysql_error()`. Because those error functions provide the same information, their use is preferred over `mysql_eof()`, which is deprecated. (In fact, they provide more information, because

`mysql_eof()` returns only a boolean value whereas the error functions indicate a reason for the error when one occurs.)

Return Values

Zero for success. Nonzero if the end of the result set has been reached.

Errors

None.

Example

The following example shows how you might use `mysql_eof()`:

```
mysql_query(&mysql,"SELECT * FROM some_table");
result = mysql_use_result(&mysql);
while((row = mysql_fetch_row(result)))
{
    // do something with data
}
if(!mysql_eof(result))  // mysql_fetch_row() failed due to an error
{
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
}
```

However, you can achieve the same effect with the standard MySQL error functions:

```
mysql_query(&mysql,"SELECT * FROM some_table");
result = mysql_use_result(&mysql);
while((row = mysql_fetch_row(result)))
{
    // do something with data
}
if(mysql_errno(&mysql))  // mysql_fetch_row() failed due to an error
{
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
}
```

23.8.7.14 mysql_errno()

```
unsigned int mysql_errno(MYSQL *mysql)
```

Description

For the connection specified by `mysql`, `mysql_errno()` returns the error code for the most recently invoked API function that can succeed or fail. A return value of zero means that no error occurred. Client error message numbers are listed in the MySQL `errmsg.h` header file. Server error message numbers are listed in `mysqld_error.h`. Errors also are listed at Appendix B, *Errors, Error Codes, and Common Problems*.

Note

Some functions such as `mysql_fetch_row()` do not set `mysql_errno()` if they succeed. A rule of thumb is that all functions that have to ask the server for information reset `mysql_errno()` if they succeed.

MySQL-specific error numbers returned by `mysql_errno()` differ from SQLSTATE values returned by `mysql_sqlstate()`. For example, the `mysql` client program displays errors using the following format, where `1146` is the `mysql_errno()` value and `'42S02'` is the corresponding `mysql_sqlstate()` value:

```
```

```
shell> SELECT * FROM no_such_table;
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
```

Return Values

An error code value for the last `mysql_xxx()` call, if it failed. zero means no error occurred.

Errors

None.

23.8.7.15 mysql_error()

```
const char *mysql_error(MYSQL *mysql)
```

Description

For the connection specified by `mysql`, `mysql_error()` returns a null-terminated string containing the error message for the most recently invoked API function that failed. If a function did not fail, the return value of `mysql_error()` may be the previous error or an empty string to indicate no error.

A rule of thumb is that all functions that have to ask the server for information reset `mysql_error()` if they succeed.

For functions that reset `mysql_error()`, either of these two tests can be used to check for an error:

```
if(*mysql_error(&mysql))
{
  // an error occurred
}

if(mysql_error(&mysql)[0])
{
  // an error occurred
}
```

The language of the client error messages may be changed by recompiling the MySQL client library. You can choose error messages in several different languages. See Section 10.2, “Setting the Error Message Language”.

Return Values

A null-terminated character string that describes the error. An empty string if no error occurred.

Errors

None.

23.8.7.16 mysql_escape_string()

Note

This function should not be used. Use `mysql_real_escape_string()` instead.

`mysql_escape_string()` is identical to `mysql_real_escape_string()` except that `mysql_real_escape_string()` takes a connection handler as its first argument and escapes the string according to the current character set. `mysql_escape_string()` does not take a connection argument and does not respect the current character set.

23.8.7.17 mysql_fetch_field()

```
MYSQL_FIELD *mysql_fetch_field(MYSQL_RES *result)
```

Description

Returns the definition of one column of a result set as a `MYSQL_FIELD` structure. Call this function repeatedly to retrieve information about all columns in the result set. `mysql_fetch_field()` returns `NULL` when no more fields are left.

`mysql_fetch_field()` is reset to return information about the first field each time you execute a new `SELECT` query. The field returned by `mysql_fetch_field()` is also affected by calls to `mysql_field_seek()`.

If you've called `mysql_query()` to perform a `SELECT` on a table but have not called `mysql_store_result()`, MySQL returns the default blob length (8KB) if you call `mysql_fetch_field()` to ask for the length of a `BLOB` field. (The 8KB size is chosen because MySQL does not know the maximum length for the `BLOB`. This should be made configurable sometime.) Once you've retrieved the result set, `field->max_length` contains the length of the largest value for this column in the specific query.

Return Values

The `MYSQL_FIELD` structure for the current column. `NULL` if no columns are left.

Errors

None.

Example

```
MYSQL_FIELD *field;

while((field = mysql_fetch_field(result)))
{
    printf("field name %s\n", field->name);
}
```

23.8.7.18 mysql_fetch_field_direct()

```
MYSQL_FIELD *mysql_fetch_field_direct(MYSQL_RES *result, unsigned int
fieldnr)
```

Description

Given a field number `fieldnr` for a column within a result set, returns that column's field definition as a `MYSQL_FIELD` structure. Use this function to retrieve the definition for an arbitrary column. Specify a value for `fieldnr` in the range from 0 to `mysql_num_fields(result)-1`.

Return Values

The `MYSQL_FIELD` structure for the specified column.

Errors

None.

Example

```
unsigned int num_fields;
unsigned int i;
MYSQL_FIELD *field;

num_fields = mysql_num_fields(result);
for(i = 0; i < num_fields; i++)
{
    field = mysql_fetch_field_direct(result, i);
```

```
    printf("Field %u is %s\n", i, field->name);
}
```

23.8.7.19 mysql_fetch_fields()

```
MYSQL_FIELD *mysql_fetch_fields(MYSQL_RES *result)
```

Description

Returns an array of all `MYSQL_FIELD` structures for a result set. Each structure provides the field definition for one column of the result set.

Return Values

An array of `MYSQL_FIELD` structures for all columns of a result set.

Errors

None.

Example

```
unsigned int num_fields;
unsigned int i;
MYSQL_FIELD *fields;

num_fields = mysql_num_fields(result);
fields = mysql_fetch_fields(result);
for(i = 0; i < num_fields; i++)
{
   printf("Field %u is %s\n", i, fields[i].name);
}
```

23.8.7.20 mysql_fetch_lengths()

```
unsigned long *mysql_fetch_lengths(MYSQL_RES *result)
```

Description

Returns the lengths of the columns of the current row within a result set. If you plan to copy field values, this length information is also useful for optimization, because you can avoid calling `strlen()`. In addition, if the result set contains binary data, you **must** use this function to determine the size of the data, because `strlen()` returns incorrect results for any field containing null characters.

The length for empty columns and for columns containing `NULL` values is zero. To see how to distinguish these two cases, see the description for `mysql_fetch_row()`.

Return Values

An array of unsigned long integers representing the size of each column (not including any terminating null bytes). `NULL` if an error occurred.

Errors

`mysql_fetch_lengths()` is valid only for the current row of the result set. It returns `NULL` if you call it before calling `mysql_fetch_row()` or after retrieving all rows in the result.

Example

```
MYSQL_ROW row;
unsigned long *lengths;
unsigned int num_fields;
unsigned int i;
```

```
row = mysql_fetch_row(result);
if (row)
{
    num_fields = mysql_num_fields(result);
    lengths = mysql_fetch_lengths(result);
    for(i = 0; i < num_fields; i++)
    {
         printf("Column %u is %lu bytes in length.\n",
                i, lengths[i]);
    }
}
```

23.8.7.21 mysql_fetch_row()

```
MYSQL_ROW mysql_fetch_row(MYSQL_RES *result)
```

Description

Retrieves the next row of a result set. When used after `mysql_store_result()`, `mysql_fetch_row()` returns `NULL` when there are no more rows to retrieve. When used after `mysql_use_result()`, `mysql_fetch_row()` returns `NULL` when there are no more rows to retrieve or if an error occurred.

The number of values in the row is given by `mysql_num_fields(result)`. If `row` holds the return value from a call to `mysql_fetch_row()`, pointers to the values are accessed as `row[0]` to `row[mysql_num_fields(result)-1]`. `NULL` values in the row are indicated by `NULL` pointers.

The lengths of the field values in the row may be obtained by calling `mysql_fetch_lengths()`. Empty fields and fields containing `NULL` both have length 0; you can distinguish these by checking the pointer for the field value. If the pointer is `NULL`, the field is `NULL`; otherwise, the field is empty.

Return Values

A `MYSQL_ROW` structure for the next row. `NULL` if there are no more rows to retrieve or if an error occurred.

Errors

Errors are not reset between calls to `mysql_fetch_row()`

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

```
MYSQL_ROW row;
unsigned int num_fields;
unsigned int i;

num_fields = mysql_num_fields(result);
while ((row = mysql_fetch_row(result)))
{
   unsigned long *lengths;
   lengths = mysql_fetch_lengths(result);
   for(i = 0; i < num_fields; i++)
   {
       printf("[%.*s] ", (int) lengths[i],
              row[i] ? row[i] : "NULL");
   }
```

```
   printf("\n");
}
```

23.8.7.22 mysql_field_count()

```
unsigned int mysql_field_count(MYSQL *mysql)
```

Description

Returns the number of columns for the most recent query on the connection.

The normal use of this function is when `mysql_store_result()` returned `NULL` (and thus you have no result set pointer). In this case, you can call `mysql_field_count()` to determine whether `mysql_store_result()` should have produced a nonempty result. This enables the client program to take proper action without knowing whether the query was a `SELECT` (or `SELECT`-like) statement. The example shown here illustrates how this may be done.

See Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”.

Return Values

An unsigned integer representing the number of columns in a result set.

Errors

None.

Example

```
MYSQL_RES *result;
unsigned int num_fields;
unsigned int num_rows;

if (mysql_query(&mysql,query_string))
{
    // error
}
else // query succeeded, process any data returned by it
{
    result = mysql_store_result(&mysql);
    if (result)  // there are rows
    {
        num_fields = mysql_num_fields(result);
        // retrieve rows, then call mysql_free_result(result)
    }
    else  // mysql_store_result() returned nothing; should it have?
    {
        if(mysql_field_count(&mysql) == 0)
        {
            // query does not return data
            // (it was not a SELECT)
            num_rows = mysql_affected_rows(&mysql);
        }
        else // mysql_store_result() should have returned data
        {
            fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
        }
    }
}
```

An alternative is to replace the `mysql_field_count(&mysql)` call with `mysql_errno(&mysql)`. In this case, you are checking directly for an error from `mysql_store_result()` rather than inferring from the value of `mysql_field_count()` whether the statement was a `SELECT`.

23.8.7.23 mysql_field_seek()

```
MYSQL_FIELD_OFFSET mysql_field_seek(MYSQL_RES *result, MYSQL_FIELD_OFFSET
offset)
```

Description

Sets the field cursor to the given offset. The next call to `mysql_fetch_field()` retrieves the field definition of the column associated with that offset.

To seek to the beginning of a row, pass an `offset` value of zero.

Return Values

The previous value of the field cursor.

Errors

None.

23.8.7.24 mysql_field_tell()

```
MYSQL_FIELD_OFFSET mysql_field_tell(MYSQL_RES *result)
```

Description

Returns the position of the field cursor used for the last `mysql_fetch_field()`. This value can be used as an argument to `mysql_field_seek()`.

Return Values

The current offset of the field cursor.

Errors

None.

23.8.7.25 mysql_free_result()

```
void mysql_free_result(MYSQL_RES *result)
```

Description

Frees the memory allocated for a result set by `mysql_store_result()`, `mysql_use_result()`, `mysql_list_dbs()`, and so forth. When you are done with a result set, you must free the memory it uses by calling `mysql_free_result()`.

Do not attempt to access a result set after freeing it.

Return Values

None.

Errors

None.

23.8.7.26 mysql_get_character_set_info()

```
void mysql_get_character_set_info(MYSQL *mysql, MY_CHARSET_INFO *cs)
```

Description

This function provides information about the default client character set. The default character set may be changed with the `mysql_set_character_set()` function.

Example

This example shows the fields that are available in the `MY_CHARSET_INFO` structure:

```
if (!mysql_set_character_set(&mysql, "utf8"))
{
    MY_CHARSET_INFO cs;
    mysql_get_character_set_info(&mysql, &cs);
    printf("character set information:\n");
    printf("character set+collation number: %d\n", cs.number);
    printf("character set name: %s\n", cs.name);
    printf("collation name: %s\n", cs.csname);
    printf("comment: %s\n", cs.comment);
    printf("directory: %s\n", cs.dir);
    printf("multi byte character min. length: %d\n", cs.mbminlen);
    printf("multi byte character max. length: %d\n", cs.mbmaxlen);
}
```

23.8.7.27 mysql_get_client_info()

```
const char *mysql_get_client_info(void)
```

Description

Returns a string that represents the MySQL client library version; for example, `"5.5.60"`.

The function value is the MySQL version. For Connector/C, this is the MySQL version on which the Connector/C distribution is based. For more information, see Section 23.8.4.4, “C API Server and Client Library Versions”.

Return Values

A character string that represents the MySQL client library version.

Errors

None.

23.8.7.28 mysql_get_client_version()

```
unsigned long mysql_get_client_version(void)
```

Description

Returns an integer that represents the MySQL client library version. The value has the format `XYYZZ` where `X` is the major version, `YY` is the release level (or minor version), and `ZZ` is the sub-version within the release level:

```
major_version*10000 + release_level*100 + sub_version
```

For example, `"5.5.60"` is returned as `50560`.

The function value is the MySQL version. For Connector/C, this is the MySQL version on which the Connector/C distribution is based. For more information, see Section 23.8.4.4, “C API Server and Client Library Versions”.

Return Values

An integer that represents the MySQL client library version.

Errors

None.

23.8.7.29 mysql_get_host_info()

```
const char *mysql_get_host_info(MYSQL *mysql)
```

Description

Returns a string describing the type of connection in use, including the server host name.

Return Values

A character string representing the server host name and the connection type.

Errors

None.

23.8.7.30 mysql_get_proto_info()

```
unsigned int mysql_get_proto_info(MYSQL *mysql)
```

Description

Returns the protocol version used by current connection.

Return Values

An unsigned integer representing the protocol version used by the current connection.

Errors

None.

23.8.7.31 mysql_get_server_info()

```
const char *mysql_get_server_info(MYSQL *mysql)
```

Description

Returns a string that represents the MySQL server version; for example, `"5.5.60"`.

Return Values

A character string that represents the MySQL server version.

Errors

None.

23.8.7.32 mysql_get_server_version()

```
unsigned long mysql_get_server_version(MYSQL *mysql)
```

Description

Returns an integer that represents the MySQL server version. The value has the format `XYYZZ` where `X` is the major version, `YY` is the release level (or minor version), and `ZZ` is the sub-version within the release level:

```
major_version*10000 + release_level*100 + sub_version
```

For example, `"5.5.60"` is returned as `50560`.

This function is useful in client programs for determining whether some version-specific server capability exists.

Return Values

An integer that represents the MySQL server version.

Errors

None.

23.8.7.33 mysql_get_ssl_cipher()

```
const char *mysql_get_ssl_cipher(MYSQL *mysql)
```

Description

`mysql_get_ssl_cipher()` returns the encryption cipher used for the given connection to the server. `mysql` is the connection handler returned from `mysql_init()`.

Return Values

A string naming the encryption cipher used for the connection, or `NULL` if the connection is not encrypted.

23.8.7.34 mysql_hex_string()

```
unsigned long mysql_hex_string(char *to, const char *from, unsigned long
length)
```

Description

This function creates a legal SQL string for use in an SQL statement. See Section 9.1.1, “String Literals”.

The string in the `from` argument is encoded in hexadecimal format, with each character encoded as two hexadecimal digits. The result is placed in the `to` argument, followed by a terminating null byte.

The string pointed to by `from` must be `length` bytes long. You must allocate the `to` buffer to be at least `length*2+1` bytes long. When `mysql_hex_string()` returns, the contents of `to` is a null-terminated string. The return value is the length of the encoded string, not including the terminating null byte.

The return value can be placed into an SQL statement using either `X'value'` or `0xvalue` format. However, the return value does not include the `X'...'` or `0x`. The caller must supply whichever of those is desired.

Example

```
char query[1000],*end;

end = strmov(query,"INSERT INTO test_table values(");
end = strmov(end,"X'");
end += mysql_hex_string(end,"What is this",12);
end = strmov(end,"',X'");
end += mysql_hex_string(end,"binary data: \0\r\n",16);
end = strmov(end,"')");

if (mysql_real_query(&mysql,query,(unsigned int) (end - query)))
{
   fprintf(stderr, "Failed to insert row, Error: %s\n",
           mysql_error(&mysql));
}
```

The `strmov()` function used in the example is included in the `libmysqlclient` library and works like `strcpy()` but returns a pointer to the terminating null of the first parameter.

Return Values

The length of the encoded string that is placed into `to`, not including the terminating null character.

Errors

None.

23.8.7.35 mysql_info()

```
const char *mysql_info(MYSQL *mysql)
```

Description

Retrieves a string providing information about the most recently executed statement, but only for the statements listed here. For other statements, `mysql_info()` returns `NULL`. The format of the string varies depending on the type of statement, as described here. The numbers are illustrative only; the string contains values appropriate for the statement.

- `INSERT INTO ... SELECT ...`

  String format: `Records: 100 Duplicates: 0 Warnings: 0`

- `INSERT INTO ... VALUES (...),(...),(...)...`

  String format: `Records: 3 Duplicates: 0 Warnings: 0`

- `LOAD DATA INFILE ...`

  String format: `Records: 1 Deleted: 0 Skipped: 0 Warnings: 0`

- `ALTER TABLE`

  String format: `Records: 3 Duplicates: 0 Warnings: 0`

- `UPDATE`

  String format: `Rows matched: 40 Changed: 40 Warnings: 0`

`mysql_info()` returns a non-`NULL` value for `INSERT ... VALUES` only for the multiple-row form of the statement (that is, only if multiple value lists are specified).

Return Values

A character string representing additional information about the most recently executed statement. `NULL` if no information is available for the statement.

Errors

None.

23.8.7.36 mysql_init()

```
MYSQL *mysql_init(MYSQL *mysql)
```

Description

Allocates or initializes a `MYSQL` object suitable for `mysql_real_connect()`. If `mysql` is a `NULL` pointer, the function allocates, initializes, and returns a new object. Otherwise, the object is initialized

and the address of the object is returned. If `mysql_init()` allocates a new object, it is freed when `mysql_close()` is called to close the connection.

In a nonmulti-threaded environment, `mysql_init()` invokes `mysql_library_init()` automatically as necessary. However, `mysql_library_init()` is not thread-safe in a multi-threaded environment, and thus neither is `mysql_init()`. Before calling `mysql_init()`, either call `mysql_library_init()` prior to spawning any threads, or use a mutex to protect the `mysql_library_init()` call. This should be done prior to any other client library call.

Return Values

An initialized `MYSQL*` handler. `NULL` if there was insufficient memory to allocate a new object.

Errors

In case of insufficient memory, `NULL` is returned.

23.8.7.37 mysql_insert_id()

```
my_ulonglong mysql_insert_id(MYSQL *mysql)
```

Description

Returns the value generated for an `AUTO_INCREMENT` column by the previous `INSERT` or `UPDATE` statement. Use this function after you have performed an `INSERT` statement into a table that contains an `AUTO_INCREMENT` field, or have used `INSERT` or `UPDATE` to set a column value with `LAST_INSERT_ID(expr)`.

The return value of `mysql_insert_id()` is always zero unless explicitly updated under one of the following conditions:

- `INSERT` statements that store a value into an `AUTO_INCREMENT` column. This is true whether the value is automatically generated by storing the special values `NULL` or `0` into the column, or is an explicit nonspecial value.
- In the case of a multiple-row `INSERT` statement, `mysql_insert_id()` returns the first automatically generated `AUTO_INCREMENT` value that was successfully inserted.

  If no rows are successfully inserted, `mysql_insert_id()` returns 0.
- If an `INSERT ... SELECT` statement is executed, and no automatically generated value is successfully inserted, `mysql_insert_id()` returns the ID of the last inserted row.
- If an `INSERT ... SELECT` statement uses `LAST_INSERT_ID(expr)`, `mysql_insert_id()` returns *`expr`*.
- `INSERT` statements that generate an `AUTO_INCREMENT` value by inserting `LAST_INSERT_ID(expr)` into any column or by updating any column to `LAST_INSERT_ID(expr)`.
- If the previous statement returned an error, the value of `mysql_insert_id()` is undefined.

The return value of `mysql_insert_id()` can be simplified to the following sequence:

1. If there is an `AUTO_INCREMENT` column, and an automatically generated value was successfully inserted, return the first such value.
2. If `LAST_INSERT_ID(expr)` occurred in the statement, return *`expr`*, even if there was an `AUTO_INCREMENT` column in the affected table.
3. The return value varies depending on the statement used. When called after an `INSERT` statement:

- If there is an AUTO_INCREMENT column in the table, and there were some explicit values for this column that were successfully inserted into the table, return the last of the explicit values.

When called after an INSERT ... ON DUPLICATE KEY UPDATE statement:

- If there is an AUTO_INCREMENT column in the table and there were some explicit successfully inserted values or some updated values, return the last of the inserted or updated values.

mysql_insert_id() returns 0 if the previous statement does not use an AUTO_INCREMENT value. If you need to save the value for later, be sure to call mysql_insert_id() immediately after the statement that generates the value.

The value of mysql_insert_id() is affected only by statements issued within the current client connection. It is not affected by statements issued by other clients.

The LAST_INSERT_ID() SQL function will contain the value of the first automatically generated value that was successfully inserted. LAST_INSERT_ID() is not reset between statements because the value of that function is maintained in the server. Another difference from mysql_insert_id() is that LAST_INSERT_ID() is not updated if you set an AUTO_INCREMENT column to a specific nonspecial value. See Section 12.14, “Information Functions”.

mysql_insert_id() returns 0 following a CALL statement for a stored procedure that generates an AUTO_INCREMENT value because in this case mysql_insert_id() applies to CALL and not the statement within the procedure. Within the procedure, you can use LAST_INSERT_ID() at the SQL level to obtain the AUTO_INCREMENT value.

The reason for the differences between LAST_INSERT_ID() and mysql_insert_id() is that LAST_INSERT_ID() is made easy to use in scripts while mysql_insert_id() tries to provide more exact information about what happens to the AUTO_INCREMENT column.

Return Values

Described in the preceding discussion.

Errors

None.

23.8.7.38 mysql_kill()

```
int mysql_kill(MYSQL *mysql, unsigned long pid)
```

Description

Asks the server to kill the thread specified by pid.

This function is deprecated. Use mysql_query() to issue an SQL KILL statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- CR_COMMANDS_OUT_OF_SYNC

  Commands were executed in an improper order.

- CR_SERVER_GONE_ERROR

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.39 mysql_library_end()

```
void mysql_library_end(void)
```

Description

This function finalizes the MySQL library. Call it when you are done using the library (for example, after disconnecting from the server). The action taken by the call depends on whether your application is linked to the MySQL client library or the MySQL embedded server library. For a client program linked against the `libmysqlclient` library by using the `-lmysqlclient` flag, `mysql_library_end()` performs some memory management to clean up. For an embedded server application linked against the `libmysqld` library by using the `-lmysqld` flag, `mysql_library_end()` shuts down the embedded server and then cleans up.

For usage information, see Section 23.8.6, “C API Function Overview”, and Section 23.8.7.40, “mysql_library_init()”.

23.8.7.40 mysql_library_init()

```
int mysql_library_init(int argc, char **argv, char **groups)
```

Description

Call this function to initialize the MySQL library before you call any other MySQL function, whether your application is a regular client program or uses the embedded server. If the application uses the embedded server, this call starts the server and initializes any subsystems (`mysys`, `InnoDB`, and so forth) that the server uses.

After your application is done using the MySQL library, call `mysql_library_end()` to clean up. See Section 23.8.7.39, “mysql_library_end()”.

The choice of whether the application operates as a regular client or uses the embedded server depends on whether you use the `libmysqlclient` or `libmysqld` library at link time to produce the final executable. For additional information, see Section 23.8.6, “C API Function Overview”.

In a nonmulti-threaded environment, the call to `mysql_library_init()` may be omitted, because `mysql_init()` will invoke it automatically as necessary. However, `mysql_library_init()` is not thread-safe in a multi-threaded environment, and thus neither is `mysql_init()`, which calls `mysql_library_init()`. You must either call `mysql_library_init()` prior to spawning any threads, or else use a mutex to protect the call, whether you invoke `mysql_library_init()` or indirectly through `mysql_init()`. Do this prior to any other client library call.

The `argc` and `argv` arguments are analogous to the arguments to `main()`, and enable passing of options to the embedded server. For convenience, `argc` may be `0` (zero) if there are no command-line arguments for the server. This is the usual case for applications intended for use only as regular (nonembedded) clients, and the call typically is written as `mysql_library_init(0, NULL, NULL)`.

```
#include <mysql.h>
#include <stdlib.h>

int main(void) {
  if (mysql_library_init(0, NULL, NULL)) {
    fprintf(stderr, "could not initialize MySQL library\n");
    exit(1);
```

```
  }

  /* Use any MySQL API functions here */

  mysql_library_end();

  return EXIT_SUCCESS;
}
```

When arguments are to be passed (`argc` is greater than `0`), the first element of `argv` is ignored (it typically contains the program name). `mysql_library_init()` makes a copy of the arguments so it is safe to destroy `argv` or `groups` after the call.

For embedded applications, if you want to connect to an external server without starting the embedded server, you have to specify a negative value for `argc`.

The `groups` argument is an array of strings that indicate the groups in option files from which to read options. See Section 4.2.6, “Using Option Files”. Make the final entry in the array `NULL`. For convenience, if the `groups` argument itself is `NULL`, the `[server]` and `[embedded]` groups are used by default.

```
#include <mysql.h>
#include <stdlib.h>

static char *server_args[] = {
  "this_program",       /* this string is not used */
  "--datadir=.",
  "--key_buffer_size=32M"
};
static char *server_groups[] = {
  "embedded",
  "server",
  "this_program_SERVER",
  (char *)NULL
};

int main(void) {
  if (mysql_library_init(sizeof(server_args) / sizeof(char *),
                         server_args, server_groups)) {
    fprintf(stderr, "could not initialize MySQL library\n");
    exit(1);
  }

  /* Use any MySQL API functions here */

  mysql_library_end();

  return EXIT_SUCCESS;
}
```

Return Values

Zero for success. Nonzero if an error occurred.

23.8.7.41 mysql_list_dbs()

```
MYSQL_RES *mysql_list_dbs(MYSQL *mysql, const char *wild)
```

Description

Returns a result set consisting of database names on the server that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters `%` or `_`, or may be a `NULL` pointer to match all databases. Calling `mysql_list_dbs()` is similar to executing the query `SHOW DATABASES [LIKE wild]`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.42 mysql_list_fields()

```
MYSQL_RES *mysql_list_fields(MYSQL *mysql, const char *table, const char
*wild)
```

Description

Returns an empty result set for which the metadata provides information about the columns in the given table that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters `%` or `_`, or may be a `NULL` pointer to match all fields. Calling `mysql_list_fields()` is similar to executing the query `SHOW COLUMNS FROM tbl_name [LIKE wild]`.

It is preferable to use `SHOW COLUMNS FROM tbl_name` instead of `mysql_list_fields()`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

```
int i;
MYSQL_RES *tbl_cols = mysql_list_fields(mysql, "mytbl", "f%");

unsigned int field_cnt = mysql_num_fields(tbl_cols);
printf("Number of columns: %d\n", field_cnt);

for (i=0; i < field_cnt; ++i)
{
  /* col describes i-th column of the table */
  MYSQL_FIELD *col = mysql_fetch_field_direct(tbl_cols, i);
  printf ("Column %d: %s\n", i, col->name);
}
mysql_free_result(tbl_cols);
```

23.8.7.43 mysql_list_processes()

```
MYSQL_RES *mysql_list_processes(MYSQL *mysql)
```

Description

Returns a result set describing the current server threads. This is the same kind of information as that reported by `mysqladmin processlist` or a `SHOW PROCESSLIST` query.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.44 mysql_list_tables()

```
MYSQL_RES *mysql_list_tables(MYSQL *mysql, const char *wild)
```

Description

Returns a result set consisting of table names in the current database that match the simple regular expression specified by the `wild` parameter. `wild` may contain the wildcard characters `%` or `_`, or may be a `NULL` pointer to match all tables. Calling `mysql_list_tables()` is similar to executing the query `SHOW TABLES [LIKE wild]`.

You must free the result set with `mysql_free_result()`.

Return Values

A `MYSQL_RES` result set for success. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.45 mysql_more_results()

```
my_bool mysql_more_results(MYSQL *mysql)
```

Description

This function is used when you execute multiple statements specified as a single statement string, or when you execute `CALL` statements, which can return multiple result sets.

`mysql_more_results()` true if more results exist from the currently executed statement, in which case the application must call `mysql_next_result()` to fetch the results.

Return Values

`TRUE` (1) if more results exist. `FALSE` (0) if no more results exist.

In most cases, you can call `mysql_next_result()` instead to test whether more results exist and initiate retrieval if so.

See Section 23.8.16, “C API Multiple Statement Execution Support”, and Section 23.8.7.46, “mysql_next_result()”.

Errors

None.

23.8.7.46 mysql_next_result()

```
int mysql_next_result(MYSQL *mysql)
```

Description

This function is used when you execute multiple statements specified as a single statement string, or when you use `CALL` statements to execute stored procedures, which can return multiple result sets.

`mysql_next_result()` reads the next statement result and returns a status to indicate whether more results exist. If `mysql_next_result()` returns an error, there are no more results.

Before each call to `mysql_next_result()`, you must call `mysql_free_result()` for the current statement if it is a statement that returned a result set (rather than just a result status).

After calling `mysql_next_result()` the state of the connection is as if you had called `mysql_real_query()` or `mysql_query()` for the next statement. This means that you can call `mysql_store_result()`, `mysql_warning_count()`, `mysql_affected_rows()`, and so forth.

If your program uses `CALL` statements to execute stored procedures, the `CLIENT_MULTI_RESULTS` flag must be enabled. This is because each `CALL` returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure. Because `CALL` can return multiple results, process them using a loop that calls `mysql_next_result()` to determine whether there are more results.

`CLIENT_MULTI_RESULTS` can be enabled when you call `mysql_real_connect()`, either explicitly by passing the `CLIENT_MULTI_RESULTS` flag itself, or implicitly by passing `CLIENT_MULTI_STATEMENTS` (which also enables `CLIENT_MULTI_RESULTS`). `CLIENT_MULTI_RESULTS` is enabled by default.

It is also possible to test whether there are more results by calling `mysql_more_results()`. However, this function does not change the connection state, so if it returns true, you must still call `mysql_next_result()` to advance to the next result.

For an example that shows how to use `mysql_next_result()`, see Section 23.8.16, “C API Multiple Statement Execution Support”.

Return Values

Return Value	Description
0	Successful and there are more results
-1	Successful and there are no more results
>0	An error occurred

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order. For example, if you did not call `mysql_use_result()` for a previous result set.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.47 mysql_num_fields()

```
unsigned int mysql_num_fields(MYSQL_RES *result)
```

To pass a `MYSQL*` argument instead, use `unsigned int mysql_field_count(MYSQL *mysql)`.

Description

Returns the number of columns in a result set.

You can get the number of columns either from a pointer to a result set or to a connection handler. You would use the connection handler if `mysql_store_result()` or `mysql_use_result()` returned `NULL` (and thus you have no result set pointer). In this case, you can call `mysql_field_count()` to determine whether `mysql_store_result()` should have produced a nonempty result. This enables the client program to take proper action without knowing whether the query was a `SELECT` (or `SELECT`-like) statement. The example shown here illustrates how this may be done.

See Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”.

Return Values

An unsigned integer representing the number of columns in a result set.

Errors

None.

Example

```
MYSQL_RES *result;
unsigned int num_fields;
unsigned int num_rows;

if (mysql_query(&mysql,query_string))
{
    // error
}
else // query succeeded, process any data returned by it
{
    result = mysql_store_result(&mysql);
    if (result)  // there are rows
    {
        num_fields = mysql_num_fields(result);
        // retrieve rows, then call mysql_free_result(result)
    }
    else  // mysql_store_result() returned nothing; should it have?
    {
        if (mysql_errno(&mysql))
        {
           fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
        }
        else if (mysql_field_count(&mysql) == 0)
        {
            // query does not return data
            // (it was not a SELECT)
            num_rows = mysql_affected_rows(&mysql);
        }
    }
}
```

An alternative (if you know that your query should have returned a result set) is to replace the `mysql_errno(&mysql)` call with a check whether `mysql_field_count(&mysql)` returns 0. This happens only if something went wrong.

23.8.7.48 mysql_num_rows()

```
my_ulonglong mysql_num_rows(MYSQL_RES *result)
```

Description

Returns the number of rows in the result set.

The use of `mysql_num_rows()` depends on whether you use `mysql_store_result()` or `mysql_use_result()` to return the result set. If you use `mysql_store_result()`, `mysql_num_rows()` may be called immediately. If you use `mysql_use_result()`, `mysql_num_rows()` does not return the correct value until all the rows in the result set have been retrieved.

`mysql_num_rows()` is intended for use with statements that return a result set, such as `SELECT`. For statements such as `INSERT`, `UPDATE`, or `DELETE`, the number of affected rows can be obtained with `mysql_affected_rows()`.

Return Values

The number of rows in the result set.

Errors

None.

23.8.7.49 mysql_options()

```
int mysql_options(MYSQL *mysql, enum mysql_option option, const void *arg)
```

Description

Can be used to set extra connect options and affect behavior for a connection. This function may be called multiple times to set several options.

Call `mysql_options()` after `mysql_init()` and before `mysql_connect()` or `mysql_real_connect()`.

The `option` argument is the option that you want to set; the `arg` argument is the value for the option. If the option is an integer, specify a pointer to the value of the integer as the `arg` argument.

Options for information such as SSL certificate and key files are used to establish an encrypted connection if such connections are available, but do not enforce any requirement that the connection obtained be encrypted. To require an encrypted connection, use the technique described in Section 23.8.15, “C API Encrypted Connection Support”.

The following list describes the possible options, their effect, and how `arg` is used for each option. For option descriptions that indicate `arg` is unused, its value is irrelevant; it is conventional to pass 0. Several of the options apply only when the application is linked against the `libmysqld` embedded server library and are unused for applications linked against the `libmysqlclient` client library.

- `MYSQL_DEFAULT_AUTH` (argument type: `char *`)

  The name of the authentication plugin to use.

- `MYSQL_ENABLE_CLEARTEXT_PLUGIN` (argument type: `my_bool *`)

  Enable the `mysql_clear_password` cleartext authentication plugin. See Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”.

- `MYSQL_INIT_COMMAND` (argument type: `char *`)

  SQL statement to execute when connecting to the MySQL server. Automatically re-executed if reconnection occurs.

- `MYSQL_OPT_COMPRESS` (argument: not used)

  Use the compressed client/server protocol.

- `MYSQL_OPT_CONNECT_TIMEOUT` (argument type: `unsigned int *`)

  The connect timeout in seconds.

- `MYSQL_OPT_GUESS_CONNECTION` (argument: not used)

  For an application linked against the `libmysqld` embedded server library, this option enables the library to guess whether to use the embedded server or a remote server. “Guess” means that if the host name is set and is not `localhost`, it uses a remote server. This behavior is the default. `MYSQL_OPT_USE_EMBEDDED_CONNECTION` and `MYSQL_OPT_USE_REMOTE_CONNECTION` can be

used to override it. This option is ignored for applications linked against the `libmysqlclient` client library.

- `MYSQL_OPT_LOCAL_INFILE` (argument type: optional pointer to `unsigned int`)

  This option affects client-side `LOCAL` capability for `LOAD DATA` operations. By default, `LOCAL` capability is determined by the default compiled into the MySQL client library (see Section 13.2.6, "LOAD DATA INFILE Syntax"). To control this capability explicitly, invoke `mysql_options()` to set the `MYSQL_OPT_LOCAL_INFILE` option:

  - `LOCAL` is disabled if the pointer points to an `unsigned int` that has a zero value.
  - `LOCAL` is enabled if no pointer is given or if the pointer points to an `unsigned int` that has a nonzero value.

  Successful use of a `LOCAL` load operation by a client also requires that the server permits it.

- `MYSQL_OPT_NAMED_PIPE` (argument: not used)

  Use a named pipe to connect to the MySQL server on Windows, if the server permits named-pipe connections.

- `MYSQL_OPT_PROTOCOL` (argument type: `unsigned int *`)

  Type of protocol to use. Specify one of the enum values of `mysql_protocol_type` defined in `mysql.h`.

- `MYSQL_OPT_READ_TIMEOUT` (argument type: `unsigned int *`)

  The timeout in seconds for each attempt to read from the server. There are retries if necessary, so the total effective timeout value is three times the option value. You can set the value so that a lost connection can be detected earlier than the TCP/IP `Close_Wait_Timeout` value of 10 minutes.

  Implementation of this timeout uses mechanisms that may not be available on all platforms. On such a platform, a client that issues a read call might under certain circumstances wait without timing out. For example, a client might not time out if the server is not responding because it is waiting for a "disk full" condition to clear.

- `MYSQL_OPT_RECONNECT` (argument type: `my_bool *`)

  Enable or disable automatic reconnection to the server if the connection is found to have been lost. Reconnect is off by default; this option provides a way to set reconnection behavior explicitly. See Section 23.8.20, "C API Automatic Reconnection Control".

- `MYSQL_OPT_SSL_MODE` (argument type: `unsigned int *`)

  The security state to use for the connection to the server. The only permitted arument value is `SSL_MODE_REQUIRED` (require an encrypted connection). If set, this option causes `mysql_real_connect()` to fail if an encrypted connection cannot be obtained, without falling back to an unencrypted connection. Thus, `mysql_real_connect()` returns an error if the server does not support SSL or the client is not configured to use SSL. For more information about the security states, see the description of `--ssl-mode` in Section 6.4.2, "Command Options for Encrypted Connections".

  To require an encrypted connection in MySQL 5.5, the standard MySQL client programs call `mysql_options()` to set `MYSQL_OPT_SSL_MODE` if the `--ssl-mode=REQUIRED` command-line option was specified. Third-party applications that must be able to require encrypted connections can use the technique described in Section 23.8.15, "C API Encrypted Connection Support".

  This option was added in MySQL 5.5.55.

- `MYSQL_OPT_SSL_VERIFY_SERVER_CERT` (argument type: `my_bool *`)

Enable or disable verification of the server's Common Name identity in its certificate against the host name used when connecting to the server. The connection is rejected if there is a mismatch. For encrypted connections, this feature can be used to prevent man-in-the-middle attacks. Identity verification is disabled by default.

- `MYSQL_OPT_USE_EMBEDDED_CONNECTION` (argument: not used)

  For an application linked against the `libmysqld` embedded server library, this option forces the use of the embedded server for the connection. It is ignored for applications linked against the `libmysqlclient` client library.

- `MYSQL_OPT_USE_REMOTE_CONNECTION` (argument: not used)

  For an application linked against the `libmysqld` embedded server library, this option forces the use of a remote server for the connection. It is ignored for applications linked against the `libmysqlclient` client library.

- `MYSQL_OPT_USE_RESULT` (argument: not used)

  This option is unused.

- `MYSQL_OPT_WRITE_TIMEOUT` (argument type: `unsigned int *`)

  The timeout in seconds for each attempt to write to the server. There is a retry if necessary, so the total effective timeout value is two times the option value.

- `MYSQL_PLUGIN_DIR` (argument type: `char *`)

  The directory in which to look for client plugins.

- `MYSQL_READ_DEFAULT_FILE` (argument type: `char *`)

  Read options from the named option file instead of from `my.cnf`.

- `MYSQL_READ_DEFAULT_GROUP` (argument type: `char *`)

  Read options from the named group from `my.cnf` or the file specified with `MYSQL_READ_DEFAULT_FILE`.

- `MYSQL_REPORT_DATA_TRUNCATION` (argument type: `my_bool *`)

  Enable or disable reporting of data truncation errors for prepared statements using the `error` member of `MYSQL_BIND` structures. (Default: enabled.)

- `MYSQL_SECURE_AUTH` (argument type: `my_bool *`)

  Whether to connect to a server that does not support the password hashing used in MySQL 4.1.1 and later.

- `MYSQL_SET_CHARSET_DIR` (argument type: `char *`)

  The path name of the directory that contains character set definition files.

- `MYSQL_SET_CHARSET_NAME` (argument type: `char *`)

  The name of the character set to use as the default character set. The argument can be `MYSQL_AUTODETECT_CHARSET_NAME` to cause the character set to be autodetected based on the operating system setting (see Section 10.1.4, “Connection Character Sets and Collations”).

- `MYSQL_SET_CLIENT_IP` (argument type: `char *`)

  For an application linked against the `libmysqld` embedded server library (when `libmysqld` is compiled with authentication support), this option means that the user is considered to have

connected from the specified IP address (specified as a string) for authentication purposes. It is ignored for applications linked against the `libmysqlclient` client library.

- `MYSQL_SHARED_MEMORY_BASE_NAME` (argument type: `char *`)

  The name of the shared-memory object for communication to the server on Windows, if the server supports shared-memory connections. Specify the same value as the `--shared-memory-base-name` option used for the `mysqld` server you want to connect to.

The `client` group is always read if you use `MYSQL_READ_DEFAULT_FILE` or `MYSQL_READ_DEFAULT_GROUP`.

The specified group in the option file may contain the following options.

Option	Description
`character-sets-dir=`*`dir_name`*	The directory where character sets are installed.
`compress`	Use the compressed client/server protocol.
`connect-timeout=`*`seconds`*	The connect timeout in seconds. On Linux this timeout is also used for waiting for the first answer from the server.
`database=`*`db_name`*	Connect to this database if no database was specified in the connect command.
`debug`	Debug options.
`default-character-set=`*`charset_name`*	The default character set to use.
`disable-local-infile`	Disable use of `LOAD DATA LOCAL INFILE`.
`enable-cleartext-plugin`	Enable the `mysql_clear_password` cleartext authentication plugin. Added in MySQL 5.5.27.
`host=`*`host_name`*	Default host name.
`init-command=`*`stmt`*	Statement to execute when connecting to MySQL server. Automatically re-executed if reconnection occurs.
`interactive-timeout=`*`seconds`*	Same as specifying `CLIENT_INTERACTIVE` to `mysql_real_connect()`. See Section 23.8.7.52, “mysql_real_connect()”.
`local-infile[={0|1}]`	If no argument or nonzero argument, enable use of `LOAD DATA LOCAL`; otherwise disable.
`max_allowed_packet=`*`bytes`*	Maximum size of packet that client can read from server.
`multi-queries`, `multi-results`	Enable multiple result sets from multiple-statement executions or stored procedures.
`multi-statements`	Enable the client to send multiple statements in a single string (separated by `;` characters).
`password=`*`password`*	Default password.
`pipe`	Use named pipes to connect to a MySQL server on Windows.
`port=`*`port_num`*	Default port number.
`protocol={TCP|SOCKET|PIPE|MEMORY}`	The protocol to use when connecting to the server.
`return-found-rows`	Tell `mysql_info()` to return found rows instead of updated rows when using `UPDATE`.
`shared-memory-base-name=`*`name`*	Shared-memory name to use to connect to server.

Option	Description
socket={*file_name*|*pipe_name*}	Default socket file.
ssl-ca=*file_name*	Certificate Authority file.
ssl-capath=*dir_name*	Certificate Authority directory.
ssl-cert=*file_name*	Certificate file.
ssl-cipher=*cipher_list*	Permissible SSL ciphers.
ssl-key=*file_name*	Key file.
timeout=*seconds*	Like connect-timeout.
user	Default user.

timeout has been replaced by connect-timeout, but timeout is still supported for backward compatibility.

For more information about option files used by MySQL programs, see Section 4.2.6, “Using Option Files”.

Return Values

Zero for success. Nonzero if you specify an unknown option.

Example

The following mysql_options() calls request the use of compression in the client/server protocol, cause options to be read from the [odbc] group in option files, and disable transaction autocommit mode:

```
MYSQL mysql;

mysql_init(&mysql);
mysql_options(&mysql,MYSQL_OPT_COMPRESS,0);
mysql_options(&mysql,MYSQL_READ_DEFAULT_GROUP,"odbc");
mysql_options(&mysql,MYSQL_INIT_COMMAND,"SET autocommit=0");
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
          mysql_error(&mysql));
}
```

23.8.7.50 mysql_ping()

```
int mysql_ping(MYSQL *mysql)
```

Description

Checks whether the connection to the server is working. If the connection has gone down and auto-reconnect is enabled an attempt to reconnect is made. If the connection is down and auto-reconnect is disabled, mysql_ping() returns an error.

Auto-reconnect is disabled by default. To enable it, call mysql_options() with the MYSQL_OPT_RECONNECT option. For details, see Section 23.8.7.49, “mysql_options()”.

mysql_ping() can be used by clients that remain idle for a long while, to check whether the server has closed the connection and reconnect if necessary.

If mysql_ping()) does cause a reconnect, there is no explicit indication of it. To determine whether a reconnect occurs, call mysql_thread_id() to get the original connection identifier before calling mysql_ping(), then call mysql_thread_id() again to see whether the identifier has changed.

If reconnect occurs, some characteristics of the connection will have been reset. For details about these characteristics, see Section 23.8.20, “C API Automatic Reconnection Control”.

Return Values

Zero if the connection to the server is active. Nonzero if an error occurred. A nonzero return does not indicate whether the MySQL server itself is down; the connection might be broken for other reasons such as network problems.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.51 mysql_query()

```
int mysql_query(MYSQL *mysql, const char *stmt_str)
```

Description

Executes the SQL statement pointed to by the null-terminated string `stmt_str`. Normally, the string must consist of a single SQL statement without a terminating semicolon (`;`) or `\g`. If multiple-statement execution has been enabled, the string can contain several statements separated by semicolons. See Section 23.8.16, “C API Multiple Statement Execution Support”.

`mysql_query()` cannot be used for statements that contain binary data; you must use `mysql_real_query()` instead. (Binary data may contain the `\0` character, which `mysql_query()` interprets as the end of the statement string.)

If you want to know whether the statement should return a result set, you can use `mysql_field_count()` to check for this. See Section 23.8.7.22, “mysql_field_count()”.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.52 mysql_real_connect()

```
MYSQL *mysql_real_connect(MYSQL *mysql, const char *host, const char
*user, const char *passwd, const char *db, unsigned int port, const char
*unix_socket, unsigned long client_flag)
```

Description

`mysql_real_connect()` attempts to establish a connection to a MySQL database engine running on `host`. `mysql_real_connect()` must complete successfully before you can execute any other API functions that require a valid `MYSQL` connection handler structure.

The parameters are specified as follows:

- For the first parameter, specify the address of an existing `MYSQL` structure. Before calling `mysql_real_connect()`, call `mysql_init()` to initialize the `MYSQL` structure. You can change a lot of connect options with the `mysql_options()` call. See Section 23.8.7.49, “mysql_options()”.
- The value of `host` may be either a host name or an IP address. If `host` is `NULL` or the string `"localhost"`, a connection to the local host is assumed. For Windows, the client connects using a shared-memory connection, if the server has shared-memory connections enabled. Otherwise, TCP/IP is used. For Unix, the client connects using a Unix socket file. For local connections, you can also influence the type of connection to use with the `MYSQL_OPT_PROTOCOL` or `MYSQL_OPT_NAMED_PIPE` options to `mysql_options()`. The type of connection must be supported by the server. For a `host` value of `"."` on Windows, the client connects using a named pipe, if the server has named-pipe connections enabled. If named-pipe connections are not enabled, an error occurs.
- The `user` parameter contains the user's MySQL login ID. If `user` is `NULL` or the empty string `""`, the current user is assumed. Under Unix, this is the current login name. Under Windows ODBC, the current user name must be specified explicitly. See the Connector/ODBC section of Chapter 23, *Connectors and APIs*.
- The `passwd` parameter contains the password for `user`. If `passwd` is `NULL`, only entries in the `user` table for the user that have a blank (empty) password field are checked for a match. This enables the database administrator to set up the MySQL privilege system in such a way that users get different privileges depending on whether they have specified a password.

  Note

  Do not attempt to encrypt the password before calling `mysql_real_connect()`; password encryption is handled automatically by the client API.

- The `user` and `passwd` parameters use whatever character set has been configured for the `MYSQL` object. By default, this is `latin1`, but can be changed by calling `mysql_options(mysql, MYSQL_SET_CHARSET_NAME, "charset_name")` prior to connecting.
- `db` is the database name. If `db` is not `NULL`, the connection sets the default database to this value.
- If `port` is not 0, the value is used as the port number for the TCP/IP connection. Note that the `host` parameter determines the type of the connection.
- If `unix_socket` is not `NULL`, the string specifies the socket or named pipe to use. Note that the `host` parameter determines the type of the connection.
- The value of `client_flag` is usually 0, but can be set to a combination of the following flags to enable certain features:
  - `CLIENT_COMPRESS`: Use compression in the client/server protocol.

- `CLIENT_FOUND_ROWS`: Return the number of found (matched) rows, not the number of changed rows.
- `CLIENT_IGNORE_SIGPIPE`: Prevents the client library from installing a `SIGPIPE` signal handler. This can be used to avoid conflicts with a handler that the application has already installed.
- `CLIENT_IGNORE_SPACE`: Permit spaces after function names. Makes all functions names reserved words.
- `CLIENT_INTERACTIVE`: Permit `interactive_timeout` seconds of inactivity (rather than `wait_timeout` seconds) before closing the connection. The client's session `wait_timeout` variable is set to the value of the session `interactive_timeout` variable.
- `CLIENT_LOCAL_FILES`: Enable `LOAD DATA LOCAL` handling.
- `CLIENT_MULTI_RESULTS`: Tell the server that the client can handle multiple result sets from multiple-statement executions or stored procedures. This flag is automatically enabled if `CLIENT_MULTI_STATEMENTS` is enabled. See the note following this table for more information about this flag.
- `CLIENT_MULTI_STATEMENTS`: Tell the server that the client may send multiple statements in a single string (separated by `;` characters). If this flag is not set, multiple-statement execution is disabled. See the note following this table for more information about this flag.
- `CLIENT_NO_SCHEMA` Do not permit *`db_name.tbl_name.col_name`* syntax. This is for ODBC. It causes the parser to generate an error if you use that syntax, which is useful for trapping bugs in some ODBC programs.
- `CLIENT_ODBC`: Unused.
- `CLIENT_SSL`: Use SSL (encrypted protocol). Do not set this option within an application program; it is set internally in the client library. Instead, use `mysql_options()` or `mysql_ssl_set()` before calling `mysql_real_connect()`.
- `CLIENT_REMEMBER_OPTIONS` Remember options specified by calls to `mysql_options()`. Without this option, if `mysql_real_connect()` fails, you must repeat the `mysql_options()` calls before trying to connect again. With this option, the `mysql_options()` calls need not be repeated.

If your program uses `CALL` statements to execute stored procedures, the `CLIENT_MULTI_RESULTS` flag must be enabled. This is because each `CALL` returns a result to indicate the call status, in addition to any result sets that might be returned by statements executed within the procedure. Because `CALL` can return multiple results, process them using a loop that calls `mysql_next_result()` to determine whether there are more results.

`CLIENT_MULTI_RESULTS` can be enabled when you call `mysql_real_connect()`, either explicitly by passing the `CLIENT_MULTI_RESULTS` flag itself, or implicitly by passing `CLIENT_MULTI_STATEMENTS` (which also enables `CLIENT_MULTI_RESULTS`). `CLIENT_MULTI_RESULTS` is enabled by default.

If you enable `CLIENT_MULTI_STATEMENTS` or `CLIENT_MULTI_RESULTS`, you should process the result for every call to `mysql_query()` or `mysql_real_query()` by using a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 23.8.16, “C API Multiple Statement Execution Support”.

For some parameters, it is possible to have the value taken from an option file rather than from an explicit value in the `mysql_real_connect()` call. To do this, call `mysql_options()` with the `MYSQL_READ_DEFAULT_FILE` or `MYSQL_READ_DEFAULT_GROUP` option before calling `mysql_real_connect()`. Then, in the `mysql_real_connect()` call, specify the “no-value” value for each parameter to be read from an option file:

- For `host`, specify a value of `NULL` or the empty string (`""`).
- For `user`, specify a value of `NULL` or the empty string.
- For `passwd`, specify a value of `NULL`. (For the password, a value of the empty string in the `mysql_real_connect()` call cannot be overridden in an option file, because the empty string indicates explicitly that the MySQL account must have an empty password.)
- For `db`, specify a value of `NULL` or the empty string.
- For `port`, specify a value of 0.
- For `unix_socket`, specify a value of `NULL`.

If no value is found in an option file for a parameter, its default value is used as indicated in the descriptions given earlier in this section.

Return Values

A `MYSQL*` connection handler if the connection was successful, `NULL` if the connection was unsuccessful. For a successful connection, the return value is the same as the value of the first parameter.

Errors

- `CR_CONN_HOST_ERROR`

  Failed to connect to the MySQL server.

- `CR_CONNECTION_ERROR`

  Failed to connect to the local MySQL server.

- `CR_IPSOCK_ERROR`

  Failed to create an IP socket.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SOCKET_CREATE_ERROR`

  Failed to create a Unix socket.

- `CR_UNKNOWN_HOST`

  Failed to find the IP address for the host name.

- `CR_VERSION_ERROR`

  A protocol mismatch resulted from attempting to connect to a server with a client library that uses a different protocol version.

- `CR_NAMEDPIPEOPEN_ERROR`

  Failed to create a named pipe on Windows.

- `CR_NAMEDPIPEWAIT_ERROR`

  Failed to wait for a named pipe on Windows.

- `CR_NAMEDPIPESETSTATE_ERROR`

  Failed to get a pipe handler on Windows.

- `CR_SERVER_LOST`

  If `connect_timeout` > 0 and it took longer than `connect_timeout` seconds to connect to the server or if the server died while executing the `init-command`.

- `CR_ALREADY_CONNECTED`

  The `MYSQL` connection handler is already connected.

Example

```
MYSQL mysql;

mysql_init(&mysql);
mysql_options(&mysql,MYSQL_READ_DEFAULT_GROUP,"your_prog_name");
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
          mysql_error(&mysql));
}
```

By using `mysql_options()` the MySQL library reads the `[client]` and `[your_prog_name]` sections in the `my.cnf` file which ensures that your program works, even if someone has set up MySQL in some nonstandard way.

Upon connection, `mysql_real_connect()` sets the `reconnect` flag (part of the `MYSQL` structure) to a value of `1` in versions of the API older than 5.0.3, or `0` in newer versions. A value of `1` for this flag indicates that if a statement cannot be performed because of a lost connection, to try reconnecting to the server before giving up. You can use the `MYSQL_OPT_RECONNECT` option to `mysql_options()` to control reconnection behavior.

23.8.7.53 mysql_real_escape_string()

```
unsigned long mysql_real_escape_string(MYSQL *mysql, char *to, const char
*from, unsigned long length)
```

Description

This function creates a legal SQL string for use in an SQL statement. See Section 9.1.1, “String Literals”.

The `mysql` argument must be a valid, open connection because character escaping depends on the character set in use by the server.

The string in the `from` argument is encoded to produce an escaped SQL string, taking into account the current character set of the connection. The result is placed in the `to` argument, followed by a terminating null byte.

Characters encoded are `\`, `'`, `"`, `NUL` (ASCII 0), `\n`, `\r`, and Control+Z. Strictly speaking, MySQL requires only that backslash and the quote character used to quote the string in the query be escaped. `mysql_real_escape_string()` quotes the other characters to make them easier to read in log files. For comparison, see the quoting rules for literal strings and the `QUOTE()` SQL function in Section 9.1.1, “String Literals”, and Section 12.5, “String Functions”.

The string pointed to by `from` must be `length` bytes long. You must allocate the `to` buffer to be at least `length*2+1` bytes long. (In the worst case, each character may need to be encoded as using two bytes, and there must be room for the terminating null byte.) When `mysql_real_escape_string()` returns, the contents of `to` is a null-terminated string. The return value is the length of the encoded string, not including the terminating null byte.

If you must change the character set of the connection, use the `mysql_set_character_set()` function rather than executing a `SET NAMES` (or `SET CHARACTER SET`) statement.

`mysql_set_character_set()` works like `SET NAMES` but also affects the character set used by `mysql_real_escape_string()`, which `SET NAMES` does not.

Example

The following example inserts two escaped strings into an `INSERT` statement, each within single quote characters:

```
char query[1000],*end;

end = strmov(query,"INSERT INTO test_table VALUES(");
*end++ = '\'';
end += mysql_real_escape_string(&mysql,end,"What is this",12);
*end++ = '\'';
*end++ = ',';
*end++ = '\'';
end += mysql_real_escape_string(&mysql,end,"binary data: \0\r\n",16);
*end++ = '\'';
*end++ = ')';

if (mysql_real_query(&mysql,query,(unsigned int) (end - query)))
{
   fprintf(stderr, "Failed to insert row, Error: %s\n",
           mysql_error(&mysql));
}
```

The `strmov()` function used in the example is included in the `libmysqlclient` library and works like `strcpy()` but returns a pointer to the terminating null of the first parameter.

Return Values

The length of the encoded string that is placed into the `to` argument, not including the terminating null character.

Errors

None.

23.8.7.54 mysql_real_query()

```
int mysql_real_query(MYSQL *mysql, const char *stmt_str, unsigned long
length)
```

Description

Executes the SQL statement pointed to by `stmt_str`, a string `length` bytes long. Normally, the string must consist of a single SQL statement without a terminating semicolon (`;`) or `\g`. If multiple-statement execution has been enabled, the string can contain several statements separated by semicolons. See Section 23.8.16, “C API Multiple Statement Execution Support”.

`mysql_query()` cannot be used for statements that contain binary data; you must use `mysql_real_query()` instead. (Binary data may contain the `\0` character, which `mysql_query()` interprets as the end of the statement string.) In addition, `mysql_real_query()` is faster than `mysql_query()` because it does not call `strlen()` on the statement string.

If you want to know whether the statement should return a result set, you can use `mysql_field_count()` to check for this. See Section 23.8.7.22, “mysql_field_count()”.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.55 mysql_refresh()

```
int mysql_refresh(MYSQL *mysql, unsigned int options)
```

Description

This function flushes tables or caches, or resets replication server information. The connected user must have the `RELOAD` privilege.

The `options` argument is a bitmask composed from any combination of the following values. Multiple values can be OR'ed together to perform multiple operations with a single call.

- `REFRESH_GRANT`

  Refresh the grant tables, like `FLUSH PRIVILEGES`.

- `REFRESH_LOG`

  Flush the logs, like `FLUSH LOGS`.

- `REFRESH_TABLES`

  Flush the table cache, like `FLUSH TABLES`.

- `REFRESH_HOSTS`

  Flush the host cache, like `FLUSH HOSTS`.

- `REFRESH_STATUS`

  Reset status variables, like `FLUSH STATUS`.

- `REFRESH_THREADS`

  Flush the thread cache.

- `REFRESH_SLAVE`

  On a slave replication server, reset the master server information and restart the slave, like `RESET SLAVE`.

- `REFRESH_MASTER`

  On a master replication server, remove the binary log files listed in the binary log index and truncate the index file, like `RESET MASTER`.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.56 mysql_reload()

```
int mysql_reload(MYSQL *mysql)
```

Description

Asks the MySQL server to reload the grant tables. The connected user must have the `RELOAD` privilege.

This function is deprecated. Use `mysql_query()` to issue an SQL `FLUSH PRIVILEGES` statement instead.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.57 mysql_rollback()

```
my_bool mysql_rollback(MYSQL *mysql)
```

Description

Rolls back the current transaction.

The action of this function is subject to the value of the `completion_type` system variable. In particular, if the value of `completion_type` is `RELEASE` (or 2), the server performs a release after terminating a transaction and closes the client connection. Call `mysql_close()` from the client program to close the connection from the client side.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

None.

23.8.7.58 mysql_row_seek()

```
MYSQL_ROW_OFFSET mysql_row_seek(MYSQL_RES *result, MYSQL_ROW_OFFSET offset)
```

Description

Sets the row cursor to an arbitrary row in a query result set. The `offset` value is a row offset, typically a value returned from `mysql_row_tell()` or from `mysql_row_seek()`. This value is not a row number; to seek to a row within a result set by number, use `mysql_data_seek()` instead.

This function requires that the result set structure contains the entire result of the query, so `mysql_row_seek()` may be used only in conjunction with `mysql_store_result()`, not with `mysql_use_result()`.

Return Values

The previous value of the row cursor. This value may be passed to a subsequent call to `mysql_row_seek()`.

Errors

None.

23.8.7.59 mysql_row_tell()

```
MYSQL_ROW_OFFSET mysql_row_tell(MYSQL_RES *result)
```

Description

Returns the current position of the row cursor for the last `mysql_fetch_row()`. This value can be used as an argument to `mysql_row_seek()`.

Use `mysql_row_tell()` only after `mysql_store_result()`, not after `mysql_use_result()`.

Return Values

The current offset of the row cursor.

Errors

None.

23.8.7.60 mysql_select_db()

```
int mysql_select_db(MYSQL *mysql, const char *db)
```

Description

Causes the database specified by `db` to become the default (current) database on the connection specified by `mysql`. In subsequent queries, this database is the default for table references that include no explicit database specifier.

`mysql_select_db()` fails unless the connected user can be authenticated as having permission to use the database.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.61 mysql_set_character_set()

```
int mysql_set_character_set(MYSQL *mysql, const char *csname)
```

Description

This function is used to set the default character set for the current connection. The string `csname` specifies a valid character set name. The connection collation becomes the default collation of the character set. This function works like the `SET NAMES` statement, but also sets the value of `mysql->charset`, and thus affects the character set used by `mysql_real_escape_string()`

Return Values

Zero for success. Nonzero if an error occurred.

Example

```
MYSQL mysql;

mysql_init(&mysql);
if (!mysql_real_connect(&mysql,"host","user","passwd","database",0,NULL,0))
{
    fprintf(stderr, "Failed to connect to database: Error: %s\n",
          mysql_error(&mysql));
}

if (!mysql_set_character_set(&mysql, "utf8"))
{
    printf("New client character set: %s\n",
           mysql_character_set_name(&mysql));
}
```

23.8.7.62 mysql_set_local_infile_default()

```
void mysql_set_local_infile_default(MYSQL *mysql);
```

Description

Sets the `LOAD DATA LOCAL INFILE` callback functions to the defaults used internally by the C client library. The library calls this function automatically if `mysql_set_local_infile_handler()` has not been called or does not supply valid functions for each of its callbacks.

Return Values

None.

Errors

None.

23.8.7.63 mysql_set_local_infile_handler()

```
void mysql_set_local_infile_handler(MYSQL *mysql, int (*local_infile_init)
(void **, const char *, void *), int (*local_infile_read)(void *, char *,
unsigned int), void (*local_infile_end)(void *), int (*local_infile_error)
(void *, char*, unsigned int), void *userdata);
```

Description

This function installs callbacks to be used during the execution of `LOAD DATA LOCAL INFILE` statements. It enables application programs to exert control over local (client-side) data file reading. The arguments are the connection handler, a set of pointers to callback functions, and a pointer to a data area that the callbacks can use to share information.

To use `mysql_set_local_infile_handler()`, you must write the following callback functions:

```
int
local_infile_init(void **ptr, const char *filename, void *userdata);
```

The initialization function. This is called once to do any setup necessary, open the data file, allocate data structures, and so forth. The first `void**` argument is a pointer to a pointer. You can set the pointer (that is, `*ptr`) to a value that will be passed to each of the other callbacks (as a `void*`). The callbacks can use this pointed-to value to maintain state information. The `userdata` argument is the same value that is passed to `mysql_set_local_infile_handler()`.

The initialization function should return zero for success, nonzero for an error.

```
int
local_infile_read(void *ptr, char *buf, unsigned int buf_len);
```

The data-reading function. This is called repeatedly to read the data file. `buf` points to the buffer where the read data is stored, and `buf_len` is the maximum number of bytes that the callback can read and store in the buffer. (It can read fewer bytes, but should not read more.)

The return value is the number of bytes read, or zero when no more data could be read (this indicates EOF). Return a value less than zero if an error occurs.

```
void
local_infile_end(void *ptr)
```

The termination function. This is called once after `local_infile_read()` has returned zero (EOF) or an error. Within this function, deallocate any memory allocated by `local_infile_init()` and perform any other cleanup necessary. It is invoked even if the initialization function returns an error.

```
int
local_infile_error(void *ptr,
                   char *error_msg,
                   unsigned int error_msg_len);
```

The error-handling function. This is called to get a textual error message to return to the user in case any of your other functions returns an error. `error_msg` points to the buffer into which the message is

written, and `error_msg_len` is the length of the buffer. Write the message as a null-terminated string, at most `error_msg_len`−1 bytes long.

The return value is the error number.

Typically, the other callbacks store the error message in the data structure pointed to by `ptr`, so that `local_infile_error()` can copy the message from there into `error_msg`.

After calling `mysql_set_local_infile_handler()` in your C code and passing pointers to your callback functions, you can then issue a `LOAD DATA LOCAL INFILE` statement (for example, by using `mysql_query()`). The client library automatically invokes your callbacks. The file name specified in `LOAD DATA LOCAL INFILE` will be passed as the second parameter to the `local_infile_init()` callback.

Return Values

None.

Errors

None.

23.8.7.64 mysql_set_server_option()

```
int mysql_set_server_option(MYSQL *mysql, enum enum_mysql_set_option option)
```

Description

Enables or disables an option for the connection. `option` can have one of the following values.

Option	Description
`MYSQL_OPTION_MULTI_STATEMENTS_ON`	Enable multiple-statement support
`MYSQL_OPTION_MULTI_STATEMENTS_OFF`	Disable multiple-statement support

If you enable multiple-statement support, you should retrieve results from calls to `mysql_query()` or `mysql_real_query()` by using a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 23.8.16, “C API Multiple Statement Execution Support”.

Enabling multiple-statement support with `MYSQL_OPTION_MULTI_STATEMENTS_ON` does not have quite the same effect as enabling it by passing the `CLIENT_MULTI_STATEMENTS` flag to `mysql_real_connect()`: `CLIENT_MULTI_STATEMENTS` also enables `CLIENT_MULTI_RESULTS`. If you are using the `CALL` SQL statement in your programs, multiple-result support must be enabled; this means that `MYSQL_OPTION_MULTI_STATEMENTS_ON` by itself is insufficient to permit the use of `CALL`.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

The connection to the server was lost during the query.

- `ER_UNKNOWN_COM_ERROR`

  The server did not support `mysql_set_server_option()` (which is the case that the server is older than 4.1.1) or the server did not support the option one tried to set.

23.8.7.65 mysql_shutdown()

```
int mysql_shutdown(MYSQL *mysql, enum mysql_enum_shutdown_level
shutdown_level)
```

Description

Asks the database server to shut down. The connected user must have the `SHUTDOWN` privilege. MySQL servers support only one type of shutdown; `shutdown_level` must be equal to `SHUTDOWN_DEFAULT`. Dynamically linked executables which have been compiled with older versions of the `libmysqlclient` headers and call `mysql_shutdown()` need to be used with the old `libmysqlclient` dynamic library.

The shutdown process is described in Section 5.1.12, “The Server Shutdown Process”.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.66 mysql_sqlstate()

```
const char *mysql_sqlstate(MYSQL *mysql)
```

Description

Returns a null-terminated string containing the SQLSTATE error code for the most recently executed SQL statement. The error code consists of five characters. `'00000'` means “no error.” The values are specified by ANSI SQL and ODBC. For a list of possible values, see Appendix B, *Errors, Error Codes, and Common Problems*.

SQLSTATE values returned by `mysql_sqlstate()` differ from MySQL-specific error numbers returned by `mysql_errno()`. For example, the `mysql` client program displays errors using the following format, where `1146` is the `mysql_errno()` value and `'42S02'` is the corresponding `mysql_sqlstate()` value:

```
shell> SELECT * FROM no_such_table;
```

```
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
```

Not all MySQL error numbers are mapped to SQLSTATE error codes. The value `'HY000'` (general error) is used for unmapped error numbers.

If you call `mysql_sqlstate()` after `mysql_real_connect()` fails, `mysql_sqlstate()` might not return a useful value. For example, this happens if a host is blocked by the server and the connection is closed without any SQLSTATE value being sent to the client.

Return Values

A null-terminated character string containing the SQLSTATE error code.

See Also

See Section 23.8.7.14, “mysql_errno()”, Section 23.8.7.15, “mysql_error()”, and Section 23.8.11.27, “mysql_stmt_sqlstate()”.

23.8.7.67 mysql_ssl_set()

```
my_bool mysql_ssl_set(MYSQL *mysql, const char *key, const char *cert, const
char *ca, const char *capath, const char *cipher)
```

Description

`mysql_ssl_set()` is used for establishing encrypted connections using SSL. The `mysql` argument must be a valid connection handler. Any unused SSL arguments may be given as `NULL`.

If used, `mysql_ssl_set()` must be called before `mysql_real_connect()`. `mysql_ssl_set()` does nothing unless SSL support is enabled in the client library.

`mysql_ssl_set()` specifies SSL information such as certificate and key files for establishing an encrypted connection if such connections are available, but does not enforce any requirement that the connection obtained be encrypted. To require an encrypted connection, use the technique described in Section 23.8.15, “C API Encrypted Connection Support”.

For additional security relative to that provided by the default encryption, clients can supply a CA certificate matching the one used by the server and enable host name identity verification. In this way, the server and client place their trust in the same CA certificate and the client verifies that the host to which it connected is the one intended. For details, see Section 23.8.15, “C API Encrypted Connection Support”.

Arguments:

- `mysql`: The connection handler returned from `mysql_init()`.
- `key`: The path name of the client private key file.
- `cert`: The path name of the client public key certificate file.
- `ca`: The path name of the Certificate Authority (CA) certificate file. This option, if used, must specify the same certificate used by the server.
- `capath`: The path name of the directory that contains trusted SSL CA certificate files.
- `cipher`: The list of permitted ciphers for SSL encryption.

Return Values

This function always returns `0`. If SSL setup is incorrect, a subsequent `mysql_real_connect()` call returns an error when you attempt to connect.

23.8.7.68 mysql_stat()

```
const char *mysql_stat(MYSQL *mysql)
```

Description

Returns a character string containing information similar to that provided by the `mysqladmin status` command. This includes uptime in seconds and the number of running threads, questions, reloads, and open tables.

Return Values

A character string describing the server status. `NULL` if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.69 mysql_store_result()

```
MYSQL_RES *mysql_store_result(MYSQL *mysql)
```

Description

After invoking `mysql_query()` or `mysql_real_query()`, you must call `mysql_store_result()` or `mysql_use_result()` for every statement that successfully produces a result set (`SELECT`, `SHOW`, `DESCRIBE`, `EXPLAIN`, `CHECK TABLE`, and so forth). You must also call `mysql_free_result()` after you are done with the result set.

You need not call `mysql_store_result()` or `mysql_use_result()` for other statements, but it does not do any harm or cause any notable performance degradation if you call `mysql_store_result()` in all cases. You can detect whether the statement has a result set by checking whether `mysql_store_result()` returns a nonzero value (more about this later).

If you enable multiple-statement support, you should retrieve results from calls to `mysql_query()` or `mysql_real_query()` by using a loop that calls `mysql_next_result()` to determine whether there are more results. For an example, see Section 23.8.16, “C API Multiple Statement Execution Support”.

If you want to know whether a statement should return a result set, you can use `mysql_field_count()` to check for this. See Section 23.8.7.22, “mysql_field_count()”.

`mysql_store_result()` reads the entire result of a query to the client, allocates a `MYSQL_RES` structure, and places the result into this structure.

`mysql_store_result()` returns a null pointer if the statement did not return a result set (for example, if it was an `INSERT` statement).

`mysql_store_result()` also returns a null pointer if reading of the result set failed. You can check whether an error occurred by checking whether `mysql_error()` returns a nonempty string, `mysql_errno()` returns nonzero, or `mysql_field_count()` returns zero.

An empty result set is returned if there are no rows returned. (An empty result set differs from a null pointer as a return value.)

After you have called `mysql_store_result()` and gotten back a result that is not a null pointer, you can call `mysql_num_rows()` to find out how many rows are in the result set.

You can call `mysql_fetch_row()` to fetch rows from the result set, or `mysql_row_seek()` and `mysql_row_tell()` to obtain or set the current row position within the result set.

See Section 23.8.21.1, "Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success".

Return Values

A `MYSQL_RES` result structure with the results. `NULL` (0) if an error occurred.

Errors

`mysql_store_result()` resets `mysql_error()` and `mysql_errno()` if it succeeds.

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.70 mysql_thread_id()

```
unsigned long mysql_thread_id(MYSQL *mysql)
```

Description

Returns the thread ID of the current connection. This value can be used as an argument to `mysql_kill()` to kill the thread.

If the connection is lost and you reconnect with `mysql_ping()`, the thread ID changes. This means you should not get the thread ID and store it for later. You should get it when you need it.

Note

This function does not work correctly if thread IDs become larger than 32 bits, which can occur on some systems. To avoid problems with `mysql_thread_id()`, do not use it. To get the connection ID, execute a `SELECT CONNECTION_ID()` query and retrieve the result.

Return Values

The thread ID of the current connection.

Errors

None.

23.8.7.71 mysql_use_result()

```
MYSQL_RES *mysql_use_result(MYSQL *mysql)
```

Description

After invoking `mysql_query()` or `mysql_real_query()`, you must call `mysql_store_result()` or `mysql_use_result()` for every statement that successfully produces a result set (`SELECT`, `SHOW`, `DESCRIBE`, `EXPLAIN`, `CHECK TABLE`, and so forth). You must also call `mysql_free_result()` after you are done with the result set.

`mysql_use_result()` initiates a result set retrieval but does not actually read the result set into the client like `mysql_store_result()` does. Instead, each row must be retrieved individually by making calls to `mysql_fetch_row()`. This reads the result of a query directly from the server without storing it in a temporary table or local buffer, which is somewhat faster and uses much less memory than `mysql_store_result()`. The client allocates memory only for the current row and a communication buffer that may grow up to `max_allowed_packet` bytes.

On the other hand, you should not use `mysql_use_result()` for locking reads if you are doing a lot of processing for each row on the client side, or if the output is sent to a screen on which the user may type a `^S` (stop scroll). This ties up the server and prevent other threads from updating any tables from which the data is being fetched.

When using `mysql_use_result()`, you must execute `mysql_fetch_row()` until a `NULL` value is returned, otherwise, the unfetched rows are returned as part of the result set for your next query. The C API gives the error `Commands out of sync; you can't run this command now` if you forget to do this!

You may not use `mysql_data_seek()`, `mysql_row_seek()`, `mysql_row_tell()`, `mysql_num_rows()`, or `mysql_affected_rows()` with a result returned from `mysql_use_result()`, nor may you issue other queries until `mysql_use_result()` has finished. (However, after you have fetched all the rows, `mysql_num_rows()` accurately returns the number of rows fetched.)

You must call `mysql_free_result()` once you are done with the result set.

When using the `libmysqld` embedded server, the memory benefits are essentially lost because memory usage incrementally increases with each row retrieved until `mysql_free_result()` is called.

Return Values

A `MYSQL_RES` result structure. `NULL` if an error occurred.

Errors

`mysql_use_result()` resets `mysql_error()` and `mysql_errno()` if it succeeds.

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.7.72 mysql_warning_count()

```
unsigned int mysql_warning_count(MYSQL *mysql)
```

Description

Returns the number of errors, warnings, and notes generated during execution of the previous SQL statement.

Return Values

The warning count.

Errors

None.

23.8.8 C API Prepared Statements

The MySQL client/server protocol provides for the use of prepared statements. This capability uses the `MYSQL_STMT` statement handler data structure returned by the `mysql_stmt_init()` initialization function. Prepared execution is an efficient way to execute a statement more than once. The statement is first parsed to prepare it for execution. Then it is executed one or more times at a later time, using the statement handler returned by the initialization function.

Prepared execution is faster than direct execution for statements executed more than once, primarily because the query is parsed only once. In the case of direct execution, the query is parsed every time it is executed. Prepared execution also can provide a reduction of network traffic because for each execution of the prepared statement, it is necessary only to send the data for the parameters.

Prepared statements might not provide a performance increase in some situations. For best results, test your application both with prepared and nonprepared statements and choose whichever yields best performance.

Another advantage of prepared statements is that it uses a binary protocol that makes data transfer between client and server more efficient.

For a list of SQL statements that can be used as prepared statements, see Section 13.5, “Prepared SQL Statement Syntax”.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation”.

23.8.9 C API Prepared Statement Data Structures

Prepared statements use several data structures:

- To obtain a statement handler, pass a `MYSQL` connection handler to `mysql_stmt_init()`, which returns a pointer to a `MYSQL_STMT` data structure. This structure is used for further operations with the statement. To specify the statement to prepare, pass the `MYSQL_STMT` pointer and the statement string to `mysql_stmt_prepare()`.

- To provide input parameters for a prepared statement, set up `MYSQL_BIND` structures and pass them to `mysql_stmt_bind_param()`. To receive output column values, set up `MYSQL_BIND` structures and pass them to `mysql_stmt_bind_result()`.
- The `MYSQL_TIME` structure is used to transfer temporal data in both directions.

The following discussion describes the prepared statement data types in detail. For examples that show how to use them, see Section 23.8.11.10, “mysql_stmt_execute()”, and Section 23.8.11.11, “mysql_stmt_fetch()”.

- `MYSQL_STMT`

  This structure is a handler for a prepared statement. A handler is created by calling `mysql_stmt_init()`, which returns a pointer to a `MYSQL_STMT`. The handler is used for all subsequent operations with the statement until you close it with `mysql_stmt_close()`, at which point the handler becomes invalid and should no longer be used.

  The `MYSQL_STMT` structure has no members intended for application use. Applications should not try to copy a `MYSQL_STMT` structure. There is no guarantee that such a copy will be usable.

  Multiple statement handlers can be associated with a single connection. The limit on the number of handlers depends on the available system resources.

- `MYSQL_BIND`

  This structure is used both for statement input (data values sent to the server) and output (result values returned from the server):

  - For input, use `MYSQL_BIND` structures with `mysql_stmt_bind_param()` to bind parameter data values to buffers for use by `mysql_stmt_execute()`.
  - For output, use `MYSQL_BIND` structures with `mysql_stmt_bind_result()` to bind buffers to result set columns, for use in fetching rows with `mysql_stmt_fetch()`.

  To use a `MYSQL_BIND` structure, zero its contents to initialize it, then set its members appropriately. For example, to declare and initialize an array of three `MYSQL_BIND` structures, use this code:

```
MYSQL_BIND bind[3];
memset(bind, 0, sizeof(bind));
```

  The `MYSQL_BIND` structure contains the following members for use by application programs. For several of the members, the manner of use depends on whether the structure is used for input or output.

  - `enum enum_field_types buffer_type`

    The type of the buffer. This member indicates the data type of the C language variable bound to a statement parameter or result set column. For input, `buffer_type` indicates the type of the variable containing the value to be sent to the server. For output, it indicates the type of the variable into which a value received from the server should be stored. For permissible `buffer_type` values, see Section 23.8.9.1, “C API Prepared Statement Type Codes”.

  - `void *buffer`

    A pointer to the buffer to be used for data transfer. This is the address of a C language variable.

    For input, `buffer` is a pointer to the variable in which you store the data value for a statement parameter. When you call `mysql_stmt_execute()`, MySQL use the value stored in the variable in place of the corresponding parameter marker in the statement (specified with `?` in the statement string).

For output, `buffer` is a pointer to the variable in which to return a result set column value. When you call `mysql_stmt_fetch()`, MySQL stores a column value from the current row of the result set in this variable. You can access the value when the call returns.

To minimize the need for MySQL to perform type conversions between C language values on the client side and SQL values on the server side, use C variables that have types similar to those of the corresponding SQL values:

- For numeric data types, `buffer` should point to a variable of the proper numeric C type. For integer variables (which can be `char` for single-byte values or an integer type for larger values), you should also indicate whether the variable has the `unsigned` attribute by setting the `is_unsigned` member, described later.
- For character (nonbinary) and binary string data types, `buffer` should point to a character buffer.
- For date and time data types, `buffer` should point to a `MYSQL_TIME` structure.

For guidelines about mapping between C types and SQL types and notes about type conversions, see Section 23.8.9.1, “C API Prepared Statement Type Codes”, and Section 23.8.9.2, “C API Prepared Statement Type Conversions”.

- `unsigned long buffer_length`

  The actual size of `*buffer` in bytes. This indicates the maximum amount of data that can be stored in the buffer. For character and binary C data, the `buffer_length` value specifies the length of `*buffer` when used with `mysql_stmt_bind_param()` to specify input values, or the maximum number of output data bytes that can be fetched into the buffer when used with `mysql_stmt_bind_result()`.

- `unsigned long *length`

  A pointer to an `unsigned long` variable that indicates the actual number of bytes of data stored in `*buffer`. `length` is used for character or binary C data.

  For input parameter data binding, set `*length` to indicate the actual length of the parameter value stored in `*buffer`. This is used by `mysql_stmt_execute()`.

  For output value binding, MySQL sets `*length` when you call `mysql_stmt_fetch()`. The `mysql_stmt_fetch()` return value determines how to interpret the length:

  - If the return value is 0, `*length` indicates the actual length of the parameter value.
  - If the return value is `MYSQL_DATA_TRUNCATED`, `*length` indicates the nontruncated length of the parameter value. In this case, the minimum of `*length` and `buffer_length` indicates the actual length of the value.

  `length` is ignored for numeric and temporal data types because the `buffer_type` value determines the length of the data value.

  If you must determine the length of a returned value before fetching it, see Section 23.8.11.11, “mysql_stmt_fetch()”, for some strategies.

- `my_bool *is_null`

  This member points to a `my_bool` variable that is true if a value is `NULL`, false if it is not `NULL`. For input, set `*is_null` to true to indicate that you are passing a `NULL` value as a statement parameter.

`is_null` is a *pointer* to a boolean scalar, not a boolean scalar, to provide flexibility in how you specify `NULL` values:

- If your data values are always `NULL`, use `MYSQL_TYPE_NULL` as the `buffer_type` value when you bind the column. The other `MYSQL_BIND` members, including `is_null`, do not matter.
- If your data values are always `NOT NULL`, set `is_null = (my_bool*) 0`, and set the other members appropriately for the variable you are binding.
- In all other cases, set the other members appropriately and set `is_null` to the address of a `my_bool` variable. Set that variable's value to true or false appropriately between executions to indicate whether the corresponding data value is `NULL` or `NOT NULL`, respectively.

For output, when you fetch a row, MySQL sets the value pointed to by `is_null` to true or false according to whether the result set column value returned from the statement is or is not `NULL`.

- `my_bool is_unsigned`

  This member applies for C variables with data types that can be `unsigned` (`char`, `short int`, `int`, `long long int`). Set `is_unsigned` to true if the variable pointed to by `buffer` is `unsigned` and false otherwise. For example, if you bind a `signed char` variable to `buffer`, specify a type code of `MYSQL_TYPE_TINY` and set `is_unsigned` to false. If you bind an `unsigned char` instead, the type code is the same but `is_unsigned` should be true. (For `char`, it is not defined whether it is signed or unsigned, so it is best to be explicit about signedness by using `signed char` or `unsigned char`.)

  `is_unsigned` applies only to the C language variable on the client side. It indicates nothing about the signedness of the corresponding SQL value on the server side. For example, if you use an `int` variable to supply a value for a `BIGINT UNSIGNED` column, `is_unsigned` should be false because `int` is a signed type. If you use an `unsigned int` variable to supply a value for a `BIGINT` column, `is_unsigned` should be true because `unsigned int` is an unsigned type. MySQL performs the proper conversion between signed and unsigned values in both directions, although a warning occurs if truncation results.

- `my_bool *error`

  For output, set this member to point to a `my_bool` variable to have truncation information for the parameter stored there after a row fetching operation. When truncation reporting is enabled, `mysql_stmt_fetch()` returns `MYSQL_DATA_TRUNCATED` and `*error` is true in the `MYSQL_BIND` structures for parameters in which truncation occurred. Truncation indicates loss of sign or significant digits, or that a string was too long to fit in a column. Truncation reporting is enabled by default, but can be controlled by calling `mysql_options()` with the `MYSQL_REPORT_DATA_TRUNCATION` option.

- `MYSQL_TIME`

This structure is used to send and receive `DATE`, `TIME`, `DATETIME`, and `TIMESTAMP` data directly to and from the server. Set the `buffer` member to point to a `MYSQL_TIME` structure, and set the `buffer_type` member of a `MYSQL_BIND` structure to one of the temporal types (`MYSQL_TYPE_TIME`, `MYSQL_TYPE_DATE`, `MYSQL_TYPE_DATETIME`, `MYSQL_TYPE_TIMESTAMP`).

The `MYSQL_TIME` structure contains the members listed in the following table.

Member	Description
`unsigned int year`	The year
`unsigned int month`	The month of the year
`unsigned int day`	The day of the month

Member	Description
`unsigned int hour`	The hour of the day
`unsigned int minute`	The minute of the hour
`unsigned int second`	The second of the minute
`my_bool neg`	A boolean flag indicating whether the time is negative
`unsigned long second_part`	The fractional part of the second in microseconds; currently unused

Only those parts of a `MYSQL_TIME` structure that apply to a given type of temporal value are used. The `year`, `month`, and `day` elements are used for `DATE`, `DATETIME`, and `TIMESTAMP` values. The `hour`, `minute`, and `second` elements are used for `TIME`, `DATETIME`, and `TIMESTAMP` values. See Section 23.8.17, “C API Prepared Statement Handling of Date and Time Values”.

23.8.9.1 C API Prepared Statement Type Codes

The `buffer_type` member of `MYSQL_BIND` structures indicates the data type of the C language variable bound to a statement parameter or result set column. For input, `buffer_type` indicates the type of the variable containing the value to be sent to the server. For output, it indicates the type of the variable into which a value received from the server should be stored.

The following table shows the permissible values for the `buffer_type` member of `MYSQL_BIND` structures for input values sent to the server. The table shows the C variable types that you can use, the corresponding type codes, and the SQL data types for which the supplied value can be used without conversion. Choose the `buffer_type` value according to the data type of the C language variable that you are binding. For the integer types, you should also set the `is_unsigned` member to indicate whether the variable is signed or unsigned.

Input Variable C Type	`buffer_type` Value	SQL Type of Destination Value
`signed char`	`MYSQL_TYPE_TINY`	`TINYINT`
`short int`	`MYSQL_TYPE_SHORT`	`SMALLINT`
`int`	`MYSQL_TYPE_LONG`	`INT`
`long long int`	`MYSQL_TYPE_LONGLONG`	`BIGINT`
`float`	`MYSQL_TYPE_FLOAT`	`FLOAT`
`double`	`MYSQL_TYPE_DOUBLE`	`DOUBLE`
`MYSQL_TIME`	`MYSQL_TYPE_TIME`	`TIME`
`MYSQL_TIME`	`MYSQL_TYPE_DATE`	`DATE`
`MYSQL_TIME`	`MYSQL_TYPE_DATETIME`	`DATETIME`
`MYSQL_TIME`	`MYSQL_TYPE_TIMESTAMP`	`TIMESTAMP`
`char[]`	`MYSQL_TYPE_STRING`	`TEXT`, `CHAR`, `VARCHAR`
`char[]`	`MYSQL_TYPE_BLOB`	`BLOB`, `BINARY`, `VARBINARY`
	`MYSQL_TYPE_NULL`	`NULL`

Use `MYSQL_TYPE_NULL` as indicated in the description for the `is_null` member in Section 23.8.9, “C API Prepared Statement Data Structures”.

For input string data, use `MYSQL_TYPE_STRING` or `MYSQL_TYPE_BLOB` depending on whether the value is a character (nonbinary) or binary string:

- `MYSQL_TYPE_STRING` indicates character input string data. The value is assumed to be in the character set indicated by the `character_set_client` system variable. If the server stores the value into a column with a different character set, it converts the value to that character set.

- `MYSQL_TYPE_BLOB` indicates binary input string data. The value is treated as having the `binary` character set. That is, it is treated as a byte string and no conversion occurs.

The following table shows the permissible values for the `buffer_type` member of `MYSQL_BIND` structures for output values received from the server. The table shows the SQL types of received values, the corresponding type codes that such values have in result set metadata, and the recommended C language data types to bind to the `MYSQL_BIND` structure to receive the SQL values without conversion. Choose the `buffer_type` value according to the data type of the C language variable that you are binding. For the integer types, you should also set the `is_unsigned` member to indicate whether the variable is signed or unsigned.

SQL Type of Received Value	`buffer_type` Value	Output Variable C Type
`TINYINT`	`MYSQL_TYPE_TINY`	`signed char`
`SMALLINT`	`MYSQL_TYPE_SHORT`	`short int`
`MEDIUMINT`	`MYSQL_TYPE_INT24`	`int`
`INT`	`MYSQL_TYPE_LONG`	`int`
`BIGINT`	`MYSQL_TYPE_LONGLONG`	`long long int`
`FLOAT`	`MYSQL_TYPE_FLOAT`	`float`
`DOUBLE`	`MYSQL_TYPE_DOUBLE`	`double`
`DECIMAL`	`MYSQL_TYPE_NEWDECIMAL`	`char[]`
`YEAR`	`MYSQL_TYPE_SHORT`	`short int`
`TIME`	`MYSQL_TYPE_TIME`	`MYSQL_TIME`
`DATE`	`MYSQL_TYPE_DATE`	`MYSQL_TIME`
`DATETIME`	`MYSQL_TYPE_DATETIME`	`MYSQL_TIME`
`TIMESTAMP`	`MYSQL_TYPE_TIMESTAMP`	`MYSQL_TIME`
`CHAR`, `BINARY`	`MYSQL_TYPE_STRING`	`char[]`
`VARCHAR`, `VARBINARY`	`MYSQL_TYPE_VAR_STRING`	`char[]`
`TINYBLOB`, `TINYTEXT`	`MYSQL_TYPE_TINY_BLOB`	`char[]`
`BLOB`, `TEXT`	`MYSQL_TYPE_BLOB`	`char[]`
`MEDIUMBLOB`, `MEDIUMTEXT`	`MYSQL_TYPE_MEDIUM_BLOB`	`char[]`
`LONGBLOB`, `LONGTEXT`	`MYSQL_TYPE_LONG_BLOB`	`char[]`
`BIT`	`MYSQL_TYPE_BIT`	`char[]`

23.8.9.2 C API Prepared Statement Type Conversions

Prepared statements transmit data between the client and server using C language variables on the client side that correspond to SQL values on the server side. If there is a mismatch between the C variable type on the client side and the corresponding SQL value type on the server side, MySQL performs implicit type conversions in both directions.

MySQL knows the type code for the SQL value on the server side. The `buffer_type` value in the `MYSQL_BIND` structure indicates the type code of the C variable that holds the value on the client side. The two codes together tell MySQL what conversion must be performed, if any. Here are some examples:

- If you use `MYSQL_TYPE_LONG` with an `int` variable to pass an integer value to the server that is to be stored into a `FLOAT` column, MySQL converts the value to floating-point format before storing it.

- If you fetch an SQL `MEDIUMINT` column value, but specify a `buffer_type` value of `MYSQL_TYPE_LONGLONG` and use a C variable of type `long long int` as the destination buffer,

MySQL converts the `MEDIUMINT` value (which requires less than 8 bytes) for storage into the `long long int` (an 8-byte variable).

- If you fetch a numeric column with a value of 255 into a `char[4]` character array and specify a `buffer_type` value of `MYSQL_TYPE_STRING`, the resulting value in the array is a 4-byte string `'255\0'`.

- MySQL returns `DECIMAL` values as the string representation of the original server-side value, which is why the corresponding C type is `char[]`. For example, `12.345` is returned to the client as `'12.345'`. If you specify `MYSQL_TYPE_NEWDECIMAL` and bind a string buffer to the `MYSQL_BIND` structure, `mysql_stmt_fetch()` stores the value in the buffer as a string without conversion. If instead you specify a numeric variable and type code, `mysql_stmt_fetch()` converts the string-format `DECIMAL` value to numeric form.

- For the `MYSQL_TYPE_BIT` type code, `BIT` values are returned into a string buffer, which is why the corresponding C type is `char[]`. The value represents a bit string that requires interpretation on the client side. To return the value as a type that is easier to deal with, you can cause the value to be cast to integer using either of the following types of expressions:

  ```
  SELECT bit_col + 0 FROM t
  SELECT CAST(bit_col AS UNSIGNED) FROM t
  ```

  To retrieve the value, bind an integer variable large enough to hold the value and specify the appropriate corresponding integer type code.

Before binding variables to the `MYSQL_BIND` structures that are to be used for fetching column values, you can check the type codes for each column of the result set. This might be desirable if you want to determine which variable types would be best to use to avoid type conversions. To get the type codes, call `mysql_stmt_result_metadata()` after executing the prepared statement with `mysql_stmt_execute()`. The metadata provides access to the type codes for the result set as described in Section 23.8.11.23, “mysql_stmt_result_metadata()”, and Section 23.8.5, “C API Data Structures”.

To determine whether output string values in a result set returned from the server contain binary or nonbinary data, check whether the `charsetnr` value of the result set metadata is 63 (see Section 23.8.5, “C API Data Structures”). If so, the character set is `binary`, which indicates binary rather than nonbinary data. This enables you to distinguish `BINARY` from `CHAR`, `VARBINARY` from `VARCHAR`, and the `BLOB` types from the `TEXT` types.

If you cause the `max_length` member of the `MYSQL_FIELD` column metadata structures to be set (by calling `mysql_stmt_attr_set()`), be aware that the `max_length` values for the result set indicate the lengths of the longest string representation of the result values, not the lengths of the binary representation. That is, `max_length` does not necessarily correspond to the size of the buffers needed to fetch the values with the binary protocol used for prepared statements. Choose the size of the buffers according to the types of the variables into which you fetch the values. For example, a `TINYINT` column containing the value -128 might have a `max_length` value of 4. But the binary representation of any `TINYINT` value requires only 1 byte for storage, so you can supply a `signed char` variable in which to store the value and set `is_unsigned` to indicate that values are signed.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation”.

23.8.10 C API Prepared Statement Function Overview

The following table summarizes the functions available for prepared statement processing. For greater detail, see the descriptions in Section 23.8.11, “C API Prepared Statement Function Descriptions”.

Function	Description
mysql_stmt_affected_rows()	Returns the number of rows changed, deleted, or inserted by prepared UPDATE, DELETE, or INSERT statement
mysql_stmt_attr_get()	Gets value of an attribute for a prepared statement
mysql_stmt_attr_set()	Sets an attribute for a prepared statement
mysql_stmt_bind_param()	Associates application data buffers with the parameter markers in a prepared SQL statement
mysql_stmt_bind_result()	Associates application data buffers with columns in a result set
mysql_stmt_close()	Frees memory used by a prepared statement
mysql_stmt_data_seek()	Seeks to an arbitrary row number in a statement result set
mysql_stmt_errno()	Returns the error number for the last statement execution
mysql_stmt_error()	Returns the error message for the last statement execution
mysql_stmt_execute()	Executes a prepared statement
mysql_stmt_fetch()	Fetches the next row of data from a result set and returns data for all bound columns
mysql_stmt_fetch_column()	Fetch data for one column of the current row of a result set
mysql_stmt_field_count()	Returns the number of result columns for the most recent statement
mysql_stmt_free_result()	Free the resources allocated to a statement handler
mysql_stmt_init()	Allocates memory for a MYSQL_STMT structure and initializes it
mysql_stmt_insert_id()	Returns the ID generated for an AUTO_INCREMENT column by a prepared statement
mysql_stmt_next_result()	Returns/initiates the next result in a multiple-result execution
mysql_stmt_num_rows()	Returns the row count from a buffered statement result set
mysql_stmt_param_count()	Returns the number of parameters in a prepared statement
mysql_stmt_param_metadata()	(Return parameter metadata in the form of a result set) This function does nothing
mysql_stmt_prepare()	Prepares an SQL statement string for execution
mysql_stmt_reset()	Resets the statement buffers in the server
mysql_stmt_result_metadata()	Returns prepared statement metadata in the form of a result set
mysql_stmt_row_seek()	Seeks to a row offset in a statement result set, using value returned from mysql_stmt_row_tell()
mysql_stmt_row_tell()	Returns the statement row cursor position
mysql_stmt_send_long_data()	Sends long data in chunks to server
mysql_stmt_sqlstate()	Returns the SQLSTATE error code for the last statement execution
mysql_stmt_store_result()	Retrieves a complete result set to the client

Call mysql_stmt_init() to create a statement handler, then mysql_stmt_prepare() to prepare the statement string, mysql_stmt_bind_param() to supply the parameter data, and mysql_stmt_execute() to execute the statement. You can repeat the mysql_stmt_execute() by changing parameter values in the respective buffers supplied through mysql_stmt_bind_param().

You can send text or binary data in chunks to server using mysql_stmt_send_long_data(). See Section 23.8.11.26, “mysql_stmt_send_long_data()”.

If the statement is a SELECT or any other statement that produces a result set, mysql_stmt_prepare() also returns the result set metadata information in the form of a MYSQL_RES result set through mysql_stmt_result_metadata().

You can supply the result buffers using `mysql_stmt_bind_result()`, so that the `mysql_stmt_fetch()` automatically returns data to these buffers. This is row-by-row fetching.

When statement execution has been completed, close the statement handler using `mysql_stmt_close()` so that all resources associated with it can be freed. At that point the handler becomes invalid and should no longer be used.

If you obtained a `SELECT` statement's result set metadata by calling `mysql_stmt_result_metadata()`, you should also free the metadata using `mysql_free_result()`.

Execution Steps

To prepare and execute a statement, an application follows these steps:

1. Create a prepared statement handler with `mysql_stmt_init()`. To prepare the statement on the server, call `mysql_stmt_prepare()` and pass it a string containing the SQL statement.
2. If the statement will produce a result set, call `mysql_stmt_result_metadata()` to obtain the result set metadata. This metadata is itself in the form of result set, albeit a separate one from the one that contains the rows returned by the query. The metadata result set indicates how many columns are in the result and contains information about each column.
3. Set the values of any parameters using `mysql_stmt_bind_param()`. All parameters must be set. Otherwise, statement execution returns an error or produces unexpected results.
4. Call `mysql_stmt_execute()` to execute the statement.
5. If the statement produces a result set, bind the data buffers to use for retrieving the row values by calling `mysql_stmt_bind_result()`.
6. Fetch the data into the buffers row by row by calling `mysql_stmt_fetch()` repeatedly until no more rows are found.
7. Repeat steps 3 through 6 as necessary, by changing the parameter values and re-executing the statement.

When `mysql_stmt_prepare()` is called, the MySQL client/server protocol performs these actions:

- The server parses the statement and sends the okay status back to the client by assigning a statement ID. It also sends total number of parameters, a column count, and its metadata if it is a result set oriented statement. All syntax and semantics of the statement are checked by the server during this call.
- The client uses this statement ID for the further operations, so that the server can identify the statement from among its pool of statements.

When `mysql_stmt_execute()` is called, the MySQL client/server protocol performs these actions:

- The client uses the statement handler and sends the parameter data to the server.
- The server identifies the statement using the ID provided by the client, replaces the parameter markers with the newly supplied data, and executes the statement. If the statement produces a result set, the server sends the data back to the client. Otherwise, it sends an okay status and the number of rows changed, deleted, or inserted.

When `mysql_stmt_fetch()` is called, the MySQL client/server protocol performs these actions:

- The client reads the data from the current row of the result set and places it into the application data buffers by doing the necessary conversions. If the application buffer type is same as that of the field type returned from the server, the conversions are straightforward.

If an error occurs, you can get the statement error number, error message, and SQLSTATE code using `mysql_stmt_errno()`, `mysql_stmt_error()`, and `mysql_stmt_sqlstate()`, respectively.

Prepared Statement Logging

For prepared statements that are executed with the `mysql_stmt_prepare()` and `mysql_stmt_execute()` C API functions, the server writes `Prepare` and `Execute` lines to the general query log so that you can tell when statements are prepared and executed.

Suppose that you prepare and execute a statement as follows:

1. Call `mysql_stmt_prepare()` to prepare the statement string `"SELECT ?"`.
2. Call `mysql_stmt_bind_param()` to bind the value `3` to the parameter in the prepared statement.
3. Call `mysql_stmt_execute()` to execute the prepared statement.

As a result of the preceding calls, the server writes the following lines to the general query log:

```
Prepare  [1] SELECT ?
Execute  [1] SELECT 3
```

Each `Prepare` and `Execute` line in the log is tagged with a `[N]` statement identifier so that you can keep track of which prepared statement is being logged. *`N`* is a positive integer. If there are multiple prepared statements active simultaneously for the client, *`N`* may be greater than 1. Each `Execute` lines shows a prepared statement after substitution of data values for `?` parameters.

23.8.11 C API Prepared Statement Function Descriptions

To prepare and execute queries, use the functions described in detail in the following sections.

All functions that operate with a `MYSQL_STMT` structure begin with the prefix `mysql_stmt_`.

To create a `MYSQL_STMT` handler, use the `mysql_stmt_init()` function.

23.8.11.1 mysql_stmt_affected_rows()

```
my_ulonglong mysql_stmt_affected_rows(MYSQL_STMT *stmt)
```

Description

`mysql_stmt_affected_rows()` may be called immediately after executing a statement with `mysql_stmt_execute()`. It is like `mysql_affected_rows()` but for prepared statements. For a description of what the affected-rows value returned by this function means, See Section 23.8.7.1, “mysql_affected_rows()”.

Errors

None.

Example

See the Example in Section 23.8.11.10, “mysql_stmt_execute()”.

23.8.11.2 mysql_stmt_attr_get()

```
my_bool mysql_stmt_attr_get(MYSQL_STMT *stmt, enum enum_stmt_attr_type
option, void *arg)
```

Description

Can be used to get the current value for a statement attribute.

The `option` argument is the option that you want to get; the `arg` should point to a variable that should contain the option value. If the option is an integer, `arg` should point to the value of the integer.

See Section 23.8.11.3, “mysql_stmt_attr_set()”, for a list of options and option types.

Return Values

Zero for success. Nonzero if `option` is unknown.

Errors

None.

23.8.11.3 mysql_stmt_attr_set()

```
my_bool mysql_stmt_attr_set(MYSQL_STMT *stmt, enum enum_stmt_attr_type
option, const void *arg)
```

Description

Can be used to affect behavior for a prepared statement. This function may be called multiple times to set several options.

The `option` argument is the option that you want to set. The `arg` argument is the value for the option. `arg` should point to a variable that is set to the desired attribute value. The variable type is as indicated in the following table.

The following table shows the possible `option` values.

Option	Argument Type	Function
`STMT_ATTR_UPDATE_MAX_LENGTH`	`my_bool *`	If set to 1, causes `mysql_stmt_store_result()` to update the metadata `MYSQL_FIELD->max_length` value.
`STMT_ATTR_CURSOR_TYPE`	`unsigned long *`	Type of cursor to open for statement when `mysql_stmt_execute()` is invoked. `*arg` can be `CURSOR_TYPE_NO_CURSOR` (the default) or `CURSOR_TYPE_READ_ONLY`.
`STMT_ATTR_PREFETCH_ROWS`	`unsigned long *`	Number of rows to fetch from server at a time when using a cursor. `*arg` can be in the range from 1 to the maximum value of `unsigned long`. The default is 1.

If you use the `STMT_ATTR_CURSOR_TYPE` option with `CURSOR_TYPE_READ_ONLY`, a cursor is opened for the statement when you invoke `mysql_stmt_execute()`. If there is already an open cursor from a previous `mysql_stmt_execute()` call, it closes the cursor before opening a new one. `mysql_stmt_reset()` also closes any open cursor before preparing the statement for re-execution. `mysql_stmt_free_result()` closes any open cursor.

If you open a cursor for a prepared statement, `mysql_stmt_store_result()` is unnecessary, because that function causes the result set to be buffered on the client side.

Return Values

Zero for success. Nonzero if `option` is unknown.

Errors

None.

Example

The following example opens a cursor for a prepared statement and sets the number of rows to fetch at a time to 5:

```
MYSQL_STMT *stmt;
int rc;
unsigned long type;
unsigned long prefetch_rows = 5;

stmt = mysql_stmt_init(mysql);
type = (unsigned long) CURSOR_TYPE_READ_ONLY;
rc = mysql_stmt_attr_set(stmt, STMT_ATTR_CURSOR_TYPE, (void*) &type);
/* ... check return value ... */
rc = mysql_stmt_attr_set(stmt, STMT_ATTR_PREFETCH_ROWS,
                         (void*) &prefetch_rows);
/* ... check return value ... */
```

23.8.11.4 mysql_stmt_bind_param()

`my_bool mysql_stmt_bind_param(MYSQL_STMT *stmt, MYSQL_BIND *bind)`

Description

`mysql_stmt_bind_param()` is used to bind input data for the parameter markers in the SQL statement that was passed to `mysql_stmt_prepare()`. It uses `MYSQL_BIND` structures to supply the data. `bind` is the address of an array of `MYSQL_BIND` structures. The client library expects the array to contain one element for each `?` parameter marker that is present in the query.

Suppose that you prepare the following statement:

```
INSERT INTO mytbl VALUES(?,?,?)
```

When you bind the parameters, the array of `MYSQL_BIND` structures must contain three elements, and can be declared like this:

```
MYSQL_BIND bind[3];
```

Section 23.8.9, “C API Prepared Statement Data Structures”, describes the members of each `MYSQL_BIND` element and how they should be set to provide input values.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_UNSUPPORTED_PARAM_TYPE`

  The conversion is not supported. Possibly the `buffer_type` value is invalid or is not one of the supported types.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

See the Example in Section 23.8.11.10, “mysql_stmt_execute()”.

23.8.11.5 mysql_stmt_bind_result()

```
my_bool mysql_stmt_bind_result(MYSQL_STMT *stmt, MYSQL_BIND *bind)
```

Description

`mysql_stmt_bind_result()` is used to associate (that is, bind) output columns in the result set to data buffers and length buffers. When `mysql_stmt_fetch()` is called to fetch data, the MySQL client/server protocol places the data for the bound columns into the specified buffers.

All columns must be bound to buffers prior to calling `mysql_stmt_fetch()`. `bind` is the address of an array of `MYSQL_BIND` structures. The client library expects the array to contain one element for each column of the result set. If you do not bind columns to `MYSQL_BIND` structures, `mysql_stmt_fetch()` simply ignores the data fetch. The buffers should be large enough to hold the data values, because the protocol does not return data values in chunks.

A column can be bound or rebound at any time, even after a result set has been partially retrieved. The new binding takes effect the next time `mysql_stmt_fetch()` is called. Suppose that an application binds the columns in a result set and calls `mysql_stmt_fetch()`. The client/server protocol returns data in the bound buffers. Then suppose that the application binds the columns to a different set of buffers. The protocol places data into the newly bound buffers when the next call to `mysql_stmt_fetch()` occurs.

To bind a column, an application calls `mysql_stmt_bind_result()` and passes the type, address, and length of the output buffer into which the value should be stored. Section 23.8.9, “C API Prepared Statement Data Structures”, describes the members of each `MYSQL_BIND` element and how they should be set to receive output values.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_UNSUPPORTED_PARAM_TYPE`

  The conversion is not supported. Possibly the `buffer_type` value is invalid or is not one of the supported types.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

See the Example in Section 23.8.11.11, “mysql_stmt_fetch()”.

23.8.11.6 mysql_stmt_close()

```
my_bool mysql_stmt_close(MYSQL_STMT *stmt)
```

Description

Closes the prepared statement. `mysql_stmt_close()` also deallocates the statement handler pointed to by `stmt`, which at that point becomes invalid and should no longer be used. For a failed `mysql_stmt_close()` call, do not call `mysql_stmt_error()`, or `mysql_stmt_errno()`, or `mysql_stmt_sqlstate()` to obtain error information because `mysql_stmt_close()` makes the statement handler invalid. Call `mysql_error()`, `mysql_errno()`, or `mysql_sqlstate()` instead.

If the current statement has pending or unread results, this function cancels them so that the next query can be executed.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

See the Example in Section 23.8.11.10, “mysql_stmt_execute()”.

23.8.11.7 mysql_stmt_data_seek()

```
void mysql_stmt_data_seek(MYSQL_STMT *stmt, my_ulonglong offset)
```

Description

Seeks to an arbitrary row in a statement result set. The `offset` value is a row number and should be in the range from `0` to `mysql_stmt_num_rows(stmt)-1`.

This function requires that the statement result set structure contains the entire result of the last executed query, so `mysql_stmt_data_seek()` may be used only in conjunction with `mysql_stmt_store_result()`.

Return Values

None.

Errors

None.

23.8.11.8 mysql_stmt_errno()

```
unsigned int mysql_stmt_errno(MYSQL_STMT *stmt)
```

Description

For the statement specified by `stmt`, `mysql_stmt_errno()` returns the error code for the most recently invoked statement API function that can succeed or fail. A return value of zero means that no error occurred. Client error message numbers are listed in the MySQL `errmsg.h` header file. Server error message numbers are listed in `mysqld_error.h`. Errors also are listed at Appendix B, *Errors, Error Codes, and Common Problems*.

If the failed statement API function was `mysql_stmt_close()`, do not call or `mysql_stmt_errno()` to obtain error information because `mysql_stmt_close()` makes the statement handler invalid. Call `mysql_errno()` instead.

Return Values

An error code value. Zero if no error occurred.

Errors

None.

23.8.11.9 mysql_stmt_error()

```
const char *mysql_stmt_error(MYSQL_STMT *stmt)
```

Description

For the statement specified by `stmt`, `mysql_stmt_error()` returns a null-terminated string containing the error message for the most recently invoked statement API function that can succeed or fail. An empty string (`""`) is returned if no error occurred. Either of these two tests can be used to check for an error:

```
if(*mysql_stmt_errno(stmt))
{
  // an error occurred
}

if (mysql_stmt_error(stmt)[0])
{
  // an error occurred
}
```

If the failed statement API function was `mysql_stmt_close()`, do not call `mysql_stmt_error()` to obtain error information because `mysql_stmt_close()` makes the statement handler invalid. Call `mysql_error()` instead.

The language of the client error messages may be changed by recompiling the MySQL client library. You can choose error messages in several different languages.

Return Values

A character string that describes the error. An empty string if no error occurred.

Errors

None.

23.8.11.10 mysql_stmt_execute()

```
int mysql_stmt_execute(MYSQL_STMT *stmt)
```

Description

`mysql_stmt_execute()` executes the prepared query associated with the statement handler. The currently bound parameter marker values are sent to server during this call, and the server replaces the markers with this newly supplied data.

Statement processing following `mysql_stmt_execute()` depends on the type of statement:

- For an `UPDATE`, `DELETE`, or `INSERT`, the number of changed, deleted, or inserted rows can be found by calling `mysql_stmt_affected_rows()`.
- For a statement such as `SELECT` that generates a result set, you must call `mysql_stmt_fetch()` to fetch the data prior to calling any other functions that result in query processing. For more information on how to fetch the results, refer to Section 23.8.11.11, “mysql_stmt_fetch()”.

  Do not following invocation of `mysql_stmt_execute()` with a call to `mysql_store_result()` or `mysql_use_result()`. Those functions are not intended for processing results from prepared statements.

For statements that generate a result set, you can request that `mysql_stmt_execute()` open a cursor for the statement by calling `mysql_stmt_attr_set()` before executing the statement. If you execute a statement multiple times, `mysql_stmt_execute()` closes any open cursor before opening a new one.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation”.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

The following example demonstrates how to create and populate a table using `mysql_stmt_init()`, `mysql_stmt_prepare()`, `mysql_stmt_param_count()`, `mysql_stmt_bind_param()`, `mysql_stmt_execute()`, and `mysql_stmt_affected_rows()`. The `mysql` variable is assumed to be a valid connection handler. For an example that shows how to retrieve data, see Section 23.8.11.11, “mysql_stmt_fetch()”.

```
#define STRING_SIZE 50

#define DROP_SAMPLE_TABLE "DROP TABLE IF EXISTS test_table"
#define CREATE_SAMPLE_TABLE "CREATE TABLE test_table(col1 INT,\
                                                     col2 VARCHAR(40),\
                                                     col3 SMALLINT,\
                                                     col4 TIMESTAMP)"
#define INSERT_SAMPLE "INSERT INTO \
                       test_table(col1,col2,col3) \
                       VALUES(?,?,?)"

MYSQL_STMT    *stmt;
MYSQL_BIND    bind[3];
my_ulonglong  affected_rows;
int           param_count;
short         small_data;
int           int_data;
char          str_data[STRING_SIZE];
unsigned long str_length;
my_bool       is_null;

if (mysql_query(mysql, DROP_SAMPLE_TABLE))
{
  fprintf(stderr, " DROP TABLE failed\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}

if (mysql_query(mysql, CREATE_SAMPLE_TABLE))
```

```
{
  fprintf(stderr, " CREATE TABLE failed\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}

/* Prepare an INSERT query with 3 parameters */
/* (the TIMESTAMP column is not named; the server */
/*  sets it to the current date and time) */
stmt = mysql_stmt_init(mysql);
if (!stmt)
{
  fprintf(stderr, " mysql_stmt_init(), out of memory\n");
  exit(0);
}
if (mysql_stmt_prepare(stmt, INSERT_SAMPLE, strlen(INSERT_SAMPLE)))
{
  fprintf(stderr, " mysql_stmt_prepare(), INSERT failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}
fprintf(stdout, " prepare, INSERT successful\n");

/* Get the parameter count from the statement */
param_count= mysql_stmt_param_count(stmt);
fprintf(stdout, " total parameters in INSERT: %d\n", param_count);

if (param_count != 3) /* validate parameter count */
{
  fprintf(stderr, " invalid parameter count returned by MySQL\n");
  exit(0);
}

/* Bind the data for all 3 parameters */

memset(bind, 0, sizeof(bind));

/* INTEGER PARAM */
/* This is a number type, so there is no need
   to specify buffer_length */
bind[0].buffer_type= MYSQL_TYPE_LONG;
bind[0].buffer= (char *)&int_data;
bind[0].is_null= 0;
bind[0].length= 0;

/* STRING PARAM */
bind[1].buffer_type= MYSQL_TYPE_STRING;
bind[1].buffer= (char *)str_data;
bind[1].buffer_length= STRING_SIZE;
bind[1].is_null= 0;
bind[1].length= &str_length;

/* SMALLINT PARAM */
bind[2].buffer_type= MYSQL_TYPE_SHORT;
bind[2].buffer= (char *)&small_data;
bind[2].is_null= &is_null;
bind[2].length= 0;

/* Bind the buffers */
if (mysql_stmt_bind_param(stmt, bind))
{
  fprintf(stderr, " mysql_stmt_bind_param() failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Specify the data values for the first row */
int_data= 10;             /* integer */
strncpy(str_data, "MySQL", STRING_SIZE); /* string  */
str_length= strlen(str_data);

/* INSERT SMALLINT data as NULL */
```

```
is_null= 1;

/* Execute the INSERT statement - 1*/
if (mysql_stmt_execute(stmt))
{
  fprintf(stderr, " mysql_stmt_execute(), 1 failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Get the number of affected rows */
affected_rows= mysql_stmt_affected_rows(stmt);
fprintf(stdout, " total affected rows(insert 1): %lu\n",
                (unsigned long) affected_rows);

if (affected_rows != 1) /* validate affected rows */
{
  fprintf(stderr, " invalid affected rows by MySQL\n");
  exit(0);
}

/* Specify data values for second row,
   then re-execute the statement */
int_data= 1000;
strncpy(str_data, "
        The most popular Open Source database",
        STRING_SIZE);
str_length= strlen(str_data);
small_data= 1000;         /* smallint */
is_null= 0;               /* reset */

/* Execute the INSERT statement - 2*/
if (mysql_stmt_execute(stmt))
{
  fprintf(stderr, " mysql_stmt_execute, 2 failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Get the total rows affected */
affected_rows= mysql_stmt_affected_rows(stmt);
fprintf(stdout, " total affected rows(insert 2): %lu\n",
                (unsigned long) affected_rows);

if (affected_rows != 1) /* validate affected rows */
{
  fprintf(stderr, " invalid affected rows by MySQL\n");
  exit(0);
}

/* Close the statement */
if (mysql_stmt_close(stmt))
{
  /* mysql_stmt_close() invalidates stmt, so call          */
  /* mysql_error(mysql) rather than mysql_stmt_error(stmt) */
  fprintf(stderr, " failed while closing the statement\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}
```

Note

For complete examples on the use of prepared statement functions, refer to the file `tests/mysql_client_test.c`. This file can be obtained from a MySQL source distribution or from the source repository (see Section 2.9, “Installing MySQL from Source”).

23.8.11.11 mysql_stmt_fetch()

```
int mysql_stmt_fetch(MYSQL_STMT *stmt)
```

Description

`mysql_stmt_fetch()` returns the next row in the result set. It can be called only while the result set exists; that is, after a call to `mysql_stmt_execute()` for a statement such as `SELECT` that produces a result set.

`mysql_stmt_fetch()` returns row data using the buffers bound by `mysql_stmt_bind_result()`. It returns the data in those buffers for all the columns in the current row set and the lengths are returned to the `length` pointer. All columns must be bound by the application before it calls `mysql_stmt_fetch()`.

By default, result sets are fetched unbuffered a row at a time from the server. To buffer the entire result set on the client, call `mysql_stmt_store_result()` after binding the data buffers and before calling `mysql_stmt_fetch()`.

If a fetched data value is a `NULL` value, the `*is_null` value of the corresponding `MYSQL_BIND` structure contains TRUE (1). Otherwise, the data and its length are returned in the `*buffer` and `*length` elements based on the buffer type specified by the application. Each numeric and temporal type has a fixed length, as listed in the following table. The length of the string types depends on the length of the actual data value, as indicated by `data_length`.

Type	Length
`MYSQL_TYPE_TINY`	1
`MYSQL_TYPE_SHORT`	2
`MYSQL_TYPE_LONG`	4
`MYSQL_TYPE_LONGLONG`	8
`MYSQL_TYPE_FLOAT`	4
`MYSQL_TYPE_DOUBLE`	8
`MYSQL_TYPE_TIME`	`sizeof(MYSQL_TIME)`
`MYSQL_TYPE_DATE`	`sizeof(MYSQL_TIME)`
`MYSQL_TYPE_DATETIME`	`sizeof(MYSQL_TIME)`
`MYSQL_TYPE_STRING`	`data length`
`MYSQL_TYPE_BLOB`	`data_length`

In some cases you might want to determine the length of a column value before fetching it with `mysql_stmt_fetch()`. For example, the value might be a long string or `BLOB` value for which you want to know how much space must be allocated. To accomplish this, you can use these strategies:

- Before invoking `mysql_stmt_fetch()` to retrieve individual rows, pass `STMT_ATTR_UPDATE_MAX_LENGTH` to `mysql_stmt_attr_set()`, then invoke `mysql_stmt_store_result()` to buffer the entire result on the client side. Setting the `STMT_ATTR_UPDATE_MAX_LENGTH` attribute causes the maximal length of column values to be indicated by the `max_length` member of the result set metadata returned by `mysql_stmt_result_metadata()`.
- Invoke `mysql_stmt_fetch()` with a zero-length buffer for the column in question and a pointer in which the real length can be stored. Then use the real length with `mysql_stmt_fetch_column()`.

```
real_length= 0;

bind[0].buffer= 0;
bind[0].buffer_length= 0;
bind[0].length= &real_length
mysql_stmt_bind_result(stmt, bind);

mysql_stmt_fetch(stmt);
if (real_length > 0)
```

```
{
  data= malloc(real_length);
  bind[0].buffer= data;
  bind[0].buffer_length= real_length;
  mysql_stmt_fetch_column(stmt, bind, 0, 0);
}
```

Return Values

Return Value	Description
0	Successful, the data has been fetched to application data buffers.
1	Error occurred. Error code and message can be obtained by calling `mysql_stmt_errno()` and `mysql_stmt_error()`.
`MYSQL_NO_DATA`	No more rows/data exists
`MYSQL_DATA_TRUNCATED`	Data truncation occurred

`MYSQL_DATA_TRUNCATED` is returned when truncation reporting is enabled. To determine which column values were truncated when this value is returned, check the `error` members of the `MYSQL_BIND` structures used for fetching values. Truncation reporting is enabled by default, but can be controlled by calling `mysql_options()` with the `MYSQL_REPORT_DATA_TRUNCATION` option.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

- `CR_UNSUPPORTED_PARAM_TYPE`

  The buffer type is `MYSQL_TYPE_DATE`, `MYSQL_TYPE_TIME`, `MYSQL_TYPE_DATETIME`, or `MYSQL_TYPE_TIMESTAMP`, but the data type is not `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP`.

- All other unsupported conversion errors are returned from `mysql_stmt_bind_result()`.

Example

The following example demonstrates how to fetch data from a table using `mysql_stmt_result_metadata()`, `mysql_stmt_bind_result()`, and `mysql_stmt_fetch()`. (This example expects to retrieve the two rows inserted by the example shown in Section 23.8.11.10, “mysql_stmt_execute()”.) The `mysql` variable is assumed to be a valid connection handler.

```
#define STRING_SIZE 50

#define SELECT_SAMPLE "SELECT col1, col2, col3, col4 \
                       FROM test_table"

MYSQL_STMT    *stmt;
```

```
MYSQL_BIND    bind[4];
MYSQL_RES     *prepare_meta_result;
MYSQL_TIME    ts;
unsigned long length[4];
int           param_count, column_count, row_count;
short         small_data;
int           int_data;
char          str_data[STRING_SIZE];
my_bool       is_null[4];
my_bool       error[4];

/* Prepare a SELECT query to fetch data from test_table */
stmt = mysql_stmt_init(mysql);
if (!stmt)
{
  fprintf(stderr, " mysql_stmt_init(), out of memory\n");
  exit(0);
}
if (mysql_stmt_prepare(stmt, SELECT_SAMPLE, strlen(SELECT_SAMPLE)))
{
  fprintf(stderr, " mysql_stmt_prepare(), SELECT failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}
fprintf(stdout, " prepare, SELECT successful\n");

/* Get the parameter count from the statement */
param_count= mysql_stmt_param_count(stmt);
fprintf(stdout, " total parameters in SELECT: %d\n", param_count);

if (param_count != 0) /* validate parameter count */
{
  fprintf(stderr, " invalid parameter count returned by MySQL\n");
  exit(0);
}

/* Fetch result set meta information */
prepare_meta_result = mysql_stmt_result_metadata(stmt);
if (!prepare_meta_result)
{
  fprintf(stderr,
         " mysql_stmt_result_metadata(), \
           returned no meta information\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Get total columns in the query */
column_count= mysql_num_fields(prepare_meta_result);
fprintf(stdout,
        " total columns in SELECT statement: %d\n",
        column_count);

if (column_count != 4) /* validate column count */
{
  fprintf(stderr, " invalid column count returned by MySQL\n");
  exit(0);
}

/* Execute the SELECT query */
if (mysql_stmt_execute(stmt))
{
  fprintf(stderr, " mysql_stmt_execute(), failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Bind the result buffers for all 4 columns before fetching them */

memset(bind, 0, sizeof(bind));

/* INTEGER COLUMN */
```

```
bind[0].buffer_type= MYSQL_TYPE_LONG;
bind[0].buffer= (char *)&int_data;
bind[0].is_null= &is_null[0];
bind[0].length= &length[0];
bind[0].error= &error[0];

/* STRING COLUMN */
bind[1].buffer_type= MYSQL_TYPE_STRING;
bind[1].buffer= (char *)str_data;
bind[1].buffer_length= STRING_SIZE;
bind[1].is_null= &is_null[1];
bind[1].length= &length[1];
bind[1].error= &error[1];

/* SMALLINT COLUMN */
bind[2].buffer_type= MYSQL_TYPE_SHORT;
bind[2].buffer= (char *)&small_data;
bind[2].is_null= &is_null[2];
bind[2].length= &length[2];
bind[2].error= &error[2];

/* TIMESTAMP COLUMN */
bind[3].buffer_type= MYSQL_TYPE_TIMESTAMP;
bind[3].buffer= (char *)&ts;
bind[3].is_null= &is_null[3];
bind[3].length= &length[3];
bind[3].error= &error[3];

/* Bind the result buffers */
if (mysql_stmt_bind_result(stmt, bind))
{
  fprintf(stderr, " mysql_stmt_bind_result() failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Now buffer all results to client (optional step) */
if (mysql_stmt_store_result(stmt))
{
  fprintf(stderr, " mysql_stmt_store_result() failed\n");
  fprintf(stderr, " %s\n", mysql_stmt_error(stmt));
  exit(0);
}

/* Fetch all rows */
row_count= 0;
fprintf(stdout, "Fetching results ...\n");
while (!mysql_stmt_fetch(stmt))
{
  row_count++;
  fprintf(stdout, "  row %d\n", row_count);

  /* column 1 */
  fprintf(stdout, "   column1 (integer)  : ");
  if (is_null[0])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %d(%ld)\n", int_data, length[0]);

  /* column 2 */
  fprintf(stdout, "   column2 (string)   : ");
  if (is_null[1])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %s(%ld)\n", str_data, length[1]);

  /* column 3 */
  fprintf(stdout, "   column3 (smallint) : ");
  if (is_null[2])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %d(%ld)\n", small_data, length[2]);
```

```
  /* column 4 */
  fprintf(stdout, "   column4 (timestamp): ");
  if (is_null[3])
    fprintf(stdout, " NULL\n");
  else
    fprintf(stdout, " %04d-%02d-%02d %02d:%02d:%02d (%ld)\n",
                     ts.year, ts.month, ts.day,
                     ts.hour, ts.minute, ts.second,
                     length[3]);
  fprintf(stdout, "\n");
}

/* Validate rows fetched */
fprintf(stdout, " total rows fetched: %d\n", row_count);
if (row_count != 2)
{
  fprintf(stderr, " MySQL failed to return all rows\n");
  exit(0);
}

/* Free the prepared result metadata */
mysql_free_result(prepare_meta_result);


/* Close the statement */
if (mysql_stmt_close(stmt))
{
  /* mysql_stmt_close() invalidates stmt, so call          */
  /* mysql_error(mysql) rather than mysql_stmt_error(stmt) */
  fprintf(stderr, " failed while closing the statement\n");
  fprintf(stderr, " %s\n", mysql_error(mysql));
  exit(0);
}
```

23.8.11.12 mysql_stmt_fetch_column()

```
int mysql_stmt_fetch_column(MYSQL_STMT *stmt, MYSQL_BIND *bind, unsigned int
column, unsigned long offset)
```

Description

Fetches one column from the current result set row. `bind` provides the buffer where data should be placed. It should be set up the same way as for `mysql_stmt_bind_result()`. `column` indicates which column to fetch. The first column is numbered 0. `offset` is the offset within the data value at which to begin retrieving data. This can be used for fetching the data value in pieces. The beginning of the value is offset 0.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_INVALID_PARAMETER_NO`

  Invalid column number.

- `CR_NO_DATA`

  The end of the result set has already been reached.

23.8.11.13 mysql_stmt_field_count()

```
unsigned int mysql_stmt_field_count(MYSQL_STMT *stmt)
```

Description

Returns the number of columns for the most recent statement for the statement handler. This value is zero for statements such as `INSERT` or `DELETE` that do not produce result sets.

`mysql_stmt_field_count()` can be called after you have prepared a statement by invoking `mysql_stmt_prepare()`.

Return Values

An unsigned integer representing the number of columns in a result set.

Errors

None.

23.8.11.14 mysql_stmt_free_result()

```
my_bool mysql_stmt_free_result(MYSQL_STMT *stmt)
```

Description

Releases memory associated with the result set produced by execution of the prepared statement. If there is a cursor open for the statement, `mysql_stmt_free_result()` closes it.

Return Values

Zero for success. Nonzero if an error occurred.

23.8.11.15 mysql_stmt_init()

```
MYSQL_STMT *mysql_stmt_init(MYSQL *mysql)
```

Description

Creates and returns a `MYSQL_STMT` handler. The handler should be freed with `mysql_stmt_close()`, at which point the handler becomes invalid and should no longer be used.

See also Section 23.8.9, “C API Prepared Statement Data Structures”, for more information.

Return Values

A pointer to a `MYSQL_STMT` structure in case of success. `NULL` if out of memory.

Errors

- `CR_OUT_OF_MEMORY`

  Out of memory.

23.8.11.16 mysql_stmt_insert_id()

```
my_ulonglong mysql_stmt_insert_id(MYSQL_STMT *stmt)
```

Description

Returns the value generated for an `AUTO_INCREMENT` column by the prepared `INSERT` or `UPDATE` statement. Use this function after you have executed a prepared `INSERT` statement on a table which contains an `AUTO_INCREMENT` field.

See Section 23.8.7.37, “mysql_insert_id()”, for more information.

Return Values

Value for `AUTO_INCREMENT` column which was automatically generated or explicitly set during execution of prepared statement, or value generated by `LAST_INSERT_ID(expr)` function. Return value is undefined if statement does not set `AUTO_INCREMENT` value.

Errors

None.

23.8.11.17 mysql_stmt_next_result()

```
int mysql_stmt_next_result(MYSQL_STMT *mysql)
```

Description

This function is used when you use prepared `CALL` statements to execute stored procedures, which can return multiple result sets. Use a loop that calls `mysql_stmt_next_result()` to determine whether there are more results. If a procedure has `OUT` or `INOUT` parameters, their values will be returned as a single-row result set following any other result sets. The values will appear in the order in which they are declared in the procedure parameter list.

`mysql_stmt_next_result()` returns a status to indicate whether more results exist. If `mysql_stmt_next_result()` returns an error, there are no more results.

Before each call to `mysql_stmt_next_result()`, you must call `mysql_stmt_free_result()` for the current result if it produced a result set (rather than just a result status).

After calling `mysql_stmt_next_result()` the state of the connection is as if you had called `mysql_stmt_execute()`. This means that you can call `mysql_stmt_bind_result()`, `mysql_stmt_affected_rows()`, and so forth.

It is also possible to test whether there are more results by calling `mysql_more_results()`. However, this function does not change the connection state, so if it returns true, you must still call `mysql_stmt_next_result()` to advance to the next result.

For an example that shows how to use `mysql_stmt_next_result()`, see Section 23.8.18, “C API Prepared CALL Statement Support”.

Return Values

Return Value	Description
0	Successful and there are more results
-1	Successful and there are no more results
>0	An error occurred

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.11.18 mysql_stmt_num_rows()

```
my_ulonglong mysql_stmt_num_rows(MYSQL_STMT *stmt)
```

Description

Returns the number of rows in the result set.

The use of `mysql_stmt_num_rows()` depends on whether you used `mysql_stmt_store_result()` to buffer the entire result set in the statement handler. If you use `mysql_stmt_store_result()`, `mysql_stmt_num_rows()` may be called immediately. Otherwise, the row count is unavailable unless you count the rows as you fetch them.

`mysql_stmt_num_rows()` is intended for use with statements that return a result set, such as `SELECT`. For statements such as `INSERT`, `UPDATE`, or `DELETE`, the number of affected rows can be obtained with `mysql_stmt_affected_rows()`.

Return Values

The number of rows in the result set.

Errors

None.

23.8.11.19 mysql_stmt_param_count()

```
unsigned long mysql_stmt_param_count(MYSQL_STMT *stmt)
```

Description

Returns the number of parameter markers present in the prepared statement.

Return Values

An unsigned long integer representing the number of parameters in a statement.

Errors

None.

Example

See the Example in Section 23.8.11.10, “mysql_stmt_execute()”.

23.8.11.20 mysql_stmt_param_metadata()

```
MYSQL_RES *mysql_stmt_param_metadata(MYSQL_STMT *stmt)
```

This function currently does nothing.

23.8.11.21 mysql_stmt_prepare()

```
int mysql_stmt_prepare(MYSQL_STMT *stmt, const char *stmt_str, unsigned long
length)
```

Description

Given the statement handler returned by `mysql_stmt_init()`, prepares the SQL statement pointed to by the string `stmt_str` and returns a status value. The string length should be given by the `length` argument. The string must consist of a single SQL statement. You should not add a terminating semicolon (`;`) or `\g` to the statement.

The application can include one or more parameter markers in the SQL statement by embedding question mark (`?`) characters into the SQL string at the appropriate positions.

The markers are legal only in certain places in SQL statements. For example, they are permitted in the `VALUES()` list of an `INSERT` statement (to specify column values for a row), or in a comparison with a column in a `WHERE` clause to specify a comparison value. However, they are not permitted for identifiers (such as table or column names), or to specify both operands of a binary operator such as the `=` equal sign. The latter restriction is necessary because it would be impossible to determine the parameter type. In general, parameters are legal only in Data Manipulation Language (DML) statements, and not in Data Definition Language (DDL) statements.

The parameter markers must be bound to application variables using `mysql_stmt_bind_param()` before executing the statement.

Metadata changes to tables or views referred to by prepared statements are detected and cause automatic repreparation of the statement when it is next executed. For more information, see Section 13.5.4, “Automatic Prepared Statement Repreparation”.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

If the prepare operation was unsuccessful (that is, `mysql_stmt_prepare()` returns nonzero), the error message can be obtained by calling `mysql_stmt_error()`.

Example

See the Example in Section 23.8.11.10, “mysql_stmt_execute()”.

23.8.11.22 mysql_stmt_reset()

```
my_bool mysql_stmt_reset(MYSQL_STMT *stmt)
```

Description

Resets a prepared statement on client and server to state after prepare. It resets the statement on the server, data sent using `mysql_stmt_send_long_data()`, unbuffered result sets and current errors. It does not clear bindings or stored result sets. Stored result sets will be cleared when executing the prepared statement (or closing it).

To re-prepare the statement with another query, use `mysql_stmt_prepare()`.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.11.23 mysql_stmt_result_metadata()

```
MYSQL_RES *mysql_stmt_result_metadata(MYSQL_STMT *stmt)
```

Description

If a statement passed to `mysql_stmt_prepare()` is one that produces a result set, `mysql_stmt_result_metadata()` returns the result set metadata in the form of a pointer to a `MYSQL_RES` structure that can be used to process the meta information such as number of fields and individual field information. This result set pointer can be passed as an argument to any of the field-based API functions that process result set metadata, such as:

- `mysql_num_fields()`
- `mysql_fetch_field()`
- `mysql_fetch_field_direct()`
- `mysql_fetch_fields()`
- `mysql_field_count()`
- `mysql_field_seek()`
- `mysql_field_tell()`
- `mysql_free_result()`

The result set structure should be freed when you are done with it, which you can do by passing it to `mysql_free_result()`. This is similar to the way you free a result set obtained from a call to `mysql_store_result()`.

The result set returned by `mysql_stmt_result_metadata()` contains only metadata. It does not contain any row results. The rows are obtained by using the statement handler with `mysql_stmt_fetch()`.

Return Values

A `MYSQL_RES` result structure. `NULL` if no meta information exists for the prepared query.

Errors

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

See the Example in Section 23.8.11.11, “mysql_stmt_fetch()”.

23.8.11.24 mysql_stmt_row_seek()

```
MYSQL_ROW_OFFSET mysql_stmt_row_seek(MYSQL_STMT *stmt, MYSQL_ROW_OFFSET
offset)
```

Description

Sets the row cursor to an arbitrary row in a statement result set. The `offset` value is a row offset that should be a value returned from `mysql_stmt_row_tell()` or from `mysql_stmt_row_seek()`. This value is not a row number; if you want to seek to a row within a result set by number, use `mysql_stmt_data_seek()` instead.

This function requires that the result set structure contains the entire result of the query, so `mysql_stmt_row_seek()` may be used only in conjunction with `mysql_stmt_store_result()`.

Return Values

The previous value of the row cursor. This value may be passed to a subsequent call to `mysql_stmt_row_seek()`.

Errors

None.

23.8.11.25 mysql_stmt_row_tell()

```
MYSQL_ROW_OFFSET mysql_stmt_row_tell(MYSQL_STMT *stmt)
```

Description

Returns the current position of the row cursor for the last `mysql_stmt_fetch()`. This value can be used as an argument to `mysql_stmt_row_seek()`.

You should use `mysql_stmt_row_tell()` only after `mysql_stmt_store_result()`.

Return Values

The current offset of the row cursor.

Errors

None.

23.8.11.26 mysql_stmt_send_long_data()

```
my_bool mysql_stmt_send_long_data(MYSQL_STMT *stmt, unsigned int
parameter_number, const char *data, unsigned long length)
```

Description

Enables an application to send parameter data to the server in pieces (or “chunks”). Call this function after `mysql_stmt_bind_param()` and before `mysql_stmt_execute()`. It can be called multiple times to send the parts of a character or binary data value for a column, which must be one of the `TEXT` or `BLOB` data types.

`parameter_number` indicates which parameter to associate the data with. Parameters are numbered beginning with 0. `data` is a pointer to a buffer containing data to be sent, and `length` indicates the number of bytes in the buffer.

Note

The next `mysql_stmt_execute()` call ignores the bind buffer for all parameters that have been used with `mysql_stmt_send_long_data()` since last `mysql_stmt_execute()` or `mysql_stmt_reset()`.

If you want to reset/forget the sent data, you can do it with `mysql_stmt_reset()`. See Section 23.8.11.22, “mysql_stmt_reset()”.

As of MySQL 5.5.11, the `max_long_data_size` system variable controls the maximum size of parameter values that can be sent with `mysql_stmt_send_long_data()`. If this variable not set at server startup, the default is the value of the `max_allowed_packet` system variable. `max_long_data_size` is deprecated. In MySQL 5.6, it is removed and the maximum parameter size is controlled by `max_allowed_packet`.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_INVALID_BUFFER_USE`

  The parameter does not have a string or binary type.

- `CR_INVALID_PARAMETER_NO`

  Invalid parameter number.

- `CR_COMMANDS_OUT_OF_SYNC`

  Commands were executed in an improper order.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

Example

The following example demonstrates how to send the data for a `TEXT` column in chunks. It inserts the data value `'MySQL - The most popular Open Source database'` into the `text_column` column. The `mysql` variable is assumed to be a valid connection handler.

```
#define INSERT_QUERY "INSERT INTO \
                      test_long_data(text_column) VALUES(?)"

MYSQL_BIND bind[1];
long       length;

stmt = mysql_stmt_init(mysql);
if (!stmt)
{
  fprintf(stderr, " mysql_stmt_init(), out of memory\n");
  exit(0);
}
if (mysql_stmt_prepare(stmt, INSERT_QUERY, strlen(INSERT_QUERY)))
{
  fprintf(stderr, "\n mysql_stmt_prepare(), INSERT failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}
 memset(bind, 0, sizeof(bind));
 bind[0].buffer_type= MYSQL_TYPE_STRING;
 bind[0].length= &length;
 bind[0].is_null= 0;

/* Bind the buffers */
if (mysql_stmt_bind_param(stmt, bind))
{
  fprintf(stderr, "\n param bind failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

 /* Supply data in chunks to server */
 if (mysql_stmt_send_long_data(stmt,0,"MySQL",5))
{
  fprintf(stderr, "\n send_long_data failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

 /* Supply the next piece of data */
 if (mysql_stmt_send_long_data(stmt,0,
           " - The most popular Open Source database",40))
{
  fprintf(stderr, "\n send_long_data failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

 /* Now, execute the query */
 if (mysql_stmt_execute(stmt))
{
  fprintf(stderr, "\n mysql_stmt_execute failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}
```

23.8.11.27 mysql_stmt_sqlstate()

```
const char *mysql_stmt_sqlstate(MYSQL_STMT *stmt)
```

Description

For the statement specified by `stmt`, `mysql_stmt_sqlstate()` returns a null-terminated string containing the SQLSTATE error code for the most recently invoked prepared statement API function that can succeed or fail. The error code consists of five characters. `"00000"` means “no error.” The values are specified by ANSI SQL and ODBC. For a list of possible values, see Appendix B, *Errors, Error Codes, and Common Problems*.

Not all MySQL errors are mapped to SQLSTATE codes. The value `"HY000"` (general error) is used for unmapped errors.

If the failed statement API function was `mysql_stmt_close()`, do not call `mysql_stmt_sqlstate()` to obtain error information because `mysql_stmt_close()` makes the statement handler invalid. Call `mysql_sqlstate()` instead.

Return Values

A null-terminated character string containing the SQLSTATE error code.

23.8.11.28 mysql_stmt_store_result()

```
int mysql_stmt_store_result(MYSQL_STMT *stmt)
```

Description

Result sets are produced by calling `mysql_stmt_execute()` to executed prepared statements for SQL statements such as `SELECT`, `SHOW`, `DESCRIBE`, and `EXPLAIN`. By default, result sets for successfully executed prepared statements are not buffered on the client and `mysql_stmt_fetch()` fetches them one at a time from the server. To cause the complete result set to be buffered on the client, call `mysql_stmt_store_result()` after binding data buffers with `mysql_stmt_bind_result()` and before calling `mysql_stmt_fetch()` to fetch rows. (For an example, see Section 23.8.11.11, “mysql_stmt_fetch()”.)

`mysql_stmt_store_result()` is optional for result set processing, unless you will call `mysql_stmt_data_seek()`, `mysql_stmt_row_seek()`, or `mysql_stmt_row_tell()`. Those functions require a seekable result set.

It is unnecessary to call `mysql_stmt_store_result()` after executing an SQL statement that does not produce a result set, but if you do, it does not harm or cause any notable performance problem. You can detect whether the statement produced a result set by checking if `mysql_stmt_result_metadata()` returns `NULL`. For more information, refer to Section 23.8.11.23, “mysql_stmt_result_metadata()”.

Note

MySQL does not by default calculate `MYSQL_FIELD->max_length` for all columns in `mysql_stmt_store_result()` because calculating this would slow down `mysql_stmt_store_result()` considerably and most applications do not need `max_length`. If you want `max_length` to be updated, you can call `mysql_stmt_attr_set(MYSQL_STMT, STMT_ATTR_UPDATE_MAX_LENGTH, &flag)` to enable this. See Section 23.8.11.3, “mysql_stmt_attr_set()”.

Return Values

Zero for success. Nonzero if an error occurred.

Errors

- `CR_COMMANDS_OUT_OF_SYNC`

Commands were executed in an improper order.

- `CR_OUT_OF_MEMORY`

  Out of memory.

- `CR_SERVER_GONE_ERROR`

  The MySQL server has gone away.

- `CR_SERVER_LOST`

  The connection to the server was lost during the query.

- `CR_UNKNOWN_ERROR`

  An unknown error occurred.

23.8.12 C API Threaded Function Descriptions

To create a threaded client, use the functions described in the following sections. See also Section 23.8.4.2, “Writing C API Threaded Client Programs”.

23.8.12.1 my_init()

```
void my_init(void)
```

Description

`my_init()` initializes some global variables that MySQL needs. It also calls `mysql_thread_init()` for this thread.

It is necessary for `my_init()` to be called early in the initialization phase of a program's use of the MySQL library. However, `my_init()` is automatically called by `mysql_init()`, `mysql_library_init()`, `mysql_server_init()`, and `mysql_connect()`. If you ensure that your program invokes one of those functions before any other MySQL calls, there is no need to invoke `my_init()` explicitly.

To access the prototype for `my_init()`, your program should include these header files:

```
#include <my_global.h>
#include <my_sys.h>
```

Return Values

None.

23.8.12.2 mysql_thread_end()

```
void mysql_thread_end(void)
```

Description

This function needs to be called before calling `pthread_exit()` to free memory allocated by `mysql_thread_init()`.

`mysql_thread_end()` *is not invoked automatically by the client library*. It must be called explicitly to avoid a memory leak.

Return Values

None.

23.8.12.3 mysql_thread_init()

```
my_bool mysql_thread_init(void)
```

Description

This function must be called early within each created thread to initialize thread-specific variables. However, you may not necessarily need to invoke it explicitly: `mysql_thread_init()` is automatically called by `my_init()`, which itself is automatically called by `mysql_init()`, `mysql_library_init()`, `mysql_server_init()`, and `mysql_connect()`. If you invoke any of those functions, `mysql_thread_init()` is called for you.

Return Values

Zero for success. Nonzero if an error occurred.

23.8.12.4 mysql_thread_safe()

```
unsigned int mysql_thread_safe(void)
```

Description

This function indicates whether the client library is compiled as thread-safe.

Return Values

1 if the client library is thread-safe, 0 otherwise.

23.8.13 C API Embedded Server Function Descriptions

MySQL applications can be written to use an embedded server. See Section 23.7, “libmysqld, the Embedded MySQL Server Library”. To write such an application, you must link it against the `libmysqld` library by using the `-lmysqld` flag rather than linking it against the `libmysqlclient` client library by using the `-lmysqlclient` flag. However, the calls to initialize and finalize the library are the same whether you write a client application or one that uses the embedded server: Call `mysql_library_init()` to initialize the library and `mysql_library_end()` when you are done with it. See Section 23.8.6, “C API Function Overview”.

23.8.13.1 mysql_server_init()

```
int mysql_server_init(int argc, char **argv, char **groups)
```

Description

This function initializes the MySQL library, which must be done before you call any other MySQL function. However, `mysql_server_init()` is deprecated and you should call `mysql_library_init()` instead. See Section 23.8.7.40, “mysql_library_init()”.

Return Values

Zero for success. Nonzero if an error occurred.

23.8.13.2 mysql_server_end()

```
void mysql_server_end(void)
```

Description

This function finalizes the MySQL library, which should be done when you are done using the library. However, `mysql_server_end()` is deprecated and `mysql_library_end()` should be used instead. See Section 23.8.7.39, “mysql_library_end()”.

Return Values

None.

23.8.14 C API Client Plugin Functions

This section describes functions used for the client-side plugin API. They enable management of client plugins. For a description of the `st_mysql_client_plugin` structure used by these functions, see Client Plugin Descriptors.

It is unlikely that a client program needs to call the functions in this section. For example, a client that supports the use of authentication plugins normally causes a plugin to be loaded by calling `mysql_options()` to set the `MYSQL_DEFAULT_AUTH` and `MYSQL_PLUGIN_DIR` options:

```
char *plugin_dir = "path_to_plugin_dir";
char *default_auth = "plugin_name";

/* ... process command-line options ... */

mysql_options(&mysql, MYSQL_PLUGIN_DIR, plugin_dir);
mysql_options(&mysql, MYSQL_DEFAULT_AUTH, default_auth);
```

Typically, the program will also accept `--plugin-dir` and `--default-auth` options that enable users to override the default values.

23.8.14.1 mysql_client_find_plugin()

```
struct st_mysql_client_plugin *mysql_client_find_plugin(MYSQL *mysql, const
char *name, int type)
```

Description

Returns a pointer to a loaded plugin, loading the plugin first if necessary. An error occurs if the type is invalid or the plugin cannot be found or loaded.

Specify the parameters as follows:

- `mysql`: A pointer to a `MYSQL` structure. The plugin API does not require a connection to a MySQL server, but this structure must be properly initialized. The structure is used to obtain connection-related information.
- `name`: The plugin name.
- `type`: The plugin type.

Return Values

A pointer to the plugin for success. `NULL` if an error occurred.

Errors

To check for errors, call the `mysql_error()` or `mysql_errno()` function. See Section 23.8.7.15, “mysql_error()”, and Section 23.8.7.14, “mysql_errno()”.

Example

```
MYSQL mysql;
struct st_mysql_client_plugin *p;

if ((p = mysql_client_find_plugin(&mysql, "myplugin",
                                  MYSQL_CLIENT_AUTHENTICATION_PLUGIN, 0)))
{
  printf("Plugin version: %d.%d.%d\n", p->version[0], p->version[1], p->version[2]);
```

```
}
```

23.8.14.2 mysql_client_register_plugin()

```
struct st_mysql_client_plugin *mysql_client_register_plugin(MYSQL *mysql,
struct st_mysql_client_plugin *plugin)
```

Description

Adds a plugin structure to the list of loaded plugins. An error occurs if the plugin is already loaded.

Specify the parameters as follows:

- `mysql`: A pointer to a `MYSQL` structure. The plugin API does not require a connection to a MySQL server, but this structure must be properly initialized. The structure is used to obtain connection-related information.
- `plugin`: A pointer to the plugin structure.

Return Values

A pointer to the plugin for success. `NULL` if an error occurred.

Errors

To check for errors, call the `mysql_error()` or `mysql_errno()` function. See Section 23.8.7.15, “mysql_error()”, and Section 23.8.7.14, “mysql_errno()”.

23.8.14.3 mysql_load_plugin()

```
struct st_mysql_client_plugin *mysql_load_plugin(MYSQL *mysql, const char
*name, int type, int argc, ...)
```

Description

Loads a MySQL client plugin, specified by name and type. An error occurs if the type is invalid or the plugin cannot be loaded.

It is not possible to load multiple plugins of the same type. An error occurs if you try to load a plugin of a type already loaded.

Specify the parameters as follows:

- `mysql`: A pointer to a `MYSQL` structure. The plugin API does not require a connection to a MySQL server, but this structure must be properly initialized. The structure is used to obtain connection-related information.
- `name`: The name of the plugin to load.
- `type`: The type of plugin to load, or −1 to disable type checking. If type is not −1, only plugins matching the type are considered for loading.
- `argc`: The number of following arguments (0 if there are none). Interpretation of any following arguments depends on the plugin type.

Another way to cause plugins to be loaded is to set the `LIBMYSQL_PLUGINS` environment variable to a semicolon-separated list of plugin names. For example:

```
shell> export LIBMYSQL_PLUGINS="myplugin1;myplugin2"
```

Plugins named by `LIBMYSQL_PLUGINS` are loaded when the client program calls `mysql_library_init()`. No error is reported if problems occur loading these plugins.

Return Values

A pointer to the plugin if it was loaded successfully. `NULL` if an error occurred.

Errors

To check for errors, call the `mysql_error()` or `mysql_errno()` function. See Section 23.8.7.15, “mysql_error()”, and Section 23.8.7.14, “mysql_errno()”.

Example

```
MYSQL mysql;

if(!mysql_load_plugin(&mysql, "myplugin",
                      MYSQL_CLIENT_AUTHENTICATION_PLUGIN, 0))
{
    fprintf(stderr, "Error: %s\n", mysql_error(&mysql));
    exit(-1);
}
```

See Also

See also Section 23.8.14.3, “mysql_load_plugin()”, Section 23.8.7.15, “mysql_error()”, Section 23.8.7.14, “mysql_errno()”.

23.8.14.4 mysql_load_plugin_v()

```
struct st_mysql_client_plugin *mysql_load_plugin_v(MYSQL *mysql, const char
*name, int type, int argc, va_list args)
```

Description

This function is equivalent to `mysql_load_plugin()`, but it accepts a `va_list` instead of a variable list of parameters.

See Also

See also Section 23.8.14.3, “mysql_load_plugin()”.

23.8.14.5 mysql_plugin_options()

```
int mysql_plugin_options(struct st_mysql_client_plugin *plugin, const char
*option, const void *value)
```

Description

Passes an option type and value to a plugin. This function can be called multiple times to set several options. If the plugin does not have an option handler, an error occurs.

Specify the parameters as follows:

- `plugin`: A pointer to the plugin structure.
- `option`: The option to be set.
- `value`: A pointer to the option value.

Return Values

Zero for success, 1 if an error occurred. If the plugin has an option handler, that handler should also return zero for success and 1 if an error occurred.

23.8.15 C API Encrypted Connection Support

For applications that require control over how encrypted connections are established, the C API provides these capabilities:

- The `mysql_ssl_set()` and `mysql_options()` functions enable applications to set the appropriate SSL/TLS options before calling `mysql_real_connect()`. For example, to require the use of an encrypted connection, see Enforcing an Encrypted Connection.
- The `mysql_get_ssl_cipher()` function enables applications to determine, after a connection has been established, whether the connection uses encryption. A `NULL` return value indicates that encryption is not being used. A non-`NULL` return value indicates an encrypted connection and names the encryption cipher. See Section 23.8.7.33, “mysql_get_ssl_cipher()”.
- C API Options for Encrypted Connections
- Enforcing an Encrypted Connection
- Improving Security of Encrypted Connections

C API Options for Encrypted Connections

`mysql_ssl_set()` takes the following arguments for control over use of encrypted connections. For more information, see Section 23.8.7.67, “mysql_ssl_set()”.

- `key`: The path name of the client private key file.
- `cert`: The path name of the client public key certificate file.
- `ca`: The path name of the Certificate Authority (CA) certificate file. This option, if used, must specify the same certificate used by the server.
- `capath`: The path name of the directory that contains trusted SSL CA certificate files.
- `cipher`: The list of permitted ciphers for SSL encryption.

`mysql_options()` provides the following options for control over use of encrypted connections. For option details, see Section 23.8.7.49, “mysql_options()”.

- `MYSQL_OPT_SSL_MODE`: The connection security state.
- `MYSQL_OPT_SSL_VERIFY_SERVER_CERT`: Whether to perform host name identity verification of the server certificate Common Name value.

Enforcing an Encrypted Connection

`mysql_ssl_set()` options for information such as SSL certificate and key files are used to establish an encrypted connection if such connections are available, but do not enforce any requirement that the connection obtained be encrypted. To require an encrypted connection, use the following technique:

1. Call `mysql_ssl_set()` and `mysql_options()` as necessary to supply the appropriate SSL parameters (certificate and key files, encryption ciphers, and so forth).
2. For MySQL 5.5.55 and higher, `MYSQL_OPT_SSL_MODE` is available, so call `mysql_options()` to pass the `MYSQL_OPT_SSL_MODE` option with a value of `SSL_MODE_REQUIRED`.

Important

In MySQL 5.5, the minor C API version number was not incremented for the addition of `MYSQL_OPT_SSL_MODE` in MySQL 5.5.55. Application programs compiled for MySQL 5.5 that require `MYSQL_OPT_SSL_MODE` may fail to

operate properly if the dynamic loader provides an older client library that does not include `MYSQL_OPT_SSL_MODE`. Such applications must be written to handle this possibility by checking whether the `mysql_options()` call succeeds or fails.

3. Call `mysql_real_connect()` to connect to the server. As of MySQL 5.5.55, the call fails if an encrypted connection cannot be obtained; exit with an error. Prior to 5.5.55 (before `MYSQL_OPT_SSL_MODE` is available), clients are required to check for themselves, after calling `mysql_real_connect()`, whether the connection is encrypted. To do this if `mysql_real_connect()` succeeds, call `mysql_get_ssl_cipher()` to check whether the resulting connection is encrypted. If not, exit with an error.

MySQL clients implement this technique using a wrapper function named `mysql_connect_ssl_check()` to establish and check the connection, rather than calling `mysql_real_connect()` directly. To see how this works, look in the `client` directory of a MySQL source distribution at the source for any of the standard MySQL clients, as well as the `client_priv.h` file that contains the `mysql_connect_ssl_check()` wrapper function implementation. A call to `mysql_connect_ssl_check()` takes arguments like the arguments to `mysql_real_connect()`, plus an extra argument indicating whether to require an encrypted connection:

```
if (!mysql_connect_ssl_check(&mysql, host, user, pass, db,
                             port, sock, flags,
                             opt_ssl_required))
{
  /* failure: connection not obtained, or not encrypted if required to be */
}
else
{
  /* success: connection obtained, encrypted if required to be */
}
```

Version notes:

- In MySQL 5.5.49, the `--ssl-mode=REQUIRED` command-line option was backported from MySQL 5.7 to MySQL 5.5. Clients can check for this option and use it to determine whether to require an encrypted connection. If so, clients must check for themselves, after calling `mysql_real_connect()`, whether the connection is encrypted, and fail if not. To do this, call `mysql_get_ssl_cipher()` and check the return value.
- In MySQL 5.5.55, the `MYSQL_OPT_SSL_MODE` option for `mysql_options()` was backported from MySQL 5.7 to MySQL 5.5. A call to `mysql_options()` to set the `MYSQL_OPT_SSL_MODE` option to value of `SSL_MODE_REQUIRED` suffices to cause `mysql_real_connect()` to fail if the connection is not encrypted. `mysql_get_ssl_cipher()` can still be called after connecting, although it is not necessary to do so.

Improving Security of Encrypted Connections

For additional security relative to that provided by the default encryption, clients can supply a CA certificate matching the one used by the server and enable host name identity verification. In this way, the server and client place their trust in the same CA certificate and the client verifies that the host to which it connected is the one intended:

- To specify the CA certificate, call `mysql_ssl_set()` to pass the `ca` (or `capath`) argument.
- To enable host name identity verification, call `mysql_options()` to enable the `MYSQL_OPT_SSL_VERIFY_SERVER_CERT` option.
- To require an encrypted connection, call `mysql_options()` to pass the `MYSQL_OPT_SSL_MODE` option with a value of `SSL_MODE_REQUIRED`. (For details about `SSL_MODE_REQUIRED`, see Enforcing an Encrypted Connection.)

23.8.16 C API Multiple Statement Execution Support

By default, `mysql_query()` and `mysql_real_query()` interpret their statement string argument as a single statement to be executed, and you process the result according to whether the statement produces a result set (a set of rows, as for `SELECT`) or an affected-rows count (as for `INSERT`, `UPDATE`, and so forth).

MySQL also supports the execution of a string containing multiple statements separated by semicolon (`;`) characters. This capability is enabled by special options that are specified either when you connect to the server with `mysql_real_connect()` or after connecting by calling `mysql_set_server_option()`.

Executing a multiple-statement string can produce multiple result sets or row-count indicators. Processing these results involves a different approach than for the single-statement case: After handling the result from the first statement, it is necessary to check whether more results exist and process them in turn if so. To support multiple-result processing, the C API includes the `mysql_more_results()` and `mysql_next_result()` functions. These functions are used at the end of a loop that iterates as long as more results are available. *Failure to process the result this way may result in a dropped connection to the server.*

Multiple-result processing also is required if you execute `CALL` statements for stored procedures. Results from a stored procedure have these characteristics:

- Statements within the procedure may produce result sets (for example, if it executes `SELECT` statements). These result sets are returned in the order that they are produced as the procedure executes.

  In general, the caller cannot know how many result sets a procedure will return. Procedure execution may depend on loops or conditional statements that cause the execution path to differ from one call to the next. Therefore, you must be prepared to retrieve multiple results.

- The final result from the procedure is a status result that includes no result set. The status indicates whether the procedure succeeded or an error occurred.

The multiple statement and result capabilities can be used only with `mysql_query()` or `mysql_real_query()`. They cannot be used with the prepared statement interface. Prepared statement handlers are defined to work only with strings that contain a single statement. See Section 23.8.8, “C API Prepared Statements”.

To enable multiple-statement execution and result processing, the following options may be used:

- The `mysql_real_connect()` function has a `flags` argument for which two option values are relevant:

  - `CLIENT_MULTI_RESULTS` enables the client program to process multiple results. This option *must* be enabled if you execute `CALL` statements for stored procedures that produce result sets. Otherwise, such procedures result in an error `Error 1312 (0A000): PROCEDURE` *`proc_name`* `can't return a result set in the given context`. `CLIENT_MULTI_RESULTS` is enabled by default.

  - `CLIENT_MULTI_STATEMENTS` enables `mysql_query()` and `mysql_real_query()` to execute statement strings containing multiple statements separated by semicolons. This option also enables `CLIENT_MULTI_RESULTS` implicitly, so a `flags` argument of `CLIENT_MULTI_STATEMENTS` to `mysql_real_connect()` is equivalent to an argument of `CLIENT_MULTI_STATEMENTS | CLIENT_MULTI_RESULTS`. That is, `CLIENT_MULTI_STATEMENTS` is sufficient to enable multiple-statement execution and all multiple-result processing.

- After the connection to the server has been established, you can use the `mysql_set_server_option()` function to enable or disable multiple-statement execution by passing it an argument of `MYSQL_OPTION_MULTI_STATEMENTS_ON` or

`MYSQL_OPTION_MULTI_STATEMENTS_OFF`. Enabling multiple-statement execution with this function also enables processing of “simple” results for a multiple-statement string where each statement produces a single result, but is *not* sufficient to permit processing of stored procedures that produce result sets.

The following procedure outlines a suggested strategy for handling multiple statements:

1. Pass `CLIENT_MULTI_STATEMENTS` to `mysql_real_connect()`, to fully enable multiple-statement execution and multiple-result processing.
2. After calling `mysql_query()` or `mysql_real_query()` and verifying that it succeeds, enter a loop within which you process statement results.
3. For each iteration of the loop, handle the current statement result, retrieving either a result set or an affected-rows count. If an error occurs, exit the loop.
4. At the end of the loop, call `mysql_next_result()` to check whether another result exists and initiate retrieval for it if so. If no more results are available, exit the loop.

One possible implementation of the preceding strategy is shown following. The final part of the loop can be reduced to a simple test of whether `mysql_next_result()` returns nonzero. The code as written distinguishes between no more results and an error, which enables a message to be printed for the latter occurrence.

```
/* connect to server with the CLIENT_MULTI_STATEMENTS option */
if (mysql_real_connect (mysql, host_name, user_name, password,
    db_name, port_num, socket_name, CLIENT_MULTI_STATEMENTS) == NULL)
{
  printf("mysql_real_connect() failed\n");
  mysql_close(mysql);
  exit(1);
}

/* execute multiple statements */
status = mysql_query(mysql,
                     "DROP TABLE IF EXISTS test_table;\
                      CREATE TABLE test_table(id INT);\
                      INSERT INTO test_table VALUES(10);\
                      UPDATE test_table SET id=20 WHERE id=10;\
                      SELECT * FROM test_table;\
                      DROP TABLE test_table");
if (status)
{
  printf("Could not execute statement(s)");
  mysql_close(mysql);
  exit(0);
}

/* process each statement result */
do {
  /* did current statement return data? */
  result = mysql_store_result(mysql);
  if (result)
  {
    /* yes; process rows and free the result set */
    process_result_set(mysql, result);
    mysql_free_result(result);
  }
  else          /* no result set or error */
  {
    if (mysql_field_count(mysql) == 0)
    {
      printf("%lld rows affected\n",
             mysql_affected_rows(mysql));
    }
    else  /* some error occurred */
    {
      printf("Could not retrieve result set\n");
```

```
      break;
    }
  }
  /* more results? -1 = no, >0 = error, 0 = yes (keep looping) */
  if ((status = mysql_next_result(mysql)) > 0)
    printf("Could not execute statement\n");
} while (status == 0);

mysql_close(mysql);
```

23.8.17 C API Prepared Statement Handling of Date and Time Values

The binary (prepared statement) protocol enables you to send and receive date and time values (`DATE`, `TIME`, `DATETIME`, and `TIMESTAMP`), using the `MYSQL_TIME` structure. The members of this structure are described in Section 23.8.9, “C API Prepared Statement Data Structures”.

To send temporal data values, create a prepared statement using `mysql_stmt_prepare()`. Then, before calling `mysql_stmt_execute()` to execute the statement, use the following procedure to set up each temporal parameter:

1. In the `MYSQL_BIND` structure associated with the data value, set the `buffer_type` member to the type that indicates what kind of temporal value you're sending. For `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP` values, set `buffer_type` to `MYSQL_TYPE_DATE`, `MYSQL_TYPE_TIME`, `MYSQL_TYPE_DATETIME`, or `MYSQL_TYPE_TIMESTAMP`, respectively.

2. Set the `buffer` member of the `MYSQL_BIND` structure to the address of the `MYSQL_TIME` structure in which you pass the temporal value.

3. Fill in the members of the `MYSQL_TIME` structure that are appropriate for the type of temporal value to pass.

Use `mysql_stmt_bind_param()` to bind the parameter data to the statement. Then you can call `mysql_stmt_execute()`.

To retrieve temporal values, the procedure is similar, except that you set the `buffer_type` member to the type of value you expect to receive, and the `buffer` member to the address of a `MYSQL_TIME` structure into which the returned value should be placed. Use `mysql_stmt_bind_result()` to bind the buffers to the statement after calling `mysql_stmt_execute()` and before fetching the results.

Here is a simple example that inserts `DATE`, `TIME`, and `TIMESTAMP` data. The `mysql` variable is assumed to be a valid connection handler.

```
MYSQL_TIME  ts;
MYSQL_BIND  bind[3];
MYSQL_STMT  *stmt;

strmov(query, "INSERT INTO test_table(date_field, time_field, \
                           timestamp_field) VALUES(?,?,?");

stmt = mysql_stmt_init(mysql);
if (!stmt)
{
  fprintf(stderr, " mysql_stmt_init(), out of memory\n");
  exit(0);
}
if (mysql_stmt_prepare(mysql, query, strlen(query)))
{
  fprintf(stderr, "\n mysql_stmt_prepare(), INSERT failed");
  fprintf(stderr, "\n %s", mysql_stmt_error(stmt));
  exit(0);
}

/* set up input buffers for all 3 parameters */
bind[0].buffer_type= MYSQL_TYPE_DATE;
bind[0].buffer= (char *)&ts;
```

```
bind[0].is_null= 0;
bind[0].length= 0;
...
bind[1]= bind[2]= bind[0];
...

mysql_stmt_bind_param(stmt, bind);

/* supply the data to be sent in the ts structure */
ts.year= 2002;
ts.month= 02;
ts.day= 03;

ts.hour= 10;
ts.minute= 45;
ts.second= 20;

mysql_stmt_execute(stmt);
..
```

23.8.18 C API Prepared CALL Statement Support

This section describes prepared-statement support in the C API for stored procedures executed using `CALL` statements:

Stored procedures executed using prepared `CALL` statements can be used in the following ways:

- A stored procedure can produce any number of result sets. The number of columns and the data types of the columns need not be the same for all result sets.
- The final values of `OUT` and `INOUT` parameters are available to the calling application after the procedure returns. These parameters are returned as an extra single-row result set following any result sets produced by the procedure itself. The row contains the values of the `OUT` and `INOUT` parameters in the order in which they are declared in the procedure parameter list.

The following discussion shows how to use these capabilities through the C API for prepared statements. To use prepared `CALL` statements through the `PREPARE` and `EXECUTE` statements, see Section 13.2.1, “CALL Syntax”.

An application that executes a prepared `CALL` statement should use a loop that fetches a result and then invokes `mysql_stmt_next_result()` to determine whether there are more results. The results consist of any result sets produced by the stored procedure followed by a final status value that indicates whether the procedure terminated successfully.

If the procedure has `OUT` or `INOUT` parameters, the result set preceding the final status value contains their values. To determine whether a result set contains parameter values, test whether the `SERVER_PS_OUT_PARAMS` bit is set in the `server_status` member of the `MYSQL` connection handler:

```
mysql->server_status & SERVER_PS_OUT_PARAMS
```

The following example uses a prepared `CALL` statement to execute a stored procedure that produces multiple result sets and that provides parameter values back to the caller by means of `OUT` and `INOUT` parameters. The procedure takes parameters of all three types (`IN`, `OUT`, `INOUT`), displays their initial values, assigns new values, displays the updated values, and returns. The expected return information from the procedure therefore consists of multiple result sets and a final status:

- One result set from a `SELECT` that displays the initial parameter values: `10`, `NULL`, `30`. (The `OUT` parameter is assigned a value by the caller, but this assignment is expected to be ineffective: `OUT` parameters are seen as `NULL` within a procedure until assigned a value within the procedure.)
- One result set from a `SELECT` that displays the modified parameter values: `100`, `200`, `300`.
- One result set containing the final `OUT` and `INOUT` parameter values: `200`, `300`.

- A final status packet.

The code to execute the procedure:

```
MYSQL_STMT *stmt;
MYSQL_BIND ps_params[3];  /* input parameter buffers */
int        int_data[3];   /* input/output values */
my_bool    is_null[3];    /* output value nullability */
int        status;

/* set up stored procedure */
status = mysql_query(mysql, "DROP PROCEDURE IF EXISTS p1");
test_error(mysql, status);

status = mysql_query(mysql,
  "CREATE PROCEDURE p1("
  "  IN p_in INT, "
  "  OUT p_out INT, "
  "  INOUT p_inout INT) "
  "BEGIN "
  "  SELECT p_in, p_out, p_inout; "
  "  SET p_in = 100, p_out = 200, p_inout = 300; "
  "  SELECT p_in, p_out, p_inout; "
  "END");
test_error(mysql, status);

/* initialize and prepare CALL statement with parameter placeholders */
stmt = mysql_stmt_init(mysql);
if (!stmt)
{
  printf("Could not initialize statement\n");
  exit(1);
}
status = mysql_stmt_prepare(stmt, "CALL p1(?, ?, ?)", 16);
test_stmt_error(stmt, status);

/* initialize parameters: p_in, p_out, p_inout (all INT) */
memset(ps_params, 0, sizeof (ps_params));

ps_params[0].buffer_type = MYSQL_TYPE_LONG;
ps_params[0].buffer = (char *) &int_data[0];
ps_params[0].length = 0;
ps_params[0].is_null = 0;

ps_params[1].buffer_type = MYSQL_TYPE_LONG;
ps_params[1].buffer = (char *) &int_data[1];
ps_params[1].length = 0;
ps_params[1].is_null = 0;

ps_params[2].buffer_type = MYSQL_TYPE_LONG;
ps_params[2].buffer = (char *) &int_data[2];
ps_params[2].length = 0;
ps_params[2].is_null = 0;

/* bind parameters */
status = mysql_stmt_bind_param(stmt, ps_params);
test_stmt_error(stmt, status);

/* assign values to parameters and execute statement */
int_data[0]= 10;  /* p_in */
int_data[1]= 20;  /* p_out */
int_data[2]= 30;  /* p_inout */

status = mysql_stmt_execute(stmt);
test_stmt_error(stmt, status);

/* process results until there are no more */
do {
  int i;
  int num_fields;       /* number of columns in result */
  MYSQL_FIELD *fields;  /* for result set metadata */
```

```
MYSQL_BIND *rs_bind;  /* for output buffers */

/* the column count is > 0 if there is a result set */
/* 0 if the result is only the final status packet */
num_fields = mysql_stmt_field_count(stmt);

if (num_fields > 0)
{
  /* there is a result set to fetch */
  printf("Number of columns in result: %d\n", (int) num_fields);

  /* what kind of result set is this? */
  printf("Data: ");
  if(mysql->server_status & SERVER_PS_OUT_PARAMS)
    printf("this result set contains OUT/INOUT parameters\n");
  else
    printf("this result set is produced by the procedure\n");

  MYSQL_RES *rs_metadata = mysql_stmt_result_metadata(stmt);
  test_stmt_error(stmt, rs_metadata == NULL);

  fields = mysql_fetch_fields(rs_metadata);

  rs_bind = (MYSQL_BIND *) malloc(sizeof (MYSQL_BIND) * num_fields);
  if (!rs_bind)
  {
    printf("Cannot allocate output buffers\n");
    exit(1);
  }
  memset(rs_bind, 0, sizeof (MYSQL_BIND) * num_fields);

  /* set up and bind result set output buffers */
  for (i = 0; i < num_fields; ++i)
  {
    rs_bind[i].buffer_type = fields[i].type;
    rs_bind[i].is_null = &is_null[i];

    switch (fields[i].type)
    {
      case MYSQL_TYPE_LONG:
        rs_bind[i].buffer = (char *) &(int_data[i]);
        rs_bind[i].buffer_length = sizeof (int_data);
        break;

      default:
        fprintf(stderr, "ERROR: unexpected type: %d.\n", fields[i].type);
        exit(1);
    }
  }

  status = mysql_stmt_bind_result(stmt, rs_bind);
  test_stmt_error(stmt, status);

  /* fetch and display result set rows */
  while (1)
  {
    status = mysql_stmt_fetch(stmt);

    if (status == 1 || status == MYSQL_NO_DATA)
      break;

    for (i = 0; i < num_fields; ++i)
    {
      switch (rs_bind[i].buffer_type)
      {
        case MYSQL_TYPE_LONG:
          if (*rs_bind[i].is_null)
            printf(" val[%d] = NULL;", i);
          else
            printf(" val[%d] = %ld;",
                   i, (long) *((int *) rs_bind[i].buffer));
          break;
```

```
          default:
            printf("  unexpected type (%d)\n",
              rs_bind[i].buffer_type);
        }
      }
      printf("\n");
    }

    mysql_free_result(rs_metadata); /* free metadata */
    free(rs_bind);                  /* free output buffers */
  }
  else
  {
    /* no columns = final status packet */
    printf("End of procedure output\n");
  }

  /* more results? -1 = no, >0 = error, 0 = yes (keep looking) */
  status = mysql_stmt_next_result(stmt);
  if (status > 0)
    test_stmt_error(stmt, status);
} while (status == 0);

mysql_stmt_close(stmt);
```

Execution of the procedure should produce the following output:

```
Number of columns in result: 3
Data: this result set is produced by the procedure
 val[0] = 10; val[1] = NULL; val[2] = 30;
Number of columns in result: 3
Data: this result set is produced by the procedure
 val[0] = 100; val[1] = 200; val[2] = 300;
Number of columns in result: 2
Data: this result set contains OUT/INOUT parameters
 val[0] = 200; val[1] = 300;
End of procedure output
```

The code uses two utility routines, `test_error()` and `test_stmt_error()`, to check for errors and terminate after printing diagnostic information if an error occurred:

```
static void test_error(MYSQL *mysql, int status)
{
  if (status)
  {
    fprintf(stderr, "Error: %s (errno: %d)\n",
            mysql_error(mysql), mysql_errno(mysql));
    exit(1);
  }
}

static void test_stmt_error(MYSQL_STMT *stmt, int status)
{
  if (status)
  {
    fprintf(stderr, "Error: %s (errno: %d)\n",
            mysql_stmt_error(stmt), mysql_stmt_errno(stmt));
    exit(1);
  }
}
```

23.8.19 C API Prepared Statement Problems

Here follows a list of the currently known problems with prepared statements:

- `TIME`, `TIMESTAMP`, and `DATETIME` do not support parts of seconds (for example, from `DATE_FORMAT()`).

- When converting an integer to string, `ZEROFILL` is honored with prepared statements in some cases where the MySQL server does not print the leading zeros. (For example, with `MIN(*number-with-zerofill*)`).
- When converting a floating-point number to a string in the client, the rightmost digits of the converted value may differ slightly from those of the original value.
- Prepared statements use the query cache under the conditions described in Section 8.10.3.1, “How the Query Cache Operates”.
- Prepared statements do not support multi-statements (that is, multiple statements within a single string separated by `;` characters).
- The capabilities of prepared `CALL` statements are described in Section 23.8.18, “C API Prepared CALL Statement Support”.

23.8.20 C API Automatic Reconnection Control

The MySQL client library can perform an automatic reconnection to the server if it finds that the connection is down when you attempt to send a statement to the server to be executed. If auto-reconnect is enabled, the library tries once to reconnect to the server and send the statement again.

Auto-reconnect is disabled by default.

If it is important for your application to know that the connection has been dropped (so that it can exit or take action to adjust for the loss of state information), be sure that auto-reconnect is disabled. To ensure this, call `mysql_options()` with the `MYSQL_OPT_RECONNECT` option:

```
my_bool reconnect = 0;
mysql_options(&mysql, MYSQL_OPT_RECONNECT, &reconnect);
```

If the connection has gone down, the effect of `mysql_ping()` depends on the auto-reconnect state. If auto-reconnect is enabled, `mysql_ping()` performs a reconnect. Otherwise, it returns an error.

Some client programs might provide the capability of controlling automatic reconnection. For example, `mysql` reconnects by default, but the `--skip-reconnect` option can be used to suppress this behavior.

If an automatic reconnection does occur (for example, as a result of calling `mysql_ping()`), there is no explicit indication of it. To check for reconnection, call `mysql_thread_id()` to get the original connection identifier before calling `mysql_ping()`, then call `mysql_thread_id()` again to see whether the identifier changed.

Automatic reconnection can be convenient because you need not implement your own reconnect code, but if a reconnection does occur, several aspects of the connection state are reset on the server side and your application will not be notified.

The connection-related state is affected as follows:

- Any active transactions are rolled back and autocommit mode is reset.
- All table locks are released.
- All `TEMPORARY` tables are closed (and dropped).
- Session system variables are reinitialized to the values of the corresponding global system variables, including system variables that are set implicitly by statements such as `SET NAMES`.
- User variable settings are lost.
- Prepared statements are released.

- `HANDLER` variables are closed.
- The value of `LAST_INSERT_ID()` is reset to 0.
- Locks acquired with `GET_LOCK()` are released.

If reconnection occurs, any SQL statement specified by calling `mysql_options()` with the `MYSQL_INIT_COMMAND` option is re-executed.

If the connection drops, it is possible that the session associated with the connection on the server side will still be running if the server has not yet detected that the client is no longer connected. In this case, any locks held by the original connection still belong to that session, so you may want to kill it by calling `mysql_kill()`.

23.8.21 C API Common Issues

23.8.21.1 Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success

It is possible for `mysql_store_result()` to return `NULL` following a successful call to `mysql_query()`. When this happens, it means one of the following conditions occurred:

- There was a `malloc()` failure (for example, if the result set was too large).
- The data could not be read (an error occurred on the connection).
- The query returned no data (for example, it was an `INSERT`, `UPDATE`, or `DELETE`).

You can always check whether the statement should have produced a nonempty result by calling `mysql_field_count()`. If `mysql_field_count()` returns zero, the result is empty and the last query was a statement that does not return values (for example, an `INSERT` or a `DELETE`). If `mysql_field_count()` returns a nonzero value, the statement should have produced a nonempty result. See the description of the `mysql_field_count()` function for an example.

You can test for an error by calling `mysql_error()` or `mysql_errno()`.

23.8.21.2 What Results You Can Get from a Query

In addition to the result set returned by a query, you can also get the following information:

- `mysql_affected_rows()` returns the number of rows affected by the last query when doing an `INSERT`, `UPDATE`, or `DELETE`.

  For a fast re-create, use `TRUNCATE TABLE`.

- `mysql_num_rows()` returns the number of rows in a result set. With `mysql_store_result()`, `mysql_num_rows()` may be called as soon as `mysql_store_result()` returns. With `mysql_use_result()`, `mysql_num_rows()` may be called only after you have fetched all the rows with `mysql_fetch_row()`.
- `mysql_insert_id()` returns the ID generated by the last query that inserted a row into a table with an `AUTO_INCREMENT` index. See Section 23.8.7.37, “mysql_insert_id()”.
- Some queries (`LOAD DATA INFILE ...`, `INSERT INTO ... SELECT ...`, `UPDATE`) return additional information. The result is returned by `mysql_info()`. See the description for `mysql_info()` for the format of the string that it returns. `mysql_info()` returns a `NULL` pointer if there is no additional information.

23.8.21.3 How to Get the Unique ID for the Last Inserted Row

If you insert a record into a table that contains an `AUTO_INCREMENT` column, you can obtain the value stored into that column by calling the `mysql_insert_id()` function.

You can check from your C applications whether a value was stored in an AUTO_INCREMENT column by executing the following code (which assumes that you've checked that the statement succeeded). It determines whether the query was an INSERT with an AUTO_INCREMENT index:

```
if ((result = mysql_store_result(&mysql)) == 0 &&
    mysql_field_count(&mysql) == 0 &&
    mysql_insert_id(&mysql) != 0)
{
    used_id = mysql_insert_id(&mysql);
}
```

When a new AUTO_INCREMENT value has been generated, you can also obtain it by executing a SELECT LAST_INSERT_ID() statement with mysql_query() and retrieving the value from the result set returned by the statement.

When inserting multiple values, the last automatically incremented value is returned.

For LAST_INSERT_ID(), the most recently generated ID is maintained in the server on a per-connection basis. It is not changed by another client. It is not even changed if you update another AUTO_INCREMENT column with a nonmagic value (that is, a value that is not NULL and not 0). Using LAST_INSERT_ID() and AUTO_INCREMENT columns simultaneously from multiple clients is perfectly valid. Each client will receive the last inserted ID for the last statement *that* client executed.

If you want to use the ID that was generated for one table and insert it into a second table, you can use SQL statements like this:

```
INSERT INTO foo (auto,text)
    VALUES(NULL,'text');         # generate ID by inserting NULL
INSERT INTO foo2 (id,text)
    VALUES(LAST_INSERT_ID(),'text');  # use ID in second table
```

mysql_insert_id() returns the value stored into an AUTO_INCREMENT column, whether that value is automatically generated by storing NULL or 0 or was specified as an explicit value. LAST_INSERT_ID() returns only automatically generated AUTO_INCREMENT values. If you store an explicit value other than NULL or 0, it does not affect the value returned by LAST_INSERT_ID().

For more information on obtaining the last ID in an AUTO_INCREMENT column:

- For information on LAST_INSERT_ID(), which can be used within an SQL statement, see Section 12.14, “Information Functions”.
- For information on mysql_insert_id(), the function you use from within the C API, see Section 23.8.7.37, “mysql_insert_id()”.
- For information on obtaining the auto-incremented value when using Connector/J, see Retrieving AUTO_INCREMENT Column Values through JDBC.
- For information on obtaining the auto-incremented value when using Connector/ODBC, see Obtaining Auto-Increment Values.

23.9 MySQL PHP API

The MySQL PHP API manual is now published in standalone form, not as part of the MySQL Reference Manual. See MySQL and PHP.

23.10 MySQL Perl API

The Perl DBI module provides a generic interface for database access. You can write a DBI script that works with many different database engines without change. To use DBI with MySQL, install the following:

1. The `DBI` module.
2. The `DBD::mysql` module. This is the DataBase Driver (DBD) module for Perl.
3. Optionally, the DBD module for any other type of database server you want to access.

Perl DBI is the recommended Perl interface. It replaces an older interface called `mysqlperl`, which should be considered obsolete.

These sections contain information about using Perl with MySQL and writing MySQL applications in Perl:

- For installation instructions for Perl DBI support, see Section 2.12, “Perl Installation Notes”.
- For an example of reading options from option files, see Section 5.6.4, “Using Client Programs in a Multiple-Server Environment”.
- For secure coding tips, see Section 6.1.1, “Security Guidelines”.
- For debugging tips, see Section 24.5.1.4, “Debugging mysqld under gdb”.
- For some Perl-specific environment variables, see Section 4.9, “MySQL Program Environment Variables”.
- For considerations for running on OS X, see Section 2.4, “Installing MySQL on OS X”.
- For ways to quote string literals, see Section 9.1.1, “String Literals”.

DBI information is available at the command line, online, or in printed form:

- Once you have the `DBI` and `DBD::mysql` modules installed, you can get information about them at the command line with the `perldoc` command:

  ```
  shell> perldoc DBI
  shell> perldoc DBI::FAQ
  shell> perldoc DBD::mysql
  ```

  You can also use `pod2man`, `pod2html`, and so on to translate this information into other formats.

- For online information about Perl DBI, visit the DBI Web site, http://dbi.perl.org/. That site hosts a general DBI mailing list. Oracle Corporation hosts a list specifically about `DBD::mysql`; see Section 1.5.2, “MySQL Mailing Lists”.

- For printed information, the official DBI book is *Programming the Perl DBI* (Alligator Descartes and Tim Bunce, O'Reilly & Associates, 2000). Information about the book is available at the DBI Web site, http://dbi.perl.org/.

  For information that focuses specifically on using DBI with MySQL, see *MySQL and Perl for the Web* (Paul DuBois, New Riders, 2001). This book's Web site is http://www.kitebird.com/mysql-perl/.

23.11 MySQL Python API

`MySQLdb` is a third-party driver that provides MySQL support for Python, compliant with the Python DB API version 2.0. It can be found at http://sourceforge.net/projects/mysql-python/.

The new MySQL Connector/Python component provides an interface to the same Python API, and is built into the MySQL Server and supported by Oracle. See MySQL Connector/Python Developer Guide for details on the Connector, as well as coding guidelines for Python applications and sample Python code.

23.12 MySQL Ruby APIs

Two APIs are available for Ruby programmers developing MySQL applications:

- The MySQL/Ruby API is based on the `libmysqlclient` API library. For information on installing and using the MySQL/Ruby API, see Section 23.12.1, “The MySQL/Ruby API”.
- The Ruby/MySQL API is written to use the native MySQL network protocol (a native driver). For information on installing and using the Ruby/MySQL API, see Section 23.12.2, “The Ruby/MySQL API”.

For background and syntax information about the Ruby language, see Ruby Programming Language.

23.12.1 The MySQL/Ruby API

The MySQL/Ruby module provides access to MySQL databases using Ruby through `libmysqlclient`.

For information on installing the module, and the functions exposed, see MySQL/Ruby.

23.12.2 The Ruby/MySQL API

The Ruby/MySQL module provides access to MySQL databases using Ruby through a native driver interface using the MySQL network protocol.

For information on installing the module, and the functions exposed, see Ruby/MySQL.

23.13 MySQL Tcl API

`MySQLtcl` is a simple API for accessing a MySQL database server from the Tcl programming language. It can be found at http://www.xdobry.de/mysqltcl/.

23.14 MySQL Eiffel Wrapper

Eiffel MySQL is an interface to the MySQL database server using the Eiffel programming language, written by Michael Ravits. It can be found at http://efsa.sourceforge.net/archive/ravits/mysql.htm.

Chapter 24 Extending MySQL

Table of Contents

24.1 MySQL Internals 2769
24.1.1 MySQL Threads 2769
24.1.2 The MySQL Test Suite 2770
24.2 The MySQL Plugin API 2771
24.2.1 Types of Plugins 2771
24.2.2 Plugin API Characteristics 2774
24.2.3 Plugin API Components 2775
24.2.4 Writing Plugins 2776
24.3 MySQL Services for Plugins 2816
24.4 Adding New Functions to MySQL 2817
24.4.1 Features of the User-Defined Function Interface 2818
24.4.2 Adding a New User-Defined Function 2818
24.4.3 Adding a New Native Function 2827
24.5 Debugging and Porting MySQL 2829
24.5.1 Debugging a MySQL Server 2829
24.5.2 Debugging a MySQL Client 2837
24.5.3 The DBUG Package 2837

24.1 MySQL Internals

This chapter describes a lot of things that you need to know when working on the MySQL code. To track or contribute to MySQL development, follow the instructions in Section 2.9.3, “Installing MySQL Using a Development Source Tree”. If you are interested in MySQL internals, you should also subscribe to our `internals` mailing list. This list has relatively low traffic. For details on how to subscribe, please see Section 1.5.2, “MySQL Mailing Lists”. Many MySQL developers at Oracle Corporation are on the `internals` list and we help other people who are working on the MySQL code. Feel free to use this list both to ask questions about the code and to send patches that you would like to contribute to the MySQL project!

24.1.1 MySQL Threads

The MySQL server creates the following threads:

- Connection manager threads handle client connection requests on the network interfaces that the server listens to. On all platforms, one manager thread handles TCP/IP connection requests. On Unix, this manager thread also handles Unix socket file connection requests. On Windows, a manager thread handles shared-memory connection requests, and another handles named-pipe connection requests. The server does not create threads to handle interfaces that it does not listen to. For example, a Windows server that does not have support for named-pipe connections enabled does not create a thread to handle them.

- Connection manager threads associate each client connection with a thread dedicated to it that handles authentication and request processing for that connection. Manager threads create a new thread when necessary but try to avoid doing so by consulting the thread cache first to see whether it contains a thread that can be used for the connection. When a connection ends, its thread is returned to the thread cache if the cache is not full.

  For information about tuning the parameters that control thread resources, see Section 8.12.5.1, “How MySQL Uses Threads for Client Connections”.

- On a master replication server, connections from slave servers are handled like client connections: There is one thread per connected slave.

- On a slave replication server, an I/O thread is started to connect to the master server and read updates from it. An SQL thread is started to apply updates read from the master. These two threads run independently and can be started and stopped independently.
- A signal thread handles all signals. This thread also normally handles alarms and calls `process_alarm()` to force timeouts on connections that have been idle too long.
- If `InnoDB` is used, there will be additional read and write threads by default. The number of these are controlled by the `innodb_read_io_threads` and `innodb_write_io_threads` parameters. See Section 14.17, “InnoDB Startup Options and System Variables”.
- If `mysqld` is compiled with `-DUSE_ALARM_THREAD`, a dedicated thread that handles alarms is created. This is only used on some systems where there are problems with `sigwait()` or if you want to use the `thr_alarm()` code in your application without a dedicated signal handling thread.
- If the server is started with the `--flush_time=val` option, a dedicated thread is created to flush all tables every *`val`* seconds.
- Each table for which `INSERT DELAYED` statements are issued gets its own thread. See Section 13.2.5.3, “INSERT DELAYED Syntax”.
- If the event scheduler is active, there is one thread for the scheduler, and a thread for each event currently running. See Section 20.4.1, “Event Scheduler Overview”.

`mysqladmin processlist` only shows the connection, `INSERT DELAYED`, replication, and event threads.

24.1.2 The MySQL Test Suite

The test system that is included in Unix source and binary distributions makes it possible for users and developers to perform regression tests on the MySQL code. These tests can be run on Unix.

You can also write your own test cases. For information about the MySQL Test Framework, including system requirements, see the manual available at http://dev.mysql.com/doc/mysqltest/2.0/en/.

The current set of test cases does not test everything in MySQL, but it should catch most obvious bugs in the SQL processing code, operating system or library issues, and is quite thorough in testing replication. Our goal is to have the tests cover 100% of the code. We welcome contributions to our test suite. You may especially want to contribute tests that examine the functionality critical to your system because this ensures that all future MySQL releases work well with your applications.

The test system consists of a test language interpreter (`mysqltest`), a Perl script to run all tests (`mysql-test-run.pl`), the actual test cases written in a special test language, and their expected results. To run the test suite on your system after a build, type `make test` from the source root directory, or change location to the `mysql-test` directory and type `./mysql-test-run.pl`. If you have installed a binary distribution, change location to the `mysql-test` directory under the installation root directory (for example, `/usr/local/mysql/mysql-test`), and run `./mysql-test-run.pl`. All tests should succeed. If any do not, feel free to try to find out why and report the problem if it indicates a bug in MySQL. See Section 1.6, “How to Report Bugs or Problems”.

If one test fails, you should run `mysql-test-run.pl` with the `--force` option to check whether any other tests fail.

If you have a copy of `mysqld` running on the machine where you want to run the test suite, you do not have to stop it, as long as it is not using ports `9306` or `9307`. If either of those ports is taken, you should set the `MTR_BUILD_THREAD` environment variable to an appropriate value, and the test suite will use a different set of ports for master, slave, and NDB). For example:

```
shell> export MTR_BUILD_THREAD=31
```

```
shell> ./mysql-test-run.pl [options] [test_name]
```

In the `mysql-test` directory, you can run an individual test case with `./mysql-test-run.pl test_name`.

If you have a question about the test suite, or have a test case to contribute, send an email message to the MySQL `internals` mailing list. See Section 1.5.2, “MySQL Mailing Lists”.

24.2 The MySQL Plugin API

MySQL supports a plugin API that enables creation of server components. Plugins can be loaded at server startup, or loaded and unloaded at runtime without restarting the server. The API is generic and does not specify what plugins can do. The components supported by this interface include, but are not limited to, storage engines, full-text parser plugins, and server extensions.

For example, full-text parser plugins can be used to replace or augment the built-in full-text parser. A plugin can parse text into words using rules that differ from those used by the built-in parser. This can be useful if you need to parse text with characteristics different from those expected by the built-in parser.

The plugin interface is more general than the older user-defined function (UDF) interface.

The plugin interface uses the `plugin` table in the `mysql` database to record information about plugins that have been installed permanently with the `INSTALL PLUGIN` statement. This table is created as part of the MySQL installation process. Plugins can also be installed for a single server invocation with the `--plugin-load` option. Plugins installed this way are not recorded in the `plugin` table. See Section 5.5.1, “Installing and Uninstalling Plugins”.

MySQL 5.5.7 and up supports an API for client plugins in addition to that for server plugins. This is used, for example, by authentication plugins where a server-side plugin and a client-side plugin cooperate to enable clients to connect to the server through a variety of authentication methods.

Additional Resources

The book *MySQL 5.1 Plugin Development* by Sergei Golubchik and Andrew Hutchings provides a wealth of detail about the plugin API. Despite the fact that the book's title refers to MySQL Server 5.1, most of the information in it applies to later versions as well.

24.2.1 Types of Plugins

The plugin API enables creation of plugins that implement several capabilities:

- Storage engines
- Full-text parsers
- Daemons
- `INFORMATION_SCHEMA` tables
- Semisynchronous replication
- Auditing
- Authentication

The following sections provide an overview of these plugin types.

Storage Engine Plugins

The pluggable storage engine architecture used by MySQL Server enables storage engines to be written as plugins and loaded into and unloaded from a running server. For a description of this architecture, see Section 15.2, “Overview of MySQL Storage Engine Architecture”.

For information on how to use the plugin API to write storage engines, see MySQL Internals: Writing a Custom Storage Engine.

Full-Text Parser Plugins

MySQL has a built-in parser that it uses by default for full-text operations (parsing text to be indexed, or parsing a query string to determine the terms to be used for a search). For full-text processing, “parsing” means extracting words from text or a query string based on rules that define which character sequences make up a word and where word boundaries lie.

When parsing for indexing purposes, the parser passes each word to the server, which adds it to a full-text index. When parsing a query string, the parser passes each word to the server, which accumulates the words for use in a search.

The parsing properties of the built-in full-text parser are described in Section 12.9, “Full-Text Search Functions”. These properties include rules for determining how to extract words from text. The parser is influenced by certain system variables such as `ft_min_word_len` and `ft_max_word_len` that cause words shorter or longer to be excluded, and by the stopword list that identifies common words to be ignored.

The plugin API enables you to provide a full-text parser of your own so that you have control over the basic duties of a parser. A parser plugin can operate in either of two roles:

- The plugin can replace the built-in parser. In this role, the plugin reads the input to be parsed, splits it up into words, and passes the words to the server (either for indexing or for word accumulation).

  One reason to use a parser this way is that you need to use different rules from those of the built-in parser for determining how to split up input into words. For example, the built-in parser considers the text “case-sensitive” to consist of two words “case” and “sensitive,” whereas an application might need to treat the text as a single word.

- The plugin can act in conjunction with the built-in parser by serving as a front end for it. In this role, the plugin extracts text from the input and passes the text to the parser, which splits up the text into words using its normal parsing rules. In particular, this parsing will be affected by the `ft_`*`xxx`* system variables and the stopword list.

  One reason to use a parser this way is that you need to index content such as PDF documents, XML documents, or `.doc` files. The built-in parser is not intended for those types of input but a plugin can pull out the text from these input sources and pass it to the built-in parser.

It is also possible for a parser plugin to operate in both roles. That is, it could extract text from noncleartext input (the front end role), and also parse the text into words (thus replacing the built-in parser).

A full-text plugin is associated with full-text indexes on a per-index basis. That is, when you install a parser plugin initially, that does not cause it to be used for any full-text operations. It simply becomes available. For example, a full-text parser plugin becomes available to be named in a `WITH PARSER` clause when creating individual `FULLTEXT` indexes. To create such an index at table-creation time, do this:

```
CREATE TABLE t
(
  doc CHAR(255),
  FULLTEXT INDEX (doc) WITH PARSER my_parser
```

```
) ENGINE=MyISAM;
```

Or you can add the index after the table has been created:

```
ALTER TABLE t ADD FULLTEXT INDEX (doc) WITH PARSER my_parser;
```

The only SQL change for associating the parser with the index is the `WITH PARSER` clause. Searches are specified as before, with no changes needed for queries.

When you associate a parser plugin with a `FULLTEXT` index, the plugin is required for using the index. If the parser plugin is dropped, any index associated with it becomes unusable. Any attempt to use a table for which a plugin is not available results in an error, although `DROP TABLE` is still possible.

For more information about full-text plugins, see Section 24.2.4.4, “Writing Full-Text Parser Plugins”. MySQL 5.5 only supports full-text plugins with `MyISAM`.

Daemon Plugins

A daemon plugin is a simple type of plugin used for code that should be run by the server but that does not communicate with it. MySQL distributions include an example daemon plugin that writes periodic heartbeat messages to a file.

For more information about daemon plugins, see Section 24.2.4.5, “Writing Daemon Plugins”.

INFORMATION_SCHEMA Plugins

`INFORMATION_SCHEMA` plugins enable the creation of tables containing server metadata that are exposed to users through the `INFORMATION_SCHEMA` database. For example, `InnoDB` uses `INFORMATION_SCHEMA` plugins to provide tables that contain information about current transactions and locks.

For more information about `INFORMATION_SCHEMA` plugins, see Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”.

Semisynchronous Replication Plugins

MySQL replication is asynchronous by default. With semisynchronous replication, a commit performed on the master side blocks before returning to the session that performed the transaction until at least one slave acknowledges that it has received and logged the events for the transaction. Semisynchronous replication is implemented through complementary master and client plugins. See Section 17.3.8, “Semisynchronous Replication”.

For more information about semisynchronous replication plugins, see Section 24.2.4.7, “Writing Semisynchronous Replication Plugins”.

Audit Plugins

As of MySQL 5.5.3, the server provides a pluggable audit interface that enables information about server operations to be reported to interested parties. Audit notification occurs for these operations (although the interface is general and the server could be modified to report others):

- Write a message to the general query log (if the log is enabled)
- Write a message to the error log
- Send a query result to a client

Audit plugins may register with the audit interface to receive notification about server operations. When an auditable event occurs within the server, the server determines whether notification is needed. For

each registered audit plugin, the server checks the event against those event classes in which the plugin is interested and passes the event to the plugin if there is a match.

This interface enables audit plugins to receive notifications only about operations in event classes they consider significant and to ignore others. The interface provides for categorization of operations into event classes and further division into event subclasses within each class.

When an audit plugin is notified of an auditable event, it receives a pointer to the current THD structure and a pointer to a structure that contains information about the event. The plugin can examine the event and perform whatever auditing actions are appropriate. For example, the plugin can see what statement produced a result set or was logged, the number of rows in a result, who the current user was for an operation, or the error code for failed operations.

For more information about audit plugins, see Section 24.2.4.8, “Writing Audit Plugins”.

Authentication Plugins

MySQL 5.5.7 and up supports pluggable authentication. Authentication plugins exist on both the server and client sides. Plugins on the server side implement authentication methods for use by clients when they connect to the server. A plugin on the client side communicates with a server-side plugin to provide the authentication information that it requires. A client-side plugin may interact with the user, performing tasks such as soliciting a password or other authentication credentials to be sent to the server. See Section 6.3.6, “Pluggable Authentication”.

Pluggable authentication also enables proxy user capability, in which one user takes the identity of another user. A server-side authentication plugin can return to the server the name of the user whose identity the connecting user should have. See Section 6.3.7, “Proxy Users”.

For more information about authentication plugins, see Section 24.2.4.9, “Writing Authentication Plugins”.

24.2.2 Plugin API Characteristics

The server plugin API has these characteristics:

- All plugins have several things in common.

  Each plugin has a name that it can be referred to in SQL statements, as well as other metadata such as an author and a description that provide other information. This information can be examined in the `INFORMATION_SCHEMA.PLUGINS` table or using the `SHOW PLUGINS` statement.

- The plugin framework is extendable to accommodate different kinds of plugins.

  Although some aspects of the plugin API are common to all types of plugins, the API also permits type-specific interface elements so that different types of plugins can be created. A plugin with one purpose can have an interface most appropriate to its own requirements and not the requirements of some other plugin type.

  Interfaces for several types of plugins exist, such as storage engines, full-text parser, and `INFORMATION_SCHEMA` tables. Others can be added.

- Plugins can expose information to users.

  A plugin can implement system and status variables that are available through the `SHOW VARIABLES` and `SHOW STATUS` statements.

- The plugin API includes versioning information.

  The version information included in the plugin API enables a plugin library and each plugin that it contains to be self-identifying with respect to the API version that was used to build the library. If the

API changes over time, the version numbers will change, but a server can examine a given plugin library's version information to determine whether it supports the plugins in the library.

There are two types of version numbers. The first is the version for the general plugin framework itself. Each plugin library includes this kind of version number. The second type of version applies to individual plugins. Each specific type of plugin has a version for its interface, so each plugin in a library has a type-specific version number. For example, a library containing a full-text parser plugin has a general plugin API version number, and the plugin has a version number specific to the full-text plugin interface.

- The plugin API implements security restrictions.

  A plugin library must be installed in a specific dedicated directory for which the location is controlled by the server and cannot be changed at runtime. Also, the library must contain specific symbols that identify it as a plugin library. The server will not load something as a plugin if it was not built as a plugin.

- Plugins have access to server services.

  The services interface exposes server functionality that plugins can access using ordinary function calls. For details, see Section 24.3, “MySQL Services for Plugins”.

In some respects, the server plugin API is similar to the older user-defined function (UDF) API that it supersedes, but the plugin API has several advantages over the older interface. For example, UDFs had no versioning information. Also, the newer plugin interface eliminates the security issues of the older UDF interface. The older interface for writing nonplugin UDFs permitted libraries to be loaded from any directory searched by the system's dynamic linker, and the symbols that identified the UDF library were relatively nonspecific.

The client plugin API has similar architectural characteristics, but client plugins have no direct access to the server the way server plugins do.

24.2.3 Plugin API Components

The server plugin implementation comprises several components.

SQL statements:

- `INSTALL PLUGIN` registers a plugin in the `mysql.plugin` table and loads the plugin code.
- `UNINSTALL PLUGIN` unregisters a plugin from the `mysql.plugin` table and unloads the plugin code.
- The `WITH PARSER` clause for full-text index creation associates a full-text parser plugin with a given `FULLTEXT` index.
- `SHOW PLUGINS` displays information about server plugins.

Command-line options and system variables:

- The `--plugin-load` option enables plugins to be loaded at server startup time.
- The `plugin_dir` system variable indicates the location of the directory where all plugins must be installed. The value of this variable can be specified at server startup with a `--plugin_dir=`*`dir_name`* option. `mysql_config --plugindir` displays the default plugin directory path name.

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

Plugin-related tables:

- The `INFORMATION_SCHEMA.PLUGINS` table contains plugin information.

- The `mysql.plugin` table lists each plugin that was installed with `INSTALL PLUGIN` and is required for plugin use. For new MySQL installations, this table is created during the installation process.

The client plugin implementation is simpler:

- For the `mysql_options()` C API function, the `MYSQL_DEFAULT_AUTH` and `MYSQL_PLUGIN_DIR` options enable client programs to load authentication plugins.
- There are C API functions that enable management of client plugins.

To examine how MySQL implements plugins, consult the following source files in a MySQL source distribution:

- In the `include/mysql` directory, `plugin.h` exposes the public plugin API. This file should be examined by anyone who wants to write a plugin library. `plugin_xxx.h` files provide additional information that pertains to specific types of plugins. `client_plugin.h` contains information specific to client plugins.
- In the `sql` directory, `sql_plugin.h` and `sql_plugin.cc` comprise the internal plugin implementation. `sql_acl.cc` is where the server uses authentication plugins. These files need not be consulted by plugin developers. They may be of interest for those who want to know more about how the server handles plugins.
- In the `sql-common` directory, `client_plugin.h` implements the C API client plugin functions, and `client.c` implements client authentication support. These files need not be consulted by plugin developers. They may be of interest for those who want to know more about how the server handles plugins.

24.2.4 Writing Plugins

To create a plugin library, you must provide the required descriptor information that indicates what plugins the library file contains, and write the interface functions for each plugin.

Every server plugin must have a general descriptor that provides information to the plugin API, and a type-specific descriptor that provides information about the plugin interface for a given type of plugin. The structure of the general descriptor is the same for all plugin types. The structure of the type-specific descriptor varies among plugin types and is determined by the requirements of what the plugin needs to do. The server plugin interface also enables plugins to expose status and system variables. These variables become visible through the `SHOW STATUS` and `SHOW VARIABLES` statements and the corresponding `INFORMATION_SCHEMA` tables.

For client-side plugins, the architecture is a bit different. Each plugin must have a descriptor, but there is no division into separate general and type-specific descriptors. Instead, the descriptor begins with a fixed set of members common to all client plugin types, and the common members are followed by any additional members required to implement the specific plugin type.

You can write plugins in C or C++ (or another language that can use C calling conventions). Plugins are loaded and unloaded dynamically, so your operating system must support dynamic loading and you must have compiled the calling application dynamically (not statically). For server plugins, this means that `mysqld` must be linked dynamically.

A server plugin contains code that becomes part of the running server, so when you write the plugin, you are bound by any and all constraints that otherwise apply to writing server code. For example, you may have problems if you attempt to use functions from the `libstdc++` library. These constraints may change in future versions of the server, so it is possible that server upgrades will require revisions to plugins originally written for older servers. For information about these constraints, see Section 2.9.4, “MySQL Source-Configuration Options”, and Section 2.9.5, “Dealing with Problems Compiling MySQL”.

Client plugin writers should avoid dependencies on what symbols the calling application has because you cannot be sure what applications will use the plugin.

24.2.4.1 Overview of Plugin Writing

The following procedure provides an overview of the steps needed to create a plugin library. The next sections provide additional details on setting plugin data structures and writing specific types of plugins.

1. In the plugin source file, include the header files that the plugin library needs. The `plugin.h` file is required, and the library might require other files as well. For example:

   ```
   #include <stdlib.h>
   #include <ctype.h>
   #include <mysql/plugin.h>
   ```

2. Set up the descriptor information for the plugin library file. For server plugins, write the library descriptor, which must contain the general plugin descriptor for each server plugin in the file. For more information, see Server Plugin Library and Plugin Descriptors. In addition, set up the type-specific descriptor for each server plugin in the library. Each plugin's general descriptor points to its type-specific descriptor.

   For client plugins, write the client descriptor. For more information, see Client Plugin Descriptors.

3. Write the plugin interface functions for each plugin. For example, each plugin's general plugin descriptor points to the initialization and deinitialization functions that the server should invoke when it loads and unloads the plugin. The plugin's type-specific description may also point to interface functions.

4. For server plugins, set up the status and system variables, if there are any.

5. Compile the plugin library as a shared library and install it in the plugin directory. For more information, see Section 24.2.4.3, “Compiling and Installing Plugin Libraries”.

6. For server plugins, register the plugin with the server. For more information, see Section 5.5.1, “Installing and Uninstalling Plugins”.

7. Test the plugin to verify that it works properly.

24.2.4.2 Plugin Data Structures

A plugin library file includes descriptor information to indicate what plugins it contains.

If the plugin library contains any server plugins, it must include the following descriptor information:

- A library descriptor indicates the general server plugin API version number used by the library and contains a general plugin descriptor for each server plugin in the library. To provide the framework for this descriptor, invoke two macros from the `plugin.h` header file:

  ```
  mysql_declare_plugin(name)
   ... one or more server plugin descriptors here ...
  mysql_declare_plugin_end;
  ```

  The macros expand to provide a declaration for the API version automatically. You must provide the plugin descriptors.

- Within the library descriptor, each general server plugin is described by a `st_mysql_plugin` structure. This plugin descriptor structure contains information that is common to every type of server plugin: A value that indicates the plugin type; the plugin name, author, description, and license type; pointers to the initialization and deinitialization functions that the server invokes when it loads and unloads the plugin, and pointers to any status or system variables the plugin implements.

- Each general server plugin descriptor within the library descriptor also contains a pointer to a type-specific plugin descriptor. The structure of the type-specific descriptors varies from one plugin type to another because each type of plugin can have its own API. A type-specific plugin descriptor contains

a type-specific API version number and pointers to the functions that are needed to implement that plugin type. For example, a full-text parser plugin has initialization and deinitialization functions, and a main parsing function. The server invokes these functions when it uses the plugin to parse text.

The plugin library also contains the interface functions that are referenced by the general and type-specific descriptors for each plugin in the library.

If the plugin library contains a client plugin, it must include a descriptor for the plugin. The descriptor begins with a fixed set of members common to all client plugins, followed by any members specific to the plugin type. To provide the descriptor framework, invoke two macros from the `client_plugin.h` header file:

```
mysql_declare_client_plugin(plugin_type)
   ... members common to all client plugins ...
   ... type-specific extra members ...
mysql_end_client_plugin;
```

The plugin library also contains any interface functions referenced by the client descriptor.

The `mysql_declare_plugin()` and `mysql_declare_client_plugin()` macros differ somewhat in how they can be invoked, which has implications for the contents of plugin libraries. The following guidelines summarize the rules:

- `mysql_declare_plugin()` and `mysql_declare_client_plugin()` can both be used in the same source file, which means that a plugin library can contain both server and client plugins. However, each of `mysql_declare_plugin()` and `mysql_declare_client_plugin()` can be used at most once.
- `mysql_declare_plugin()` permits multiple server plugin declarations, so a plugin library can contain multiple server plugins.
- `mysql_declare_client_plugin()` permits only a single client plugin declaration. To create multiple client plugins, separate plugin libraries must be used.

When a client program looks for a client plugin that is in a plugin library and not built into `libmysqlclient`, it looks for a file with a base name that is the same as the plugin name. For example, if a program needs to use a client authentication plugin named `auth_xxx` on a system that uses `.so` as the library suffix, it looks in the file named `auth_xxx.so`. (On OS X, the program looks first for `auth_xxx.dylib`, then for `auth_xxx.so`.) For this reason, if a plugin library contains a client plugin, the library must have the same base name as that plugin.

The same is not true for a library that contains server plugins. The `--plugin-load` option and the `INSTALL PLUGIN` statement provide the library file name explicitly, so there need be no explicit relationship between the library name and the name of any server plugins it contains.

Server Plugin Library and Plugin Descriptors

Every plugin library that contains server plugins must include a library descriptor that contains the general plugin descriptor for each server plugin in the file. This section discusses how to write the library and general descriptors for server plugins.

The library descriptor must define two symbols:

- `_mysql_plugin_interface_version_` specifies the version number of the general plugin framework. This is given by the `MYSQL_PLUGIN_INTERFACE_VERSION` symbol, which is defined in the `plugin.h` file.
- `_mysql_plugin_declarations_` defines an array of plugin declarations, terminated by a declaration with all members set to 0. Each declaration is an instance of the `st_mysql_plugin` structure (also defined in `plugin.h`). There must be one of these for each server plugin in the library.

If the server does not find those two symbols in a library, it does not accept it as a legal plugin library and rejects it with an error. This prevents use of a library for plugin purposes unless it was built specifically as a plugin library.

The conventional way to define the two required symbols is by using the `mysql_declare_plugin()` and `mysql_declare_plugin_end` macros from the `plugin.h` file:

```
mysql_declare_plugin(name)
 ... one or more server plugin descriptors here ...
mysql_declare_plugin_end;
```

Each server plugin must have a general descriptor that provides information to the server plugin API. The general descriptor has the same structure for all plugin types. The `st_mysql_plugin` structure in the `plugin.h` file defines this descriptor:

```
struct st_mysql_plugin
{
  int type;             /* the plugin type (a MYSQL_XXX_PLUGIN value)   */
  void *info;           /* pointer to type-specific plugin descriptor   */
  const char *name;     /* plugin name                                  */
  const char *author;   /* plugin author (for I_S.PLUGINS)              */
  const char *descr;    /* general descriptive text (for I_S.PLUGINS)   */
  int license;          /* the plugin license (PLUGIN_LICENSE_XXX)      */
  int (*init)(void *);  /* the function to invoke when plugin is loaded */
  int (*deinit)(void *);/* the function to invoke when plugin is unloaded */
  unsigned int version; /* plugin version (for I_S.PLUGINS)             */
  struct st_mysql_show_var *status_vars;
  struct st_mysql_sys_var **system_vars;
  void * __reserved1;   /* reserved for dependency checking             */
  unsigned long flags;  /* flags for plugin */
};
```

The `st_mysql_plugin` descriptor structure members are used as follows. `char *` members should be specified as null-terminated strings.

- `type`: The plugin type. This must be one of the plugin-type values from `plugin.h`:

  ```
  /*
    The allowable types of plugins
  */
  #define MYSQL_UDF_PLUGIN              0  /* User-defined function        */
  #define MYSQL_STORAGE_ENGINE_PLUGIN   1  /* Storage Engine               */
  #define MYSQL_FTPARSER_PLUGIN         2  /* Full-text parser plugin      */
  #define MYSQL_DAEMON_PLUGIN           3  /* The daemon/raw plugin type */
  #define MYSQL_INFORMATION_SCHEMA_PLUGIN  4  /* The I_S plugin type */
  #define MYSQL_AUDIT_PLUGIN            5  /* The Audit plugin type        */
  #define MYSQL_REPLICATION_PLUGIN      6  /* The replication plugin type */
  #define MYSQL_AUTHENTICATION_PLUGIN   7  /* The authentication plugin type */
  ...
  ```

  For example, for a full-text parser plugin, the `type` value is `MYSQL_FTPARSER_PLUGIN`.

- `info`: A pointer to the type-specific descriptor for the plugin. This descriptor's structure depends on the particular type of plugin, unlike that of the general plugin descriptor structure. For version-control purposes, the first member of the type-specific descriptor for every plugin type is expected to be the interface version for the type. This enables the server to check the type-specific version for every plugin no matter its type. Following the version number, the descriptor includes any other members needed, such as callback functions and other information needed by the server to invoke the plugin properly. Later sections on writing particular types of server plugins describe the structure of their type-specific descriptors.

- `name`: A string that gives the plugin name. This is the name that will be listed in the `mysql.plugin` table and by which you refer to the plugin in SQL statements such as `INSTALL PLUGIN` and

`UNINSTALL PLUGIN`, or with the `--plugin-load` option. The name is also visible in the `INFORMATION_SCHEMA.PLUGINS` table or the output from `SHOW PLUGINS`.

The plugin name should not begin with the name of any server option. If it does, the server will fail to initialize it. For example, the server has a `--socket` option, so you should not use a plugin name such as `socket`, `socket_plugin`, and so forth.

- `author`: A string naming the plugin author. This can be whatever you like.
- `desc`: A string that provides a general description of the plugin. This can be whatever you like.
- `license`: The plugin license type. The value can be one of `PLUGIN_LICENSE_PROPRIETARY`, `PLUGIN_LICENSE_GPL`, or `PLUGIN_LICENSE_BSD`.
- `init`: A once-only initialization function, or `NULL` if there is no such function. The server executes this function when it loads the plugin, which happens for `INSTALL PLUGIN` or, for plugins listed in the `mysql.plugin` table, at server startup. The function takes one argument that points to the internal structure used to identify the plugin. It returns zero for success and nonzero for failure.
- `deinit`: A once-only deinitialization function, or `NULL` if there is no such function. The server executes this function when it unloads the plugin, which happens for `UNINSTALL PLUGIN` or, for plugins listed in the `mysql.plugin` table, at server shutdown. The function takes one argument that points to the internal structure used to identify the plugin It returns zero for success and nonzero for failure.
- `version`: The plugin version number. When the plugin is installed, this value can be retrieved from the `INFORMATION_SCHEMA.PLUGINS` table. The value includes major and minor numbers. If you write the value as a hex constant, the format is `0x`*`MMNN`*, where *`MM`* and `NN` are the major and minor numbers, respectively. For example, `0x0302` represents version 3.2.
- `status_vars`: A pointer to a structure for status variables associated with the plugin, or `NULL` if there are no such variables. When the plugin is installed, these variables are displayed in the output of the `SHOW STATUS` statement.

  The `status_vars` member, if not `NULL`, points to an array of `st_mysql_show_var` structures that describe status variables. See Server Plugin Status and System Variables.
- `system_vars`: A pointer to a structure for system variables associated with the plugin, or `NULL` if there are no such variables. These options and system variables can be used to help initialize variables within the plugin.

  The `system_vars` member, if not `NULL`, points to an array of `st_mysql_sys_var` structures that describe system variables. See Server Plugin Status and System Variables.
- `__reserved1`: A placeholder for the future. It should be set to `NULL`.
- `flags`: Plugin flags. Individual bits correspond to different flags. The value should be set to the OR of the applicable flags. These flags are available:

```
#define PLUGIN_OPT_NO_INSTALL   1UL   /* Not dynamically loadable */
#define PLUGIN_OPT_NO_UNINSTALL 2UL   /* Not dynamically unloadable */
```

  `PLUGIN_OPT_NO_INSTALL` indicates that the plugin cannot be loaded at runtime with the `INSTALL PLUGIN` statement. This is appropriate for plugins that must be loaded at server startup with the `--plugin-load` option. `PLUGIN_OPT_NO_UNINSTALL` indicates that the plugin cannot be unloaded at runtime with the `UNINSTALL PLUGIN` statement.

  This member was added in MySQL 5.5.16.

The server invokes the `init` and `deinit` functions in the general plugin descriptor only when loading and unloading the plugin. They have nothing to do with use of the plugin such as happens when an SQL statement causes the plugin to be invoked.

For example, the descriptor information for a library that contains a single full-text parser plugin named `simple_parser` looks like this:

```
mysql_declare_plugin(ftexample)
{
  MYSQL_FTPARSER_PLUGIN,      /* type                            */
  &simple_parser_descriptor,  /* descriptor                      */
  "simple_parser",            /* name                            */
  "Oracle Corporation",       /* author                          */
  "Simple Full-Text Parser",  /* description                     */
  PLUGIN_LICENSE_GPL,         /* plugin license                  */
  simple_parser_plugin_init,  /* init function (when loaded)     */
  simple_parser_plugin_deinit,/* deinit function (when unloaded) */
  0x0001,                     /* version                         */
  simple_status,              /* status variables                */
  simple_system_variables,    /* system variables                */
  NULL,
  0
}
mysql_declare_plugin_end;
```

For a full-text parser plugin, the type must be `MYSQL_FTPARSER_PLUGIN`. This is the value that identifies the plugin as being legal for use in a `WITH PARSER` clause when creating a `FULLTEXT` index. (No other plugin type is legal for this clause.)

`plugin.h` defines the `mysql_declare_plugin()` and `mysql_declare_plugin_end` macros like this:

```
#ifndef MYSQL_DYNAMIC_PLUGIN
#define __MYSQL_DECLARE_PLUGIN(NAME, VERSION, PSIZE, DECLS) \
MYSQL_PLUGIN_EXPORT int VERSION= MYSQL_PLUGIN_INTERFACE_VERSION; \
MYSQL_PLUGIN_EXPORT int PSIZE= sizeof(struct st_mysql_plugin); \
MYSQL_PLUGIN_EXPORT struct st_mysql_plugin DECLS[]= {
#else
#define __MYSQL_DECLARE_PLUGIN(NAME, VERSION, PSIZE, DECLS) \
MYSQL_PLUGIN_EXPORT int _mysql_plugin_interface_version_= MYSQL_PLUGIN_INTERFACE_VERSION; \
MYSQL_PLUGIN_EXPORT int _mysql_sizeof_struct_st_plugin_= sizeof(struct st_mysql_plugin); \
MYSQL_PLUGIN_EXPORT struct st_mysql_plugin _mysql_plugin_declarations_[]= {
#endif

#define mysql_declare_plugin(NAME) \
__MYSQL_DECLARE_PLUGIN(NAME, \
                 builtin_ ## NAME ## _plugin_interface_version, \
                 builtin_ ## NAME ## _sizeof_struct_st_plugin, \
                 builtin_ ## NAME ## _plugin)

#define mysql_declare_plugin_end ,{0,0,0,0,0,0,0,0,0,0,0,0,0,0}}
```

Note

Those declarations define the `_mysql_plugin_interface_version_` symbol only if the `MYSQL_DYNAMIC_PLUGIN` symbol is defined. This means that `-DMYSQL_DYNAMIC_PLUGIN` must be provided as part of the compilation command to build the plugin as a shared library.

When the macros are used as just shown, they expand to the following code, which defines both of the required symbols (`_mysql_plugin_interface_version_` and `_mysql_plugin_declarations_`):

```
int _mysql_plugin_interface_version_= MYSQL_PLUGIN_INTERFACE_VERSION;
int _mysql_sizeof_struct_st_plugin_= sizeof(struct st_mysql_plugin);
struct st_mysql_plugin _mysql_plugin_declarations_[]= {
{
  MYSQL_FTPARSER_PLUGIN,      /* type                            */
  &simple_parser_descriptor,  /* descriptor                      */
```

```
  "simple_parser",            /* name                             */
  "Oracle Corporation",       /* author                           */
  "Simple Full-Text Parser",  /* description                      */
  PLUGIN_LICENSE_GPL,         /* plugin license                   */
  simple_parser_plugin_init,  /* init function (when loaded)      */
  simple_parser_plugin_deinit,/* deinit function (when unloaded) */
  0x0001,                     /* version                          */
  simple_status,              /* status variables                 */
  simple_system_variables,    /* system variables                 */
  NULL,
  0
}
  ,{0,0,0,0,0,0,0,0,0,0,0,0}}
};
```

The preceding example declares a single plugin in the general descriptor, but it is possible to declare multiple plugins. List the declarations one after the other between `mysql_declare_plugin()` and `mysql_declare_plugin_end`, separated by commas.

MySQL server plugins can be written in C or C++ (or another language that can use C calling conventions). If you write a C++ plugin, one C++ feature that you should not use is nonconstant variables to initialize global structures. Members of structures such as the `st_mysql_plugin` structure should be initialized only with constant variables. The `simple_parser` descriptor shown earlier is permissible in a C++ plugin because it satisfies that requirement:

```
mysql_declare_plugin(ftexample)
{
  MYSQL_FTPARSER_PLUGIN,      /* type                             */
  &simple_parser_descriptor,  /* descriptor                       */
  "simple_parser",            /* name                             */
  "Oracle Corporation",       /* author                           */
  "Simple Full-Text Parser",  /* description                      */
  PLUGIN_LICENSE_GPL,         /* plugin license                   */
  simple_parser_plugin_init,  /* init function (when loaded)      */
  simple_parser_plugin_deinit,/* deinit function (when unloaded) */
  0x0001,                     /* version                          */
  simple_status,              /* status variables                 */
  simple_system_variables,    /* system variables                 */
  NULL,
  0
}
mysql_declare_plugin_end;
```

Here is another valid way to write the general descriptor. It uses constant variables to indicate the plugin name, author, and description:

```
const char *simple_parser_name = "simple_parser";
const char *simple_parser_author = "Oracle Corporation";
const char *simple_parser_description = "Simple Full-Text Parser";

mysql_declare_plugin(ftexample)
{
  MYSQL_FTPARSER_PLUGIN,      /* type                             */
  &simple_parser_descriptor,  /* descriptor                       */
  simple_parser_name,         /* name                             */
  simple_parser_author,       /* author                           */
  simple_parser_description,  /* description                      */
  PLUGIN_LICENSE_GPL,         /* plugin license                   */
  simple_parser_plugin_init,  /* init function (when loaded)      */
  simple_parser_plugin_deinit,/* deinit function (when unloaded) */
  0x0001,                     /* version                          */
  simple_status,              /* status variables                 */
  simple_system_variables,    /* system variables                 */
  NULL,
  0
}
mysql_declare_plugin_end;
```

However, the following general descriptor is invalid. It uses structure members to indicate the plugin name, author, and description, but structures are not considered constant initializers in C++:

```
typedef struct
{
  const char *name;
  const char *author;
  const char *description;
} plugin_info;

plugin_info parser_info = {
  "simple_parser",
  "Oracle Corporation",
  "Simple Full-Text Parser"
};

mysql_declare_plugin(ftexample)
{
  MYSQL_FTPARSER_PLUGIN,      /* type                            */
  &simple_parser_descriptor,  /* descriptor                      */
  parser_info.name,           /* name                            */
  parser_info.author,         /* author                          */
  parser_info.description,    /* description                     */
  PLUGIN_LICENSE_GPL,         /* plugin license                  */
  simple_parser_plugin_init,  /* init function (when loaded)     */
  simple_parser_plugin_deinit,/* deinit function (when unloaded) */
  0x0001,                     /* version                         */
  simple_status,              /* status variables                */
  simple_system_variables,    /* system variables                */
  NULL,
  0
}
mysql_declare_plugin_end;
```

Server Plugin Status and System Variables

The server plugin interface enables plugins to expose status and system variables using the `status_vars` and `system_vars` members of the general plugin descriptor.

The `status_vars` member of the general plugin descriptor, if not 0, points to an array of `st_mysql_show_var` structures, each of which describes one status variable, followed by a structure with all members set to 0. The `st_mysql_show_var` structure has this definition:

```
struct st_mysql_show_var {
  const char *name;
  char *value;
  enum enum_mysql_show_type type;
};
```

When the plugin is installed, the plugin name and the `name` value are joined with an underscore to form the name displayed by `SHOW STATUS`.

The following table shows the permissible status variable `type` values and what the corresponding variable should be.

Table 24.1 Server Plugin Status Variable Types

Variable Type	Meaning
`SHOW_BOOL`	Pointer to a boolean variable
`SHOW_INT`	Pointer to an integer variable
`SHOW_LONG`	Pointer to a long integer variable
`SHOW_LONGLONG`	Pointer to a longlong integer variable

Variable Type	Meaning
SHOW_CHAR	A string
SHOW_CHAR_PTR	Pointer to a string
SHOW_ARRAY	Pointer to another st_mysql_show_var array
SHOW_FUNC	Pointer to a function
SHOW_DOUBLE	Pointer to a double

For the SHOW_FUNC type, the function is called and fills in its out parameter, which then provides information about the variable to be displayed. The function has this signature:

```
#define SHOW_VAR_FUNC_BUFF_SIZE 1024

typedef int (*mysql_show_var_func) (void *thd,
                                    struct st_mysql_show_var *out,
                                    char *buf);
```

The system_vars member, if not 0, points to an array of st_mysql_sys_var structures, each of which describes one system variable (which can also be set from the command-line or configuration file), followed by a structure with all members set to 0. The st_mysql_sys_var structure is defined as follows:

```
struct st_mysql_sys_var {
 int flags;
 const char *name, *comment;
 int (*check)(THD*, struct st_mysql_sys_var *, void*, st_mysql_value*);
 void (*update)(THD*, struct st_mysql_sys_var *, void*, const void*);
};
```

Additional fields are append as required depending upon the flags.

For convenience, a number of macros are defined that make creating new system variables within a plugin much simpler.

Throughout the macros, the following fields are available:

- name: An unquoted identifier for the system variable.
- varname: The identifier for the static variable. Where not available, it is the same as the name field.
- opt: Additional use flags for the system variable. The following table shows the permissible flags.

  Table 24.2 Server Plugin System Variable Flags

Flag Value	Description
PLUGIN_VAR_READONLY	The system variable is read only
PLUGIN_VAR_NOSYSVAR	The system variable is not user visible at runtime
PLUGIN_VAR_NOCMDOPT	The system variable is not configurable from the command line
PLUGIN_VAR_NOCMDARG	No argument is required at the command line (typically used for boolean variables)
PLUGIN_VAR_RQCMDARG	An argument is required at the command line (this is the default)
PLUGIN_VAR_OPCMDARG	An argument is optional at the command line
PLUGIN_VAR_MEMALLOC	Used for string variables; indicates that memory is to be allocated for storage of the string

- comment: A descriptive comment to be displayed in the server help message. NULL if this variable is to be hidden.

- `check`: The check function, `NULL` for default.
- `update`: The update function, `NULL` for default.
- `default`: The variable default value.
- `minimum`: The variable minimum value.
- `maximum`: The variable maximum value.
- `blocksize`: The variable block size. When the value is set, it is rounded to the nearest multiple of `blocksize`.

A system variable may be accessed either by using the static variable directly or by using the `SYSVAR()`accessor macro. The `SYSVAR()` macro is provided for completeness. Usually it should be used only when the code cannot directly access the underlying variable.

For example:

```
static int my_foo;
static MYSQL_SYSVAR_INT(foo_var, my_foo,
                        PLUGIN_VAR_RQCMDARG, "foo comment",
                        NULL, NULL, 0, 0, INT_MAX, 0);
 ...
   SYSVAR(foo_var)= value;
   value= SYSVAR(foo_var);
   my_foo= value;
   value= my_foo;
```

Session variables may be accessed only through the `THDVAR()` accessor macro. For example:

```
static MYSQL_THDVAR_BOOL(some_flag,
                         PLUGIN_VAR_NOCMDARG, "flag comment",
                         NULL, NULL, FALSE);
 ...
   if (THDVAR(thd, some_flag))
   {
     do_something();
     THDVAR(thd, some_flag)= FALSE;
   }
```

All global and session system variables must be published to `mysqld` before use. This is done by constructing a `NULL`-terminated array of the variables and linking to it in the plugin public interface. For example:

```
static struct st_mysql_sys_var *my_plugin_vars[]= {
  MYSQL_SYSVAR(foo_var),
  MYSQL_SYSVAR(some_flag),
  NULL
};
mysql_declare_plugin(fooplug)
{
  MYSQL_..._PLUGIN,
  &plugin_data,
  "fooplug",
  "foo author",
  "This does foo!",
  PLUGIN_LICENSE_GPL,
  foo_init,
  foo_fini,
  0x0001,
  NULL,
  my_plugin_vars,
  NULL,
  0
}
```

```
mysql_declare_plugin_end;
```

The following convenience macros enable you to declare different types of system variables:

- Boolean system variables of type `my_bool`, which is a 1-byte boolean. (0 = FALSE, 1 = TRUE)

```
MYSQL_THDVAR_BOOL(name, opt, comment, check, update, default)
MYSQL_SYSVAR_BOOL(name, varname, opt, comment, check, update, default)
```

- String system variables of type `char*`, which is a pointer to a null-terminated string.

```
MYSQL_THDVAR_STR(name, opt, comment, check, update, default)
MYSQL_SYSVAR_STR(name, varname, opt, comment, check, update, default)
```

- Integer system variables, of which there are several varieties.
  - An `int` system variable, which is typically a 4-byte signed word.

```
MYSQL_THDVAR_INT(name, opt, comment, check, update, default, min, max, blk)
MYSQL_SYSVAR_INT(name, varname, opt, comment, check, update, default,
                 minimum, maximum, blocksize)
```

  - An `unsigned int` system variable, which is typically a 4-byte unsigned word.

```
MYSQL_THDVAR_UINT(name, opt, comment, check, update, default, min, max, blk)
MYSQL_SYSVAR_UINT(name, varname, opt, comment, check, update, default,
                  minimum, maximum, blocksize)
```

  - A `long` system variable, which is typically either a 4- or 8-byte signed word.

```
MYSQL_THDVAR_LONG(name, opt, comment, check, update, default, min, max, blk)
MYSQL_SYSVAR_LONG(name, varname, opt, comment, check, update, default,
                  minimum, maximum, blocksize)
```

  - An `unsigned long` system variable, which is typically either a 4- or 8-byte unsigned word.

```
MYSQL_THDVAR_ULONG(name, opt, comment, check, update, default, min, max, blk)
MYSQL_SYSVAR_ULONG(name, varname, opt, comment, check, update, default,
                   minimum, maximum, blocksize)
```

  - A `long long` system variable, which is typically an 8-byte signed word.

```
MYSQL_THDVAR_LONGLONG(name, opt, comment, check, update,
                      default, minimum, maximum, blocksize)
MYSQL_SYSVAR_LONGLONG(name, varname, opt, comment, check, update,
                      default, minimum, maximum, blocksize)
```

  - An `unsigned long long` system variable, which is typically an 8-byte unsigned word.

```
MYSQL_THDVAR_ULONGLONG(name, opt, comment, check, update,
                       default, minimum, maximum, blocksize)
MYSQL_SYSVAR_ULONGLONG(name, varname, opt, comment, check, update,
                       default, minimum, maximum, blocksize)
```

  - An `unsigned long` system variable, which is typically either a 4- or 8-byte unsigned word. The range of possible values is an ordinal of the number of elements in the `typelib`, starting from 0.

```
MYSQL_THDVAR_ENUM(name, opt, comment, check, update, default, typelib)
MYSQL_SYSVAR_ENUM(name, varname, opt, comment, check, update,
                  default, typelib)
```

- An `unsigned long long` system variable, which is typically an 8-byte unsigned word. Each bit represents an element in the `typelib`.

```
MYSQL_THDVAR_SET(name, opt, comment, check, update, default, typelib)
MYSQL_SYSVAR_SET(name, varname, opt, comment, check, update,
                 default, typelib)
```

Internally, all mutable and plugin system variables are stored in a `HASH` structure.

Display of the server command-line help text is handled by compiling a `DYNAMIC_ARRAY` of all variables relevant to command-line options, sorting them, and then iterating through them to display each option.

When a command-line option has been handled, it is then removed from the `argv` by the `handle_option()` function (`my_getopt.c`); in effect, it is consumed.

The server processes command-line options during the plugin installation process, immediately after the plugin has been successfully loaded but before the plugin initialization function has been called

Plugins loaded at runtime do not benefit from any configuration options and must have usable defaults. Once they are installed, they are loaded at `mysqld` initialization time and configuration options can be set at the command line or within `my.cnf`.

Plugins should consider the `thd` parameter to be read only.

Client Plugin Descriptors

Each client plugin must have a descriptor that provides information to the client plugin API. The descriptor structure begins with a fixed set of members common to all client plugins, followed by any members specific to the plugin type.

The `st_mysql_client_plugin` structure in the `client_plugin.h` file defines a “generic” descriptor that contains the common members:

```
struct st_mysql_client_plugin
{
  int type;
  unsigned int interface_version;
  const char *name;
  const char *author;
  const char *desc;
  unsigned int version[3];
  const char *license;
  void *mysql_api;
  int (*init)(char *, size_t, int, va_list);
  int (*deinit)();
  int (*options)(const char *option, const void *);
};
```

The common `st_mysql_client_plugin` descriptor structure members are used as follows. `char *` members should be specified as null-terminated strings.

- `type`: The plugin type. This must be one of the plugin-type values from `client_plugin.h`, such as `MYSQL_CLIENT_AUTHENTICATION_PLUGIN`.
- `interface_version`: The plugin interface version. For example, this is `MYSQL_CLIENT_AUTHENTICATION_PLUGIN_INTERFACE_VERSION` for an authentication plugin.
- `name`: A string that gives the plugin name. This is the name by which you refer to the plugin when you call `mysql_options()` with the `MYSQL_DEFAULT_AUTH` option or specify the `--default-auth` option to a MySQL client program.

- `author`: A string naming the plugin author. This can be whatever you like.
- `desc`: A string that provides a general description of the plugin. This can be whatever you like.
- `version`: The plugin version as an array of three integers indicating the major, minor, and teeny versions. For example, `{1,2,3}` indicates version 1.2.3.
- `license`: A string that specifies the license type.
- `mysql_api`: For internal use. Specify it as `NULL` in the plugin descriptor.
- `init`: A once-only initialization function, or `NULL` if there is no such function. The client library executes this function when it loads the plugin. The function returns zero for success and nonzero for failure.

  The `init` function uses its first two arguments to return an error message if an error occurs. The first argument is a pointer to a `char` buffer, and the second argument indicates the buffer length. Any message returned by the `init` function must be null-terminated, so the maximum message length is the buffer length minus one. The next arguments are passed to `mysql_load_plugin()`. The first indicates how many more arguments there are (0 if none), followed by any remaining arguments.
- `deinit`: A once-only deinitialization function, or `NULL` if there is no such function. The client library executes this function when it unloads the plugin. The function takes no arguments. It returns zero for success and nonzero for failure.
- `options`: A function for handling options passed to the plugin, or `NULL` if there is no such function. The function takes two arguments representing the option name and a pointer to its value. The function returns zero for success and nonzero for failure.

For a given client plugin type, the common descriptor members may be followed by additional members necessary to implement plugins of that type. For example, the `st_mysql_client_plugin_AUTHENTICATION` structure for authentication plugins has a function at the end that the client library calls to perform authentication.

To declare a plugin, use the `mysql_declare_client_plugin()` and `mysql_end_client_plugin` macros:

```
mysql_declare_client_plugin(plugin_type)
   ... members common to all client plugins ...
   ... type-specific extra members ...
mysql_end_client_plugin;
```

Do not specify the `type` or `interface_version` member explicitly. The `mysql_declare_client_plugin()` macro uses the *`plugin_type`* argument to generate their values automatically. For example, declare an authentication client plugin like this:

```
mysql_declare_client_plugin(AUTHENTICATION)
  "my_auth_plugin",
  "Author Name",
  "My Client Authentication Plugin",
  {1,0,0},
  "GPL",
  NULL,
  my_auth_init,
  my_auth_deinit,
  my_auth_options,
  my_auth_main
mysql_end_client_plugin;
```

This declaration uses the `AUTHENTICATION` argument to set the `type` and `interface_version` members to `MYSQL_CLIENT_AUTHENTICATION_PLUGIN` and `MYSQL_CLIENT_AUTHENTICATION_PLUGIN_INTERFACE_VERSION`.

Depending on the plugin type, the descriptor may have other members following the common members. For example, for an authentication plugin, there is a function (`my_auth_main()` in the descriptor just shown) that handles communication with the server. See Section 24.2.4.9, “Writing Authentication Plugins”.

Normally, a client program that supports the use of authentication plugins causes a plugin to be loaded by calling `mysql_options()` to set the `MYSQL_DEFAULT_AUTH` and `MYSQL_PLUGIN_DIR` options:

```
char *plugin_dir = "path_to_plugin_dir";
char *default_auth = "plugin_name";

/* ... process command-line options ... */

mysql_options(&mysql, MYSQL_PLUGIN_DIR, plugin_dir);
mysql_options(&mysql, MYSQL_DEFAULT_AUTH, default_auth);
```

Typically, the program will also accept `--plugin-dir` and `--default-auth` options that enable users to override the default values.

Should a client program require lower-level plugin management, the client library contains functions that take an `st_mysql_client_plugin` argument. See Section 23.8.14, “C API Client Plugin Functions”.

24.2.4.3 Compiling and Installing Plugin Libraries

After your plugin is written, you must compile it and install it. The procedure for compiling shared objects varies from system to system. If you build your library using `CMake`, it should be able to generate the correct compilation commands for your system. If the library is named `somepluglib`, you should end up with a shared library file that has a name something like `somepluglib.so`. (The `.so` file name suffix might differ on your system.)

To use `CMake`, you'll need to set up the configuration files to enable the plugin to be compiled and installed. Use the plugin examples under the `plugin` directory of a MySQL source distribution as a guide.

Create `CMakeLists.txt`, which should look something like this:

```
MYSQL_ADD_PLUGIN(somepluglib somepluglib.c
  MODULE_ONLY MODULE_OUTPUT_NAME "somepluglib")
```

When `CMake` generates the `Makefile`, it should take care of passing to the compilation command the `-DMYSQL_DYNAMIC_PLUGIN` flag, and passing to the linker the `-lmysqlservices` flag, which is needed to link in any functions from services provided through the plugin services interface. See Section 24.3, “MySQL Services for Plugins”.

Run `CMake`, then run `make`:

```
shell> cmake .
shell> make
```

If you need to specify configuration options to `CMake`, see Section 2.9.4, “MySQL Source-Configuration Options”, for a list. For example, you might want to specify `CMAKE_INSTALL_PREFIX` to indicate the MySQL base directory under which the plugin should be installed. You can see what value to use for this option with `SHOW VARIABLES`:

```
mysql> SHOW VARIABLES LIKE 'basedir';
+---------------+------------------+
| Variable_name | Value            |
+---------------+------------------+
| base          | /usr/local/mysql |
```

```
+--------------+-----------------+
```

The location of the plugin directory where you should install the library is given by the `plugin_dir` system variable. For example:

```
mysql> SHOW VARIABLES LIKE 'plugin_dir';
+---------------+---------------------------------+
| Variable_name | Value                           |
+---------------+---------------------------------+
| plugin_dir    | /usr/local/mysql/lib/mysql/plugin |
+---------------+---------------------------------+
```

To install the plugin library, use `make`:

```
shell> make install
```

Verify that `make install` installed the plugin library in the proper directory. After installing it, make sure that the library permissions permit it to be executed by the server.

24.2.4.4 Writing Full-Text Parser Plugins

MySQL supports server-side full-text parser plugins only with `MyISAM`. For introductory information about full-text parser plugins, see Full-Text Parser Plugins.

A full-text parser plugin can be used to replace or modify the built-in full-text parser. This section describes how to write a full-text parser plugin named `simple_parser`. This plugin performs parsing based on simpler rules than those used by the MySQL built-in full-text parser: Words are nonempty runs of whitespace characters.

The instructions use the source code in the `plugin/fulltext` directory of MySQL source distributions, so change location into that directory. The following procedure describes how the plugin library is created:

1. To write a full-text parser plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

   ```
   #include <mysql/plugin.h>
   ```

   `plugin.h` defines the `MYSQL_FTPARSER_PLUGIN` server plugin type and the data structures needed to declare the plugin.

2. Set up the library descriptor for the plugin library file.

   This descriptor contains the general plugin descriptor for the server plugin. For a full-text parser plugin, the type must be `MYSQL_FTPARSER_PLUGIN`. This is the value that identifies the plugin as being legal for use in a `WITH PARSER` clause when creating a `FULLTEXT` index. (No other plugin type is legal for this clause.)

   For example, the library descriptor for a library that contains a single full-text parser plugin named `simple_parser` looks like this:

   ```
   mysql_declare_plugin(ftexample)
   {
     MYSQL_FTPARSER_PLUGIN,      /* type                            */
     &simple_parser_descriptor,  /* descriptor                      */
     "simple_parser",            /* name                            */
     "Oracle Corporation",       /* author                          */
     "Simple Full-Text Parser",  /* description                     */
     PLUGIN_LICENSE_GPL,         /* plugin license                  */
     simple_parser_plugin_init,  /* init function (when loaded)     */
     simple_parser_plugin_deinit,/* deinit function (when unloaded) */
   ```

```
  0x0001,                     /* version                         */
  simple_status,              /* status variables                */
  simple_system_variables,    /* system variables                */
  NULL,
  0
}
mysql_declare_plugin_end;
```

The `name` member (`simple_parser`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

For more information, see Server Plugin Library and Plugin Descriptors.

3. Set up the type-specific plugin descriptor.

   Each general plugin descriptor in the library descriptor points to a type-specific descriptor. For a full-text parser plugin, the type-specific descriptor is an instance of the `st_mysql_ftparser` structure in the `plugin.h` file:

```
struct st_mysql_ftparser
{
  int interface_version;
  int (*parse)(MYSQL_FTPARSER_PARAM *param);
  int (*init)(MYSQL_FTPARSER_PARAM *param);
  int (*deinit)(MYSQL_FTPARSER_PARAM *param);
};
```

   As shown by the structure definition, the descriptor has an interface version number and contains pointers to three functions.

   The interface version number is specified using a symbol, which is in the form: `MYSQL_xxx_INTERFACE_VERSION`. For full-text parser plugins, the symbol is `MYSQL_FTPARSER_INTERFACE_VERSION`. In the source code, you will find the actual interface version number for the full-text parser plugin defined in `include/mysql/plugin_ftparser.h`.

   The `init` and `deinit` members should point to a function or be set to 0 if the function is not needed. The `parse` member must point to the function that performs the parsing.

   In the `simple_parser` declaration, that descriptor is indicated by `&simple_parser_descriptor`. The descriptor specifies the version number for the full-text plugin interface (as given by `MYSQL_FTPARSER_INTERFACE_VERSION`), and the plugin's parsing, initialization, and deinitialization functions:

```
static struct st_mysql_ftparser simple_parser_descriptor=
{
  MYSQL_FTPARSER_INTERFACE_VERSION, /* interface version      */
  simple_parser_parse,              /* parsing function       */
  simple_parser_init,               /* parser init function   */
  simple_parser_deinit              /* parser deinit function */
};
```

   A full-text parser plugin is used in two different contexts, indexing and searching. In both contexts, the server calls the initialization and deinitialization functions at the beginning and end of processing each SQL statement that causes the plugin to be invoked. However, during statement processing, the server calls the main parsing function in context-specific fashion:

   - For indexing, the server calls the parser for each column value to be indexed.
   - For searching, the server calls the parser to parse the search string. The parser might also be called for rows processed by the statement. In natural language mode, there is no need for the server to call the parser. For boolean mode phrase searches or natural language searches with query expansion, the parser is used to parse column values for information that is not in the

index. Also, if a boolean mode search is done for a column that has no FULLTEXT index, the built-in parser will be called. (Plugins are associated with specific indexes. If there is no index, no plugin is used.)

The plugin declaration in the general plugin descriptor has init and deinit members that point initialization and deinitialization functions, and so does the type-specific plugin descriptor to which it points. However, these pairs of functions have different purposes and are invoked for different reasons:

- For the plugin declaration in the general plugin descriptor, the initialization and deinitialization functions are invoked when the plugin is loaded and unloaded.
- For the type-specific plugin descriptor, the initialization and deinitialization functions are invoked per SQL statement for which the plugin is used.

Each interface function named in the plugin descriptor should return zero for success or nonzero for failure, and each of them receives an argument that points to a MYSQL_FTPARSER_PARAM structure containing the parsing context. The structure has this definition:

```
typedef struct st_mysql_ftparser_param
{
  int (*mysql_parse)(struct st_mysql_ftparser_param *,
                     char *doc, int doc_len);
  int (*mysql_add_word)(struct st_mysql_ftparser_param *,
                        char *word, int word_len,
                        MYSQL_FTPARSER_BOOLEAN_INFO *boolean_info);
  void *ftparser_state;
  void *mysql_ftparam;
  struct charset_info_st *cs;
  char *doc;
  int length;
  int flags;
  enum enum_ftparser_mode mode;
} MYSQL_FTPARSER_PARAM;
```

The structure members are used as follows:

- mysql_parse: A pointer to a callback function that invokes the server's built-in parser. Use this callback when the plugin acts as a front end to the built-in parser. That is, when the plugin parsing function is called, it should process the input to extract the text and pass the text to the mysql_parse callback.

  The first parameter for this callback function should be the param value itself:

  ```
  param->mysql_parse(param, ...);
  ```

  A front end plugin can extract text and pass it all at once to the built-in parser, or it can extract and pass text to the built-in parser a piece at a time. However, in this case, the built-in parser treats the pieces of text as though there are implicit word breaks between them.

- mysql_add_word: A pointer to a callback function that adds a word to a full-text index or to the list of search terms. Use this callback when the parser plugin replaces the built-in parser. That is, when the plugin parsing function is called, it should parse the input into words and invoke the mysql_add_word callback for each word.

  The first parameter for this callback function should be the param value itself:

  ```
  param->mysql_add_word(param, ...);
  ```

- ftparser_state: This is a generic pointer. The plugin can set it to point to information to be used internally for its own purposes.

- `mysql_ftparam`: This is set by the server. It is passed as the first argument to the `mysql_parse` or `mysql_add_word` callback.
- `cs`: A pointer to information about the character set of the text, or 0 if no information is available.
- `doc`: A pointer to the text to be parsed.
- `length`: The length of the text to be parsed, in bytes.
- `flags`: Parser flags. This is zero if there are no special flags. The only nonzero flag is `MYSQL_FTFLAGS_NEED_COPY`, which means that `mysql_add_word()` must save a copy of the word (that is, it cannot use a pointer to the word because the word is in a buffer that will be overwritten.) This member was added in MySQL 5.1.12.

  This flag might be set or reset by MySQL before calling the parser plugin, by the parser plugin itself, or by the `mysql_parse()` function.
- `mode`: The parsing mode. This value will be one of the following constants:
  - `MYSQL_FTPARSER_SIMPLE_MODE`: Parse in fast and simple mode, which is used for indexing and for natural language queries. The parser should pass to the server only those words that should be indexed. If the parser uses length limits or a stopword list to determine which words to ignore, it should not pass such words to the server.
  - `MYSQL_FTPARSER_WITH_STOPWORDS`: Parse in stopword mode. This is used in boolean searches for phrase matching. The parser should pass all words to the server, even stopwords or words that are outside any normal length limits.
  - `MYSQL_FTPARSER_FULL_BOOLEAN_INFO`: Parse in boolean mode. This is used for parsing boolean query strings. The parser should recognize not only words but also boolean-mode operators and pass them to the server as tokens using the `mysql_add_word` callback. To tell the server what kind of token is being passed, the plugin needs to fill in a `MYSQL_FTPARSER_BOOLEAN_INFO` structure and pass a pointer to it.

If the parser is called in boolean mode, the `param->mode` value will be `MYSQL_FTPARSER_FULL_BOOLEAN_INFO`. The `MYSQL_FTPARSER_BOOLEAN_INFO` structure that the parser uses for passing token information to the server looks like this:

```
typedef struct st_mysql_ftparser_boolean_info
{
  enum enum_ft_token_type type;
  int yesno;
  int weight_adjust;
  char wasign;
  char trunc;
  /* These are parser state and must be removed. */
  char prev;
  char *quot;
} MYSQL_FTPARSER_BOOLEAN_INFO;
```

The parser should fill in the structure members as follows:

- `type`: The token type. The following table shows the permissible types.

Table 24.3 Full-Text Parser Token Types

Token Value	Meaning
`FT_TOKEN_EOF`	End of data
`FT_TOKEN_WORD`	A regular word
`FT_TOKEN_LEFT_PAREN`	The beginning of a group or subexpression

Token Value	Meaning
FT_TOKEN_RIGHT_PAREN	The end of a group or subexpression
FT_TOKEN_STOPWORD	A stopword

- yesno: Whether the word must be present for a match to occur. 0 means that the word is optional but increases the match relevance if it is present. Values larger than 0 mean that the word must be present. Values smaller than 0 mean that the word must not be present.
- weight_adjust: A weighting factor that determines how much a match for the word counts. It can be used to increase or decrease the word's importance in relevance calculations. A value of zero indicates no weight adjustment. Values greater than or less than zero mean higher or lower weight, respectively. The examples at Section 12.9.2, “Boolean Full-Text Searches”, that use the < and > operators illustrate how weighting works.
- wasign: The sign of the weighting factor. A negative value acts like the ~ boolean-search operator, which causes the word's contribution to the relevance to be negative.
- trunc: Whether matching should be done as if the boolean-mode * truncation operator had been given.

Plugins should not use the prev and quot members of the MYSQL_FTPARSER_BOOLEAN_INFO structure.

Note

The plugin parser framework does not support:

- The @distance boolean operator.
- A leading plus sign (+) or minus sign (-) boolean operator followed by a space and then a word ('+ apple' or '- apple'). The leading plus or minus sign must be directly adjacent to the word, for example: '+apple' or '-apple'.

For information about boolean full-text search operators, see Section 12.9.2, “Boolean Full-Text Searches”.

4. Set up the plugin interface functions.

   The general plugin descriptor in the library descriptor names the initialization and deinitialization functions that the server should invoke when it loads and unloads the plugin. For simple_parser, these functions do nothing but return zero to indicate that they succeeded:

```
static int simple_parser_plugin_init(void *arg __attribute__((unused)))
{
  return(0);
}

static int simple_parser_plugin_deinit(void *arg __attribute__((unused)))
{
  return(0);
}
```

   Because those functions do not actually do anything, you could omit them and specify 0 for each of them in the plugin declaration.

   The type-specific plugin descriptor for simple_parser names the initialization, deinitialization, and parsing functions that the server invokes when the plugin is used. For simple_parser, the initialization and deinitialization functions do nothing:

```
static int simple_parser_init(MYSQL_FTPARSER_PARAM *param
                              __attribute__((unused)))
{
  return(0);
}

static int simple_parser_deinit(MYSQL_FTPARSER_PARAM *param
                                __attribute__((unused)))
{
  return(0);
}
```

Here too, because those functions do nothing, you could omit them and specify 0 for each of them in the plugin descriptor.

The main parsing function, `simple_parser_parse()`, acts as a replacement for the built-in full-text parser, so it needs to split text into words and pass each word to the server. The parsing function's first argument is a pointer to a structure that contains the parsing context. This structure has a `doc` member that points to the text to be parsed, and a `length` member that indicates how long the text is. The simple parsing done by the plugin considers nonempty runs of whitespace characters to be words, so it identifies words like this:

```
static int simple_parser_parse(MYSQL_FTPARSER_PARAM *param)
{
  char *end, *start, *docend= param->doc + param->length;

  for (end= start= param->doc;; end++)
  {
    if (end == docend)
    {
      if (end > start)
        add_word(param, start, end - start);
      break;
    }
    else if (isspace(*end))
    {
      if (end > start)
        add_word(param, start, end - start);
      start= end + 1;
    }
  }
  return(0);
}
```

As the parser finds each word, it invokes a function `add_word()` to pass the word to the server. `add_word()` is a helper function only; it is not part of the plugin interface. The parser passes the parsing context pointer to `add_word()`, as well as a pointer to the word and a length value:

```
static void add_word(MYSQL_FTPARSER_PARAM *param, char *word, size_t len)
{
  MYSQL_FTPARSER_BOOLEAN_INFO bool_info=
    { FT_TOKEN_WORD, 0, 0, 0, 0, ' ', 0 };

  param->mysql_add_word(param, word, len, &bool_info);
}
```

For boolean-mode parsing, `add_word()` fills in the members of the `bool_info` structure as described earlier in the discussion of the `st_mysql_ftparser_boolean_info` structure.

5. Set up the status variables. For the `simple_parser` plugin, the following status variable array sets up one status variable with a value that is static text, and another with a value that is stored in a long integer variable:

```
long number_of_calls= 0;
```

```
struct st_mysql_show_var simple_status[]=
{
  {"static", (char *)"just a static text", SHOW_CHAR},
  {"called", (char *)&number_of_calls,     SHOW_LONG},
  {0,0,0}
};
```

When the plugin is installed, the plugin name and the `name` value are joined with an underscore to form the name displayed by `SHOW STATUS`. For the array just shown, the resulting status variable names are `simple_parser_static` and `simple_parser_called`. This convention means that you can easily display the variables for a plugin using its name:

```
mysql> SHOW STATUS LIKE 'simple_parser%';
+----------------------+--------------------+
| Variable_name        | Value              |
+----------------------+--------------------+
| simple_parser_static | just a static text |
| simple_parser_called | 0                  |
+----------------------+--------------------+
```

6. To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable). For the `simple_parser` plugin, it is compiled and installed when you build MySQL from source. It is also included in binary distributions. The build process produces a shared object library with a name of `mypluglib.so` (the `.so` suffix might differ depending on your platform).

7. To use the plugin, register it with the server. For example, to register the plugin at runtime, use this statement (adjust the `.so` suffix for your platform as necessary):

   ```
   INSTALL PLUGIN simple_parser SONAME 'mypluglib.so';
   ```

   For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

8. To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement. See Section 5.5.2, “Obtaining Server Plugin Information”.

9. Test the plugin to verify that it works properly.

   Create a table that contains a string column and associate the parser plugin with a `FULLTEXT` index on the column:

   ```
   mysql> CREATE TABLE t (c VARCHAR(255),
       ->   FULLTEXT (c) WITH PARSER simple_parser
       -> ) ENGINE=MyISAM;
   Query OK, 0 rows affected (0.01 sec)
   ```

   Insert some text into the table and try some searches. These should verify that the parser plugin treats all nonwhitespace characters as word characters:

   ```
   mysql> INSERT INTO t VALUES
       ->   ('latin1_general_cs is a case-sensitive collation'),
       ->   ('I\'d like a case of oranges'),
       ->   ('this is sensitive information'),
       ->   ('another row'),
       ->   ('yet another row');
   Query OK, 5 rows affected (0.02 sec)
   Records: 5  Duplicates: 0  Warnings: 0

   mysql> SELECT c FROM t;
   +-----------------------------------------------+
   | c                                             |
   ```

```
+-----------------------------------------------+
| latin1_general_cs is a case-sensitive collation |
| I'd like a case of oranges                    |
| this is sensitive information                 |
| another row                                   |
| yet another row                               |
+-----------------------------------------------+
5 rows in set (0.00 sec)

mysql> SELECT MATCH(c) AGAINST('case') FROM t;
+-------------------------+
| MATCH(c) AGAINST('case') |
+-------------------------+
|                       0 |
|         1.2968142032623 |
|                       0 |
|                       0 |
|                       0 |
+-------------------------+
5 rows in set (0.00 sec)

mysql> SELECT MATCH(c) AGAINST('sensitive') FROM t;
+-----------------------------+
| MATCH(c) AGAINST('sensitive') |
+-----------------------------+
|                           0 |
|                           0 |
|              1.3253291845322 |
|                           0 |
|                           0 |
+-----------------------------+
5 rows in set (0.01 sec)

mysql> SELECT MATCH(c) AGAINST('case-sensitive') FROM t;
+---------------------------------+
| MATCH(c) AGAINST('case-sensitive') |
+---------------------------------+
|                  1.3109166622162 |
|                                0 |
|                                0 |
|                                0 |
|                                0 |
+---------------------------------+
5 rows in set (0.01 sec)

mysql> SELECT MATCH(c) AGAINST('I\'d') FROM t;
+-------------------------+
| MATCH(c) AGAINST('I\'d') |
+-------------------------+
|                       0 |
|         1.2968142032623 |
|                       0 |
|                       0 |
|                       0 |
+-------------------------+
5 rows in set (0.01 sec)
```

Neither “case” nor “insensitive” match “case-insensitive” the way that they would for the built-in parser.

24.2.4.5 Writing Daemon Plugins

A daemon plugin is a simple type of plugin used for code that should be run by the server but that does not communicate with it. This section describes how to write a daemon server plugin, using the example plugin found in the `plugin/daemon_example` directory of MySQL source distributions. That directory contains the `daemon_example.cc` source file for a daemon plugin named `daemon_example` that writes a heartbeat string at regular intervals to a file named `mysql-heartbeat.log` in the data directory.

To write a daemon plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```
#include <mysql/plugin.h>
```

`plugin.h` defines the `MYSQL_DAEMON_PLUGIN` server plugin type and the data structures needed to declare the plugin.

The `daemon_example.cc` file sets up the library descriptor as follows. The library descriptor includes a single general server plugin descriptor.

```
mysql_declare_plugin(daemon_example)
{
  MYSQL_DAEMON_PLUGIN,
  &daemon_example_plugin,
  "daemon_example",
  "Brian Aker",
  "Daemon example, creates a heartbeat beat file in mysql-heartbeat.log",
  PLUGIN_LICENSE_GPL,
  daemon_example_plugin_init, /* Plugin Init */
  daemon_example_plugin_deinit, /* Plugin Deinit */
  0x0100 /* 1.0 */,
  NULL,                       /* status variables                */
  NULL,                       /* system variables                */
  NULL,                       /* config options                  */
  0,                          /* flags                           */
}
mysql_declare_plugin_end;
```

The `name` member (`daemon_example`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

The second member of the plugin descriptor, `daemon_example_plugin`, points to the type-specific daemon plugin descriptor. This structure consists only of the type-specific API version number:

```
struct st_mysql_daemon daemon_example_plugin=
{ MYSQL_DAEMON_INTERFACE_VERSION  };
```

The type-specific structure has no interface functions. There is no communication between the server and the plugin, except that the server calls the initialization and deinitialization functions from the general plugin descriptor to start and stop the plugin:

- `daemon_example_plugin_init()` opens the heartbeat file and spawns a thread that wakes up periodically and writes the next message to the file.
- `daemon_example_plugin_deinit()` closes the file and performs other cleanup.

To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable). For the `daemon_example` plugin, it is compiled and installed when you build MySQL from source. It is also included in binary distributions. The build process produces a shared object library with a name of `libdaemon_example.so` (the `.so` suffix might differ depending on your platform).

To use the plugin, register it with the server. For example, to register the plugin at runtime, use this statement (adjust the `.so` suffix for your platform as necessary):

```
INSTALL PLUGIN daemon_example SONAME 'libdaemon_example.so';
```

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement. See Section 5.5.2, “Obtaining Server Plugin Information”.

While the plugin is loaded, it writes a heartbeat string at regular intervals to a file named `mysql-heartbeat.log` in the data directory. This file grows without limit, so after you have satistifed yourself that the plugin operates correctly, unload it:

```
UNINSTALL PLUGIN daemon_example;
```

24.2.4.6 Writing INFORMATION_SCHEMA Plugins

This section describes how to write a server-side `INFORMATION_SCHEMA` table plugin. For example code that implements such plugins, see the `sql/sql_show.cc` file of a MySQL source distribution. You can also look at the example plugins found in the `InnoDB` source. See the `handler/i_s.cc` and `handler/ha_innodb.cc` files within the `InnoDB` source tree (in the `storage/innobase` directory).

To write an `INFORMATION_SCHEMA` table plugin, include the following header files in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```
#include <sql_class.h>
#include <table.h>
```

These header files are located in the `sql` directory of MySQL source distributions. They contain C++ structures, so the source file for an `INFORMATION_SCHEMA` plugin must be compiled as C++ (not C) code.

The source file for the example plugin developed here is named `simple_i_s_table.cc`. It creates a simple `INFORMATION_SCHEMA` table named `SIMPLE_I_S_TABLE` that has two columns named `NAME` and `VALUE`. The general descriptor for a plugin library that implements the table looks like this:

```
mysql_declare_plugin(simple_i_s_library)
{
  MYSQL_INFORMATION_SCHEMA_PLUGIN,
  &simple_table_info,               /* type-specific descriptor */
  "SIMPLE_I_S_TABLE",               /* table name */
  "Author Name",                    /* author */
  "Simple INFORMATION_SCHEMA table", /* description */
  PLUGIN_LICENSE_GPL,               /* license type */
  simple_table_init,                /* init function */
  NULL,
  0x0100,                           /* version = 1.0 */
  NULL,                             /* no status variables */
  NULL,                             /* no system variables */
  NULL,                             /* no reserved information */
  0                                 /* no flags */
}
mysql_declare_plugin_end;
```

The `name` member (`SIMPLE_I_S_TABLE`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

The `simple_table_info` member of the general descriptor points to the type-specific descriptor, which consists only of the type-specific API version number:

```
static struct st_mysql_information_schema simple_table_info =
{ MYSQL_INFORMATION_SCHEMA_INTERFACE_VERSION };
```

The general descriptor points to the initialization and deinitialization functions:

- The initialization function provides information about the table structure and a function that populates the table.
- The deinitialization function performs any required cleanup. If no cleanup is needed, this descriptor member can be `NULL` (as in the example shown).

The initialization function should return 0 for success, 1 if an error occurs. The function receives a generic pointer, which it should interpret as a pointer to the table structure:

```
static int table_init(void *ptr)
{
  ST_SCHEMA_TABLE *schema_table= (ST_SCHEMA_TABLE*)ptr;

  schema_table->fields_info= simple_table_fields;
  schema_table->fill_table= simple_fill_table;
  return 0;
}
```

The function should set these two members of the table structure:

- `fields_info`: An array of `ST_FIELD_INFO` structures that contain information about each column.
- `fill_table`: A function that populates the table.

The array pointed to by `fields_info` should contain one element per column of the `INFORMATION_SCHEMA` plus a terminating element. The following `simple_table_fields` array for the example plugin indicates that `SIMPLE_I_S_TABLE` has two columns. `NAME` is string-valued with a length of 10 and `VALUE` is integer-valued with a display width of 20. The last structure marks the end of the array.

```
static ST_FIELD_INFO simple_table_fields[]=
{
  {"NAME", 10, MYSQL_TYPE_STRING, 0, 0 0, 0},
  {"VALUE", 6, MYSQL_TYPE_LONG, 0, MY_I_S_UNSIGNED, 0, 0},
  {0, 0, MYSQL_TYPE_NULL, 0, 0, 0, 0}
};
```

For more information about the column information structure, see the definition of `ST_FIELD_INFO` in the `table.h` header file. The permissible `MYSQL_TYPE_`*`xxx`* type values are those used in the C API; see Section 23.8.5, “C API Data Structures”.

The `fill_table` member should be set to a function that populates the table and returns 0 for success, 1 if an error occurs. For the example plugin, the `simple_fill_table()` function looks like this:

```
static int simple_fill_table(THD *thd, TABLE_LIST *tables, COND *cond)
{
  TABLE *table= tables->table;

  table->field[0]->store("Name 1", 6, system_charset_info);
  table->field[1]->store(1);
  if (schema_table_store_record(thd, table))
    return 1;
  table->field[0]->store("Name 2", 6, system_charset_info);
  table->field[1]->store(2);
  if (schema_table_store_record(thd, table))
    return 1;
  return 0;
}
```

For each row of the `INFORMATION_SCHEMA` table, this function initializes each column, then calls `schema_table_store_record()` to install the row. The `store()` method arguments depend on the type of value to be stored. For column 0 (`NAME`, a string), `store()` takes a pointer to a string, its length, and information about the character set of the string:

```
store(const char *to, uint length, CHARSET_INFO *cs);
```

For column 1 (`VALUE`, an integer), `store()` takes the value and a flag indicating whether it is unsigned:

```
store(longlong nr, bool unsigned_value);
```

For other examples of how to populate `INFORMATION_SCHEMA` tables, search for instances of `schema_table_store_record()` in `sql_show.cc`.

To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable).

To test the plugin, install it:

```
mysql> INSTALL PLUGIN SIMPLE_I_S_TABLE SONAME 'simple_i_s_table.so';
```

Verify that the table is present:

```
mysql> SELECT TABLE_NAME FROM INFORMATION_SCHEMA.TABLES
    -> WHERE TABLE_NAME = 'SIMPLE_I_S_TABLE';
+------------------+
| TABLE_NAME       |
+------------------+
| SIMPLE_I_S_TABLE |
+------------------+
```

Try to select from it:

```
mysql> SELECT * FROM INFORMATION_SCHEMA.SIMPLE_I_S_TABLE;
+--------+-------+
| NAME   | VALUE |
+--------+-------+
| Name 1 |     1 |
| Name 2 |     2 |
+--------+-------+
```

Uninstall it:

```
mysql> UNINSTALL PLUGIN SIMPLE_I_S_TABLE;
```

24.2.4.7 Writing Semisynchronous Replication Plugins

This section describes how to write server-side semisynchronous replication plugins, using the example plugins found in the `plugin/semisync` directory of MySQL source distributions. That directory contains the source files for master and slave plugins named `rpl_semi_sync_master` and `rpl_semi_sync_slave`. The information here covers only how to set up the plugin framework. For details about how the plugins implement replication functions, see the source.

To write a semisynchronous replication plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```
#include <mysql/plugin.h>
```

`plugin.h` defines the `MYSQL_REPLICATION_PLUGIN` server plugin type and the data structures needed to declare the plugin.

For the master side, `semisync_master_plugin.cc` contains this general descriptor for a plugin named `rpl_semi_sync_master`:

```
mysql_declare_plugin(semi_sync_master)
{
  MYSQL_REPLICATION_PLUGIN,
  &semi_sync_master_plugin,
  "rpl_semi_sync_master",
  "He Zhenxing",
  "Semi-synchronous replication master",
  PLUGIN_LICENSE_GPL,
  semi_sync_master_plugin_init, /* Plugin Init */
  semi_sync_master_plugin_deinit, /* Plugin Deinit */
  0x0100 /* 1.0 */,
  semi_sync_master_status_vars, /* status variables */
  semi_sync_master_system_vars, /* system variables */
  NULL,                         /* config options */
  0,                            /* flags */
}
mysql_declare_plugin_end;
```

For the slave side, `semisync_slave_plugin.cc` contains this general descriptor for a plugin named `rpl_semi_sync_slave`:

```
mysql_declare_plugin(semi_sync_slave)
{
  MYSQL_REPLICATION_PLUGIN,
  &semi_sync_slave_plugin,
  "rpl_semi_sync_slave",
  "He Zhenxing",
  "Semi-synchronous replication slave",
  PLUGIN_LICENSE_GPL,
  semi_sync_slave_plugin_init, /* Plugin Init */
  semi_sync_slave_plugin_deinit, /* Plugin Deinit */
  0x0100 /* 1.0 */,
  semi_sync_slave_status_vars,  /* status variables */
  semi_sync_slave_system_vars,  /* system variables */
  NULL,                         /* config options */
  0,                            /* flags */
}
mysql_declare_plugin_end;
```

For both the master and slave plugins, the general descriptor has pointers to the type-specific descriptor, the initialization and deinitialization functions, and to the status and system variables implemented by the plugin. For information about variable setup, see Server Plugin Status and System Variables. The following remarks discuss the type-specific descriptor and the initialization and deinitialization functions for the master plugin but apply similarly to the slave plugin.

The `semi_sync_master_plugin` member of the master general descriptor points to the type-specific descriptor, which consists only of the type-specific API version number:

```
struct Mysql_replication semi_sync_master_plugin= {
  MYSQL_REPLICATION_INTERFACE_VERSION
};
```

The initialization and deinitialization function declarations look like this:

```
static int semi_sync_master_plugin_init(void *p);
static int semi_sync_master_plugin_deinit(void *p);
```

The initialization function uses the pointer to register transaction and binary logging “observers” with the server. After successful initialization, the server takes care of invoking the observers at the appropriate times. (For details on the observers, see the source files.) The deinitialization function cleans up by deregistering the observers. Each function returns 0 for success or 1 if an error occurs.

To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable). For the `rpl_semi_sync_master` and `rpl_semi_sync_slave` plugins, they are compiled and installed when you build MySQL from source. They are also included in binary distributions. The build process produces shared object libraries with names of `semisync_master.so` and `semisync_slave.so` (the `.so` suffix might differ depending on your platform).

24.2.4.8 Writing Audit Plugins

This section describes how to write a server-side audit plugin, using the example plugin found in the `plugin/audit_null` directory of MySQL source distributions. The `audit_null.c` source file in that directory implements a simple example audit plugin named `NULL_AUDIT`.

Within the server, the pluggable audit interface is implemented in the `sql_audit.h` and `sql_audit.cc` files in the `sql` directory of MySQL source distributions. Additionally, several places in the server call the audit interface when an auditable event occurs, so that registered audit plugins can be notified about the event if necessary. To see where such calls occur, look for invocations of functions with names of the form `mysql_audit_xxx()`. Audit notification occurs for server operations such as these:

- Writing a message to the general query log (if the log is enabled)
- Writing a message to the error log
- Sending a query result to a client
- Client connect and disconnect events

To write an audit plugin, include the following header file in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

```
#include <mysql/plugin_audit.h>
```

`plugin_audit.h` includes `plugin.h`, so you need not include the latter file explicitly. `plugin.h` defines the `MYSQL_AUDIT_PLUGIN` server plugin type and the data structures needed to declare the plugin. `plugin_audit.h` defines data structures specific to audit plugins.

An audit plugin, like any MySQL server plugin, has a general plugin descriptor (see Server Plugin Library and Plugin Descriptors). In `audit_null.c`, the general descriptor for `audit_null` looks like this:

```
mysql_declare_plugin(audit_null)
{
  MYSQL_AUDIT_PLUGIN,         /* type                            */
  &audit_null_descriptor,     /* descriptor                      */
  "NULL_AUDIT",               /* name                            */
  "Oracle Corp",              /* author                          */
  "Simple NULL Audit",        /* description                     */
  PLUGIN_LICENSE_GPL,
  audit_null_plugin_init,     /* init function (when loaded)     */
  audit_null_plugin_deinit,   /* deinit function (when unloaded) */
  0x0002,                     /* version                         */
  simple_status,              /* status variables                */
  NULL,                       /* system variables                */
  NULL,
  0,
}
mysql_declare_plugin_end;
```

The `name` member (`NULL_AUDIT`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `INFORMATION_SCHEMA.PLUGINS` or `SHOW PLUGINS`.

The general descriptor also refers to `simple_status`, a structure that exposes several status variables to the `SHOW STATUS` statement:

```
static struct st_mysql_show_var simple_status[]=
{
  { "Audit_null_called", (char *) &number_of_calls, SHOW_INT },
  { "Audit_null_general_log", (char *) &number_of_calls_general_log,
    SHOW_INT },
  { "Audit_null_general_error", (char *) &number_of_calls_general_error,
    SHOW_INT },
  { "Audit_null_general_result", (char *) &number_of_calls_general_result,
    SHOW_INT },
  { 0, 0, 0}
};
```

The `audit_null_plugin_init` initialization function sets the status variables to zero when the plugin is loaded. The `audit_null_plugin_deinit` function performs cleanup when the plugin is unloaded. During operation, the plugin increments the first status variable for each notification it receives. It also increments the others according to the event class and subclass. In effect, the first variable is the aggregate of the counts for the event subclasses.

The `audit_null_descriptor` value in the general descriptor points to the type-specific descriptor. For audit plugins, this descriptor has the following structure:

```
struct st_mysql_audit
{
  int interface_version;
  void (*release_thd)(MYSQL_THD);
  void (*event_notify)(MYSQL_THD, unsigned int, const void *);
  unsigned long class_mask[MYSQL_AUDIT_CLASS_MASK_SIZE];
};
```

The type-specific descriptor has these members:

- `interface_version`: By convention, type-specific plugin descriptors begin with the interface version for the given plugin type. The server checks `interface_version` when it loads the plugin to see whether the plugin is compatible with it. For audit plugins, the value of the `interface_version` member is `MYSQL_AUDIT_INTERFACE_VERSION` (defined in `plugin_audit.h`).
- `release_thd`: A function that the server calls to inform the plugin that it is being dissociated from its thread context. This should be `NULL` if there is no such function.
- `event_notify`: A function that the server calls to notify the plugin that an auditable event has occurred. This function should not be `NULL`; that would not make sense because no auditing would occur.
- `class_mask`: A bitmask that indicates the event classes for which the plugin wants to receive notification. If this value is 0, the server passes no events to the plugin.

The server uses the `event_notify` and `release_thd` functions together. They are called within the context of a specific thread, and a thread might perform an activity that produces several event notifications. The first time the server calls `event_notify` for a thread, it creates a binding of the plugin to the thread. The plugin cannot be uninstalled while this binding exists. When no more events for the thread will occur, the server informs the plugin of this by calling the `release_thd` function, and then destroys the binding. For example, when a client issues a statement, the thread processing the statement might notify audit plugins about the result set produced by the statement and about the statement being logged. After these notifications occur, the server releases the plugin before putting the thread to sleep until the client issues another statement.

This design enables the plugin to allocate resources needed for a given thread in the first call to the `event_notify` function and release them in the `release_thd` function:

```
event_notify function:
  if memory is needed to service the thread
    allocate memory
  ... rest of notification processing ...

release_thd function:
  if memory was allocated
    release memory
  ... rest of release processing ...
```

That is more efficient than allocating and releasing memory repeatedly in the notification function.

For the `NULL_AUDIT` example audit plugin, the type-specific descriptor looks like this:

```
static struct st_mysql_audit audit_null_descriptor=
{
  MYSQL_AUDIT_INTERFACE_VERSION,                  /* interface version    */
  NULL,                                           /* release_thd function */
  audit_null_notify,                              /* notify function      */
  { (unsigned long) MYSQL_AUDIT_GENERAL_CLASSMASK } /* class mask         */
};
```

The server calls `audit_null_notify` to pass audit event information to the plugin. There is no `release_thd` function.

The event class mask indicates an interest in all events of the “general” class. `plugin_audit.h` defines its symbol, `MYSQL_AUDIT_GENERAL_CLASS`, and a mask with a bit for this class:

```
#define MYSQL_AUDIT_GENERAL_CLASS 0
#define MYSQL_AUDIT_GENERAL_CLASSMASK (1 << MYSQL_AUDIT_GENERAL_CLASS)
```

`plugin_audit.h` also has defines for a “connection” event class, although the `NULL_AUDIT` plugin does nothing with such events:

```
#define MYSQL_AUDIT_CONNECTION_CLASS 1
#define MYSQL_AUDIT_CONNECTION_CLASSMASK (1 << MYSQL_AUDIT_CONNECTION_CLASS)
```

A plugin could be written to receive both general and connection events by setting its type-specific descriptor class mask like this:

```
  { (unsigned long) MYSQL_AUDIT_GENERAL_CLASSMASK |
                    MYSQL_AUDIT_CONNECTION_CLASSMASK } /* class mask        */
```

In the type-specific descriptor, the second and third parameters of the `event_notify` function prototype represent the event class and a generic pointer to an event structure:

```
void (*event_notify)(MYSQL_THD, unsigned int, const void *);
```

Events in different classes may have different structures, so the notification function should use the event class value to determine how to interpret the pointer to the event structure.

If the server calls the notification function with an event class of `MYSQL_AUDIT_GENERAL_CLASS`, it passes the event structure as a pointer to a `mysql_event_general` structure:

```
struct mysql_event_general
{
  unsigned int event_subclass;
  int general_error_code;
  unsigned long general_thread_id;
  const char *general_user;
  unsigned int general_user_length;
  const char *general_command;
```

```
  unsigned int general_command_length;
  const char *general_query;
  unsigned int general_query_length;
  struct charset_info_st *general_charset;
  unsigned long long general_time;
  unsigned long long general_rows;
};
```

Audit plugins can interpret `mysql_event_general` members as follows:

- `event_subclass`: The event subclass, one of the following values:

  ```
  #define MYSQL_AUDIT_GENERAL_LOG 0
  #define MYSQL_AUDIT_GENERAL_ERROR 1
  #define MYSQL_AUDIT_GENERAL_RESULT 2
  #define MYSQL_AUDIT_GENERAL_STATUS 3
  ```

- `general_error_code`: The error code. This is a value like that returned by the `mysql_errno()` C API function; 0 means “no error.”
- `general_thread_id`: The ID of the thread for which the event occurred.
- `general_user`: The current user for the event.
- `general_user_length`: The length of `general_user`, in bytes.
- `general_command`: For general query log events, the type of operation. Examples: `Connect`, `Query`, `Shutdown`. For error log events, the error message. This is a value like that returned by the `mysql_error()` C API function; an empty string means “no error.” For result events, this is empty.
- `general_command_length`: The length of `general_command`, in bytes.
- `general_query`: The SQL statement that was logged or produced a result.
- `general_query_length`: The length of `general_query`, in bytes.
- `general_charset`: Character set information for the event.
- `general_time`: A `TIMESTAMP` value indicating the time just before the notification function was called.
- `general_rows`: For general query log events, zero. For error log events, the row number at which an error occurred. For result events, the number of rows in the result plus one. For statements that produce no result set, the value is 0. This encoding enables statements that produce no result set to be distinguished from those that produce an empty result set. For example, for a `DELETE` statement, this value is 0. For a `SELECT`, the result is always 1 or more, where 1 represents an empty result set.
- `general_host`: For general query log events, a string representing the client host name.
- `general_sql_command`: For general query log events, a string that indicates the type of action performed, such as `connect` or `drop_table`.
- `general_external_user`: For general query log events, a string representing the external user (empty if none).
- `general_ip`: For general query log events, a string representing the client IP address.

The `general_host`, `general_sql_command`, `general_external_user`, and `general_ip` members are new in MySQL 5.5.34. These are `MYSQL_LEX_STRING` structures that pair a string and its length. For example, if `event_general` is a pointer to a general event, you can access the members of the `general_host` value as follows:

```
event_general->general_host.length
event_general->general_host.str
```

The `NULL_AUDIT` plugin notification function is quite simple. It increments a global event counter, verifies that the event is of the “general” class, then looks at the event subclass to determine which subclass counter to increment:

```
static void audit_null_notify(MYSQL_THD thd __attribute__((unused)),
                              unsigned int event_class,
                              const void *event)
{
  number_of_calls++;
  if (event_class == MYSQL_AUDIT_GENERAL_CLASS)
  {
    const struct mysql_event_general *event_general=
      (const struct mysql_event_general *) event;
    switch (event_general->event_subclass)
    {
    case MYSQL_AUDIT_GENERAL_LOG:
      number_of_calls_general_log++;
      break;
    case MYSQL_AUDIT_GENERAL_ERROR:
      number_of_calls_general_error++;
      break;
    case MYSQL_AUDIT_GENERAL_RESULT:
      number_of_calls_general_result++;
      break;
    default:
      break;
    }
  }
}
```

To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable). For the `NULL_AUDIT` plugin, it is compiled and installed when you build MySQL from source. It is also included in binary distributions. The build process produces a shared object library with a name of `adt_null.so` (the `.so` suffix might differ depending on your platform).

To register the plugin at runtime, use this statement (adjust the `.so` suffix for your platform as necessary):

```
INSTALL PLUGIN NULL_AUDIT SONAME 'adt_null.so';
```

For additional information about plugin loading, see Section 5.5.1, “Installing and Uninstalling Plugins”.

To verify plugin installation, examine the `INFORMATION_SCHEMA.PLUGINS` table or use the `SHOW PLUGINS` statement. See Section 5.5.2, “Obtaining Server Plugin Information”.

While the audit plugin is installed, it exposes status variables that indicate the events for which the plugin has been called:

```
mysql> SHOW STATUS LIKE 'Audit_null%';
+--------------------------+-------+
| Variable_name            | Value |
+--------------------------+-------+
| Audit_null_called        | 1385  |
| Audit_null_general_error | 1     |
| Audit_null_general_log   | 741   |
| Audit_null_general_result | 643   |
+--------------------------+-------+
```

`Audit_null_called` counts all events, and the other variables count instances of event subclasses. For example, the preceding `SHOW STATUS` statement causes the server to send a result to the client and to write a message to the general query log if that log is enabled. Thus, a client that issues the statement repeatedly causes `Audit_null_called` and `Audit_null_general_result` to be incremented each time, and `Audit_null_general_log` to be incremented if the log is enabled.

To disable the plugin after testing it, use this statement to unload it:

```
UNINSTALL PLUGIN NULL_AUDIT;
```

24.2.4.9 Writing Authentication Plugins

MySQL supports pluggable authentication, in which plugins are invoked to authenticate client connections. Authentication plugins enable the use of authentication methods other than the built-in method of passwords stored in the `mysql.user` table. For example, plugins can be written to access external authentication methods. Also, authentication plugins can support the proxy user capability, such that the connecting user is a proxy for another user and is treated, for purposes of access control, as having the privileges of a different user. For more information, see Section 6.3.6, “Pluggable Authentication”, and Section 6.3.7, “Proxy Users”.

An authentication plugin can be written for the server side or the client side. Server-side plugins use the same plugin API that is used for the other server plugin types such as full-text parser or audit plugins (although with a different type-specific descriptor). Client-side plugins use the client plugin API.

Several header files contain information relevant to authentication plugins:

- `plugin.h`: Defines the `MYSQL_AUTHENTICATION_PLUGIN` server plugin type.
- `client_plugin.h`: Defines the API for client plugins. This includes the client plugin descriptor and function prototypes for client plugin C API calls (see Section 23.8.14, “C API Client Plugin Functions”).
- `plugin_auth.h`: Defines the part of the server plugin API specific to authentication plugins. This includes the type-specific descriptor for server-side authentication plugins and the `MYSQL_SERVER_AUTH_INFO` structure.
- `plugin_auth_common.h`: Contains common elements of client and server authentication plugins. This includes return value definitions and the `MYSQL_PLUGIN_VIO` structure.

To write an authentication plugin, include the following header files in the plugin source file. Other MySQL or general header files might also be needed, depending on the plugin capabilities and requirements.

- For a source file that implements a server authentication plugin, include this file:

```
#include <mysql/plugin_auth.h>
```

- For a source file that implements a client authentication plugin, or both client and server plugins, include these files:

```
#include <mysql/plugin_auth.h>
#include <mysql/client_plugin.h>
#include <mysql.h>
```

`plugin_auth.h` includes `plugin.h` and `plugin_auth_common.h`, so you need not include the latter files explicitly.

This section describes how to write a pair of simple server and client authentication plugins that work together.

Warning

These plugins accept any non-empty password and the password is sent in clear text. This is insecure, so the plugins *should not be used in production environments.*

The server-side and client-side plugins developed here both are named `auth_simple`. As described in Section 24.2.4.2, “Plugin Data Structures”, the plugin library file must have the same base name as the client plugin, so the source file name is `auth_simple.c` and produces a library named `auth_simple.so` (assuming that your system uses `.so` as the suffix for library files).

In MySQL source distributions, authentication plugin source is located in the `plugin/auth` directory and can be examined as a guide to writing other authentication plugins. Also, to see how the built-in authentication plugins are implemented, see `sql/sql_acl.cc` for plugins that are built in to the MySQL server and `sql-common/client.c` for plugins that are built in to the `libmysqlclient` client library. (For the built-in client plugins, note that the `auth_plugin_t` structures used there differ from the structures used with the usual client plugin declaration macros. In particular, the first two members are provided explicitly, not by declaration macros.)

Writing the Server-Side Authentication Plugin

Declare the server-side plugin with the usual general descriptor format that is used for all server plugin types (see Server Plugin Library and Plugin Descriptors). For the `auth_simple` plugin, the descriptor looks like this:

```
mysql_declare_plugin(auth_simple)
{
  MYSQL_AUTHENTICATION_PLUGIN,
  &auth_simple_handler,                /* type-specific descriptor */
  "auth_simple",                       /* plugin name */
  "Author Name",                       /* author */
  "Any-password authentication plugin", /* description */
  PLUGIN_LICENSE_GPL,                  /* license type */
  NULL,                                /* no init function */
  NULL,                                /* no deinit function */
  0x0100,                              /* version = 1.0 */
  NULL,                                /* no status variables */
  NULL,                                /* no system variables */
  NULL,                                /* no reserved information */
  0                                    /* no flags */
}
mysql_declare_plugin_end;
```

The `name` member (`auth_simple`) indicates the name to use for references to the plugin in statements such as `INSTALL PLUGIN` or `UNINSTALL PLUGIN`. This is also the name displayed by `SHOW PLUGINS` or `INFORMATION_SCHEMA.PLUGINS`.

The `auth_simple_handler` member of the general descriptor points to the type-specific descriptor. For an authentication plugin, the type-specific descriptor is an instance of the `st_mysql_auth` structure (defined in `plugin_auth.h`):

```
struct st_mysql_auth
{
  int interface_version;
  const char *client_auth_plugin;
  int (*authenticate_user)(MYSQL_PLUGIN_VIO *vio, MYSQL_SERVER_AUTH_INFO *info);
};
```

The `st_mysql_auth` structure has these members:

- `interface_version`: The type-specific API version number, always `MYSQL_AUTHENTICATION_INTERFACE_VERSION`
- `client_auth_plugin`: The client plugin name
- `authenticate_user`: A pointer to the main plugin function that communicates with the client

The `client_auth_plugin` member should indicate the name of the client plugin if a specific plugin is required. A value of `NULL` means “any plugin.” In the latter case, whatever plugin the client uses will do. This is useful if the server plugin does not care about the client plugin or what user name or password

it sends. For example, this might be true if the server plugin authenticates only local clients and uses some property of the operating system rather than the information sent by the client plugin.

For `auth_simple`, the type-specific descriptor looks like this:

```
static struct st_mysql_auth auth_simple_handler =
{
  MYSQL_AUTHENTICATION_INTERFACE_VERSION,
  "auth_simple",           /* required client-side plugin name */
  auth_simple_server       /* server-side plugin main function */
};
```

The main function, `auth_simple_server()`, takes two arguments representing an I/O structure and a `MYSQL_SERVER_AUTH_INFO` structure. The structure definition, found in `plugin_auth.h`, looks like this:

```
typedef struct st_mysql_server_auth_info
{
  char *user_name;
  unsigned int user_name_length;
  const char *auth_string;
  unsigned long auth_string_length;
  char authenticated_as[MYSQL_USERNAME_LENGTH+1];
  char external_user[512];
  int  password_used;
  const char *host_or_ip;
  unsigned int host_or_ip_length;
} MYSQL_SERVER_AUTH_INFO;
```

The character set for string members is UTF-8. If there is a `_length` member associated with a string, it indicates the string length in bytes. Strings are also null-terminated.

When an authentication plugin is invoked by the server, it should interpret the `MYSQL_SERVER_AUTH_INFO` structure members as follows. Some of these are used to set the value of SQL functions or system variables within the client session, as indicated.

- `user_name`: The user name sent by the client. The value becomes the `USER()` function value.
- `user_name_length`: The length of `user_name` in bytes.
- `auth_string`: The value of the `authentication_string` column of the `mysql.user` table row for the matching account name (that is, the row that matches the client user name and host name and that the server uses to determine how to authenticate the client).

  Suppose that you create an account using the following statement:

  ```
  CREATE USER 'my_user'@'localhost'
    IDENTIFIED WITH my_plugin AS 'my_auth_string';
  ```

  When `my_user` connects from the local host, the server invokes `my_plugin` and passes `'my_auth_string'` to it as the `auth_string` value.
- `auth_string_length`: The length of `auth_string` in bytes.
- `authenticated_as`: The server sets this to the user name (the value of `user_name`). The plugin can alter it to indicate that the client should have the privileges of a different user. For example, if the plugin supports proxy users, the initial value is the name of the connecting (proxy) user, and the plugin can change this member to the proxied user name. The server then treats the proxy user as having the privileges of the proxied user (assuming that the other conditions for proxy user support are satisfied; see Implementing Proxy User Support in Authentication Plugins). The value is represented as a string at most `MYSQL_USER_NAME_LENGTH` bytes long, plus a terminating null. The value becomes the `CURRENT_USER()` function value.

- `external_user`: The server sets this to the empty string (null terminated). Its value becomes the `external_user` system variable value. If the plugin wants that system variable to have a different value, it should set this member accordingly; for example, to the connecting user name. The value is represented as a string at most 511 bytes long, plus a terminating null.
- `password_used`: This member applies when authentication fails. The plugin can set it or ignore it. The value is used to construct the failure error message of `Authentication fails. Password used: %s`. The value of `password_used` determines how `%s` is handled, as shown in the following table.

`password_used`	`%s` Handling
0	NO
1	YES
2	There will be no `%s`

- `host_or_ip`: The name of the client host if it can be resolved, or the IP address otherwise.
- `host_or_ip_length`: The length of `host_or_ip` in bytes.

The `auth_simple` main function, `auth_simple_server()`, reads the password (a null-terminated string) from the client and succeeds if the password is nonempty (first byte not null):

```
static int auth_simple_server (MYSQL_PLUGIN_VIO *vio,
                               MYSQL_SERVER_AUTH_INFO *info)
{
  unsigned char *pkt;
  int pkt_len;

  /* read the password as null-terminated string, fail on error */
  if ((pkt_len= vio->read_packet(vio, &pkt)) < 0)
    return CR_ERROR;

  /* fail on empty password */
  if (!pkt_len || *pkt == '\0')
  {
    info->password_used= PASSWORD_USED_NO;
    return CR_ERROR;
  }

  /* accept any nonempty password */
  info->password_used= PASSWORD_USED_YES;

  return CR_OK;
}
```

The main function should return one of the error codes shown in the following table.

Error Code	Meaning
`CR_OK`	Success
`CR_OK_HANDSHAKE_COMPLETE`	Do not send a status packet back to client
`CR_ERROR`	Error

For an example of how the handshake works, see the `plugin/auth/dialog.c` source file.

`auth_simple_server()` is so basic that it does not use the authentication information structure except to set the member that indicates whether a password was received.

A plugin that supports proxy users must return to the server the name of the proxied user (the MySQL user whose privileges the client user should get). To do this, the plugin must set the `info->authenticated_as` member to the proxied user name. For information about proxying, see Section 6.3.7, “Proxy Users”, and Implementing Proxy User Support in Authentication Plugins.

Writing the Client-Side Authentication Plugin

Declare the client-side plugin descriptor with the `mysql_declare_client_plugin()` and `mysql_end_client_plugin` macros (see Client Plugin Descriptors). For the `auth_simple` plugin, the descriptor looks like this:

```
mysql_declare_client_plugin(AUTHENTICATION)
  "auth_simple",                        /* plugin name */
  "Author Name",                        /* author */
  "Any-password authentication plugin", /* description */
  {1,0,0},                              /* version = 1.0.0 */
  "GPL",                                /* license type */
  NULL,                                 /* for internal use */
  NULL,                                 /* no init function */
  NULL,                                 /* no deinit function */
  NULL,                                 /* no option-handling function */
  auth_simple_client                    /* main function */
mysql_end_client_plugin;
```

The descriptor members from the plugin name through the option-handling function are common to all client plugin types. (For descriptions, see Client Plugin Descriptors.) Following the common members, the descriptor has an additional member specific to authentication plugins. This is the “main” function, which handles communication with the server. The function takes two arguments representing an I/O structure and a connection handler. For our simple any-password plugin, the main function does nothing but write to the server the password provided by the user:

```
static int auth_simple_client (MYSQL_PLUGIN_VIO *vio, MYSQL *mysql)
{
  int res;

  /* send password as null-terminated string in clear text */
  res= vio->write_packet(vio, (const unsigned char *) mysql->passwd,
                         strlen(mysql->passwd) + 1);

  return res ? CR_ERROR : CR_OK;
}
```

The main function should return one of the error codes shown in the following table.

Error Code	Meaning
`CR_OK`	Success
`CR_OK_HANDSHAKE_COMPLETE`	Success, client done
`CR_ERROR`	Error

`CR_OK_HANDSHAKE_COMPLETE` indicates that the client has done its part successfully and has read the last packet. A client plugin may return `CR_OK_HANDSHAKE_COMPLETE` if the number of round trips in the authentication protocol is not known in advance and the plugin must read another packet to determine whether authentication is finished.

Using the Authentication Plugins

To compile and install a plugin library file, use the instructions in Section 24.2.4.3, “Compiling and Installing Plugin Libraries”. To make the library file available for use, install it in the plugin directory (the directory named by the `plugin_dir` system variable).

Register the server-side plugin with the server. For example, to load the plugin at server startup, use a `--plugin-load=auth_simple.so` option (adjust the `.so` suffix for your platform as necessary).

Create a user for whom the server will use the `auth_simple` plugin for authentication:

```
mysql> CREATE USER 'x'@'localhost'
```

```
    -> IDENTIFIED WITH auth_simple;
```

Use a client program to connect to the server as user `x`. The server-side `auth_simple` plugin communicates with the client program that it should use the client-side `auth_simple` plugin, and the latter sends the password to the server. The server plugin should reject connections that send an empty password and accept connections that send a nonempty password. Invoke the client program each way to verify this:

```
shell> mysql --user=x --skip-password
ERROR 1045 (28000): Access denied for user 'x'@'localhost' (using password: NO)

shell> mysql --user=x --password
Enter password: abc
mysql>
```

Because the server plugin accepts any nonempty password, it should be considered insecure. After testing the plugin to verify that it works, restart the server without the `--plugin-load` option so as not to indavertently leave the server running with an insecure authentication plugin loaded. Also, drop the user with `DROP USER 'x'@'localhost'`.

For additional information about loading and using authentication plugins, see Section 5.5.1, “Installing and Uninstalling Plugins”, and Section 6.3.6, “Pluggable Authentication”.

If you are writing a client program that supports the use of authentication plugins, normally such a program causes a plugin to be loaded by calling `mysql_options()` to set the `MYSQL_DEFAULT_AUTH` and `MYSQL_PLUGIN_DIR` options:

```
char *plugin_dir = "path_to_plugin_dir";
char *default_auth = "plugin_name";

/* ... process command-line options ... */

mysql_options(&mysql, MYSQL_PLUGIN_DIR, plugin_dir);
mysql_options(&mysql, MYSQL_DEFAULT_AUTH, default_auth);
```

Typically, the program will also accept `--plugin-dir` and `--default-auth` options that enable users to override the default values.

Should a client program require lower-level plugin management, the client library contains functions that take an `st_mysql_client_plugin` argument. See Section 23.8.14, “C API Client Plugin Functions”.

Implementing Proxy User Support in Authentication Plugins

One of the capabilities that pluggable authentication makes possible is proxy users (see Section 6.3.7, “Proxy Users”). For a server-side authentication plugin to participate in proxy user support, these conditions must be satisfied:

- When a connecting client should be treated as a proxy user, the plugin must return a different name in the `authenticated_as` member of the `MYSQL_SERVER_AUTH_INFO` structure, to indicate the proxied user name. It may also optionally set the `external_user` member, to set the value of the `external_user` system variable.
- Proxy user accounts must be set up to be authenticated by the plugin. Use the `CREATE USER` or `GRANT` statement to associate accounts with plugins.
- Proxy user accounts must have the `PROXY` privilege for the proxied accounts. Use the `GRANT` statement to grant this privilege.

In other words, the only aspect of proxy user support required of the plugin is that it set `authenticated_as` to the proxied user name. The rest is optional (setting `external_user`) or done by the DBA using SQL statements.

How does an authentication plugin determine which proxied user to return when the proxy user connects? That depends on the plugin. Typically, the plugin maps clients to proxied users based on the authentication string passed to it by the server. This string comes from the `AS` part of the `IDENTIFIED WITH` clause of the `CREATE USER` statement that specifies use of the plugin for authentication.

The plugin developer determines the syntax rules for the authentication string and implements the plugin according to those rules. Suppose that a plugin takes a comma-separated list of pairs that map external users to MySQL users. For example:

```
CREATE USER ''@'%.example.com'
  IDENTIFIED WITH my_plugin AS 'extuser1=mysqlusera, extuser2=mysqluserb'
CREATE USER ''@'%.example.org'
  IDENTIFIED WITH my_plugin AS 'extuser1=mysqluserc, extuser2=mysqluserd'
```

When the server invokes a plugin to authenticate a client, it passes the appropriate authentication string to the plugin. The plugin is responsible to:

1. Parse the string into its components to determine the mapping to use
2. Compare the client user name to the mapping
3. Return the proper MySQL user name

For example, if `extuser2` connects from an `example.com` host, the server passes `'extuser1=mysqlusera, extuser2=mysqluserb'` to the plugin, and the plugin should copy `mysqluserb` into `authenticated_as`, with a terminating null byte. If `extuser2` connects from an `example.org` host, the server passes `'extuser1=mysqluserc, extuser2=mysqluserd'`, and the plugin should copy `mysqluserd` instead.

If there is no match in the mapping, the action depends on the plugin. If a match is required, the plugin likely will return an error. Or the plugin might simply return the client name; in this case, it should not change `authenticated_as`, and the server will not treat the client as a proxy.

The following example demonstrates how to handle proxy users using a plugin named `auth_simple_proxy`. Like the `auth_simple` plugin described earlier, `auth_simple_proxy` accepts any nonempty password as valid (and thus should not be used in production environments). In addition, it examines the `auth_string` authentication string member and uses these very simple rules for interpreting it:

- If the string is empty, the plugin returns the user name as given and no proxying occurs. That is, the plugin leaves the value of `authenticated_as` unchanged.
- If the string is nonempty, the plugin treats it as the name of the proxied user and copies it to `authenticated_as` so that proxying occurs.

For testing, set up one account that is not proxied according to the preceding rules, and one that is. This means that one account has no `AS` clause, and one includes an `AS` clause that names the proxied user:

```
CREATE USER 'plugin_user1'@'localhost'
  IDENTIFIED WITH auth_simple_proxy;
CREATE USER 'plugin_user2'@'localhost'
  IDENTIFIED WITH auth_simple_proxy AS 'proxied_user';
```

In addition, create an account for the proxied user and grant `plugin_user2` the `PROXY` privilege for it:

```
CREATE USER 'proxied_user'@'localhost'
  IDENTIFIED BY 'proxied_user_pass';
GRANT PROXY
  ON 'proxied_user'@'localhost'
  TO 'plugin_user2'@'localhost';
```

Before the server invokes an authentication plugin, it sets `authenticated_as` to the client user name. To indicate that the user is a proxy, the plugin should set `authenticated_as` to the proxied user name. For `auth_simple_proxy`, this means that it must examine the `auth_string` value, and, if the value is nonempty, copy it to the `authenticated_as` member to return it as the name of the proxied user. In addition, when proxying occurs, the plugin sets the `external_user` member to the client user name; this becomes the value of the `external_user` system variable.

```
static int auth_simple_proxy_server (MYSQL_PLUGIN_VIO *vio,
                                     MYSQL_SERVER_AUTH_INFO *info)
{
  unsigned char *pkt;
  int pkt_len;

  /* read the password as null-terminated string, fail on error */
  if ((pkt_len= vio->read_packet(vio, &pkt)) < 0)
    return CR_ERROR;

  /* fail on empty password */
  if (!pkt_len || *pkt == '\0')
  {
    info->password_used= PASSWORD_USED_NO;
    return CR_ERROR;
  }

  /* accept any nonempty password */
  info->password_used= PASSWORD_USED_YES;

  /* if authentication string is nonempty, use as proxied user name */
  /* and use client name as external_user value */
  if (info->auth_string_length > 0)
  {
    strcpy (info->authenticated_as, info->auth_string);
    strcpy (info->external_user, info->user_name);
  }

  return CR_OK;
}
```

After a successful connection, the `USER()` function should indicate the connecting client user and host name, and `CURRENT_USER()` should indicate the account whose privileges apply during the session. The latter value should be the connecting user account if no proxying occurs or the proxied account if proxying does occur.

Compile and install the plugin, then test it. First, connect as `plugin_user1`:

```
shell> mysql --user=plugin_user1 --password
Enter password: x
```

In this case, there should be no proxying:

```
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user, @@external_user\G
*************************** 1. row ***************************
        USER(): plugin_user1@localhost
 CURRENT_USER(): plugin_user1@localhost
   @@proxy_user: NULL
@@external_user: NULL
```

Then connect as `plugin_user2`:

```
shell> mysql --user=plugin_user2 --password
Enter password: x
```

In this case, `plugin_user2` should be proxied to `proxied_user`:

```
mysql> SELECT USER(), CURRENT_USER(), @@proxy_user, @@external_user\G
*************************** 1. row ***************************
        USER(): plugin_user2@localhost
 CURRENT_USER(): proxied_user@localhost
   @@proxy_user: 'plugin_user2'@'localhost'
@@external_user: 'plugin_user2'@'localhost'
```

24.3 MySQL Services for Plugins

MySQL server plugins have access to server “plugin services.” The plugin services interface exposes server functionality that plugins can call. It complements the plugin API and has these characteristics:

- Services enable plugins to access code inside the server using ordinary function calls. Services are also available to user-defined functions (UDFs).
- Services are portable and work on multiple platforms.
- The interface includes a versioning mechanism so that service versions supported by the server can be checked at load time against plugin versions. Versioning protects against incompatibilities between the version of a service that the server provides and the version of the service expected or required by a plugin.

The plugin services interface differs from the plugin API as follows:

- The plugin API enables plugins to be used by the server. The calling initiative lies with the server to invoke plugins. This enables plugins to extend server functionality or register to receive notifications about server processing.
- The plugin services interface enables plugins to call code inside the server. The calling initiative lies with plugins to invoke service functions. This enables functionality already implemented in the server to be used by many plugins; they need not individually implement it themselves.

To determine what services exist and what functions they provide, look in the `include/mysql` directory of a MySQL source distribution. The relevant files are:

- `plugin.h` includes `services.h`, which is the “umbrella” header that includes all available service-specific header files.
- Service-specific headers have names of the form `service_`*`xxx`*`.h`.

Each service-specific header should contain comments that provide full usage documentation for a given service, including what service functions are available, their calling sequences, and return values.

For developers who wish to modify the server to add a new service, see MySQL Internals: MySQL Services for Plugins.

Available services include the following:

- `my_snprintf`: A string-formatting service that produces consistent results across platforms.
- `my_thd_scheduler`: A service for plugins to select a thread scheduler.
- `thd_alloc`: A memory-allocation service.
- `thd_wait`: A service for plugins to report when they are going to sleep or stall.

The remainder of this section describes how a plugin uses server functionality that is available as a service. See also the source for the “daemon” example plugin, which uses the `my_snprintf` service. Within a MySQL source distribution, that plugin is located in the `plugin/daemon_example` directory.

To use a service or services from within a plugin, the plugin source file must include the `plugin.h` header file to access service-related information:

```
#include <mysql/plugin.h>
```

This does not represent any additional setup cost. A plugin must include that file anyway because it contains definitions and structures that every plugin needs.

To access a service, a plugin calls service functions like any other function. For example, to format a string into a buffer for printing, call the `my_snprintf()` function provided by the service of the same name:

```
char buffer[BUFFER_SIZE];

my_snprintf(buffer, sizeof(buffer), format_string, argument_to_format, ...);
```

When you build your plugin, use the `-lmysqlservices` flag at link time to link in the `libmysqlservices` library. For example, for `CMake`, put this in the top-level `CMakeLists.txt` file:

```
FIND_LIBRARY(MYSQLSERVICES_LIB mysqlservices
 PATHS "${MYSQL_SRCDIR}/libservices" NO_DEFAULT_PATH)
```

Put this in the `CMakeLists.txt` file in the directory containing the plugin source:

```
# the plugin needs the mysql services library for error logging
TARGET_LINK_LIBRARIES (your_plugin_library_name ${MYSQLSERVICES_LIB})
```

24.4 Adding New Functions to MySQL

There are three ways to add new functions to MySQL:

- You can add functions through the user-defined function (UDF) interface. User-defined functions are compiled as library files and then added to and removed from the server dynamically using the `CREATE FUNCTION` and `DROP FUNCTION` statements. See Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”.
- You can add functions as native (built-in) MySQL functions. Native functions are compiled into the `mysqld` server and become available on a permanent basis.
- Another way to add functions is by creating stored functions. These are written using SQL statements rather than by compiling object code. The syntax for writing stored functions is not covered here. See Section 20.2, “Using Stored Routines (Procedures and Functions)”.

Each method of creating compiled functions has advantages and disadvantages:

- If you write user-defined functions, you must install object files in addition to the server itself. If you compile your function into the server, you need not do that.
- Native functions require you to modify a source distribution. UDFs do not. You can add UDFs to a binary MySQL distribution. No access to MySQL source is necessary.
- If you upgrade your MySQL distribution, you can continue to use your previously installed UDFs, unless you upgrade to a newer version for which the UDF interface changes. For native functions, you must repeat your modifications each time you upgrade.

Whichever method you use to add new functions, they can be invoked in SQL statements just like native functions such as `ABS()` or `SOUNDEX()`.

See Section 9.2.4, “Function Name Parsing and Resolution”, for the rules describing how the server interprets references to different kinds of functions.

The following sections describe features of the UDF interface, provide instructions for writing UDFs, discuss security precautions that MySQL takes to prevent UDF misuse, and describe how to add native MySQL functions.

For example source code that illustrates how to write UDFs, take a look at the `sql/udf_example.c` file that is provided in MySQL source distributions.

24.4.1 Features of the User-Defined Function Interface

The MySQL interface for user-defined functions provides the following features and capabilities:

- Functions can return string, integer, or real values and can accept arguments of those same types.
- You can define simple functions that operate on a single row at a time, or aggregate functions that operate on groups of rows.
- Information is provided to functions that enables them to check the number, types, and names of the arguments passed to them.
- You can tell MySQL to coerce arguments to a given type before passing them to a function.
- You can indicate that a function returns `NULL` or that an error occurred.

24.4.2 Adding a New User-Defined Function

For the UDF mechanism to work, functions must be written in C or C++ and your operating system must support dynamic loading. MySQL source distributions include a file `sql/udf_example.c` that defines five UDF functions. Consult this file to see how UDF calling conventions work. The `include/mysql_com.h` header file defines UDF-related symbols and data structures, although you need not include this header file directly; it is included by `mysql.h`.

A UDF contains code that becomes part of the running server, so when you write a UDF, you are bound by any and all constraints that apply to writing server code. For example, you may have problems if you attempt to use functions from the `libstdc++` library. These constraints may change in future versions of the server, so it is possible that server upgrades will require revisions to UDFs that were originally written for older servers. For information about these constraints, see Section 2.9.4, “MySQL Source-Configuration Options”, and Section 2.9.5, “Dealing with Problems Compiling MySQL”.

To be able to use UDFs, you must link `mysqld` dynamically. If you want to use a UDF that needs to access symbols from `mysqld` (for example, the `metaphone` function in `sql/udf_example.c` uses `default_charset_info`), you must link the program with `-rdynamic` (see `man dlopen`).

For each function that you want to use in SQL statements, you should define corresponding C (or C++) functions. In the following discussion, the name “xxx” is used for an example function name. To distinguish between SQL and C/C++ usage, `XXX()` (uppercase) indicates an SQL function call, and `xxx()` (lowercase) indicates a C/C++ function call.

Note

When using C++ you can encapsulate your C functions within:

```
extern "C" { ... }
```

This ensures that your C++ function names remain readable in the completed UDF.

The following list describes the C/C++ functions that you write to implement the interface for a function named `XXX()`. The main function, `xxx()`, is required. In addition, a UDF requires at least one of the other functions described here, for reasons discussed in Section 24.4.2.6, “UDF Security Precautions”.

- `xxx()`

  The main function. This is where the function result is computed. The correspondence between the SQL function data type and the return type of your C/C++ function is shown here.

SQL Type	C/C++ Type
`STRING`	`char *`
`INTEGER`	`long long`
`REAL`	`double`

It is also possible to declare a `DECIMAL` function, but currently the value is returned as a string, so you should write the UDF as though it were a `STRING` function. `ROW` functions are not implemented.

- `xxx_init()`

  The initialization function for `xxx()`. If present, it can be used for the following purposes:

  - To check the number of arguments to `XXX()`.
  - To verify that the arguments are of a required type or, alternatively, to tell MySQL to coerce arguments to the required types when the main function is called.
  - To allocate any memory required by the main function.
  - To specify the maximum length of the result.
  - To specify (for `REAL` functions) the maximum number of decimal places in the result.
  - To specify whether the result can be `NULL`.

- `xxx_deinit()`

  The deinitialization function for `xxx()`. If present, it should deallocate any memory allocated by the initialization function.

When an SQL statement invokes `XXX()`, MySQL calls the initialization function `xxx_init()` to let it perform any required setup, such as argument checking or memory allocation. If `xxx_init()` returns an error, MySQL aborts the SQL statement with an error message and does not call the main or deinitialization functions. Otherwise, MySQL calls the main function `xxx()` once for each row. After all rows have been processed, MySQL calls the deinitialization function `xxx_deinit()` so that it can perform any required cleanup.

For aggregate functions that work like `SUM()`, you must also provide the following functions:

- `xxx_clear()`

  Reset the current aggregate value but do not insert the argument as the initial aggregate value for a new group.

- `xxx_add()`

  Add the argument to the current aggregate value.

MySQL handles aggregate UDFs as follows:

1. Call `xxx_init()` to let the aggregate function allocate any memory it needs for storing results.
2. Sort the table according to the `GROUP BY` expression.
3. Call `xxx_clear()` for the first row in each new group.
4. Call `xxx_add()` for each row that belongs in the same group.
5. Call `xxx()` to get the result for the aggregate when the group changes or after the last row has been processed.

6. Repeat steps 3 to 5 until all rows has been processed

7. Call `xxx_deinit()` to let the UDF free any memory it has allocated.

All functions must be thread-safe. This includes not just the main function, but the initialization and deinitialization functions as well, and also the additional functions required by aggregate functions. A consequence of this requirement is that you are not permitted to allocate any global or static variables that change! If you need memory, you should allocate it in `xxx_init()` and free it in `xxx_deinit()`.

24.4.2.1 UDF Calling Sequences for Simple Functions

This section describes the different functions that you need to define when you create a simple UDF. Section 24.4.2, “Adding a New User-Defined Function”, describes the order in which MySQL calls these functions.

The main `xxx()` function should be declared as shown in this section. Note that the return type and parameters differ, depending on whether you declare the SQL function `XXX()` to return `STRING`, `INTEGER`, or `REAL` in the `CREATE FUNCTION` statement:

For `STRING` functions:

```
char *xxx(UDF_INIT *initid, UDF_ARGS *args,
          char *result, unsigned long *length,
          char *is_null, char *error);
```

For `INTEGER` functions:

```
long long xxx(UDF_INIT *initid, UDF_ARGS *args,
              char *is_null, char *error);
```

For `REAL` functions:

```
double xxx(UDF_INIT *initid, UDF_ARGS *args,
              char *is_null, char *error);
```

`DECIMAL` functions return string values and should be declared the same way as `STRING` functions. `ROW` functions are not implemented.

The initialization and deinitialization functions are declared like this:

```
my_bool xxx_init(UDF_INIT *initid, UDF_ARGS *args, char *message);

void xxx_deinit(UDF_INIT *initid);
```

The `initid` parameter is passed to all three functions. It points to a `UDF_INIT` structure that is used to communicate information between functions. The `UDF_INIT` structure members follow. The initialization function should fill in any members that it wishes to change. (To use the default for a member, leave it unchanged.)

- `my_bool maybe_null`

  `xxx_init()` should set `maybe_null` to `1` if `xxx()` can return `NULL`. The default value is `1` if any of the arguments are declared `maybe_null`.

- `unsigned int decimals`

  The number of decimal digits to the right of the decimal point. The default value is the maximum number of decimal digits in the arguments passed to the main function. For example, if the function is passed `1.34`, `1.345`, and `1.3`, the default would be 3, because `1.345` has 3 decimal digits.

For arguments that have no fixed number of decimals, the `decimals` value is set to 31, which is 1 more than the maximum number of decimals permitted for the `DECIMAL`, `FLOAT`, and `DOUBLE` data types. As of MySQL 5.5.3, this value is available as the constant `NOT_FIXED_DEC` in the `mysql_com.h` header file.

A `decimals` value of 31 is used for arguments in cases such as a `FLOAT` or `DOUBLE` column declared without an explicit number of decimals (for example, `FLOAT` rather than `FLOAT(10,3)`) and for floating-point constants such as `1345E-3`. It is also used for string and other nonnumber arguments that might be converted within the function to numeric form.

The value to which the `decimals` member is initialized is only a default. It can be changed within the function to reflect the actual calculation performed. The default is determined such that the largest number of decimals of the arguments is used. If the number of decimals is `NOT_FIXED_DEC` for even one of the arguments, that is the value used for `decimals`.

- `unsigned int max_length`

  The maximum length of the result. The default `max_length` value differs depending on the result type of the function. For string functions, the default is the length of the longest argument. For integer functions, the default is 21 digits. For real functions, the default is 13 plus the number of decimal digits indicated by `initid->decimals`. (For numeric functions, the length includes any sign or decimal point characters.)

  If you want to return a blob value, you can set `max_length` to 65KB or 16MB. This memory is not allocated, but the value is used to decide which data type to use if there is a need to temporarily store the data.

- `char *ptr`

  A pointer that the function can use for its own purposes. For example, functions can use `initid->ptr` to communicate allocated memory among themselves. `xxx_init()` should allocate the memory and assign it to this pointer:

  ```
  initid->ptr = allocated_memory;
  ```

  In `xxx()` and `xxx_deinit()`, refer to `initid->ptr` to use or deallocate the memory.

- `my_bool const_item`

  `xxx_init()` should set `const_item` to `1` if `xxx()` always returns the same value and to `0` otherwise.

24.4.2.2 UDF Calling Sequences for Aggregate Functions

This section describes the different functions that you need to define when you create an aggregate UDF. Section 24.4.2, “Adding a New User-Defined Function”, describes the order in which MySQL calls these functions.

- `xxx_reset()`

  This function is called when MySQL finds the first row in a new group. It should reset any internal summary variables and then use the given `UDF_ARGS` argument as the first value in your internal summary value for the group. Declare `xxx_reset()` as follows:

  ```
  void xxx_reset(UDF_INIT *initid, UDF_ARGS *args,
                 char *is_null, char *error);
  ```

  `xxx_reset()` is not needed or used in MySQL 5.5, in which the UDF interface uses `xxx_clear()` instead. However, you can define both `xxx_reset()` and `xxx_clear()` if you want to have your

UDF work with older versions of the server. (If you do include both functions, the `xxx_reset()` function in many cases can be implemented internally by calling `xxx_clear()` to reset all variables, and then calling `xxx_add()` to add the `UDF_ARGS` argument as the first value in the group.)

- `xxx_clear()`

  This function is called when MySQL needs to reset the summary results. It is called at the beginning for each new group but can also be called to reset the values for a query where there were no matching rows. Declare `xxx_clear()` as follows:

```
void xxx_clear(UDF_INIT *initid, char *is_null, char *error);
```

  `is_null` is set to point to `CHAR(0)` before calling `xxx_clear()`.

  If something went wrong, you can store a value in the variable to which the `error` argument points. `error` points to a single-byte variable, not to a string buffer.

  `xxx_clear()` is required by MySQL 5.5.

- `xxx_add()`

  This function is called for all rows that belong to the same group. You should use it to add the value in the `UDF_ARGS` argument to your internal summary variable.

```
void xxx_add(UDF_INIT *initid, UDF_ARGS *args,
             char *is_null, char *error);
```

The `xxx()` function for an aggregate UDF should be declared the same way as for a nonaggregate UDF. See Section 24.4.2.1, “UDF Calling Sequences for Simple Functions”.

For an aggregate UDF, MySQL calls the `xxx()` function after all rows in the group have been processed. You should normally never access its `UDF_ARGS` argument here but instead return a value based on your internal summary variables.

Return value handling in `xxx()` should be done the same way as for a nonaggregate UDF. See Section 24.4.2.4, “UDF Return Values and Error Handling”.

The `xxx_reset()` and `xxx_add()` functions handle their `UDF_ARGS` argument the same way as functions for nonaggregate UDFs. See Section 24.4.2.3, “UDF Argument Processing”.

The pointer arguments to `is_null` and `error` are the same for all calls to `xxx_reset()`, `xxx_clear()`, `xxx_add()` and `xxx()`. You can use this to remember that you got an error or whether the `xxx()` function should return `NULL`. You should not store a string into `*error`! `error` points to a single-byte variable, not to a string buffer.

`*is_null` is reset for each group (before calling `xxx_clear()`). `*error` is never reset.

If `*is_null` or `*error` are set when `xxx()` returns, MySQL returns `NULL` as the result for the group function.

24.4.2.3 UDF Argument Processing

The `args` parameter points to a `UDF_ARGS` structure that has the members listed here:

- `unsigned int arg_count`

  The number of arguments. Check this value in the initialization function if you require your function to be called with a particular number of arguments. For example:

```
if (args->arg_count != 2)
```

```
{
    strcpy(message,"XXX() requires two arguments");
    return 1;
}
```

For other `UDF_ARGS` member values that are arrays, array references are zero-based. That is, refer to array members using index values from 0 to `args->arg_count` − 1.

- `enum Item_result *arg_type`

  A pointer to an array containing the types for each argument. The possible type values are `STRING_RESULT`, `INT_RESULT`, `REAL_RESULT`, and `DECIMAL_RESULT`.

  To make sure that arguments are of a given type and return an error if they are not, check the `arg_type` array in the initialization function. For example:

```
if (args->arg_type[0] != STRING_RESULT ||
    args->arg_type[1] != INT_RESULT)
{
    strcpy(message,"XXX() requires a string and an integer");
    return 1;
}
```

  Arguments of type `DECIMAL_RESULT` are passed as strings, so you should handle them the same way as `STRING_RESULT` values.

  As an alternative to requiring your function's arguments to be of particular types, you can use the initialization function to set the `arg_type` elements to the types you want. This causes MySQL to coerce arguments to those types for each call to `xxx()`. For example, to specify that the first two arguments should be coerced to string and integer, respectively, do this in `xxx_init()`:

```
args->arg_type[0] = STRING_RESULT;
args->arg_type[1] = INT_RESULT;
```

  Exact-value decimal arguments such as `1.3` or `DECIMAL` column values are passed with a type of `DECIMAL_RESULT`. However, the values are passed as strings. If you want to receive a number, use the initialization function to specify that the argument should be coerced to a `REAL_RESULT` value:

```
args->arg_type[2] = REAL_RESULT;
```

- `char **args`

  `args->args` communicates information to the initialization function about the general nature of the arguments passed to your function. For a constant argument `i`, `args->args[i]` points to the argument value. (See later for instructions on how to access the value properly.) For a nonconstant argument, `args->args[i]` is `0`. A constant argument is an expression that uses only constants, such as `3` or `4*7-2` or `SIN(3.14)`. A nonconstant argument is an expression that refers to values that may change from row to row, such as column names or functions that are called with nonconstant arguments.

  For each invocation of the main function, `args->args` contains the actual arguments that are passed for the row currently being processed.

  If argument `i` represents `NULL`, `args->args[i]` is a null pointer (0). If the argument is not `NULL`, functions can refer to it as follows:

  - An argument of type `STRING_RESULT` is given as a string pointer plus a length, to enable handling of binary data or data of arbitrary length. The string contents are available as `args->args[i]` and the string length is `args->lengths[i]`. Do not assume that the string is null-terminated.
  - For an argument of type `INT_RESULT`, you must cast `args->args[i]` to a `long long` value:

```
long long int_val;
int_val = *((long long*) args->args[i]);
```

- For an argument of type `REAL_RESULT`, you must cast `args->args[i]` to a `double` value:

```
double    real_val;
real_val = *((double*) args->args[i]);
```

- For an argument of type `DECIMAL_RESULT`, the value is passed as a string and should be handled like a `STRING_RESULT` value.
- `ROW_RESULT` arguments are not implemented.

- `unsigned long *lengths`

  For the initialization function, the `lengths` array indicates the maximum string length for each argument. You should not change these. For each invocation of the main function, `lengths` contains the actual lengths of any string arguments that are passed for the row currently being processed. For arguments of types `INT_RESULT` or `REAL_RESULT`, `lengths` still contains the maximum length of the argument (as for the initialization function).

- `char *maybe_null`

  For the initialization function, the `maybe_null` array indicates for each argument whether the argument value might be null (0 if no, 1 if yes).

- `char **attributes`

  `args->attributes` communicates information about the names of the UDF arguments. For argument `i`, the attribute name is available as a string in `args->attributes[i]` and the attribute length is `args->attribute_lengths[i]`. Do not assume that the string is null-terminated.

  By default, the name of a UDF argument is the text of the expression used to specify the argument. For UDFs, an argument may also have an optional `[AS] alias_name` clause, in which case the argument name is *`alias_name`*. The `attributes` value for each argument thus depends on whether an alias was given.

  Suppose that a UDF `my_udf()` is invoked as follows:

```
SELECT my_udf(expr1, expr2 AS alias1, expr3 alias2);
```

  In this case, the `attributes` and `attribute_lengths` arrays will have these values:

```
args->attributes[0] = "expr1"
args->attribute_lengths[0] = 5

args->attributes[1] = "alias1"
args->attribute_lengths[1] = 6

args->attributes[2] = "alias2"
args->attribute_lengths[2] = 6
```

- `unsigned long *attribute_lengths`

  The `attribute_lengths` array indicates the length of each argument name.

24.4.2.4 UDF Return Values and Error Handling

The initialization function should return `0` if no error occurred and `1` otherwise. If an error occurs, `xxx_init()` should store a null-terminated error message in the `message` parameter. The message

is returned to the client. The message buffer is `MYSQL_ERRMSG_SIZE` characters long, but you should try to keep the message to less than 80 characters so that it fits the width of a standard terminal screen.

The return value of the main function `xxx()` is the function value, for `long long` and `double` functions. A string function should return a pointer to the result and set `*length` to the length (in bytes) of the return value. For example:

```
memcpy(result, "result string", 13);
*length = 13;
```

MySQL passes a buffer to the `xxx()` function using the `result` parameter. This buffer is sufficiently long to hold 255 characters, which can be multibyte characters. The `xxx()` function can store the result in this buffer if it fits, in which case the return value should be a pointer to the buffer. If the function stores the result in a different buffer, it should return a pointer to that buffer.

If your string function does not use the supplied buffer (for example, if it needs to return a string longer than 255 characters), you must allocate the space for your own buffer with `malloc()` in your `xxx_init()` function or your `xxx()` function and free it in your `xxx_deinit()` function. You can store the allocated memory in the `ptr` slot in the `UDF_INIT` structure for reuse by future `xxx()` calls. See Section 24.4.2.1, “UDF Calling Sequences for Simple Functions”.

To indicate a return value of `NULL` in the main function, set `*is_null` to `1`:

```
*is_null = 1;
```

To indicate an error return in the main function, set `*error` to `1`:

```
*error = 1;
```

If `xxx()` sets `*error` to `1` for any row, the function value is `NULL` for the current row and for any subsequent rows processed by the statement in which `XXX()` was invoked. (`xxx()` is not even called for subsequent rows.)

24.4.2.5 UDF Compiling and Installing

Files implementing UDFs must be compiled and installed on the host where the server runs. This process is described below for the example UDF file `sql/udf_example.c` that is included in MySQL source distributions.

If a UDF will be referred to in statements that will be replicated to slave servers, you must ensure that every slave also has the function available. Otherwise, replication will fail on the slaves when they attempt to invoke the function.

The immediately following instructions are for Unix. Instructions for Windows are given later in this section.

The `udf_example.c` file contains the following functions:

- `metaphon()` returns a metaphon string of the string argument. This is something like a soundex string, but it is more tuned for English.
- `myfunc_double()` returns the sum of the ASCII values of the characters in its arguments, divided by the sum of the length of its arguments.
- `myfunc_int()` returns the sum of the length of its arguments.
- `sequence([const int])` returns a sequence starting from the given number or 1 if no number has been given.

- `lookup()` returns the IP address for a host name.
- `reverse_lookup()` returns the host name for an IP address. The function may be called either with a single string argument of the form `'xxx.xxx.xxx.xxx'` or with four numbers.
- `avgcost()` returns an average cost. This is an aggregate function.

A dynamically loadable file should be compiled as a sharable library file, using a command something like this:

```
shell> gcc -shared -o udf_example.so udf_example.c
```

If you are using `gcc` with `CMake` (which is how MySQL is configured), you should be able to create `udf_example.so` with a simpler command:

```
shell> make udf_example
```

After you compile a shared object containing UDFs, you must install it and tell MySQL about it. Compiling a shared object from `udf_example.c` using `gcc` directly produces a file named `udf_example.so`. Copy the shared object to the server's plugin directory and name it `udf_example.so`. This directory is given by the value of the `plugin_dir` system variable.

On some systems, the `ldconfig` program that configures the dynamic linker does not recognize a shared object unless its name begins with `lib`. In this case you should rename a file such as `udf_example.so` to `libudf_example.so`.

On Windows, you can compile user-defined functions by using the following procedure:

1. Obtain a MySQL source distribution. See Section 2.1.2, “How to Get MySQL”.
2. Obtain the `CMake` build utility, if necessary, from http://www.cmake.org. (Version 2.6 or later is required).
3. In the source tree, look in the `sql` directory. There are files named `udf_example.def` `udf_example.c` there. Copy both files from this directory to your working directory.
4. Create a `CMake makefile` (`CMakeLists.txt`) with these contents:

   ```
   PROJECT(udf_example)

   # Path for MySQL include directory
   INCLUDE_DIRECTORIES("c:/mysql/include")

   ADD_DEFINITIONS("-DHAVE_DLOPEN")
   ADD_LIBRARY(udf_example MODULE udf_example.c udf_example.def)
   TARGET_LINK_LIBRARIES(udf_example wsock32)
   ```

5. Create the VC project and solution files:

   ```
   cmake -G "<Generator>"
   ```

   Invoking `cmake --help` shows you a list of valid Generators.

6. Create `udf_example.dll`:

   ```
   devenv udf_example.sln /build Release
   ```

After the shared library file has been installed, notify `mysqld` about the new functions with the following statements. If library files have a suffix different from `.so` on your system, substitute the correct suffix throughout (for example, `.dll` on Windows).

```
mysql> CREATE FUNCTION metaphon RETURNS STRING SONAME 'udf_example.so';
mysql> CREATE FUNCTION myfunc_double RETURNS REAL SONAME 'udf_example.so';
mysql> CREATE FUNCTION myfunc_int RETURNS INTEGER SONAME 'udf_example.so';
mysql> CREATE FUNCTION sequence RETURNS INTEGER SONAME 'udf_example.so';
mysql> CREATE FUNCTION lookup RETURNS STRING SONAME 'udf_example.so';
mysql> CREATE FUNCTION reverse_lookup
    ->        RETURNS STRING SONAME 'udf_example.so';
mysql> CREATE AGGREGATE FUNCTION avgcost
    ->        RETURNS REAL SONAME 'udf_example.so';
```

Once installed, a function remains installed until it is uninstalled.

To delete functions, use `DROP FUNCTION`:

```
mysql> DROP FUNCTION metaphon;
mysql> DROP FUNCTION myfunc_double;
mysql> DROP FUNCTION myfunc_int;
mysql> DROP FUNCTION sequence;
mysql> DROP FUNCTION lookup;
mysql> DROP FUNCTION reverse_lookup;
mysql> DROP FUNCTION avgcost;
```

The `CREATE FUNCTION` and `DROP FUNCTION` statements update the `func` system table in the `mysql` database. The function's name, type and shared library name are saved in the table. You must have the `INSERT` or `DELETE` privilege for the `mysql` database to create or drop functions, respectively.

You should not use `CREATE FUNCTION` to add a function that has previously been created. If you need to reinstall a function, you should remove it with `DROP FUNCTION` and then reinstall it with `CREATE FUNCTION`. You would need to do this, for example, if you recompile a new version of your function, so that `mysqld` gets the new version. Otherwise, the server continues to use the old version.

An active function is one that has been loaded with `CREATE FUNCTION` and not removed with `DROP FUNCTION`. All active functions are reloaded each time the server starts, unless you start `mysqld` with the `--skip-grant-tables` option. In this case, UDF initialization is skipped and UDFs are unavailable.

24.4.2.6 UDF Security Precautions

MySQL takes several measures to prevent misuse of user-defined functions.

UDF library files cannot be placed in arbitrary directories. They must be located in the server's plugin directory. This directory is given by the value of the `plugin_dir` system variable.

To use `CREATE FUNCTION` or `DROP FUNCTION`, you must have the `INSERT` or `DELETE` privilege, respectively, for the `mysql` database. This is necessary because those statements add and delete rows from the `mysql.func` table.

UDFs should have at least one symbol defined in addition to the `xxx` symbol that corresponds to the main `xxx()` function. These auxiliary symbols correspond to the `xxx_init()`, `xxx_deinit()`, `xxx_reset()`, `xxx_clear()`, and `xxx_add()` functions. `mysqld` also supports an `--allow-suspicious-udfs` option that controls whether UDFs that have only an `xxx` symbol can be loaded. By default, the option is off, to prevent attempts at loading functions from shared library files other than those containing legitimate UDFs. If you have older UDFs that contain only the `xxx` symbol and that cannot be recompiled to include an auxiliary symbol, it may be necessary to specify the `--allow-suspicious-udfs` option. Otherwise, you should avoid enabling this capability.

24.4.3 Adding a New Native Function

To add a new native MySQL function, use the procedure described here, which requires that you use a source distribution. You cannot add native functions to a binary distribution because it is necessary

to modify MySQL source code and compile MySQL from the modified source. If you migrate to another version of MySQL (for example, when a new version is released), you must repeat the procedure with the new version.

If the new native function will be referred to in statements that will be replicated to slave servers, you must ensure that every slave server also has the function available. Otherwise, replication will fail on the slaves when they attempt to invoke the function.

To add a new native function, follow these steps to modify source files in the `sql` directory:

1. Create a subclass for the function in `item_create.cc`:

   - If the function takes a fixed number of arguments, create a subclass of `Create_func_arg0`, `Create_func_arg1`, `Create_func_arg2`, or `Create_func_arg3`, respectively, depending on whether the function takes zero, one, two, or three arguments. For examples, see the `Create_func_uuid`, `Create_func_abs`, `Create_func_pow`, and `Create_func_lpad` classes.

   - If the function takes a variable number of arguments, create a subclass of `Create_native_func`. For an example, see `Create_func_concat`.

2. To provide a name by which the function can be referred to in SQL statements, register the name in `item_create.cc` by adding a line to this array:

   ```
   static Native_func_registry func_array[]
   ```

   You can register several names for the same function. For example, see the lines for `"LCASE"` and `"LOWER"`, which are aliases for `Create_func_lcase`.

3. In `item_func.h`, declare a class inheriting from `Item_num_func` or `Item_str_func`, depending on whether your function returns a number or a string.

4. In `item_func.cc`, add one of the following declarations, depending on whether you are defining a numeric or string function:

   ```
   double   Item_func_newname::val()
   longlong Item_func_newname::val_int()
   String  *Item_func_newname::Str(String *str)
   ```

   If you inherit your object from any of the standard items (like `Item_num_func`), you probably only have to define one of these functions and let the parent object take care of the other functions. For example, the `Item_str_func` class defines a `val()` function that executes `atof()` on the value returned by `::str()`.

5. If the function is nondeterministic, include the following statement in the item constructor to indicate that function results should not be cached:

   ```
   current_thd->lex->safe_to_cache_query=0;
   ```

   A function is nondeterministic if, given fixed values for its arguments, it can return different results for different invocations.

6. You should probably also define the following object function:

   ```
   void Item_func_newname::fix_length_and_dec()
   ```

   This function should at least calculate `max_length` based on the given arguments. `max_length` is the maximum number of characters the function may return. This function should also set `maybe_null = 0` if the main function cannot return a `NULL` value. The function can check whether

any of the function arguments can return `NULL` by checking the arguments' `maybe_null` variable. Look at `Item_func_mod::fix_length_and_dec` for a typical example of how to do this.

All functions must be thread-safe. In other words, do not use any global or static variables in the functions without protecting them with mutexes.

If you want to return `NULL` from `::val()`, `::val_int()`, or `::str()`, you should set `null_value` to 1 and return 0.

For `::str()` object functions, there are additional considerations to be aware of:

- The `String *str` argument provides a string buffer that may be used to hold the result. (For more information about the `String` type, take a look at the `sql_string.h` file.)
- The `::str()` function should return the string that holds the result, or `(char*) 0` if the result is `NULL`.
- All current string functions try to avoid allocating any memory unless absolutely necessary!

24.5 Debugging and Porting MySQL

This section helps you port MySQL to other operating systems. Do check the list of currently supported operating systems first. See http://www.mysql.com/support/supportedplatforms/database.html. If you have created a new port of MySQL, please let us know so that we can list it here and on our Web site (http://www.mysql.com/), recommending it to other users.

Note

If you create a new port of MySQL, you are free to copy and distribute it under the GPL license, but it does not make you a copyright holder of MySQL.

A working POSIX thread library is needed for the server.

To build MySQL from source, your system must satisfy the tool requirements listed at Section 2.9, “Installing MySQL from Source”.

Important

If you are trying to build MySQL 5.5 with `icc` on the IA64 platform, and need support for NDB Cluster, you should first ensure that you are using `icc` version 9.1.043 or later. (For details, see Bug #21875.)

If you run into problems with a new port, you may have to do some debugging of MySQL! See Section 24.5.1, “Debugging a MySQL Server”.

Note

Before you start debugging `mysqld`, first get the test programs `mysys/thr_alarm` and `mysys/thr_lock` to work. This ensures that your thread installation has even a remote chance to work!

24.5.1 Debugging a MySQL Server

If you are using some functionality that is very new in MySQL, you can try to run `mysqld` with the `--skip-new` (which disables all new, potentially unsafe functionality). See Section B.5.3.3, “What to Do If MySQL Keeps Crashing”.

If `mysqld` does not want to start, verify that you have no `my.cnf` files that interfere with your setup! You can check your `my.cnf` arguments with `mysqld --print-defaults` and avoid using them by starting with `mysqld --no-defaults ...`.

If `mysqld` starts to eat up CPU or memory or if it "hangs," you can use `mysqladmin processlist status` to find out if someone is executing a query that takes a long time. It may be a good idea to run `mysqladmin -i10 processlist status` in some window if you are experiencing performance problems or problems when new clients cannot connect.

The command `mysqladmin debug` dumps some information about locks in use, used memory and query usage to the MySQL log file. This may help solve some problems. This command also provides some useful information even if you have not compiled MySQL for debugging!

If the problem is that some tables are getting slower and slower you should try to optimize the table with `OPTIMIZE TABLE` or `myisamchk`. See Chapter 5, *MySQL Server Administration*. You should also check the slow queries with `EXPLAIN`.

You should also read the OS-specific section in this manual for problems that may be unique to your environment. See Section 2.1, "General Installation Guidance".

24.5.1.1 Compiling MySQL for Debugging

If you have some very specific problem, you can always try to debug MySQL. To do this you must configure MySQL with the `-DWITH_DEBUG=1` option. You can check whether MySQL was compiled with debugging by doing: `mysqld --help`. If the `--debug` flag is listed with the options then you have debugging enabled. `mysqladmin ver` also lists the `mysqld` version as `mysql ... --debug` in this case.

If `mysqld` stops crashing when you configure it with the `-DWITH_DEBUG=1` CMake option, you probably have found a compiler bug or a timing bug within MySQL. In this case, you can try to add `-g` using the `CMAKE_C_FLAGS` and `CMAKE_CXX_FLAGS` CMake options and not use `-DWITH_DEBUG=1`. If `mysqld` dies, you can at least attach to it with `gdb` or use `gdb` on the core file to find out what happened.

When you configure MySQL for debugging you automatically enable a lot of extra safety check functions that monitor the health of `mysqld`. If they find something "unexpected," an entry is written to `stderr`, which `mysqld_safe` directs to the error log! This also means that if you are having some unexpected problems with MySQL and are using a source distribution, the first thing you should do is to configure MySQL for debugging! (The second thing is to send mail to a MySQL mailing list and ask for help. See Section 1.5.2, "MySQL Mailing Lists". If you believe that you have found a bug, please use the instructions at Section 1.6, "How to Report Bugs or Problems".

In the Windows MySQL distribution, `mysqld.exe` is by default compiled with support for trace files.

24.5.1.2 Creating Trace Files

If the `mysqld` server does not start or it crashes easily, you can try to create a trace file to find the problem.

To do this, you must have a `mysqld` that has been compiled with debugging support. You can check this by executing `mysqld -V`. If the version number ends with `-debug`, it is compiled with support for trace files. (On Windows, the debugging server is named `mysqld-debug` rather than `mysqld`.)

Start the `mysqld` server with a trace log in `/tmp/mysqld.trace` on Unix or `\mysqld.trace` on Windows:

```
shell> mysqld --debug
```

On Windows, you should also use the `--standalone` flag to not start `mysqld` as a service. In a console window, use this command:

```
C:\> mysqld-debug --debug --standalone
```

After this, you can use the `mysql.exe` command-line tool in a second console window to reproduce the problem. You can stop the `mysqld` server with `mysqladmin shutdown`.

The trace file can become **very large**! To generate a smaller trace file, you can use debugging options something like this:

```
mysqld --debug=d,info,error,query,general,where:O,/tmp/mysqld.trace
```

This only prints information with the most interesting tags to the trace file.

If you make a bug report about this, please only send the lines from the trace file to the appropriate mailing list where something seems to go wrong! If you cannot locate the wrong place, you can open a bug report and upload the trace file to the report, so that a MySQL developer can take a look at it. For instructions, see Section 1.6, “How to Report Bugs or Problems”.

The trace file is made with the **DBUG** package by Fred Fish. See Section 24.5.3, “The DBUG Package”.

24.5.1.3 Using WER with PDB to create a Windows crashdump

Program Database (PDB) files (with file name suffix `pdb`) are included in ZIP Archive distributions (but not MSI distributions) of MySQL. These files provide information for debugging your MySQL installation in the event of a problem.

Note

As of MySQL 5.7.6, the PDB files are available in a separate file labeled "ZIP Archive Debug Binaries & Test Suite".

The PDB file contains more detailed information about `mysqld` and other tools that enables more detailed trace and dump files to be created. You can use these with `WinDbg` or Visual Studio to debug `mysqld`.

Note

The older *Dr. Watson* debugging tool was removed in Microsoft Vista, with `WinDbg` being a common alternative. Both methods are documented here.

For more information on PDB files, see Microsoft Knowledge Base Article 121366. For more information on the debugging options available, see Debugging Tools for Windows.

Using WinDbg

To use WinDbg, either install the full Windows Driver Kit (WDK) or install the standalone version.

Important

The `.exe` and `.pbd` files must be an exact match (both version number and MySQL server edition) or WinDBG will complain while attempting to load the symbols.

1. To generate a minidump `mysqld.dmp`, enable the `core-file` option under the [mysqld] section in `my.ini`. Restart the MySQL server after making these changes.
2. Create a directory to store the generated files, such as `c:\symbols`
3. Determine the path to your `windbg.exe` executable using the Find GUI or from the command line, for example: `dir /s /b windbg.exe` -- a common default is *C:\Program Files\Debugging Tools for Windows (x64)\windbg.exe*
4. Launch `windbg.exe` giving it the paths to `mysqld.exe`, `mysqld.pdb`, `mysqld.dmp`, and the source code. Alternatively, pass in each path from the WinDbg GUI. For example:

```
windbg.exe -i "C:\mysql-5.5.60-winx64\bin\"^
 -z "C:\mysql-5.5.60-winx64\data\mysqld.dmp"^
 -srcpath "E:\ade\mysql_archives\5.5\5.5.60\mysql-5.5.60"^
 -y "C:\mysql-5.5.60-winx64\bin;SRV*c:\symbols*http://msdl.microsoft.com/download/symbols"^
 -v -n -c "!analyze -vvvvv"
```

Note

The `^` character and newline are removed by the Windows command line processor, so be sure the spaces remain intact.

Using Dr. Watson

To generate a crash file using Dr Watson (for Microsoft Vista and below), follow these steps:

1. Start Dr Watson by running `drwtsn32.exe` interactively using the `-i` option:

   ```
   C:\> drwtsn32 -i
   ```

2. Set the **Log File Path** to the directory where you want to store trace files.
3. Make sure **Dump All Thread Contexts** and **Append To Existing Log File**.
4. Uncheck **Dump Symbol Table**, **Visual Notification**, **Sound Notification** and **Create Crash Dump File**.
5. Set the **Number of Instructions** to a suitable value to capture enough calls in the stacktrace. A value of at 25 should be enough.

Note that the file generated can become very large.

24.5.1.4 Debugging mysqld under gdb

On most systems you can also start `mysqld` from `gdb` to get more information if `mysqld` crashes.

With some older `gdb` versions on Linux you must use `run --one-thread` if you want to be able to debug `mysqld` threads. In this case, you can only have one thread active at a time. It is best to upgrade to `gdb` 5.1 because thread debugging works much better with this version!

NPTL threads (the new thread library on Linux) may cause problems while running `mysqld` under `gdb`. Some symptoms are:

- `mysqld` hangs during startup (before it writes `ready for connections`).
- `mysqld` crashes during a `pthread_mutex_lock()` or `pthread_mutex_unlock()` call.

In this case, you should set the following environment variable in the shell before starting `gdb`:

```
LD_ASSUME_KERNEL=2.4.1
export LD_ASSUME_KERNEL
```

When running `mysqld` under `gdb`, you should disable the stack trace with `--skip-stack-trace` to be able to catch segfaults within `gdb`.

Use the `--gdb` option to `mysqld` to install an interrupt handler for `SIGINT` (needed to stop `mysqld` with `^C` to set breakpoints) and disable stack tracing and core file handling.

It is very hard to debug MySQL under `gdb` if you do a lot of new connections the whole time as `gdb` does not free the memory for old threads. You can avoid this problem by starting `mysqld` with

`thread_cache_size` set to a value equal to `max_connections` + 1. In most cases just using `--thread_cache_size=5'` helps a lot!

If you want to get a core dump on Linux if `mysqld` dies with a SIGSEGV signal, you can start `mysqld` with the `--core-file` option. This core file can be used to make a backtrace that may help you find out why `mysqld` died:

```
shell> gdb mysqld core
gdb>   backtrace full
gdb>   quit
```

See Section B.5.3.3, “What to Do If MySQL Keeps Crashing”.

If you are using `gdb` 4.17.x or above on Linux, you should install a `.gdb` file, with the following information, in your current directory:

```
set print sevenbit off
handle SIGUSR1 nostop noprint
handle SIGUSR2 nostop noprint
handle SIGWAITING nostop noprint
handle SIGLWP nostop noprint
handle SIGPIPE nostop
handle SIGALRM nostop
handle SIGHUP nostop
handle SIGTERM nostop noprint
```

If you have problems debugging threads with `gdb`, you should download gdb 5.x and try this instead. The new `gdb` version has very improved thread handling!

Here is an example how to debug `mysqld`:

```
shell> gdb /usr/local/libexec/mysqld
gdb> run
...
backtrace full # Do this when mysqld crashes
```

Include the preceding output in a bug report, which you can file using the instructions in Section 1.6, “How to Report Bugs or Problems”.

If `mysqld` hangs, you can try to use some system tools like `strace` or `/usr/proc/bin/pstack` to examine where `mysqld` has hung.

```
strace /tmp/log libexec/mysqld
```

If you are using the Perl `DBI` interface, you can turn on debugging information by using the `trace` method or by setting the `DBI_TRACE` environment variable.

24.5.1.5 Using a Stack Trace

On some operating systems, the error log contains a stack trace if `mysqld` dies unexpectedly. You can use this to find out where (and maybe why) `mysqld` died. See Section 5.4.2, “The Error Log”. To get a stack trace, you must not compile `mysqld` with the `-fomit-frame-pointer` option to gcc. See Section 24.5.1.1, “Compiling MySQL for Debugging”.

A stack trace in the error log looks something like this:

```
mysqld got signal 11;
Attempting backtrace. You can use the following information
to find out where mysqld died. If you see no messages after
this, something went terribly wrong...
```

```
stack_bottom = 0x41fd0110 thread_stack 0x40000
mysqld(my_print_stacktrace+0x32)[0x9da402]
mysqld(handle_segfault+0x28a)[0x6648e9]
/lib/libpthread.so.0[0x7f1a5af000f0]
/lib/libc.so.6(strcmp+0x2)[0x7f1a5a10f0f2]
mysqld(_Z21check_change_passwordP3THDPKcS2_Pcj+0x7c)[0x7412cb]
mysqld(_ZN16set_var_password5checkEP3THD+0xd0)[0x688354]
mysqld(_Z17sql_set_variablesP3THDP4ListI12set_var_baseE+0x68)[0x688494]
mysqld(_Z21mysql_execute_commandP3THD+0x41a0)[0x67a170]
mysqld(_Z11mysql_parseP3THDPKcjPS2_+0x282)[0x67f0ad]
mysqld(_Z16dispatch_command19enum_server_commandP3THDPcj+0xbb7[0x67fdf8]
mysqld(_Z10do_commandP3THD+0x24d)[0x6811b6]
mysqld(handle_one_connection+0x11c)[0x66e05e]
```

If resolution of function names for the trace fails, the trace contains less information:

```
mysqld got signal 11;
Attempting backtrace. You can use the following information
to find out where mysqld died. If you see no messages after
this, something went terribly wrong...

stack_bottom = 0x41fd0110 thread_stack 0x40000
[0x9da402]
[0x6648e9]
[0x7f1a5af000f0]
[0x7f1a5a10f0f2]
[0x7412cb]
[0x688354]
[0x688494]
[0x67a170]
[0x67f0ad]
[0x67fdf8]
[0x6811b6]
[0x66e05e]
```

In the latter case, you can use the `resolve_stack_dump` utility to determine where `mysqld` died by using the following procedure:

1. Copy the numbers from the stack trace to a file, for example `mysqld.stack`. The numbers should not include the surrounding square brackets:

   ```
   0x9da402
   0x6648e9
   0x7f1a5af000f0
   0x7f1a5a10f0f2
   0x7412cb
   0x688354
   0x688494
   0x67a170
   0x67f0ad
   0x67fdf8
   0x6811b6
   0x66e05e
   ```

2. Make a symbol file for the `mysqld` server:

   ```
   shell> nm -n libexec/mysqld > /tmp/mysqld.sym
   ```

   If `mysqld` is not linked statically, use the following command instead:

   ```
   shell> nm -D -n libexec/mysqld > /tmp/mysqld.sym
   ```

   If you want to decode C++ symbols, use the `--demangle`, if available, to `nm`. If your version of `nm` does not have this option, you will need to use the `c++filt` command after the stack dump has been produced to demangle the C++ names.

3. Execute the following command:

```
shell> resolve_stack_dump -s /tmp/mysqld.sym -n mysqld.stack
```

   If you were not able to include demangled C++ names in your symbol file, process the `resolve_stack_dump` output using `c++filt`:

```
shell> resolve_stack_dump -s /tmp/mysqld.sym -n mysqld.stack | c++filt
```

   This prints out where `mysqld` died. If that does not help you find out why `mysqld` died, you should create a bug report and include the output from the preceding command with the bug report.

   However, in most cases it does not help us to have just a stack trace to find the reason for the problem. To be able to locate the bug or provide a workaround, in most cases we need to know the statement that killed `mysqld` and preferably a test case so that we can repeat the problem! See Section 1.6, “How to Report Bugs or Problems”.

Newer versions of `glibc` stack trace functions also print the address as relative to the object. On `glibc`-based systems (Linux), the trace for a crash within a plugin looks something like:

```
plugin/auth/auth_test_plugin.so(+0x9a6)[0x7ff4d11c29a6]
```

To translate the relative address (`+0x9a6`) into a file name and line number, use this command:

```
shell> addr2line -fie auth_test_plugin.so 0x9a6
auth_test_plugin
mysql-trunk/plugin/auth/test_plugin.c:65
```

The `addr2line` utility is part of the `binutils` package on Linux.

On Solaris, the procedure is similar. The Solaris `printstack()` already prints relative addresses:

```
plugin/auth/auth_test_plugin.so:0x1510
```

To translate, use this command:

```
shell> gaddr2line -fie auth_test_plugin.so 0x1510
mysql-trunk/plugin/auth/test_plugin.c:88
```

Windows already prints the address, function name and line:

```
000007FEF07E10A4 auth_test_plugin.dll!auth_test_plugin()[test_plugin.c:72]
```

24.5.1.6 Using Server Logs to Find Causes of Errors in mysqld

Note that before starting `mysqld` with the general query log enabled, you should check all your tables with `myisamchk`. See Chapter 5, *MySQL Server Administration*.

If `mysqld` dies or hangs, you should start `mysqld` with the general query log enabled. See Section 5.4.3, “The General Query Log”. When `mysqld` dies again, you can examine the end of the log file for the query that killed `mysqld`.

If you use the default general query log file, the log is stored in the database directory as *`host_name`*`.log` In most cases it is the last query in the log file that killed `mysqld`, but if possible you should verify this by restarting `mysqld` and executing the found query from the `mysql` command-line tools. If this works, you should also test all complicated queries that did not complete.

You can also try the command `EXPLAIN` on all `SELECT` statements that takes a long time to ensure that `mysqld` is using indexes properly. See Section 13.8.2, “EXPLAIN Syntax”.

You can find the queries that take a long time to execute by starting `mysqld` with the slow query log enabled. See Section 5.4.5, “The Slow Query Log”.

If you find the text `mysqld restarted` in the error log (normally a file named *`host_name`*`.err`) you probably have found a query that causes `mysqld` to fail. If this happens, you should check all your tables with `myisamchk` (see Chapter 5, *MySQL Server Administration*), and test the queries in the MySQL log files to see whether one fails. If you find such a query, try first upgrading to the newest MySQL version. If this does not help and you cannot find anything in the `mysql` mail archive, you should report the bug to a MySQL mailing list. The mailing lists are described at http://lists.mysql.com/, which also has links to online list archives.

If you have started `mysqld` with `--myisam-recover-options`, MySQL automatically checks and tries to repair `MyISAM` tables if they are marked as 'not closed properly' or 'crashed'. If this happens, MySQL writes an entry in the `hostname.err` file `'Warning: Checking table ...'` which is followed by `Warning: Repairing table` if the table needs to be repaired. If you get a lot of these errors, without `mysqld` having died unexpectedly just before, then something is wrong and needs to be investigated further. See Section 5.1.4, “Server Command Options”.

As of MySQL 5.5.3, when the server detects `MyISAM` table corruption, it writes additional information to the error log, such as the name and line number of the source file, and the list of threads accessing the table. Example: `Got an error from thread_id=1, mi_dynrec.c:368`. This is useful information to include in bug reports.

It is not a good sign if `mysqld` did die unexpectedly, but in this case, you should not investigate the `Checking table...` messages, but instead try to find out why `mysqld` died.

24.5.1.7 Making a Test Case If You Experience Table Corruption

The following procedure applies to `MyISAM` tables. For information about steps to take when encountering `InnoDB` table corruption, see Section 1.6, “How to Report Bugs or Problems”.

If you encounter corrupted `MyISAM` tables or if `mysqld` always fails after some update statements, you can test whether the issue is reproducible by doing the following:

1. Stop the MySQL daemon with `mysqladmin shutdown`.
2. Make a backup of the tables to guard against the very unlikely case that the repair does something bad.
3. Check all tables with `myisamchk -s database/*.MYI`. Repair any corrupted tables with `myisamchk -r database/`*`table`*`.MYI`.
4. Make a second backup of the tables.
5. Remove (or move away) any old log files from the MySQL data directory if you need more space.
6. Start `mysqld` with the binary log enabled. If you want to find a statement that crashes `mysqld`, you should start the server with the general query log enabled as well. See Section 5.4.3, “The General Query Log”, and Section 5.4.4, “The Binary Log”.
7. When you have gotten a crashed table, stop the `mysqld` server.
8. Restore the backup.
9. Restart the `mysqld` server *without* the binary log enabled.
10. Re-execute the statements with `mysqlbinlog binary-log-file | mysql`. The binary log is saved in the MySQL database directory with the name `hostname-bin.`*`NNNNNN`*.
11. If the tables are corrupted again or you can get `mysqld` to die with the above command, you have found a reproducible bug. FTP the tables and the binary log to our bugs database using the

instructions given in Section 1.6, “How to Report Bugs or Problems”. If you are a support customer, you can use the MySQL Customer Support Center (http://www.mysql.com/support/) to alert the MySQL team about the problem and have it fixed as soon as possible.

You can also use the script `mysql_find_rows` to just execute some of the update statements if you want to narrow down the problem.

24.5.2 Debugging a MySQL Client

To be able to debug a MySQL client with the integrated debug package, you should configure MySQL with `-DWITH_DEBUG=1`. See Section 2.9.4, “MySQL Source-Configuration Options”.

Before running a client, you should set the `MYSQL_DEBUG` environment variable:

```
shell> MYSQL_DEBUG=d:t:O,/tmp/client.trace
shell> export MYSQL_DEBUG
```

This causes clients to generate a trace file in `/tmp/client.trace`.

If you have problems with your own client code, you should attempt to connect to the server and run your query using a client that is known to work. Do this by running `mysql` in debugging mode (assuming that you have compiled MySQL with debugging on):

```
shell> mysql --debug=d:t:O,/tmp/client.trace
```

This provides useful information in case you mail a bug report. See Section 1.6, “How to Report Bugs or Problems”.

If your client crashes at some 'legal' looking code, you should check that your `mysql.h` include file matches your MySQL library file. A very common mistake is to use an old `mysql.h` file from an old MySQL installation with new MySQL library.

24.5.3 The DBUG Package

The MySQL server and most MySQL clients are compiled with the DBUG package originally created by Fred Fish. When you have configured MySQL for debugging, this package makes it possible to get a trace file of what the program is doing. See Section 24.5.1.2, “Creating Trace Files”.

This section summarizes the argument values that you can specify in debug options on the command line for MySQL programs that have been built with debugging support. For more information about programming with the DBUG package, see the DBUG manual in the `dbug` directory of MySQL source distributions. It's best to use a recent distribution to get the most updated DBUG manual.

The DBUG package can be used by invoking a program with the `--debug[=`*`debug_options`*`]` or `-#[`*`debug_options`*`]` option. If you specify the `--debug` or `-#` option without a *`debug_options`* value, most MySQL programs use a default value. The server default is `d:t:i:o,/tmp/mysqld.trace` on Unix and `d:t:i:O,\mysqld.trace` on Windows. The effect of this default is:

- `d`: Enable output for all debug macros
- `t`: Trace function calls and exits
- `i`: Add PID to output lines
- `o,/tmp/mysqld.trace`, `O,\mysqld.trace`: Set the debug output file.

Most client programs use a default *`debug_options`* value of `d:t:o,/tmp/`*`program_name`*`.trace`, regardless of platform.

Here are some example debug control strings as they might be specified on a shell command line:

```
--debug=d:t
--debug=d:f,main,subr1:F:L:t,20
--debug=d,input,output,files:n
--debug=d:t:i:O,\\mysqld.trace
```

For `mysqld`, it is also possible to change DBUG settings at runtime by setting the `debug` system variable. This variable has global and session values:

```
mysql> SET GLOBAL debug = 'debug_options';
mysql> SET SESSION debug = 'debug_options';
```

Changes at runtime require the `SUPER` privilege, even for the session value.

The *`debug_options`* value is a sequence of colon-separated fields:

```
field_1:field_2:...:field_N
```

Each field within the value consists of a mandatory flag character, optionally preceded by a `+` or `-` character, and optionally followed by a comma-delimited list of modifiers:

```
[+|-]flag[,modifier,modifier,...,modifier]
```

The following table describes the permitted flag characters. Unrecognized flag characters are silently ignored.

Flag	Description
`d`	Enable output from DBUG_*XXX* macros for the current state. May be followed by a list of keywords, which enables output only for the DBUG macros with that keyword. An empty list of keywords enables output for all macros. In MySQL, common debug macro keywords to enable are `enter`, `exit`, `error`, `warning`, `info`, and `loop`.
`D`	Delay after each debugger output line. The argument is the delay, in tenths of seconds, subject to machine capabilities. For example, `D,20` specifies a delay of two seconds.
`f`	Limit debugging, tracing, and profiling to the list of named functions. An empty list enables all functions. The appropriate `d` or `t` flags must still be given; this flag only limits their actions if they are enabled.
`F`	Identify the source file name for each line of debug or trace output.
`i`	Identify the process with the PID or thread ID for each line of debug or trace output.
`L`	Identify the source file line number for each line of debug or trace output.
`n`	Print the current function nesting depth for each line of debug or trace output.
`N`	Number each line of debug output.
`o`	Redirect the debugger output stream to the specified file. The default output is `stderr`.
`O`	Like `o`, but the file is really flushed between each write. When needed, the file is closed and reopened between each write.
`p`	Limit debugger actions to specified processes. A process must be identified with the `DBUG_PROCESS` macro and match one in the list for debugger actions to occur.
`P`	Print the current process name for each line of debug or trace output.
`r`	When pushing a new state, do not inherit the previous state's function nesting level. Useful when the output is to start at the left margin.
`S`	Do function `_sanity(_file_,_line_)` at each debugged function until `_sanity()` returns something that differs from 0.

t	Enable function call/exit trace lines. May be followed by a list (containing only one modifier) giving a numeric maximum trace level, beyond which no output occurs for either debugging or tracing macros. The default is a compile time option.

The leading + or - character and trailing list of modifiers are used for flag characters such as d or f that can enable a debug operation for all applicable modifiers or just some of them:

- With no leading + or -, the flag value is set to exactly the modifier list as given.
- With a leading + or -, the modifiers in the list are added to or subtracted from the current modifier list.

The following examples show how this works for the d flag. An empty d list enabled output for all debug macros. A nonempty list enables output only for the macro keywords in the list.

These statements set the d value to the modifier list as given:

```
mysql> SET debug = 'd';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| d       |
+---------+
mysql> SET debug = 'd,error,warning';
mysql> SELECT @@debug;
+-----------------+
| @@debug         |
+-----------------+
| d,error,warning |
+-----------------+
```

A leading + or - adds to or subtracts from the current d value:

```
mysql> SET debug = '+d,loop';
mysql> SELECT @@debug;
+----------------------+
| @@debug              |
+----------------------+
| d,error,warning,loop |
+----------------------+
mysql> SET debug = '-d,error,loop';
mysql> SELECT @@debug;
+-----------+
| @@debug   |
+-----------+
| d,warning |
+-----------+
```

Adding to “all macros enabled” results in no change:

```
mysql> SET debug = 'd';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| d       |
+---------+
mysql> SET debug = '+d,loop';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
| d       |
+---------+
```

Disabling all enabled macros disables the d flag entirely:

```
mysql> SET debug = 'd,error,loop';
mysql> SELECT @@debug;
+--------------+
| @@debug      |
+--------------+
| d,error,loop |
+--------------+
mysql> SET debug = '-d,error,loop';
mysql> SELECT @@debug;
+---------+
| @@debug |
+---------+
|         |
+---------+
```

Note

The `+` and `-` modifiers are not always handled correctly and can leave a flag value in an incorrect state. Verify your `debug`-setting sequence in advance or set it without using `+` or `-`.

Chapter 25 MySQL Enterprise Edition

Table of Contents

25.1 MySQL Enterprise Monitor Overview 2841
25.2 MySQL Enterprise Backup Overview 2842
25.3 MySQL Enterprise Security Overview 2842
25.4 MySQL Enterprise Encryption Overview 2843
25.5 MySQL Enterprise Audit Overview 2843
25.6 MySQL Enterprise Firewall Overview 2843
25.7 MySQL Enterprise Thread Pool Overview 2844

MySQL Enterprise Edition is a commercial product. Like MySQL Community Edition, MySQL Enterprise Edition includes MySQL Server, a fully integrated transaction-safe, ACID-compliant database with full commit, rollback, crash-recovery, and row-level locking capabilities. In addition, MySQL Enterprise Edition includes the following components designed to provide monitoring and online backup, as well as improved security and scalability:

The following sections briefly discuss each of these components and indicate where to find more detailed information. To learn more about commercial products, see http://www.mysql.com/products/.

- MySQL Enterprise Monitor
- MySQL Enterprise Backup
- MySQL Enterprise Security
- MySQL Enterprise Encryption
- MySQL Enterprise Audit
- MySQL Enterprise Firewall
- MySQL Enterprise Thread Pool

25.1 MySQL Enterprise Monitor Overview

MySQL Enterprise Monitor is an enterprise monitoring system for MySQL that keeps an eye on your MySQL servers, notifies you of potential issues and problems, and advises you how to fix the issues. MySQL Enterprise Monitor can monitor all kinds of configurations, from a single MySQL server that is important to your business, all the way up to a huge farm of MySQL servers powering a busy web site.

The following discussion briefly summarizes the basic components that make up the MySQL Enterprise Monitor product. For more information, see the MySQL Enterprise Monitor manual, available at http://dev.mysql.com/doc/mysql-monitor/en/.

MySQL Enterprise Monitor components can be installed in various configurations depending on your database and network topology, to give you the best combination of reliable and responsive monitoring data, with minimal overhead on the database server machines. A typical MySQL Enterprise Monitor installation consists of:

- One or more MySQL servers to monitor. MySQL Enterprise Monitor can monitor both Community and Enterprise MySQL server releases.
- A MySQL Enterprise Monitor Agent for each monitored host.
- A single MySQL Enterprise Service Manager, which collates information from the agents and provides the user interface to the collected data.

MySQL Enterprise Monitor is designed to monitor one or more MySQL servers. The monitoring information is collected by using an agent, *MySQL Enterprise Monitor Agent*. The agent communicates with the hosts and MySQL servers that it monitors, collecting variables, status and health information, and sending this information to the MySQL Enterprise Service Manager.

The information collected by the agent about each MySQL server and host you are monitoring is sent to the *MySQL Enterprise Service Manager*. This server collates all of the information from the agents. As it collates the information sent by the agents, the MySQL Enterprise Service Manager continually tests the collected data, comparing the status of the server to reasonable values. When thresholds are reached, the server can trigger an event (including an alarm and notification) to highlight a potential issue, such as low memory, high CPU usage, or more complex conditions such insufficient buffer sizes and status information. We call each test, with its associated threshold value, a *rule*.

These rules, and the alarms and notifications, are each known as a *MySQL Enterprise Advisors*. Advisors form a critical part of the MySQL Enterprise Service Manager, as they provide warning information and troubleshooting advice about potential problems.

The MySQL Enterprise Service Manager includes a web server, and you interact with it through any web browser. This interface, the MySQL Enterprise Monitor User Interface, displays all of the information collected by the agents, and lets you view all of your servers and their current status as a group or individually. You control and configure all aspects of the service using the MySQL Enterprise Monitor User Interface.

The information supplied by the MySQL Enterprise Monitor Agent processes also includes statistical and query information, which you can view in the form of graphs. For example, you can view aspects such as server load, query numbers, or index usage information as a graph over time. The graph lets you pinpoint problems or potential issues on your server, and can help diagnose the impact from database or external problems (such as external system or network failure) by examining the data from a specific time interval.

The MySQL Enterprise Monitor Agent can also be configured to collect detailed information about the queries executed on your server, including the row counts and performance times for executing each query. You can correlate the detailed query data with the graphical information to identify which queries were executing when you experienced a particularly high load, index or other issue. The query data is supported by a system called Query Analyzer, and the data can be presented in different ways depending on your needs.

25.2 MySQL Enterprise Backup Overview

MySQL Enterprise Backup performs hot backup operations for MySQL databases. The product is architected for efficient and reliable backups of tables created by the InnoDB storage engine. For completeness, it can also back up tables from MyISAM and other storage engines.

The following discussion briefly summarizes MySQL Enterprise Backup. For more information, see the MySQL Enterprise Backup manual, available at http://dev.mysql.com/doc/mysql-enterprise-backup/en/.

Hot backups are performed while the database is running and applications are reading and writing to it. This type of backup does not block normal database operations, and it captures even changes that occur while the backup is happening. For these reasons, hot backups are desirable when your database “grows up” -- when the data is large enough that the backup takes significant time, and when your data is important enough to your business that you must capture every last change, without taking your application, web site, or web service offline.

MySQL Enterprise Backup does a hot backup of all tables that use the InnoDB storage engine. For tables using MyISAM or other non-InnoDB storage engines, it does a “warm” backup, where the database continues to run, but those tables cannot be modified while being backed up. For efficient backup operations, you can designate InnoDB as the default storage engine for new tables, or convert existing tables to use the InnoDB storage engine.

25.3 MySQL Enterprise Security Overview

MySQL Enterprise Edition provides plugins that implement authentication using external services:

- MySQL Enterprise Edition includes an authentication plugin that enables MySQL Server to use PAM (Pluggable Authentication Modules) to authenticate MySQL users. PAM enables a system to use a standard interface to access various kinds of authentication methods, such as Unix passwords or an LDAP directory. For more information, see Section 6.5.1.4, “PAM Pluggable Authentication”.
- MySQL Enterprise Edition includes an authentication plugin that performs external authentication on Windows, enabling MySQL Server to use native Windows services to authenticate client connections. Users who have logged in to Windows can connect from MySQL client programs to the server based on the information in their environment without specifying an additional password. For more information, see Section 6.5.1.5, “Windows Pluggable Authentication”.
- MySQL Enterprise Edition includes a keyring plugin that uses Oracle Key Vault as a back end for keyring storage. For more information, see The MySQL Keyring.

For other related Enterprise security features, see Section 25.4, “MySQL Enterprise Encryption Overview”.

25.4 MySQL Enterprise Encryption Overview

MySQL Enterprise Edition includes a set of encryption functions based on the OpenSSL library that expose OpenSSL capabilities at the SQL level. These functions enable Enterprise applications to perform the following operations:

- Implement added data protection using public-key asymmetric cryptography
- Create public and private keys and digital signatures
- Perform asymmetric encryption and decryption
- Use cryptographic hashing for digital signing and data verification and validation

For more information, see MySQL Enterprise Encryption Functions.

For other related Enterprise security features, see Section 25.3, “MySQL Enterprise Security Overview”.

25.5 MySQL Enterprise Audit Overview

MySQL Enterprise Edition includes MySQL Enterprise Audit, implemented using a server plugin. MySQL Enterprise Audit uses the open MySQL Audit API to enable standard, policy-based monitoring and logging of connection and query activity executed on specific MySQL servers. Designed to meet the Oracle audit specification, MySQL Enterprise Audit provides an out of box, easy to use auditing and compliance solution for applications that are governed by both internal and external regulatory guidelines.

When installed, the audit plugin enables MySQL Server to produce a log file containing an audit record of server activity. The log contents include when clients connect and disconnect, and what actions they perform while connected, such as which databases and tables they access.

For more information, see Section 6.5.2, “MySQL Enterprise Audit”.

25.6 MySQL Enterprise Firewall Overview

MySQL Enterprise Edition includes MySQL Enterprise Firewall, an application-level firewall that enables database administrators to permit or deny SQL statement execution based on matching against whitelists of accepted statement patterns. This helps harden MySQL Server against attacks such as SQL injection or attempts to exploit applications by using them outside of their legitimate query workload characteristics.

Each MySQL account registered with the firewall has its own statement whitelist, enabling protection to be tailored per account. For a given account, the firewall can operate in recording or protecting mode, for training in the accepted statement patterns or protection against unacceptable statements.

For more information, see MySQL Enterprise Firewall.

25.7 MySQL Enterprise Thread Pool Overview

MySQL Enterprise Edition includes MySQL Enterprise Thread Pool, implemented using a server plugin. The default thread-handling model in MySQL Server executes statements using one thread per client connection. As more clients connect to the server and execute statements, overall performance degrades. In MySQL Enterprise Edition, a thread pool plugin provides an alternative thread-handling model designed to reduce overhead and improve performance. The plugin implements a thread pool that increases server performance by efficiently managing statement execution threads for large numbers of client connections.

For more information, see Section 5.5.3, “MySQL Enterprise Thread Pool”.

Chapter 26 MySQL Workbench

MySQL Workbench provides a graphical tool for working with MySQL servers and databases. MySQL Workbench fully supports MySQL versions 5.1 and above.

The following discussion briefly describes MySQL Workbench capabilities. For more information, see the MySQL Workbench manual, available at http://dev.mysql.com/doc/workbench/en/.

MySQL Workbench provides five main areas of functionality:

- **SQL Development**: Enables you to create and manage connections to database servers. As well as enabling you to configure connection parameters, MySQL Workbench provides the capability to execute SQL queries on the database connections using the built-in SQL Editor. This functionality replaces that previously provided by the Query Browser standalone application.
- **Data Modeling**: Enables you to create models of your database schema graphically, reverse and forward engineer between a schema and a live database, and edit all aspects of your database using the comprehensive Table Editor. The Table Editor provides easy-to-use facilities for editing Tables, Columns, Indexes, Triggers, Partitioning, Options, Inserts and Privileges, Routines and Views.
- **Server Administration**: Enables you to create and administer server instances.
- **Data Migration**: Allows you to migrate from Microsoft SQL Server, Sybase ASE, SQLite, SQL Anywhere, PostreSQL, and other RDBMS tables, objects and data to MySQL. Migration also supports migrating from earlier versions of MySQL to the latest releases.
- **MySQL Enterprise Support**: Support for Enterprise products such as MySQL Enterprise Backup and MySQL Audit.

MySQL Workbench is available in two editions, the Community Edition and the Commercial Edition. The Community Edition is available free of charge. The Commercial Edition provides additional Enterprise features, such as database documentation generation, at low cost.

Appendix A MySQL 5.5 Frequently Asked Questions

Table of Contents

A.1 MySQL 5.5 FAQ: General 2847
A.2 MySQL 5.5 FAQ: Storage Engines 2849
A.3 MySQL 5.5 FAQ: Server SQL Mode 2849
A.4 MySQL 5.5 FAQ: Stored Procedures and Functions 2850
A.5 MySQL 5.5 FAQ: Triggers 2853
A.6 MySQL 5.5 FAQ: Views 2856
A.7 MySQL 5.5 FAQ: INFORMATION_SCHEMA 2856
A.8 MySQL 5.5 FAQ: Migration 2857
A.9 MySQL 5.5 FAQ: Security 2857
A.10 MySQL FAQ: MySQL 5.5 and NDB Cluster 2858
A.11 MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets 2871
A.12 MySQL 5.5 FAQ: Connectors & APIs 2883
A.13 MySQL 5.5 FAQ: Replication 2883
A.14 MySQL 5.5 FAQ: MySQL Enterprise Thread Pool 2887
A.15 MySQL 5.5 FAQ: InnoDB Change Buffer 2888
A.16 MySQL 5.5 FAQ: Virtualization Support 2890

A.1 MySQL 5.5 FAQ: General

A.1.1 Which version of MySQL is production-ready (GA)? 2847
A.1.2 What is the state of development (non-GA) versions? 2847
A.1.3 Can MySQL 5.5 do subqueries? 2848
A.1.4 Can MySQL 5.5 perform multiple-table inserts, updates, and deletes? 2848
A.1.5 Does MySQL 5.5 have a Query Cache? Does it work on Server, Instance or Database? 2848
A.1.6 Does MySQL 5.5 have Sequences? 2848
A.1.7 Does MySQL 5.5 have a `NOW()` function with fractions of seconds? 2848
A.1.8 Does MySQL 5.5 work with multi-core processors? 2848
A.1.9 Why do I see multiple processes for `mysqld`? 2848
A.1.10 Can MySQL 5.5 perform ACID transactions? 2848

A.1.1. Which version of MySQL is production-ready (GA)?

MySQL 5.7 and MySQL 5.6 are supported for production use.

MySQL 5.7 achieved General Availability (GA) status with MySQL 5.7.9, which was released for production use on 21 October 2015.

MySQL 5.6 achieved General Availability (GA) status with MySQL 5.6.10, which was released for production use on 5 February 2013.

MySQL 5.5 achieved General Availability (GA) status with MySQL 5.5.8, which was released for production use on 3 December 2010. The MySQL 5.5 series is no longer current, but still supported in production.

MySQL 5.1 achieved General Availability (GA) status with MySQL 5.1.30, which was released for production use on 14 November 2008. Active development for MySQL 5.1 has ended.

MySQL 5.0 achieved General Availability (GA) status with MySQL 5.0.15, which was released for production use on 19 October 2005. Active development for MySQL 5.0 has ended.

A.1.2. What is the state of development (non-GA) versions?

MySQL follows a milestone release model that introduces pre-production-quality features and stabilizes them to release quality (see http://dev.mysql.com/doc/mysql-development-cycle/en/

index.html). This process then repeats, so releases cycle between pre-production and release quality status. Please check the change logs to identify the status of a given release.

MySQL 8.0, a successor to MySQL 5.7, is being actively developed using the milestone release methodology described above.

A.1.3. Can MySQL 5.5 do subqueries?

Yes. See Section 13.2.10, “Subquery Syntax”.

A.1.4. Can MySQL 5.5 perform multiple-table inserts, updates, and deletes?

Yes. For the syntax required to perform multiple-table updates, see Section 13.2.11, “UPDATE Syntax”; for that required to perform multiple-table deletes, see Section 13.2.2, “DELETE Syntax”.

A multiple-table insert can be accomplished using a trigger whose `FOR EACH ROW` clause contains multiple `INSERT` statements within a `BEGIN ... END` block. See Section 20.3, “Using Triggers”.

A.1.5. Does MySQL 5.5 have a Query Cache? Does it work on Server, Instance or Database?

Yes. The query cache operates on the server level, caching complete result sets matched with the original query string. If an exactly identical query is made (which often happens, particularly in web applications), no parsing or execution is necessary; the result is sent directly from the cache. Various tuning options are available. See Section 8.10.3, “The MySQL Query Cache”.

A.1.6. Does MySQL 5.5 have Sequences?

No. However, MySQL has an `AUTO_INCREMENT` system, which in MySQL 5.5 can also handle inserts in a multi-master replication setup. With the `auto_increment_increment` and `auto_increment_offset` system variables, you can set each server to generate auto-increment values that don't conflict with other servers. The `auto_increment_increment` value should be greater than the number of servers, and each server should have a unique offset.

A.1.7. Does MySQL 5.5 have a `NOW()` function with fractions of seconds?

No, but support was added in 5.6.4.

Also, MySQL does parse time strings with a fractional component. See Section 11.3.2, “The TIME Type”.

A.1.8. Does MySQL 5.5 work with multi-core processors?

Yes. MySQL is fully multi-threaded, and will make use of multiple CPUs, provided that the operating system supports them.

A.1.9. Why do I see multiple processes for `mysqld`?

When using LinuxThreads, you should see a minimum of three `mysqld` processes running. These are in fact threads. There is one thread for the LinuxThreads manager, one thread to handle connections, and one thread to handle alarms and signals.

A.1.10. Can MySQL 5.5 perform ACID transactions?

Yes. All current MySQL versions support transactions. The `InnoDB` storage engine offers full ACID transactions with row-level locking, multi-versioning, nonlocking repeatable reads, and all four SQL standard isolation levels.

The `NDB` storage engine supports the `READ COMMITTED` transaction isolation level only.

A.2 MySQL 5.5 FAQ: Storage Engines

A.2.1 Where can I obtain complete documentation for MySQL storage engines? 2849
A.2.2 Are there any new storage engines in MySQL 5.5? 2849
A.2.3 Have any storage engines been removed in MySQL 5.5? 2849
A.2.4 What are the unique benefits of the ARCHIVE storage engine? 2849

A.2.1. Where can I obtain complete documentation for MySQL storage engines?

See Chapter 15, *Alternative Storage Engines*. That chapter contains information about all MySQL storage engines except for the `InnoDB` storage engine and the `NDB` storage engine (used for MySQL Cluster). `InnoDB` is covered in Chapter 14, *The InnoDB Storage Engine*. `NDB` is covered in Chapter 18, *MySQL NDB Cluster 7.2*.

A.2.2. Are there any new storage engines in MySQL 5.5?

The features from the optional `InnoDB Plugin` from MySQL 5.1 are folded into the built-in `InnoDB` storage engine, so you can take advantage of features such as the Barracuda file format, `InnoDB` table compression, and the new configuration options for performance. `InnoDB` also becomes the default storage engine for new tables. See Section 14.1, “Introduction to InnoDB” for details.

A.2.3. Have any storage engines been removed in MySQL 5.5?

No.

A.2.4. What are the unique benefits of the `ARCHIVE` storage engine?

The `ARCHIVE` storage engine stores large amounts of data without indexes; it has a small footprint, and performs selects using table scans. See Section 15.6, “The ARCHIVE Storage Engine”, for details.

A.3 MySQL 5.5 FAQ: Server SQL Mode

A.3.1 What are server SQL modes? 2849
A.3.2 How many server SQL modes are there? 2849
A.3.3 How do you determine the server SQL mode? 2849
A.3.4 Is the mode dependent on the database or connection? 2849
A.3.5 Can the rules for strict mode be extended? 2850
A.3.6 Does strict mode impact performance? 2850
A.3.7 What is the default server SQL mode when MySQL 5.5 is installed? 2850

A.3.1. What are server SQL modes?

Server SQL modes define what SQL syntax MySQL should support and what kind of data validation checks it should perform. This makes it easier to use MySQL in different environments and to use MySQL together with other database servers. The MySQL Server apply these modes individually to different clients. For more information, see Section 5.1.8, “Server SQL Modes”.

A.3.2. How many server SQL modes are there?

Each mode can be independently switched on and off. See Section 5.1.8, “Server SQL Modes”, for a complete list of available modes.

A.3.3. How do you determine the server SQL mode?

You can set the default SQL mode (for `mysqld` startup) with the `--sql-mode` option. Using the statement `SET [GLOBAL|SESSION] sql_mode='modes'`, you can change the settings from within a connection, either locally to the connection, or to take effect globally. You can retrieve the current mode by issuing a `SELECT @@sql_mode` statement.

A.3.4. Is the mode dependent on the database or connection?

A mode is not linked to a particular database. Modes can be set locally to the session (connection), or globally for the server. you can change these settings using `SET [GLOBAL|SESSION] sql_mode='modes'`.

A.3.5. Can the rules for strict mode be extended?

When we refer to *strict mode*, we mean a mode where at least one of the modes `TRADITIONAL`, `STRICT_TRANS_TABLES`, or `STRICT_ALL_TABLES` is enabled. Options can be combined, so you can add restrictions to a mode. See Section 5.1.8, “Server SQL Modes”, for more information.

A.3.6. Does strict mode impact performance?

The intensive validation of input data that some settings requires more time than if the validation is not done. While the performance impact is not that great, if you do not require such validation (perhaps your application already handles all of this), then MySQL gives you the option of leaving strict mode disabled. However, if you do require it, strict mode can provide such validation.

A.3.7. What is the default server SQL mode when MySQL 5.5 is installed?

By default, no special modes are enabled. For information about all available modes and default MySQL behavior, see Section 5.1.8, “Server SQL Modes”.

A.4 MySQL 5.5 FAQ: Stored Procedures and Functions

A.4.1 Does MySQL 5.5 support stored procedures and functions? 2850
A.4.2 Where can I find documentation for MySQL stored procedures and stored functions? 2851
A.4.3 Is there a discussion forum for MySQL stored procedures? 2851
A.4.4 Where can I find the ANSI SQL 2003 specification for stored procedures? 2851
A.4.5 How do you manage stored routines? 2851
A.4.6 Is there a way to view all stored procedures and stored functions in a given database? 2851
A.4.7 Where are stored procedures stored? 2851
A.4.8 Is it possible to group stored procedures or stored functions into packages? 2851
A.4.9 Can a stored procedure call another stored procedure? 2851
A.4.10 Can a stored procedure call a trigger? 2851
A.4.11 Can a stored procedure access tables? 2851
A.4.12 Do stored procedures have a statement for raising application errors? 2852
A.4.13 Do stored procedures provide exception handling? 2852
A.4.14 Can MySQL 5.5 stored routines return result sets? 2852
A.4.15 Is `WITH RECOMPILE` supported for stored procedures? 2852
A.4.16 Is there a MySQL equivalent to using `mod_plsql` as a gateway on Apache to talk directly to a stored procedure in the database? 2852
A.4.17 Can I pass an array as input to a stored procedure? 2852
A.4.18 Can I pass a cursor as an `IN` parameter to a stored procedure? 2852
A.4.19 Can I return a cursor as an `OUT` parameter from a stored procedure? 2852
A.4.20 Can I print out a variable's value within a stored routine for debugging purposes? 2852
A.4.21 Can I commit or roll back transactions inside a stored procedure? 2852
A.4.22 Do MySQL 5.5 stored procedures and functions work with replication? 2852
A.4.23 Are stored procedures and functions created on a master server replicated to a slave? 2852
A.4.24 How are actions that take place inside stored procedures and functions replicated? 2853
A.4.25 Are there special security requirements for using stored procedures and functions together with replication? 2853
A.4.26 What limitations exist for replicating stored procedure and function actions? 2853
A.4.27 Do the preceding limitations affect the ability of MySQL to do point-in-time recovery? 2853
A.4.28 What is being done to correct the aforementioned limitations? 2853

A.4.1. Does MySQL 5.5 support stored procedures and functions?

Yes. MySQL 5.5 supports two types of stored routines, stored procedures and stored functions.

A.4.2. Where can I find documentation for MySQL stored procedures and stored functions?

See Section 20.2, “Using Stored Routines (Procedures and Functions)”.

A.4.3. Is there a discussion forum for MySQL stored procedures?

Yes. See http://forums.mysql.com/list.php?98.

A.4.4. Where can I find the ANSI SQL 2003 specification for stored procedures?

Unfortunately, the official specifications are not freely available (ANSI makes them available for purchase). However, there are books, such as *SQL-99 Complete, Really* by Peter Gulutzan and Trudy Pelzer, that provide a comprehensive overview of the standard, including coverage of stored procedures.

A.4.5. How do you manage stored routines?

It is always good practice to use a clear naming scheme for your stored routines. You can manage stored procedures with `CREATE [FUNCTION|PROCEDURE]`, `ALTER [FUNCTION|PROCEDURE]`, `DROP [FUNCTION|PROCEDURE]`, and `SHOW CREATE [FUNCTION|PROCEDURE]`. You can obtain information about existing stored procedures using the `ROUTINES` table in the `INFORMATION_SCHEMA` database (see Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”).

A.4.6. Is there a way to view all stored procedures and stored functions in a given database?

Yes. For a database named *`dbname`*, use this query on the `INFORMATION_SCHEMA.ROUTINES` table:

```
SELECT ROUTINE_TYPE, ROUTINE_NAME
    FROM INFORMATION_SCHEMA.ROUTINES
    WHERE ROUTINE_SCHEMA='dbname';
```

For more information, see Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”.

The body of a stored routine can be viewed using `SHOW CREATE FUNCTION` (for a stored function) or `SHOW CREATE PROCEDURE` (for a stored procedure). See Section 13.7.5.11, “SHOW CREATE PROCEDURE Syntax”, for more information.

A.4.7. Where are stored procedures stored?

In the `proc` table of the `mysql` system database. However, you should not access the tables in the system database directly. Instead, query the `INFORMATION_SCHEMA ROUTINES` and `PARAMETERS` tables. See Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”, and Section 21.11, “The INFORMATION_SCHEMA PARAMETERS Table”.

You can also use `SHOW CREATE FUNCTION` to obtain information about stored functions, and `SHOW CREATE PROCEDURE` to obtain information about stored procedures. See Section 13.7.5.11, “SHOW CREATE PROCEDURE Syntax”.

A.4.8. Is it possible to group stored procedures or stored functions into packages?

No. This is not supported in MySQL 5.5.

A.4.9. Can a stored procedure call another stored procedure?

Yes.

A.4.10. Can a stored procedure call a trigger?

A stored procedure can execute an SQL statement, such as an `UPDATE`, that causes a trigger to activate.

A.4.11. Can a stored procedure access tables?

Yes. A stored procedure can access one or more tables as required.

A.4.12 Do stored procedures have a statement for raising application errors?

Yes. MySQL 5.5 implements the SQL standard `SIGNAL` and `RESIGNAL` statements. See Section 13.6.7, “Condition Handling”.

A.4.13 Do stored procedures provide exception handling?

MySQL implements `HANDLER` definitions according to the SQL standard. See Section 13.6.7.2, “DECLARE ... HANDLER Syntax”, for details.

A.4.14 Can MySQL 5.5 stored routines return result sets?

Stored procedures can, but stored functions cannot. If you perform an ordinary `SELECT` inside a stored procedure, the result set is returned directly to the client. You need to use the MySQL 4.1 (or higher) client/server protocol for this to work. This means that, for example, in PHP, you need to use the `mysqli` extension rather than the old `mysql` extension.

A.4.15 Is `WITH RECOMPILE` supported for stored procedures?

Not in MySQL 5.5.

A.4.16 Is there a MySQL equivalent to using `mod_plsql` as a gateway on Apache to talk directly to a stored procedure in the database?

There is no equivalent in MySQL 5.5.

A.4.17 Can I pass an array as input to a stored procedure?

Not in MySQL 5.5.

A.4.18 Can I pass a cursor as an `IN` parameter to a stored procedure?

In MySQL 5.5, cursors are available inside stored procedures only.

A.4.19 Can I return a cursor as an `OUT` parameter from a stored procedure?

In MySQL 5.5, cursors are available inside stored procedures only. However, if you do not open a cursor on a `SELECT`, the result will be sent directly to the client. You can also `SELECT INTO` variables. See Section 13.2.9, “SELECT Syntax”.

A.4.20 Can I print out a variable's value within a stored routine for debugging purposes?

Yes, you can do this in a *stored procedure*, but not in a stored function. If you perform an ordinary `SELECT` inside a stored procedure, the result set is returned directly to the client. You will need to use the MySQL 4.1 (or above) client/server protocol for this to work. This means that, for example, in PHP, you need to use the `mysqli` extension rather than the old `mysql` extension.

A.4.21 Can I commit or roll back transactions inside a stored procedure?

Yes. However, you cannot perform transactional operations within a stored function.

A.4.22 Do MySQL 5.5 stored procedures and functions work with replication?

Yes, standard actions carried out in stored procedures and functions are replicated from a master MySQL server to a slave server. There are a few limitations that are described in detail in Section 20.7, “Binary Logging of Stored Programs”.

A.4.23 Are stored procedures and functions created on a master server replicated to a slave?

Yes, creation of stored procedures and functions carried out through normal DDL statements on a master server are replicated to a slave, so the objects will exist on both servers. `ALTER` and `DROP` statements for stored procedures and functions are also replicated.

A.4.24. How are actions that take place inside stored procedures and functions replicated?

MySQL records each DML event that occurs in a stored procedure and replicates those individual actions to a slave server. The actual calls made to execute stored procedures are not replicated.

Stored functions that change data are logged as function invocations, not as the DML events that occur inside each function.

A.4.25. Are there special security requirements for using stored procedures and functions together with replication?

Yes. Because a slave server has authority to execute any statement read from a master's binary log, special security constraints exist for using stored functions with replication. If replication or binary logging in general (for the purpose of point-in-time recovery) is active, then MySQL DBAs have two security options open to them:

1. Any user wishing to create stored functions must be granted the `SUPER` privilege.
2. Alternatively, a DBA can set the `log_bin_trust_function_creators` system variable to 1, which enables anyone with the standard `CREATE ROUTINE` privilege to create stored functions.

A.4.26. What limitations exist for replicating stored procedure and function actions?

Nondeterministic (random) or time-based actions embedded in stored procedures may not replicate properly. By their very nature, randomly produced results are not predictable and cannot be exactly reproduced, and therefore, random actions replicated to a slave will not mirror those performed on a master. Declaring stored functions to be `DETERMINISTIC` or setting the `log_bin_trust_function_creators` system variable to 0 will not allow random-valued operations to be invoked.

In addition, time-based actions cannot be reproduced on a slave because the timing of such actions in a stored procedure is not reproducible through the binary log used for replication. It records only DML events and does not factor in timing constraints.

Finally, nontransactional tables for which errors occur during large DML actions (such as bulk inserts) may experience replication issues in that a master may be partially updated from DML activity, but no updates are done to the slave because of the errors that occurred. A workaround is for a function's DML actions to be carried out with the `IGNORE` keyword so that updates on the master that cause errors are ignored and updates that do not cause errors are replicated to the slave.

A.4.27. Do the preceding limitations affect the ability of MySQL to do point-in-time recovery?

The same limitations that affect replication do affect point-in-time recovery.

A.4.28. What is being done to correct the aforementioned limitations?

You can choose either statement-based replication or row-based replication. The original replication implementation is based on statement-based binary logging. Row-based binary logging resolves the limitations mentioned earlier.

Mixed replication is also available (by starting the server with `--binlog-format=mixed`). This hybrid, “smart” form of replication “knows” whether statement-level replication can safely be used, or row-level replication is required.

For additional information, see Section 17.1.2, “Replication Formats”.

A.5 MySQL 5.5 FAQ: Triggers

A.5.1 Where can I find the documentation for MySQL 5.5 triggers? 2854

A.5.2 Is there a discussion forum for MySQL Triggers? 2854
A.5.3 Does MySQL 5.5 have statement-level or row-level triggers? 2854
A.5.4 Are there any default triggers? 2854
A.5.5 How are triggers managed in MySQL? 2854
A.5.6 Is there a way to view all triggers in a given database? 2854
A.5.7 Where are triggers stored? 2854
A.5.8 Can a trigger call a stored procedure? 2854
A.5.9 Can triggers access tables? 2855
A.5.10 Can a table have multiple triggers with the same trigger event and action time? 2855
A.5.11 Can triggers call an external application through a UDF? 2855
A.5.12 Is it possible for a trigger to update tables on a remote server? 2855
A.5.13 Do triggers work with replication? 2855
A.5.14 How are actions carried out through triggers on a master replicated to a slave? 2855

A.5.1. Where can I find the documentation for MySQL 5.5 triggers?

See Section 20.3, “Using Triggers”.

A.5.2. Is there a discussion forum for MySQL Triggers?

Yes. It is available at http://forums.mysql.com/list.php?99.

A.5.3. Does MySQL 5.5 have statement-level or row-level triggers?

In MySQL 5.5, all triggers are `FOR EACH ROW`; that is, the trigger is activated for each row that is inserted, updated, or deleted. MySQL 5.5 does not support triggers using `FOR EACH STATEMENT`.

A.5.4. Are there any default triggers?

Not explicitly. MySQL does have specific special behavior for some `TIMESTAMP` columns, as well as for columns which are defined using `AUTO_INCREMENT`.

A.5.5. How are triggers managed in MySQL?

In MySQL 5.5, triggers can be created using the `CREATE TRIGGER` statement, and dropped using `DROP TRIGGER`. See Section 13.1.19, “CREATE TRIGGER Syntax”, and Section 13.1.30, “DROP TRIGGER Syntax”, for more about these statements.

Information about triggers can be obtained by querying the `INFORMATION_SCHEMA.TRIGGERS` table. See Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”.

A.5.6. Is there a way to view all triggers in a given database?

Yes. You can obtain a listing of all triggers defined on database `dbname` using a query on the `INFORMATION_SCHEMA.TRIGGERS` table such as the one shown here:

```
SELECT TRIGGER_NAME, EVENT_MANIPULATION, EVENT_OBJECT_TABLE, ACTION_STATEMENT
    FROM INFORMATION_SCHEMA.TRIGGERS
    WHERE TRIGGER_SCHEMA='dbname';
```

For more information about this table, see Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”.

You can also use the `SHOW TRIGGERS` statement, which is specific to MySQL. See Section 13.7.5.39, “SHOW TRIGGERS Syntax”.

A.5.7. Where are triggers stored?

Triggers are stored in `.TRG` files, with one such file one per table.

A.5.8. Can a trigger call a stored procedure?

Yes.

A.5.9. Can triggers access tables?

A trigger can access both old and new data in its own table. A trigger can also affect other tables, but it is not permitted to modify a table that is already being used (for reading or writing) by the statement that invoked the function or trigger.

A.5.10. Can a table have multiple triggers with the same trigger event and action time?

In MySQL 5.5, there cannot be multiple triggers for a given table that have the same trigger event and action time. For example, you cannot have two `BEFORE UPDATE` triggers for a table. This limitation is lifted in MySQL 5.7.

A.5.11. Can triggers call an external application through a UDF?

Yes. For example, a trigger could invoke the `sys_exec()` UDF.

A.5.12. Is it possible for a trigger to update tables on a remote server?

Yes. A table on a remote server could be updated using the `FEDERATED` storage engine. (See Section 15.9, “The FEDERATED Storage Engine”).

A.5.13. Do triggers work with replication?

Yes. However, the way in which they work depends whether you are using MySQL's “classic” statement-based replication available in all versions of MySQL, or the row-based replication format introduced in MySQL 5.1.

When using statement-based replication, triggers on the slave are executed by statements that are executed on the master (and replicated to the slave).

When using row-based replication, triggers are not executed on the slave due to statements that were run on the master and then replicated to the slave. Instead, when using row-based replication, the changes caused by executing the trigger on the master are applied on the slave.

For more information, see Section 17.4.1.36, “Replication and Triggers”.

A.5.14. How are actions carried out through triggers on a master replicated to a slave?

Again, this depends on whether you are using statement-based or row-based replication.

Statement-based replication. First, the triggers that exist on a master must be re-created on the slave server. Once this is done, the replication flow works as any other standard DML statement that participates in replication. For example, consider a table `EMP` that has an `AFTER` insert trigger, which exists on a master MySQL server. The same `EMP` table and `AFTER` insert trigger exist on the slave server as well. The replication flow would be:

1. An `INSERT` statement is made to `EMP`.
2. The `AFTER` trigger on `EMP` activates.
3. The `INSERT` statement is written to the binary log.
4. The replication slave picks up the `INSERT` statement to `EMP` and executes it.
5. The `AFTER` trigger on `EMP` that exists on the slave activates.

Row-based replication. When you use row-based replication, the changes caused by executing the trigger on the master are applied on the slave. However, the triggers themselves are not actually executed on the slave under row-based replication. This is because, if both the master and the slave applied the changes from the master and, in addition, the trigger causing

these changes were applied on the slave, the changes would in effect be applied twice on the slave, leading to different data on the master and the slave.

In most cases, the outcome is the same for both row-based and statement-based replication. However, if you use different triggers on the master and slave, you cannot use row-based replication. (This is because the row-based format replicates the changes made by triggers executing on the master to the slaves, rather than the statements that caused the triggers to execute, and the corresponding triggers on the slave are not executed.) Instead, any statements causing such triggers to be executed must be replicated using statement-based replication.

For more information, see Section 17.4.1.36, “Replication and Triggers”.

A.6 MySQL 5.5 FAQ: Views

A.6.1 Where can I find documentation covering MySQL Views? 2856
A.6.2 Is there a discussion forum for MySQL Views? 2856
A.6.3 What happens to a view if an underlying table is dropped or renamed? 2856
A.6.4 Does MySQL 5.5 have table snapshots? 2856
A.6.5 Does MySQL 5.5 have materialized views? 2856
A.6.6 Can you insert into views that are based on joins? 2856

A.6.1. Where can I find documentation covering MySQL Views?

See Section 20.5, “Using Views”.

A.6.2. Is there a discussion forum for MySQL Views?

Yes. See http://forums.mysql.com/list.php?100

A.6.3. What happens to a view if an underlying table is dropped or renamed?

After a view has been created, it is possible to drop or alter a table or view to which the definition refers. To check a view definition for problems of this kind, use the `CHECK TABLE` statement. (See Section 13.7.2.2, “CHECK TABLE Syntax”.)

A.6.4. Does MySQL 5.5 have table snapshots?

No.

A.6.5. Does MySQL 5.5 have materialized views?

No.

A.6.6. Can you insert into views that are based on joins?

It is possible, provided that your `INSERT` statement has a column list that makes it clear there is only one table involved.

You *cannot* insert into multiple tables with a single insert on a view.

A.7 MySQL 5.5 FAQ: INFORMATION_SCHEMA

A.7.1 Where can I find documentation for the MySQL `INFORMATION_SCHEMA` database? 2856
A.7.2 Is there a discussion forum for `INFORMATION_SCHEMA`? 2856
A.7.3 Where can I find the ANSI SQL 2003 specification for `INFORMATION_SCHEMA`? 2857
A.7.4 What is the difference between the Oracle Data Dictionary and MySQL `INFORMATION_SCHEMA`? 2857
A.7.5 Can I add to or otherwise modify the tables found in the `INFORMATION_SCHEMA` database? 2857

A.7.1. Where can I find documentation for the MySQL `INFORMATION_SCHEMA` database?

See Chapter 21, *INFORMATION_SCHEMA Tables*

A.7.2. Is there a discussion forum for `INFORMATION_SCHEMA`?

See http://forums.mysql.com/list.php?101.

A.7.3. Where can I find the ANSI SQL 2003 specification for `INFORMATION_SCHEMA`?

Unfortunately, the official specifications are not freely available. (ANSI makes them available for purchase.) However, there are books available, such as *SQL-99 Complete, Really* by Peter Gulutzan and Trudy Pelzer, that provide a comprehensive overview of the standard, including `INFORMATION_SCHEMA`.

A.7.4. What is the difference between the Oracle Data Dictionary and MySQL `INFORMATION_SCHEMA`?

Both Oracle and MySQL provide metadata in tables. However, Oracle and MySQL use different table names and column names. The MySQL implementation is more similar to those found in DB2 and SQL Server, which also support `INFORMATION_SCHEMA` as defined in the SQL standard.

A.7.5. Can I add to or otherwise modify the tables found in the `INFORMATION_SCHEMA` database?

No. Since applications may rely on a certain standard structure, this should not be modified. For this reason, *we cannot support bugs or other issues which result from modifying `INFORMATION_SCHEMA` tables or data*.

A.8 MySQL 5.5 FAQ: Migration

A.8.1 Where can I find information on how to migrate from MySQL 5.1 to MySQL 5.5? 2857
A.8.2 How has storage engine (table type) support changed in MySQL 5.5 from previous versions? 2857

A.8.1. Where can I find information on how to migrate from MySQL 5.1 to MySQL 5.5?

For detailed upgrade information, see Section 2.11.1, “Upgrading MySQL”. Do not skip a major version when upgrading, but rather complete the process in steps, upgrading from one major version to the next in each step. This may seem more complicated, but it will you save time and trouble. If you encounter problems during the upgrade, their origin will be easier to identify, either by you or, if you have a MySQL Enterprise subscription, by MySQL support.

A.8.2. How has storage engine (table type) support changed in MySQL 5.5 from previous versions?

Storage engine support has changed as follows:

- Support for `ISAM` tables was removed in MySQL 5.0 and you should now use the `MyISAM` storage engine in place of `ISAM`. To convert a table *`tblname`* from `ISAM` to `MyISAM`, simply issue a statement such as this one:

```
ALTER TABLE tblname ENGINE=MYISAM;
```

- Internal `RAID` for `MyISAM` tables was also removed in MySQL 5.0. This was formerly used to allow large tables in file systems that did not support file sizes greater than 2GB. All modern file systems allow for larger tables; in addition, there are now other solutions such as `MERGE` tables and views.
- The `VARCHAR` column type now retains trailing spaces in all storage engines.
- `MEMORY` tables (formerly known as `HEAP` tables) can also contain `VARCHAR` columns.

A.9 MySQL 5.5 FAQ: Security

A.9.1 Where can I find documentation that addresses security issues for MySQL? 2858
A.9.2 Does MySQL 5.5 have native support for SSL? 2858
A.9.3 Is SSL support built into MySQL binaries, or must I recompile the binary myself to enable it? 2858
A.9.4 Does MySQL 5.5 have built-in authentication against LDAP directories? 2858
A.9.5 Does MySQL 5.5 include support for Roles Based Access Control (RBAC)? 2858

A.9.1. Where can I find documentation that addresses security issues for MySQL?

The best place to start is Chapter 6, *Security*.

Other portions of the MySQL Documentation which you may find useful with regard to specific security concerns include the following:

- Section 6.1.1, “Security Guidelines”.
- Section 6.1.3, “Making MySQL Secure Against Attackers”.
- Section B.5.3.2, “How to Reset the Root Password”.
- Section 6.1.5, “How to Run MySQL as a Normal User”.
- Section 24.4.2.6, “UDF Security Precautions”.
- Section 6.1.4, “Security-Related mysqld Options and Variables”.
- Section 6.1.6, “Security Issues with LOAD DATA LOCAL”.
- Section 2.10, “Postinstallation Setup and Testing”.
- Section 6.4, “Using Encrypted Connections”.

A.9.2. Does MySQL 5.5 have native support for SSL?

Most 5.5 binaries have support for SSL connections between the client and server. See Section 6.4, “Using Encrypted Connections”.

You can also tunnel a connection using SSH, if (for example) the client application does not support SSL connections. For an example, see Section 6.4.7, “Connecting to MySQL Remotely from Windows with SSH”.

A.9.3. Is SSL support built into MySQL binaries, or must I recompile the binary myself to enable it?

Most 5.5 binaries have SSL enabled for client/server connections that are secured, authenticated, or both. See Section 6.4, “Using Encrypted Connections”.

A.9.4. Does MySQL 5.5 have built-in authentication against LDAP directories?

The Enterprise edition includes a PAM Authentication Plugin that supports authentication against an LDAP directory.

A.9.5. Does MySQL 5.5 include support for Roles Based Access Control (RBAC)?

Not at this time.

A.10 MySQL FAQ: MySQL 5.5 and NDB Cluster

In the following section, we answer questions that are frequently asked about NDB Cluster and the `NDBCLUSTER` storage engine.

A.10.1 Which versions of the MySQL software support NDB Cluster? Do I have to compile from source? 2859
A.10.2 What do “NDB” and “NDBCLUSTER” mean? 2860
A.10.3 What is the difference between using NDB Cluster versus using MySQL Replication? 2860
A.10.4 Do I need any special networking to run NDB Cluster? How do computers in a cluster communicate? 2860
A.10.5 How many computers do I need to run an NDB Cluster, and why? 2861
A.10.6 What do the different computers do in an NDB Cluster? 2861
A.10.7 When I run the `SHOW` command in the NDB Cluster management client, I see a line of output that looks like this: 2861

A.10.8 With which operating systems can I use NDB Cluster? 2862
A.10.9 What are the hardware requirements for running NDB Cluster? 2862
A.10.10 How much RAM do I need to use NDB Cluster? Is it possible to use disk memory at all? . 2862
A.10.11 What file systems can I use with NDB Cluster? What about network file systems or network shares? 2863
A.10.12 Can I run NDB Cluster nodes inside virtual machines (such as those created by VMWare, Parallels, or Xen)? 2864
A.10.13 I am trying to populate an NDB Cluster database. The loading process terminates prematurely and I get an error message like this one: 2864
A.10.14 NDB Cluster uses TCP/IP. Does this mean that I can run it over the Internet, with one or more nodes in remote locations? 2864
A.10.15 Do I have to learn a new programming or query language to use NDB Cluster? 2864
A.10.16 What programming languages and APIs are supported by NDB Cluster? 2865
A.10.17 Does NDB Cluster include any management tools? 2865
A.10.18 How do I find out what an error or warning message means when using NDB Cluster? ... 2865
A.10.19 Is NDB Cluster transaction-safe? What isolation levels are supported? 2865
A.10.20 What storage engines are supported by NDB Cluster? 2866
A.10.21 In the event of a catastrophic failure— for example, the whole city loses power *and* my UPS fails—would I lose all my data? 2866
A.10.22 Is it possible to use FULLTEXT indexes with NDB Cluster? 2866
A.10.23 Can I run multiple nodes on a single computer? 2866
A.10.24 Can I add data nodes to an NDB Cluster without restarting it? 2866
A.10.25 Are there any limitations that I should be aware of when using NDB Cluster? 2866
A.10.26 Does NDB Cluster support foreign keys? 2867
A.10.27 How do I import an existing MySQL database into an NDB Cluster? 2867
A.10.28 How do NDB Cluster nodes communicate with one another? 2867
A.10.29 What is an *arbitrator*? 2868
A.10.30 What data types are supported by NDB Cluster? 2868
A.10.31 How do I start and stop NDB Cluster? 2868
A.10.32 What happens to NDB Cluster data when the NDB Cluster is shut down? 2869
A.10.33 Is it a good idea to have more than one management node for an NDB Cluster? 2869
A.10.34 Can I mix different kinds of hardware and operating systems in one NDB Cluster? 2869
A.10.35 Can I run two data nodes on a single host? Two SQL nodes? 2869
A.10.36 Can I use host names with NDB Cluster? 2870
A.10.37 Does NDB Cluster support IPv6? 2870
A.10.38 How do I handle MySQL users in an NDB Cluster having multiple MySQL servers? 2870
A.10.39 How do I continue to send queries in the event that one of the SQL nodes fails? 2870
A.10.40 How do I back up and restore an NDB Cluster? 2870
A.10.41 What is an “angel process”? 2870

A.10.1. Which versions of the MySQL software support NDB Cluster? Do I have to compile from source?

NDB Cluster is not supported in standard MySQL Server 5.5 releases. Instead, MySQL NDB Cluster is provided as a separate product. Available NDB Cluster release series include the following:

- **NDB Cluster 7.2.** This series is a previous General Availability (GA) version of NDB Cluster, still available for production, although we recommend that new deployments use the latest NDB Cluster 7.5 release. The most recent NDB Cluster 7.2 release can be obtained from http://dev.mysql.com/downloads/cluster/.

- **NDB Cluster 7.3.** This series is a General Availability (GA) version of NDB Cluster, still available for production, although we recommend that new deployments use the latest NDB Cluster 7.5 release. The most recent NDB Cluster 7.3 release can be obtained from http://dev.mysql.com/downloads/cluster/.

- **NDB Cluster 7.4.** This series is the latest Generally Available (GA) version of NDB Cluster, based on version 7.4 of the NDB storage engine and MySQL Server 5.6, and still available for

production, although we recommend that new deployments use the latest NDB Cluster 7.5 release The most recent NDB Cluster 7.4 release can be obtained from http://dev.mysql.com/downloads/cluster/.

- **NDB Cluster 7.5.** This series is the most recent General Availability (GA) version of NDB Cluster, based on version 7.5 of the `NDB` storage engine and MySQL Server 5.7. NDB Cluster 7.5 is available for production use; new deployments intended for production should use the latest GA release in this series, which is currently NDB Cluster 7.5.9. The latest NDB Cluster 7.5 releases can be obtained from http://dev.mysql.com/downloads/cluster/.

- **NDB Cluster 7.6.** This series, based on version 7.6 of the `NDB` storage engine, is currently under development, but not yet considered ready for use in a production setting. It is available as a Developer Preview release for evaluation and testing purposes. You can obtain the most recent NDB Cluster 7.6 release from http://dev.mysql.com/downloads/cluster/. For information about new features and other important changes in this series, see What is New in NDB Cluster 7.6.

You should use NDB Cluster 7.5 for any new deployments; if you are using an older version of NDB Cluster, you should upgrade to this version soon as possible. For an overview of improvements made in NDB Cluster 7.5, see What is New in NDB Cluster. For an overview of improvements made in NDB Cluster 7.4, see What is New in NDB Cluster 7.4; for information about improvements made in NDB Cluster 7.3, see What is New in NDB Cluster 7.3. For information about improvements made in NDB Cluster 7.2, see Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”.

NDB Cluster 7.6, based on MySQL Server 5.7 and version 7.6 of the `NDB` storage engine, is also now available as a Developer Preview release for evaluation and testing purposes. You can obtain the most recent NDB Cluster 7.6 release from http://dev.mysql.com/downloads/cluster/. For information about new features and other important changes in this series, see What is New in NDB Cluster 7.6.

You can determine whether your MySQL Server has `NDB` support using one of the statements `SHOW VARIABLES LIKE 'have_%'`, `SHOW ENGINES`, or `SHOW PLUGINS`.

A.10.2 What do “NDB” and “NDBCLUSTER” mean?

“NDB” stands for “**N**etwork **D**ata**b**ase”. `NDB` and `NDBCLUSTER` are both names for the storage engine that enables clustering support with MySQL. `NDB` is preferred, but either name is correct.

A.10.3 What is the difference between using NDB Cluster versus using MySQL Replication?

In traditional MySQL replication, a master MySQL server updates one or more slaves. Transactions are committed sequentially, and a slow transaction can cause the slave to lag behind the master. This means that if the master fails, it is possible that the slave might not have recorded the last few transactions. If a transaction-safe engine such as `InnoDB` is being used, a transaction will either be complete on the slave or not applied at all, but replication does not guarantee that all data on the master and the slave will be consistent at all times. In NDB Cluster, all data nodes are kept in synchrony, and a transaction committed by any one data node is committed for all data nodes. In the event of a data node failure, all remaining data nodes remain in a consistent state.

In short, whereas standard MySQL replication is *asynchronous*, NDB Cluster is *synchronous*.

Asynchronous replication is also available in NDB Cluster. *NDB Cluster Replication* (also sometimes known as “geo-replication”) includes the capability to replicate both between two NDB Clusters, and from an NDB Cluster to a non-Cluster MySQL server. See Section 18.6, “NDB Cluster Replication”.

A.10.4 Do I need any special networking to run NDB Cluster? How do computers in a cluster communicate?

NDB Cluster is intended to be used in a high-bandwidth environment, with computers connecting using TCP/IP. Its performance depends directly upon the connection speed between the cluster's computers. The minimum connectivity requirements for NDB Cluster include a typical 100-megabit Ethernet network or the equivalent. We recommend you use gigabit Ethernet whenever available.

A.10.5. How many computers do I need to run an NDB Cluster, and why?

A minimum of three computers is required to run a viable cluster. However, the minimum *recommended* number of computers in an NDB Cluster is four: one each to run the management and SQL nodes, and two computers to serve as data nodes. The purpose of the two data nodes is to provide redundancy; the management node must run on a separate machine to guarantee continued arbitration services in the event that one of the data nodes fails.

To provide increased throughput and high availability, you should use multiple SQL nodes (MySQL Servers connected to the cluster). It is also possible (although not strictly necessary) to run multiple management servers.

A.10.6. What do the different computers do in an NDB Cluster?

An NDB Cluster has both a physical and logical organization, with computers being the physical elements. The logical or functional elements of a cluster are referred to as *nodes*, and a computer housing a cluster node is sometimes referred to as a *cluster host*. There are three types of nodes, each corresponding to a specific role within the cluster. These are:

- **Management node.** This node provides management services for the cluster as a whole, including startup, shutdown, backups, and configuration data for the other nodes. The management node server is implemented as the application `ndb_mgmd`; the management client used to control NDB Cluster is `ndb_mgm`. See Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”, and Section 18.4.5, “`ndb_mgm` — The NDB Cluster Management Client”, for information about these programs.

- **Data node.** This type of node stores and replicates data. Data node functionality is handled by instances of the `NDB` data node process `ndbd`. For more information, see Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”.

- **SQL node.** This is simply an instance of MySQL Server (`mysqld`) that is built with support for the `NDBCLUSTER` storage engine and started with the `--ndb-cluster` option to enable the engine and the `--ndb-connectstring` option to enable it to connect to an NDB Cluster management server. For more about these options, see MySQL Server Options for NDB Cluster.

Note

An *API node* is any application that makes direct use of Cluster data nodes for data storage and retrieval. An SQL node can thus be considered a type of API node that uses a MySQL Server to provide an SQL interface to the Cluster. You can write such applications (that do not depend on a MySQL Server) using the NDB API, which supplies a direct, object-oriented transaction and scanning interface to NDB Cluster data; see NDB Cluster API Overview: The NDB API, for more information.

A.10.7. When I run the `SHOW` command in the NDB Cluster management client, I see a line of output that looks like this:

```
id=2    @10.100.10.32  (Version: 5.6.38-ndb-7.4.18 Nodegroup: 0, *)
```

What does the `*` mean? How is this node different from the others?

The simplest answer is, “It's not something you can control, and it's nothing that you need to worry about in any case, unless you're a software engineer writing or analyzing the NDB Cluster source code”.

If you don't find that answer satisfactory, here's a longer and more technical version:

A number of mechanisms in NDB Cluster require distributed coordination among the data nodes. These distributed algorithms and protocols include global checkpointing, DDL (schema) changes, and node restart handling. To make this coordination simpler, the data nodes “elect” one of their number to act as leader. (This node was once referred to as a “master”, but this terminology was dropped to avoid confusion with master server in MySQL Replication.) There is no user-facing mechanism for influencing this selection, which is completely automatic; the fact that it *is* automatic is a key part of NDB Cluster's internal architecture.

When a node acts as the “leader” for any of these mechanisms, it is usually the point of coordination for the activity, and the other nodes act as “followers”, carrying out their parts of the activity as directed by the leader. If the node acting as leader fails, then the remaining nodes elect a new leader. Tasks in progress that were being coordinated by the old leader may either fail or be continued by the new leader, depending on the actual mechanism involved.

It is possible for some of these different mechanisms and protocols to have different leader nodes, but in general the same leader is chosen for all of them. The node indicated as the leader in the output of `SHOW` in the management client is known internally as the `DICT` manager (see The DBDICT Block, in the *NDB Cluster API Developer Guide*, for more information), responsible for coordinating DDL and metadata activity.

NDB Cluster is designed in such a way that the choice of leader has no discernible effect outside the cluster itself. For example, the current leader does not have significantly higher CPU or resource usage than the other data nodes, and failure of the leader should not have a significantly different impact on the cluster than the failure of any other data node.

A.10.8. With which operating systems can I use NDB Cluster?

NDB Cluster is supported on most Unix-like operating systems. NDB Cluster is also supported in production settings on Microsoft Windows operating systems.

For more detailed information concerning the level of support which is offered for NDB Cluster on various operating system versions, operating system distributions, and hardware platforms, please refer to http://www.mysql.com/support/supportedplatforms/cluster.html.

A.10.9. What are the hardware requirements for running NDB Cluster?

NDB Cluster should run on any platform for which `NDB`-enabled binaries are available. For data nodes and API nodes, faster CPUs and more memory are likely to improve performance, and 64-bit CPUs are likely to be more effective than 32-bit processors. There must be sufficient memory on machines used for data nodes to hold each node's share of the database (see *How much RAM do I Need?* for more information). For a computer which is used only for running the NDB Cluster management server, the requirements are minimal; a common desktop PC (or the equivalent) is generally sufficient for this task. Nodes can communicate through the standard TCP/IP network and hardware. They can also use the high-speed SCI protocol; however, special networking hardware and software are required to use SCI (see Section 18.3.4, “Using High-Speed Interconnects with NDB Cluster”).

A.10.10. How much RAM do I need to use NDB Cluster? Is it possible to use disk memory at all?

NDB Cluster was originally implemented as in-memory only, but all versions currently available also provide the ability to store NDB Cluster on disk. See Section 18.5.12, “NDB Cluster Disk Data Tables”, for more information.

For in-memory `NDB` tables, you can use the following formula for obtaining a rough estimate of how much RAM is needed for each data node in the cluster:

```
(SizeofDatabase × NumberOfReplicas × 1.1 ) / NumberOfDataNodes
```

To calculate the memory requirements more exactly requires determining, for each table in the cluster database, the storage space required per row (see Section 11.7, “Data Type Storage Requirements”, for details), and multiplying this by the number of rows. You must also remember to account for any column indexes as follows:

- Each primary key or hash index created for an `NDBCLUSTER` table requires 21−25 bytes per record. These indexes use `IndexMemory`.
- Each ordered index requires 10 bytes storage per record, using `DataMemory`.
- Creating a primary key or unique index also creates an ordered index, unless this index is created with `USING HASH`. In other words:
  - A primary key or unique index on a Cluster table normally takes up 31 to 35 bytes per record.
  - However, if the primary key or unique index is created with `USING HASH`, then it requires only 21 to 25 bytes per record.

Creating NDB Cluster tables with `USING HASH` for all primary keys and unique indexes will generally cause table updates to run more quickly—in some cases by a much as 20 to 30 percent faster than updates on tables where `USING HASH` was not used in creating primary and unique keys. This is due to the fact that less memory is required (because no ordered indexes are created), and that less CPU must be utilized (because fewer indexes must be read and possibly updated). However, it also means that queries that could otherwise use range scans must be satisfied by other means, which can result in slower selects.

When calculating Cluster memory requirements, you may find useful the `ndb_size.pl` utility which is available in recent MySQL 5.5 releases. This Perl script connects to a current (non-Cluster) MySQL database and creates a report on how much space that database would require if it used the `NDBCLUSTER` storage engine. For more information, see Section 18.4.25, “`ndb_size.pl` — NDBCLUSTER Size Requirement Estimator”.

It is especially important to keep in mind that *every NDB Cluster table must have a primary key*. The `NDB` storage engine creates a primary key automatically if none is defined; this primary key is created without `USING HASH`.

You can determine how much memory is being used for storage of NDB Cluster data and indexes at any given time using the `REPORT MEMORYUSAGE` command in the `ndb_mgm` client; see Section 18.5.2, “Commands in the NDB Cluster Management Client”, for more information. In addition, warnings are written to the cluster log when 80% of available `DataMemory` or `IndexMemory` is in use, and again when usage reaches 85%, 90%, and so on.

A.10.11. What file systems can I use with NDB Cluster? What about network file systems or network shares?

Generally, any file system that is native to the host operating system should work well with NDB Cluster. If you find that a given file system works particularly well (or not so especially well) with NDB Cluster, we invite you to discuss your findings in the NDB Cluster Forums.

For Windows, we recommend that you use `NTFS` file systems for NDB Cluster, just as we do for standard MySQL. We do not test NDB Cluster with `FAT` or `VFAT` file systems. Because of this, we do not recommend their use with MySQL or NDB Cluster.

NDB Cluster is implemented as a shared-nothing solution; the idea behind this is that the failure of a single piece of hardware should not cause the failure of multiple cluster nodes, or possibly even the failure of the cluster as a whole. For this reason, the use of network shares or network

file systems is not supported for NDB Cluster. This also applies to shared storage devices such as SANs.

A.10.12. Can I run NDB Cluster nodes inside virtual machines (such as those created by VMWare, Parallels, or Xen)?

NDB Cluster is supported for use in virtual machines. We currently support and test using Oracle VM.

Some NDB Cluster users have successfully deployed NDB Cluster using other virtualization products; in such cases, Oracle can provide NDB Cluster support, but issues specific to the virtual environment must be referred to that product's vendor.

A.10.13. I am trying to populate an NDB Cluster database. The loading process terminates prematurely and I get an error message like this one:

```
ERROR 1114: The table 'my_cluster_table' is full
```

Why is this happening?

The cause is very likely to be that your setup does not provide sufficient RAM for all table data and all indexes, *including the primary key required by the `NDB` storage engine and automatically created in the event that the table definition does not include the definition of a primary key*.

It is also worth noting that all data nodes should have the same amount of RAM, since no data node in a cluster can use more memory than the least amount available to any individual data node. For example, if there are four computers hosting Cluster data nodes, and three of these have 3GB of RAM available to store Cluster data while the remaining data node has only 1GB RAM, then each data node can devote at most 1GB to NDB Cluster data and indexes.

In some cases it is possible to get `Table is full` errors in MySQL client applications even when `ndb_mgm -e "ALL REPORT MEMORYUSAGE"` shows significant free `DataMemory`. You can force `NDB` to create extra partitions for NDB Cluster tables and thus have more memory available for hash indexes by using the `MAX_ROWS` option for `CREATE TABLE`. In general, setting `MAX_ROWS` to twice the number of rows that you expect to store in the table should be sufficient.

For similar reasons, you can also sometimes encounter problems with data node restarts on nodes that are heavily loaded with data. The `MinFreePct` parameter can help with this issue by reserving a portion (5% by default) of `DataMemory` and `IndexMemory` for use in restarts. This reserved memory is not available for storing `NDB` tables or data.

A.10.14. NDB Cluster uses TCP/IP. Does this mean that I can run it over the Internet, with one or more nodes in remote locations?

It is *very* unlikely that a cluster would perform reliably under such conditions, as NDB Cluster was designed and implemented with the assumption that it would be run under conditions guaranteeing dedicated high-speed connectivity such as that found in a LAN setting using 100 Mbps or gigabit Ethernet—preferably the latter. We neither test nor warrant its performance using anything slower than this.

Also, it is extremely important to keep in mind that communications between the nodes in an NDB Cluster are not secure; they are neither encrypted nor safeguarded by any other protective mechanism. The most secure configuration for a cluster is in a private network behind a firewall, with no direct access to any Cluster data or management nodes from outside. (For SQL nodes, you should take the same precautions as you would with any other instance of the MySQL server.) For more information, see Section 18.5.11, “NDB Cluster Security Issues”.

A.10.15. Do I have to learn a new programming or query language to use NDB Cluster?

No. Although some specialized commands are used to manage and configure the cluster itself, only standard (My)SQL statements are required for the following operations:

- Creating, altering, and dropping tables
- Inserting, updating, and deleting table data
- Creating, changing, and dropping primary and unique indexes

Some specialized configuration parameters and files are required to set up an NDB Cluster—see Section 18.3.3, “NDB Cluster Configuration Files”, for information about these.

A few simple commands are used in the NDB Cluster management client (`ndb_mgm`) for tasks such as starting and stopping cluster nodes. See Section 18.5.2, “Commands in the NDB Cluster Management Client”.

A.10.16. What programming languages and APIs are supported by NDB Cluster?

NDB Cluster supports the same programming APIs and languages as the standard MySQL Server, including ODBC, .Net, the MySQL C API, and numerous drivers for popular scripting languages such as PHP, Perl, and Python. NDB Cluster applications written using these APIs behave similarly to other MySQL applications; they transmit SQL statements to a MySQL Server (in the case of NDB Cluster, an SQL node), and receive responses containing rows of data. For more information about these APIs, see Chapter 23, *Connectors and APIs*.

NDB Cluster also supports application programming using the NDB API, which provides a low-level C++ interface to NDB Cluster data without needing to go through a MySQL Server. See The NDB API. In addition, many `NDBCLUSTER` management functions are exposed by the C-language MGM API; see The MGM API, for more information.

NDB Cluster also supports Java application programming using ClusterJ, which supports a domain object model of data using sessions and transactions. See Java and NDB Cluster, for more information.

In addition, NDB Cluster provides support for `memcached`, allowing developers to access data stored in NDB Cluster using the `memcached` interface; for more information, see ndbmemcache—Memcache API for NDB Cluster.

A.10.17. Does NDB Cluster include any management tools?

NDB Cluster includes a command line client for performing basic management functions. See Section 18.4.5, “`ndb_mgm` — The NDB Cluster Management Client”, and Section 18.5.2, “Commands in the NDB Cluster Management Client”.

NDB Cluster is also supported by MySQL Cluster Manager, a separate product providing an advanced command line interface that can automate many NDB Cluster management tasks such as rolling restarts and configuration changes. For more information about MySQL Cluster Manager, see MySQL™ Cluster Manager 1.4.3 User Manual.

A.10.18. How do I find out what an error or warning message means when using NDB Cluster?

There are two ways in which this can be done:

- From within the `mysql` client, use `SHOW ERRORS` or `SHOW WARNINGS` immediately upon being notified of the error or warning condition.
- From a system shell prompt, use `perror --ndb error_code`.

A.10.19. Is NDB Cluster transaction-safe? What isolation levels are supported?

Yes. For tables created with the `NDB` storage engine, transactions are supported. Currently, NDB Cluster supports only the `READ COMMITTED` transaction isolation level.

A.10.20. What storage engines are supported by NDB Cluster?

Clustering with MySQL is supported only by the `NDB` storage engine. That is, in order for a table to be shared between nodes in an NDB Cluster, the table must be created using `ENGINE=NDB` (or the equivalent option `ENGINE=NDBCLUSTER`).

It is possible to create tables using other storage engines (such as `InnoDB` or `MyISAM`) on a MySQL server being used with an NDB Cluster, but since these tables do not use `NDB`, they do not participate in clustering; each such table is strictly local to the individual MySQL server instance on which it is created.

A.10.21. In the event of a catastrophic failure— for example, the whole city loses power *and* my UPS fails —would I lose all my data?

All committed transactions are logged. Therefore, although it is possible that some data could be lost in the event of a catastrophe, this should be quite limited. Data loss can be further reduced by minimizing the number of operations per transaction. (It is not a good idea to perform large numbers of operations per transaction in any case.)

A.10.22. Is it possible to use `FULLTEXT` indexes with NDB Cluster?

`FULLTEXT` indexing is currently supported only by the `MyISAM` storage engine. See Section 12.9, “Full-Text Search Functions”, for more information.

A.10.23. Can I run multiple nodes on a single computer?

It is possible but not always advisable. One of the chief reasons to run a cluster is to provide redundancy. To obtain the full benefits of this redundancy, each node should reside on a separate machine. If you place multiple nodes on a single machine and that machine fails, you lose all of those nodes. For this reason, if you do run multiple data nodes on a single machine, it is *extremely* important that they be set up in such a way that the failure of this machine does not cause the loss of all the data nodes in a given node group.

Given that NDB Cluster can be run on commodity hardware loaded with a low-cost (or even no-cost) operating system, the expense of an extra machine or two is well worth it to safeguard mission-critical data. It also worth noting that the requirements for a cluster host running a management node are minimal. This task can be accomplished with a 300 MHz Pentium or equivalent CPU and sufficient RAM for the operating system, plus a small amount of overhead for the `ndb_mgmd` and `ndb_mgm` processes.

It is acceptable to run multiple cluster data nodes on a single host that has multiple CPUs, cores, or both. The NDB Cluster distribution also provides a multi-threaded version of the data node binary intended for use on such systems. For more information, see Section 18.4.3, “`ndbmtd` — The NDB Cluster Data Node Daemon (Multi-Threaded)”.

It is also possible in some cases to run data nodes and SQL nodes concurrently on the same machine; how well such an arrangement performs is dependent on a number of factors such as number of cores and CPUs as well as the amount of disk and memory available to the data node and SQL node processes, and you must take these factors into account when planning such a configuration.

A.10.24. Can I add data nodes to an NDB Cluster without restarting it?

It is possible to add new data nodes to a running NDB Cluster without taking the cluster offline. For more information, see Section 18.5.13, “Adding NDB Cluster Data Nodes Online”.

For other types of NDB Cluster nodes, a rolling restart is all that is required (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”).

A.10.25. Are there any limitations that I should be aware of when using NDB Cluster?

Limitations on `NDB` tables in MySQL NDB Cluster 7.2 include the following:

- Temporary tables are not supported; a `CREATE TEMPORARY TABLE` statement using `ENGINE=NDB` or `ENGINE=NDBCLUSTER` fails with an error.
- The only types of user-defined partitioning supported for `NDBCLUSTER` tables are `KEY` and `LINEAR KEY`. Trying to create an `NDB` table using any other partitioning type fails with an error.
- `FULLTEXT` indexes are not supported.
- Index prefixes are not supported. Only complete columns may be indexed.
- Spatial indexes are not supported (although spatial columns can be used). See Section 11.5, “Spatial Data Types”.
- Support for partial transactions and partial rollbacks is comparable to that of other transactional storage engines such as `InnoDB` that can roll back individual statements.
- The maximum number of attributes allowed per table is 512. Attribute names cannot be any longer than 31 characters. For each table, the maximum combined length of the table and database names is 122 characters.
- The maximum size for a table row is 14 kilobytes, not counting `BLOB` values.

  There is no set limit for the number of rows per `NDB` table. Limits on table size depend on a number of factors, in particular on the amount of RAM available to each data node.
- The `NDBCLUSTER` engine does not support foreign key constraints. As with `MyISAM` tables, if these are specified in a `CREATE TABLE` or `ALTER TABLE` statement, they are ignored.

For a complete listing of limitations in NDB Cluster, see Section 18.1.6, “Known Limitations of NDB Cluster”. See also Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”.

A.10.26. Does NDB Cluster support foreign keys?

NDB Cluster 7.2 does not support foreign key contraints, and ignores foreign keys in `CREATE TABLE` statements (similarly to how `MyISAM` treats foreign key syntax).

Foreign key support comparable to that found in the `InnoDB` storage engine is provided by `NDB` beginning with NDB 7.3. Applications requiring foreign key support should use NDB Cluster 7.3 or later.

A.10.27. How do I import an existing MySQL database into an NDB Cluster?

You can import databases into NDB Cluster much as you would with any other version of MySQL. Other than the limitations mentioned elsewhere in this FAQ, the only other special requirement is that any tables to be included in the cluster must use the `NDB` storage engine. This means that the tables must be created with `ENGINE=NDB` or `ENGINE=NDBCLUSTER`.

It is also possible to convert existing tables that use other storage engines to `NDBCLUSTER` using one or more `ALTER TABLE` statement. However, the definition of the table must be compatible with the `NDBCLUSTER` storage engine prior to making the conversion. In MySQL 5.5, an additional workaround is also required; see Section 18.1.6, “Known Limitations of NDB Cluster”, for details.

A.10.28. How do NDB Cluster nodes communicate with one another?

Cluster nodes can communicate through any of three different transport mechanisms: TCP/IP, SHM (shared memory), and SCI (Scalable Coherent Interface). Where available, SHM is used by default between nodes residing on the same cluster host; however, this is considered experimental. SCI is a high-speed (1 gigabit per second and higher), high-availability protocol

used in building scalable multi-processor systems; it requires special hardware and drivers. See Section 18.3.4, “Using High-Speed Interconnects with NDB Cluster”, for more about using SCI as a transport mechanism for NDB Cluster.

A.10.29 What is an *arbitrator*?

If one or more data nodes in a cluster fail, it is possible that not all cluster data nodes will be able to “see” one another. In fact, it is possible that two sets of data nodes might become isolated from one another in a network partitioning, also known as a “split-brain” scenario. This type of situation is undesirable because each set of data nodes tries to behave as though it is the entire cluster. An arbitrator is required to decide between the competing sets of data nodes.

When all data nodes in at least one node group are alive, network partitioning is not an issue, because no single subset of the cluster can form a functional cluster on its own. The real problem arises when no single node group has all its nodes alive, in which case network partitioning (the “split-brain” scenario) becomes possible. Then an arbitrator is required. All cluster nodes recognize the same node as the arbitrator, which is normally the management server; however, it is possible to configure any of the MySQL Servers in the cluster to act as the arbitrator instead. The arbitrator accepts the first set of cluster nodes to contact it, and tells the remaining set to shut down. Arbitrator selection is controlled by the `ArbitrationRank` configuration parameter for MySQL Server and management server nodes. You can also use the `ArbitrationRank` configuration parameter to control the arbitrator selection process. For more information about these parameters, see Section 18.3.3.5, “Defining an NDB Cluster Management Server”.

The role of arbitrator does not in and of itself impose any heavy demands upon the host so designated, and thus the arbitrator host does not need to be particularly fast or to have extra memory especially for this purpose.

A.10.30 What data types are supported by NDB Cluster?

NDB Cluster supports all of the usual MySQL data types, including those associated with MySQL's spatial extensions; however, the `NDB` storage engine does not support spatial indexes. (Spatial indexes are supported only by `MyISAM`; see Section 11.5, “Spatial Data Types”, for more information.) In addition, there are some differences with regard to indexes when used with `NDB` tables.

Note

NDB Cluster Disk Data tables (that is, tables created with `TABLESPACE ... STORAGE DISK ENGINE=NDB` or `TABLESPACE ... STORAGE DISK ENGINE=NDBCLUSTER`) have only fixed-width rows. This means that (for example) each Disk Data table record containing a `VARCHAR(255)` column requires space for 255 characters (as required for the character set and collation being used for the table), regardless of the actual number of characters stored therein.

See Section 18.1.6, “Known Limitations of NDB Cluster”, for more information about these issues.

A.10.31 How do I start and stop NDB Cluster?

It is necessary to start each node in the cluster separately, in the following order:

1. Start the management node, using the `ndb_mgmd` command.

   You must include the `-f` or `--config-file` option to tell the management node where its configuration file can be found.

2. Start each data node with the `ndbd` command.

Each data node must be started with the `-c` or `--ndb-connectstring` option so that the data node knows how to connect to the management server.

3. Start each MySQL Server (SQL node) using your preferred startup script, such as `mysqld_safe`.

   Each MySQL Server must be started with the `--ndbcluster` and `--ndb-connectstring` options. These options cause mysqld to enable `NDBCLUSTER` storage engine support and how to connect to the management server.

Each of these commands must be run from a system shell on the machine housing the affected node. (You do not have to be physically present at the machine—a remote login shell can be used for this purpose.) You can verify that the cluster is running by starting the `NDB` management client `ndb_mgm` on the machine housing the management node and issuing the `SHOW` or `ALL STATUS` command.

To shut down a running cluster, issue the command `SHUTDOWN` in the management client. Alternatively, you may enter the following command in a system shell:

```
shell> ndb_mgm -e "SHUTDOWN"
```

(The quotation marks in this example are optional, since there are no spaces in the command string following the `-e` option; in addition, the `SHUTDOWN` command, like other management client commands, is not case-sensitive.)

Either of these commands causes the `ndb_mgm`, `ndb_mgm`, and any `ndbd` processes to terminate gracefully. MySQL servers running as SQL nodes can be stopped using `mysqladmin shutdown`.

For more information, see Section 18.5.2, “Commands in the NDB Cluster Management Client”, and Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”.

A.10.32. What happens to NDB Cluster data when the NDB Cluster is shut down?

The data that was held in memory by the cluster's data nodes is written to disk, and is reloaded into memory the next time that the cluster is started.

A.10.33. Is it a good idea to have more than one management node for an NDB Cluster?

It can be helpful as a fail-safe. Only one management node controls the cluster at any given time, but it is possible to configure one management node as primary, and one or more additional management nodes to take over in the event that the primary management node fails.

See Section 18.3.3, “NDB Cluster Configuration Files”, for information on how to configure NDB Cluster management nodes.

A.10.34. Can I mix different kinds of hardware and operating systems in one NDB Cluster?

Yes, as long as all machines and operating systems have the same “endianness” (all big-endian or all little-endian).

It is also possible to use software from different NDB Cluster releases on different nodes. However, we support this only as part of a rolling upgrade procedure (see Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”).

A.10.35. Can I run two data nodes on a single host? Two SQL nodes?

Yes, it is possible to do this. In the case of multiple data nodes, it is advisable (but not required) for each node to use a different data directory. If you want to run multiple SQL nodes on one machine, each instance of `mysqld` must use a different TCP/IP port.

Running data nodes and SQL nodes together on the same host is possible, but you should be aware that the `ndbd` (or `ndbmtd`) and `mysqld` processes may compete for memory.

A.10.36. Can I use host names with NDB Cluster?

Yes, it is possible to use DNS and DHCP for cluster hosts. However, if your application requires “five nines” availability, you should use fixed (numeric) IP addresses, since making communication between Cluster hosts dependent on services such as DNS and DHCP introduces additional potential points of failure.

A.10.37. Does NDB Cluster support IPv6?

IPv6 is supported for connections between SQL nodes (MySQL servers), but connections between all other types of NDB Cluster nodes must use IPv4.

In practical terms, this means that you can use IPv6 for replication between NDB Clusters, but connections between nodes in the same NDB Cluster must use IPv4. For more information, see Section 18.6.3, “Known Issues in NDB Cluster Replication”.

A.10.38. How do I handle MySQL users in an NDB Cluster having multiple MySQL servers?

MySQL user accounts and privileges are normally not automatically propagated between different MySQL servers accessing the same NDB Cluster. MySQL NDB Cluster provides support for distributed privileges, which you can enable by following a procedure provided in the documentation; see Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”, for more information.

A.10.39. How do I continue to send queries in the event that one of the SQL nodes fails?

MySQL NDB Cluster does not provide any sort of automatic failover between SQL nodes. Your application must be prepared to handle the loss of SQL nodes and to fail over between them.

A.10.40. How do I back up and restore an NDB Cluster?

You can use the NDB Cluster native backup and restore functionality in the NDB management client and the `ndb_restore` program. See Section 18.5.3, “Online Backup of NDB Cluster”, and Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”.

You can also use the traditional functionality provided for this purpose in `mysqldump` and the MySQL server. See Section 4.5.4, “`mysqldump` — A Database Backup Program”, for more information.

A.10.41. What is an “angel process”?

This process monitors and, if necessary, attempts to restart the data node process. If you check the list of active processes on your system after starting `ndbd`, you can see that there are actually 2 processes running by that name, as shown here (we omit the output from `ndb_mgmd` and `ndbd` for brevity):

```
shell> ./ndb_mgmd

shell> ps aux | grep ndb
me      23002  0.0  0.0 122948  3104 ?        Ssl  14:14   0:00 ./ndb_mgmd
me      23025  0.0  0.0   5284   820 pts/2    S+   14:14   0:00 grep ndb

shell> ./ndbd -c 127.0.0.1 --initial

shell> ps aux | grep ndb
me      23002  0.0  0.0 123080  3356 ?        Ssl  14:14   0:00 ./ndb_mgmd
me      23096  0.0  0.0  35876  2036 ?        Ss   14:14   0:00 ./ndbd -c 127.0.0.1 --initial
me      23097  1.0  2.4 524116 91096 ?        Sl   14:14   0:00 ./ndbd -c 127.0.0.1 --initial
me      23168  0.0  0.0   5284   812 pts/2    R+   14:15   0:00 grep ndb
```

The ndbd process showing 0 memory and CPU usage is the angel process. It actually does use a very small amount of each, of course. It simply checks to see if the main ndbd process (the primary data node process that actually handles the data) is running. If permitted to do so (for example, if the StopOnError configuration parameter is set to false—see Section 18.3.2.1, "NDB Cluster Data Node Configuration Parameters"), the angel process tries to restart the primary data node process.

A.11 MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets

This set of Frequently Asked Questions derives from the experience of MySQL's Support and Development groups in handling many inquiries about CJK (Chinese-Japanese-Korean) issues.

A.11.1 What CJK character sets are available in MySQL? 2871
A.11.2 I have inserted CJK characters into my table. Why does SELECT display them as "?" characters? 2872
A.11.3 What problems should I be aware of when working with the Big5 Chinese character set? .. 2874
A.11.4 Why do Japanese character set conversions fail? 2874
A.11.5 What should I do if I want to convert SJIS 81CA to cp932? 2875
A.11.6 How does MySQL represent the Yen (¥) sign? 2875
A.11.7 Of what issues should I be aware when working with Korean character sets in MySQL? 2875
A.11.8 Why do I get Incorrect string value error messages? 2876
A.11.9 Why does my GUI front end or browser display CJK characters incorrectly in my application using Access, PHP, or another API? 2876
A.11.10 I've upgraded to MySQL 5.5. How can I revert to behavior like that in MySQL 4.0 with regard to character sets? 2877
A.11.11 Why do some LIKE and FULLTEXT searches with CJK characters fail? 2878
A.11.12 How do I know whether character X is available in all character sets? 2879
A.11.13 Why do CJK strings sort incorrectly in Unicode? (I) 2880
A.11.14 Why do CJK strings sort incorrectly in Unicode? (II) 2881
A.11.15 Why are my supplementary characters rejected by MySQL? 2882
A.11.16 Should "CJK" be "CJKV"? 2882
A.11.17 Does MySQL permit CJK characters to be used in database and table names? 2882
A.11.18 Where can I find translations of the MySQL Manual into Chinese, Japanese, and Korean? 2882
A.11.19 Where can I get help with CJK and related issues in MySQL? 2883

A.11.1 What CJK character sets are available in MySQL?

The list of CJK character sets may vary depending on your MySQL version. For example, the gb18030 character set is not supported prior to MySQL 5.7.4. However, since the name of the applicable language appears in the DESCRIPTION column for every entry in the INFORMATION_SCHEMA.CHARACTER_SETS table, you can obtain a current list of all the non-Unicode CJK character sets using this query:

```
mysql> SELECT CHARACTER_SET_NAME, DESCRIPTION
       FROM INFORMATION_SCHEMA.CHARACTER_SETS
       WHERE DESCRIPTION LIKE '%Chin%'
       OR DESCRIPTION LIKE '%Japanese%'
       OR DESCRIPTION LIKE '%Korean%'
       ORDER BY CHARACTER_SET_NAME;
+--------------------+--------------------------------+
| CHARACTER_SET_NAME | DESCRIPTION                    |
+--------------------+--------------------------------+
| big5               | Big5 Traditional Chinese       |
| cp932              | SJIS for Windows Japanese      |
| eucjpms            | UJIS for Windows Japanese      |
| euckr              | EUC-KR Korean                  |
| gb18030            | China National Standard GB18030 |
| gb2312             | GB2312 Simplified Chinese      |
```

```
| gbk                | GBK Simplified Chinese          |
| sjis               | Shift-JIS Japanese              |
| ujis               | EUC-JP Japanese                 |
+--------------------+---------------------------------+
```

(For more information, see Section 21.1, “The INFORMATION_SCHEMA CHARACTER_SETS Table”.)

MySQL supports three variants of the *GB* (*Guojia Biaozhun*, or *National Standard*, or *Simplified Chinese*) character sets which are official in the People's Republic of China: `gb2312`, `gbk`, and (as of MySQL 5.7.4) `gb18030`.

Sometimes people try to insert `gbk` characters into `gb2312`, and it works most of the time because `gbk` is a superset of `gb2312`. But eventually they try to insert a rarer Chinese character and it does not work. (For an example, see Bug #16072).

Here, we try to clarify exactly what characters are legitimate in `gb2312` or `gbk`, with reference to the official documents. Please check these references before reporting `gb2312` or `gbk` bugs:

- The MySQL `gbk` character set is in reality “Microsoft code page 936”. This differs from the official `gbk` for characters `A1A4` (middle dot), `A1AA` (em dash), `A6E0-A6F5`, and `A8BB-A8C0`.
- For a listing of `gbk`/Unicode mappings, see http://www.unicode.org/Public/MAPPINGS/VENDORS/MICSFT/WINDOWS/CP936.TXT.

It is also possible to store CJK characters in Unicode character sets, although the available collations may not sort characters quite as you expect:

- The `utf8` and `ucs2` character sets support the characters from Unicode Basic Multilingual Plane (BMP). These characters have code point values between `U+0000` and `U+FFFF`.
- The `utf8mb4`, `utf16`, `utf16le`, and `utf32` character sets support BMP characters, as well as supplementary characters that lie outside the BMP. Supplementary characters have code point values between `U+10000` and `U+10FFFF`.

The collation used for a Unicode character set determines the ability to sort (that is, distinguish) characters in the set:

- Collations based on Unicode Collation Algorithm (UCA) 4.0.0 distinguish only BMP characters.
- Collations based on UCA 5.2.0 or 9.0.0 distinguish BMP and supplementary characters.
- Non-UCA collations may not distinguish all Unicode characters. For example, the `utf8mb4` default collation is `utf8mb4_general_ci`, which distinguishes only BMP characters.

Moreover, distinguishing characters is not the same as ordering them per the conventions of a given CJK language. Currently, MySQL has only one CJK-specific UCA collation, `gb18030_unicode_520_ci` (which requires use of the non-Unicode `gb18030` character set).

For information about Unicode collations and their differentiating properties, including collation properties for supplementary characters, see Section 10.1.10.1, “Unicode Character Sets”.

A.11.2. I have inserted CJK characters into my table. Why does `SELECT` display them as “?” characters?

This problem is usually due to a setting in MySQL that does not match the settings for the application program or the operating system. Here are some common steps for correcting these types of issues:

- *Be certain of what MySQL version you are using*.

  Use the statement `SELECT VERSION();` to determine this.

- *Make sure that the database is actually using the desired character set*.

  People often think that the client character set is always the same as either the server character set or the character set used for display purposes. However, both of these are false assumptions. You can make sure by checking the result of `SHOW CREATE TABLE tablename` or, better yet, by using this statement:

```
SELECT character_set_name, collation_name
    FROM information_schema.columns
    WHERE table_schema = your_database_name
        AND table_name = your_table_name
        AND column_name = your_column_name;
```

- *Determine the hexadecimal value of the character or characters that are not being displayed correctly*.

  You can obtain this information for a column `column_name` in the table `table_name` using the following query:

```
SELECT HEX(column_name)
FROM table_name;
```

  `3F` is the encoding for the `?` character; this means that `?` is the character actually stored in the column. This most often happens because of a problem converting a particular character from your client character set to the target character set.

- *Make sure that a round trip is possible. When you select `literal` (or `_introducer hexadecimal-value`), do you obtain `literal` as a result*?

  For example, the Japanese Katakana character *Pe* (`ペ`) exists in all CJK character sets, and has the code point value (hexadecimal coding) `0x30da`. To test a round trip for this character, use this query:

```
SELECT 'ペ' AS `ペ`;         /* or SELECT _ucs2 0x30da; */
```

  If the result is not also `ペ`, the round trip failed.

  For bug reports regarding such failures, we might ask you to follow up with `SELECT HEX('ペ');`. Then we can determine whether the client encoding is correct.

- *Make sure that the problem is not with the browser or other application, rather than with MySQL*.

  Use the `mysql` client program to accomplish this task. If `mysql` displays characters correctly but your application does not, your problem is probably due to system settings.

  To determine your settings, use the `SHOW VARIABLES` statement, whose output should resemble what is shown here:

```
mysql> SHOW VARIABLES LIKE 'char%';
+--------------------------+----------------------------------------+
| Variable_name            | Value                                  |
+--------------------------+----------------------------------------+
| character_set_client     | utf8                                   |
| character_set_connection | utf8                                   |
| character_set_database   | latin1                                 |
| character_set_filesystem | binary                                 |
| character_set_results    | utf8                                   |
| character_set_server     | latin1                                 |
| character_set_system     | utf8                                   |
```

```
| character_sets_dir       | /usr/local/mysql/share/mysql/charsets/ |
+--------------------------+----------------------------------------+
```

These are typical character-set settings for an international-oriented client (notice the use of `utf8` Unicode) connected to a server in the West (`latin1` is a West Europe character set).

Although Unicode (usually the `utf8` variant on Unix, and the `ucs2` variant on Windows) is preferable to Latin, it is often not what your operating system utilities support best. Many Windows users find that a Microsoft character set, such as `cp932` for Japanese Windows, is suitable.

If you cannot control the server settings, and you have no idea what setting your underlying computer uses, try changing to a common character set for the country that you're in (`euckr` = Korea; `gb18030`, `gb2312` or `gbk` = People's Republic of China; `big5` = Taiwan; `sjis`, `ujis`, `cp932`, or `eucjpms` = Japan; `ucs2` or `utf8` = anywhere). Usually it is necessary to change only the client and connection and results settings. The `SET NAMES`. statement changes all three at once. For example:

```
SET NAMES 'big5';
```

Once the setting is correct, you can make it permanent by editing `my.cnf` or `my.ini`. For example you might add lines looking like these:

```
[mysqld]
character-set-server=big5
[client]
default-character-set=big5
```

It is also possible that there are issues with the API configuration setting being used in your application; see *Why does my GUI front end or browser not display CJK characters correctly...?* for more information.

A.11.3 What problems should I be aware of when working with the Big5 Chinese character set?

MySQL supports the Big5 character set which is common in Hong Kong and Taiwan (Republic of China). The MySQL `big5` character set is in reality Microsoft code page 950, which is very similar to the original `big5` character set.

A feature request for adding `HKSCS` extensions has been filed. People who need this extension may find the suggested patch for Bug #13577 to be of interest.

A.11.4 Why do Japanese character set conversions fail?

MySQL supports the `sjis`, `ujis`, `cp932`, and `eucjpms` character sets, as well as Unicode. A common need is to convert between character sets. For example, there might be a Unix server (typically with `sjis` or `ujis`) and a Windows client (typically with `cp932`).

In the following conversion table, the `ucs2` column represents the source, and the `sjis`, `cp932`, `ujis`, and `eucjpms` columns represent the destinations; that is, the last 4 columns provide the hexadecimal result when we use `CONVERT(ucs2)` or we assign a `ucs2` column containing the value to an `sjis`, `cp932`, `ujis`, or `eucjpms` column.

Character Name	ucs2	sjis	cp932	ujis	eucjpms
BROKEN BAR	00A6	3F	3F	8FA2C3	3F
FULLWIDTH BROKEN BAR	FFE4	3F	FA55	3F	8FA2
YEN SIGN	00A5	3F	3F	20	3F
FULLWIDTH YEN SIGN	FFE5	818F	818F	A1EF	3F
TILDE	007E	7E	7E	7E	7E

Character Name	ucs2	sjis	cp932	ujis	eucjpms
OVERLINE	203E	3F	3F	20	3F
HORIZONTAL BAR	2015	815C	815C	A1BD	A1BD
EM DASH	2014	3F	3F	3F	3F
REVERSE SOLIDUS	005C	815F	5C	5C	5C
FULLWIDTH ""	FF3C	3F	815F	3F	A1C0
WAVE DASH	301C	8160	3F	A1C1	3F
FULLWIDTH TILDE	FF5E	3F	8160	3F	A1C1
DOUBLE VERTICAL LINE	2016	8161	3F	A1C2	3F
PARALLEL TO	2225	3F	8161	3F	A1C2
MINUS SIGN	2212	817C	3F	A1DD	3F
FULLWIDTH HYPHEN-MINUS	FF0D	3F	817C	3F	A1DD
CENT SIGN	00A2	8191	3F	A1F1	3F
FULLWIDTH CENT SIGN	FFE0	3F	8191	3F	A1F1
POUND SIGN	00A3	8192	3F	A1F2	3F
FULLWIDTH POUND SIGN	FFE1	3F	8192	3F	A1F2
NOT SIGN	00AC	81CA	3F	A2CC	3F
FULLWIDTH NOT SIGN	FFE2	3F	81CA	3F	A2CC

Now consider the following portion of the table.

	ucs2	sjis	cp932
NOT SIGN	00AC	81CA	3F
FULLWIDTH NOT SIGN	FFE2	3F	81CA

This means that MySQL converts the `NOT SIGN` (Unicode `U+00AC`) to `sjis` code point `0x81CA` and to `cp932` code point `3F`. (`3F` is the question mark (“?”. This is what is always used when the conversion cannot be performed.)

A.11.5. What should I do if I want to convert SJIS `81CA` to `cp932`?

Our answer is: “?”. There are disadvantages to this, and many people would prefer a “loose” conversion, so that `81CA (NOT SIGN)` in `sjis` becomes `81CA (FULLWIDTH NOT SIGN)` in `cp932`.

A.11.6. How does MySQL represent the Yen (¥) sign?

A problem arises because some versions of Japanese character sets (both `sjis` and `euc`) treat `5C` as a *reverse solidus* (`\`, also known as a backslash), whereas others treat it as a yen sign (¥).

MySQL follows only one version of the JIS (Japanese Industrial Standards) standard description. In MySQL, *`5C` is always the reverse solidus (`\`)*.

A.11.7. Of what issues should I be aware when working with Korean character sets in MySQL?

In theory, while there have been several versions of the `euckr` (*Extended Unix Code Korea*) character set, only one problem has been noted. We use the “ASCII” variant of EUC-KR, in which the code point `0x5c` is REVERSE SOLIDUS, that is `\`, instead of the “KS-Roman” variant of EUC-KR, in which the code point `0x5c` is `WON SIGN` (₩). This means that you cannot convert Unicode `U+20A9` to `euckr`:

```
mysql> SELECT
           CONVERT('₩' USING euckr) AS euckr,
           HEX(CONVERT('₩' USING euckr)) AS hexeuckr;
+-------+----------+
| euckr | hexeuckr |
+-------+----------+
| ?     | 3F       |
+-------+----------+
```

A.11.8 Why do I get `Incorrect string value` error messages?

To see the problem, create a table with one Unicode (`ucs2`) column and one Chinese (`gb2312`) column.

```
mysql> CREATE TABLE ch
       (ucs2 CHAR(3) CHARACTER SET ucs2,
       gb2312 CHAR(3) CHARACTER SET gb2312);
```

In nonstrict SQL mode, try to place the rare character 汃 in both columns.

```
mysql> SET sql_mode = '';
mysql> INSERT INTO ch VALUES ('A汃B','A汃B');
Query OK, 1 row affected, 1 warning (0.00 sec)
```

The `INSERT` produces a warning. Use the following statement to see what it is:

```
mysql> SHOW WARNINGS\G
*************************** 1. row ***************************
  Level: Warning
   Code: 1366
Message: Incorrect string value: '\xE6\xB1\x8CB' for column 'gb2312' at row 1
```

So it is a warning about the `gb2312` column only.

```
mysql> SELECT ucs2,HEX(ucs2),gb2312,HEX(gb2312) FROM ch;
+-------+--------------+--------+-------------+
| ucs2  | HEX(ucs2)    | gb2312 | HEX(gb2312) |
+-------+--------------+--------+-------------+
| A汃B | 00416C4C0042 | A?B    | 413F42      |
+-------+--------------+--------+-------------+
```

Several things need explanation here:

1. The 汃 character is not in the `gb2312` character set, as described earlier.
2. If you are using an old version of MySQL, you may see a different message.
3. A warning occurs rather than an error because MySQL is not set to use strict SQL mode. In nonstrict mode, MySQL tries to do what it can, to get the best fit, rather than give up. With strict SQL mode, the `Incorrect string value` message occurs as an error rather than a warning, and the `INSERT` fails.

A.11.9 Why does my GUI front end or browser display CJK characters incorrectly in my application using Access, PHP, or another API?

Obtain a direct connection to the server using the `mysql` client, and try the same query there. If `mysql` responds correctly, the trouble may be that your application interface requires initialization. Use `mysql` to tell you what character set or sets it uses with the statement `SHOW VARIABLES LIKE 'char%';`. If you are using Access, you are most likely connecting with Connector/ODBC. In this case, you should check Configuring Connector/ODBC. If, for example, you use `big5`, you would enter `SET NAMES 'big5'`. (In this case, no `;` character is required.)

If you are using ASP, you might need to add `SET NAMES` in the code. Here is an example that has worked in the past:

```
<%
Session.CodePage=0
Dim strConnection
Dim Conn
strConnection="driver={MySQL ODBC 3.51 Driver};server=server;uid=username;" \
              & "pwd=password;database=database;stmt=SET NAMES 'big5';"
Set Conn = Server.CreateObject("ADODB.Connection")
Conn.Open strConnection
%>
```

In much the same way, if you are using any character set other than `latin1` with Connector/Net, you must specify the character set in the connection string. See Connecting to MySQL Using Connector/Net, for more information.

If you are using PHP, try this:

```
<?php
  $link = new mysqli($host, $usr, $pwd, $db);

  if( mysqli_connect_errno() )
  {
    printf("Connect failed: %s\n", mysqli_connect_error());
    exit();
  }

  $link->query("SET NAMES 'utf8'");
?>
```

In this case, we used `SET NAMES` to change `character_set_client`, `character_set_connection`, and `character_set_results`.

Another issue often encountered in PHP applications has to do with assumptions made by the browser. Sometimes adding or changing a `<meta>` tag suffices to correct the problem: for example, to insure that the user agent interprets page content as `UTF-8`, include `<meta http-equiv="Content-Type" content="text/html; charset=utf-8">` in the `<head>` section of the HTML page.

If you are using Connector/J, see Using Character Sets and Unicode.

A.11.10. I've upgraded to MySQL 5.5. How can I revert to behavior like that in MySQL 4.0 with regard to character sets?

In MySQL Version 4.0, there was a single “global” character set for both server and client, and the decision as to which character to use was made by the server administrator. This changed starting with MySQL Version 4.1. What happens now is a “handshake”, as described in Section 10.1.4, “Connection Character Sets and Collations”:

> When a client connects, it sends to the server the name of the character set that it wants to use. The server uses the name to set the `character_set_client`, `character_set_results`, and `character_set_connection` system variables. In effect, the server performs a `SET NAMES` operation using the character set name.

The effect of this is that you cannot control the client character set by starting `mysqld` with `--character-set-server=utf8`. However, some Asian customers prefer the MySQL 4.0 behavior. To make it possible to retain this behavior, we added a `mysqld` switch, `--character-set-client-handshake`, which can be turned off with `--skip-character-set-client-handshake`. If you start `mysqld` with `--skip-character-set-client-`

`handshake`, then, when a client connects, it sends to the server the name of the character set that it wants to use. However, *the server ignores this request from the client*.

By way of example, suppose that your favorite server character set is `latin1` (unlikely in a CJK area, but this is the default value). Suppose further that the client uses `utf8` because this is what the client's operating system supports. Now, start the server with `latin1` as its default character set:

```
mysqld --character-set-server=latin1
```

And then start the client with the default character set `utf8`:

```
mysql --default-character-set=utf8
```

The resulting settings can be seen by viewing the output of `SHOW VARIABLES`:

```
mysql> SHOW VARIABLES LIKE 'char%';
+--------------------------+----------------------------------------+
| Variable_name            | Value                                  |
+--------------------------+----------------------------------------+
| character_set_client     | utf8                                   |
| character_set_connection | utf8                                   |
| character_set_database   | latin1                                 |
| character_set_filesystem | binary                                 |
| character_set_results    | utf8                                   |
| character_set_server     | latin1                                 |
| character_set_system     | utf8                                   |
| character_sets_dir       | /usr/local/mysql/share/mysql/charsets/ |
+--------------------------+----------------------------------------+
```

Now stop the client, and stop the server using `mysqladmin`. Then start the server again, but this time tell it to skip the handshake like so:

```
mysqld --character-set-server=utf8 --skip-character-set-client-handshake
```

Start the client with `utf8` once again as the default character set, then display the resulting settings:

```
mysql> SHOW VARIABLES LIKE 'char%';
+--------------------------+----------------------------------------+
| Variable_name            | Value                                  |
+--------------------------+----------------------------------------+
| character_set_client     | latin1                                 |
| character_set_connection | latin1                                 |
| character_set_database   | latin1                                 |
| character_set_filesystem | binary                                 |
| character_set_results    | latin1                                 |
| character_set_server     | latin1                                 |
| character_set_system     | utf8                                   |
| character_sets_dir       | /usr/local/mysql/share/mysql/charsets/ |
+--------------------------+----------------------------------------+
```

As you can see by comparing the differing results from `SHOW VARIABLES`, the server ignores the client's initial settings if the `--skip-character-set-client-handshake` option is used.

A.11.11 Why do some `LIKE` and `FULLTEXT` searches with CJK characters fail?

For `LIKE` searches, there is a very simple problem with binary string column types such as `BINARY` and `BLOB`: we must know where characters end. With multibyte character sets, different characters might have different octet lengths. For example, in `utf8`, `A` requires one byte but ペ requires three bytes, as shown here:

```
+------------------------+--------------------------+
| OCTET_LENGTH(_utf8 'A') | OCTET_LENGTH(_utf8 'ペ') |
+------------------------+--------------------------+
|                      1 |                        3 |
+------------------------+--------------------------+
```

If we do not know where the first character in a string ends, we do not know where the second character begins, in which case even very simple searches such as `LIKE '_A%'` fail. The solution is to use a nonbinary string column type defined to have the proper CJK character set. For example: `mycol TEXT CHARACTER SET sjis`. Alternatively, convert to a CJK character set before comparing.

This is one reason why MySQL cannot permit encodings of nonexistent characters. If it is not strict about rejecting bad input, it has no way of knowing where characters end.

For `FULLTEXT` searches, we must know where words begin and end. With Western languages, this is rarely a problem because most (if not all) of these use an easy-to-identify word boundary: the space character. However, this is not usually the case with Asian writing. We could use arbitrary halfway measures, like assuming that all Han characters represent words, or (for Japanese) depending on changes from Katakana to Hiragana due to grammatical endings. However, the only sure solution requires a comprehensive word list, which means that we would have to include a dictionary in the server for each Asian language supported. This is simply not feasible.

A.11.12. How do I know whether character *X* is available in all character sets?

The majority of simplified Chinese and basic nonhalfwidth Japanese Kana characters appear in all CJK character sets. The following stored procedure accepts a `UCS-2` Unicode character, converts it to other character sets, and displays the results in hexadecimal.

```
DELIMITER //

CREATE PROCEDURE p_convert(ucs2_char CHAR(1) CHARACTER SET ucs2)
BEGIN

CREATE TABLE tj
             (ucs2 CHAR(1) character set ucs2,
              utf8 CHAR(1) character set utf8,
              big5 CHAR(1) character set big5,
              cp932 CHAR(1) character set cp932,
              eucjpms CHAR(1) character set eucjpms,
              euckr CHAR(1) character set euckr,
              gb2312 CHAR(1) character set gb2312,
              gbk CHAR(1) character set gbk,
              sjis CHAR(1) character set sjis,
              ujis CHAR(1) character set ujis);

INSERT INTO tj (ucs2) VALUES (ucs2_char);

UPDATE tj SET utf8=ucs2,
              big5=ucs2,
              cp932=ucs2,
              eucjpms=ucs2,
              euckr=ucs2,
              gb2312=ucs2,
              gbk=ucs2,
              sjis=ucs2,
              ujis=ucs2;

/* If there are conversion problems, UPDATE produces warnings. */

SELECT hex(ucs2) AS ucs2,
       hex(utf8) AS utf8,
       hex(big5) AS big5,
       hex(cp932) AS cp932,
```

```
       hex(eucjpms) AS eucjpms,
       hex(euckr) AS euckr,
       hex(gb2312) AS gb2312,
       hex(gbk) AS gbk,
       hex(sjis) AS sjis,
       hex(ujis) AS ujis
FROM tj;

DROP TABLE tj;

END//

DELIMITER ;
```

The input can be any single `ucs2` character, or it can be the code value (hexadecimal representation) of that character. For example, from Unicode's list of `ucs2` encodings and names (http://www.unicode.org/Public/UNIDATA/UnicodeData.txt), we know that the Katakana character *Pe* appears in all CJK character sets, and that its code value is `X'30DA'`. If we use this value as the argument to `p_convert()`, the result is as shown here:

```
mysql> CALL p_convert(X'30DA');
+------+--------+------+-------+---------+-------+--------+------+------+------+
| ucs2 | utf8   | big5 | cp932 | eucjpms | euckr | gb2312 | gbk  | sjis | ujis |
+------+--------+------+-------+---------+-------+--------+------+------+------+
| 30DA | E3839A | C772 | 8379  | A5DA    | ABDA  | A5DA   | A5DA | 8379 | A5DA |
+------+--------+------+-------+---------+-------+--------+------+------+------+
```

Since none of the column values is `3F` (that is, the question mark character, `?`), we know that every conversion worked.

A.11.13 Why do CJK strings sort incorrectly in Unicode? (I)

Note

The CJK sorting problems described here can occur for MySQL versions prior to MySQL 8.0. As of MySQL 8.0, they can be solved by using the `utf8mb4` character set and the `utf8mb4_ja_0900_as_cs` collation.

Sometimes people observe that the result of a `utf8_unicode_ci` or `ucs2_unicode_ci` search, or of an `ORDER BY` sort is not what they think a native would expect. Although we never rule out the possibility that there is a bug, we have found in the past that many people do not correctly read the standard table of weights for the Unicode Collation Algorithm. MySQL uses the tables found under http://www.unicode.org/Public/UCA/:

- UCA 4.0.0 table: http://www.unicode.org/Public/UCA/4.0.0/allkeys-4.0.0.txt

  This includes *`xxx`*`_unicode_ci` collations with no version number in the collation name.

- UCA 5.2.0 table: http://www.unicode.org/Public/UCA/5.2.0/allkeys.txt

  This includes collations with `_520_` in the collation name.

- UCA 9.0.0 table: http://www.unicode.org/Public/UCA/9.0.0/allkeys.txt

  This includes collations with `_0900_` in the collation name.

To handle newer UCA versions, we create new collations. We are very wary about changing ordering of existing collations because that affects indexes, which can bring about situations such as that reported in Bug #16526, illustrated as follows:

```
mysql> CREATE TABLE tj (s1 CHAR(1) CHARACTER SET utf8 COLLATE utf8_unicode_ci);
Query OK, 0 rows affected (0.05 sec)
```

```
mysql> INSERT INTO tj VALUES ('が'),('か');
Query OK, 2 rows affected (0.00 sec)
Records: 2  Duplicates: 0  Warnings: 0

mysql> SELECT * FROM tj WHERE s1 = 'か';
+------+
| s1   |
+------+
| が   |
| か   |
+------+
```

The character in the first result row is not the one that we searched for. Why did MySQL retrieve it? First we look for the Unicode code point value, which is possible by reading the hexadecimal number for the `ucs2` version of the characters:

```
mysql> SELECT s1, HEX(CONVERT(s1 USING ucs2)) FROM tj;
+------+-----------------------------+
| s1   | HEX(CONVERT(s1 USING ucs2)) |
+------+-----------------------------+
| が   | 304C                        |
| か   | 304B                        |
+------+-----------------------------+
```

Now we search for `304B` and `304C` in the `4.0.0 allkeys` table, and find these lines:

```
304B  ; [.1E57.0020.000E.304B] # HIRAGANA LETTER KA
304C  ; [.1E57.0020.000E.304B][.0000.0140.0002.3099] # HIRAGANA LETTER GA; QQCM
```

The official Unicode names (following the "#" mark) tell us the Japanese syllabary (Hiragana), the informal classification (letter, digit, or punctuation mark), and the Western identifier (`KA` or `GA`, which happen to be voiced and unvoiced components of the same letter pair). More importantly, the *primary weight* (the first hexadecimal number inside the square brackets) is `1E57` on both lines. For comparisons in both searching and sorting, MySQL pays attention to the primary weight only, ignoring all the other numbers. This means that we are sorting が and か correctly according to the Unicode specification. If we wanted to distinguish them, we'd have to use a non-UCA (Unicode Collation Algorithm) collation (`utf8_bin` or `utf8_general_ci`), or to compare the `HEX()` values, or use `ORDER BY CONVERT(s1 USING sjis)`. Being correct "according to Unicode" is not enough, of course: the person who submitted the bug was equally correct. To solve this, we need another collation for Japanese according to the JIS X 4061 standard, in which voiced/unvoiced letter pairs like `KA`/`GA` are distinguishable for ordering purposes.

A.11.14 Why do CJK strings sort incorrectly in Unicode? (II)

Note

The CJK sorting problems described here can occur for MySQL versions prior to MySQL 8.0. As of MySQL 8.0, they can be solved by using the `utf8mb4` character set and the `utf8mb4_ja_0900_as_cs` collation.

If you are using Unicode (`ucs2` or `utf8`), and you know what the Unicode sort order is (see Section A.11, "MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets"), but MySQL still seems to sort your table incorrectly, first verify the character set in the table definition:

```
mysql> SHOW CREATE TABLE t\G
*************************** 1. row ***************
Table: t
Create Table: CREATE TABLE `t` (
`s1` char(1) CHARACTER SET ucs2 DEFAULT NULL
) ENGINE=MyISAM DEFAULT CHARSET=latin1
```

Since the character set for the column `s1` appears to be correct (`ucs2`), check what information the `INFORMATION_SCHEMA.COLUMNS` table can provide about this column:

```
mysql> SELECT COLUMN_NAME, CHARACTER_SET_NAME, COLLATION_NAME
       FROM INFORMATION_SCHEMA.COLUMNS
       WHERE COLUMN_NAME = 's1'
       AND TABLE_NAME = 't';
+-------------+--------------------+-----------------+
| COLUMN_NAME | CHARACTER_SET_NAME | COLLATION_NAME  |
+-------------+--------------------+-----------------+
| s1          | ucs2               | ucs2_general_ci |
+-------------+--------------------+-----------------+
```

(See Section 21.4, “The INFORMATION_SCHEMA COLUMNS Table”, for more information.)

You can see that the collation is `ucs2_general_ci` instead of `ucs2_unicode_ci`. The reason why this is so can be found using `SHOW CHARACTER SET`, as shown here:

```
mysql> SHOW CHARSET LIKE 'ucs2%';
+---------+--------------+-------------------+--------+
| Charset | Description   | Default collation | Maxlen |
+---------+--------------+-------------------+--------+
| ucs2    | UCS-2 Unicode | ucs2_general_ci   |      2 |
+---------+--------------+-------------------+--------+
```

For `ucs2` and `utf8`, the default collation is “general”. To specify a Unicode UCA collation, use `COLLATE ucs2_unicode_ci`, as shown in the preceding item.

A.11.15. Why are my supplementary characters rejected by MySQL?

Supplementary characters lie outside the Unicode *Basic Multilingual Plane / Plane 0*. BMP characters have code point values between `U+0000` and `U+FFFF`. Supplementary characters have code point values between `U+10000` and `U+10FFFF`.

To store supplementary characters, you must use a character set that permits them:

- The `utf8` and `ucs2` character sets support BMP characters only.

  The `utf8` character set permits only `UTF-8` characters that take up to three bytes. This has led to reports such as that found in Bug #12600, which we rejected as “not a bug”. With `utf8`, MySQL must truncate an input string when it encounters bytes that it does no understand. Otherwise, it is unknown how long the bad multibyte character is.

  One possible workaround is to use `ucs2` instead of `utf8`, in which case the “bad” characters are changed to question marks. However, no truncation takes place. You can also change the data type to `BLOB` or `BINARY`, which perform no validity checking.

- The `utf8mb4`, `utf16`, `utf16le`, and `utf32` character sets support BMP characters, as well as supplementary characters outside the BMP.

A.11.16. Should “CJK” be “CJKV”?

No. The term “CJKV” (*Chinese Japanese Korean Vietnamese*) refers to Vietnamese character sets which contain Han (originally Chinese) characters. MySQL supports the modern Vietnamese script with Western characters, but does not support the old Vietnamese script using Han characters.

A.11.17. Does MySQL permit CJK characters to be used in database and table names?

Yes.

A.11.18. Where can I find translations of the MySQL Manual into Chinese, Japanese, and Korean?

The Japanese translation of the MySQL 5.6 manual can be downloaded from http://dev.mysql.com/doc/.

A.11.19 Where can I get help with CJK and related issues in MySQL?

The following resources are available:

- A listing of MySQL user groups can be found at https://wikis.oracle.com/display/mysql/List+of+MySQL+User+Groups.
- View feature requests relating to character set issues at http://tinyurl.com/y6xcuf.
- Visit the MySQL Character Sets, Collation, Unicode Forum. http://forums.mysql.com/ also provides foreign-language forums.

A.12 MySQL 5.5 FAQ: Connectors & APIs

For common questions, issues, and answers relating to the MySQL Connectors and other APIs, see the following areas of the Manual:

- Section 23.8.21, “C API Common Issues”
- Common Problems with MySQL and PHP
- Connector/ODBC Notes and Tips
- Connector/Net Programming
- MySQL Connector/J 5.1 Developer Guide

A.13 MySQL 5.5 FAQ: Replication

In the following section, we provide answers to questions that are most frequently asked about MySQL Replication.

A.13.1 Must the slave be connected to the master all the time? 2883
A.13.2 Must I enable networking on my master and slave to enable replication? 2884
A.13.3 How do I know how late a slave is compared to the master? In other words, how do I know the date of the last statement replicated by the slave? 2884
A.13.4 How do I force the master to block updates until the slave catches up? 2884
A.13.5 What issues should I be aware of when setting up two-way replication? 2884
A.13.6 How can I use replication to improve performance of my system? 2885
A.13.7 What should I do to prepare client code in my own applications to use performance-enhancing replication? 2885
A.13.8 When and how much can MySQL replication improve the performance of my system? 2885
A.13.9 How can I use replication to provide redundancy or high availability? 2886
A.13.10 How do I tell whether a master server is using statement-based or row-based binary logging format? 2886
A.13.11 How do I tell a slave to use row-based replication? 2886
A.13.12 How do I prevent `GRANT` and `REVOKE` statements from replicating to slave machines? 2886
A.13.13 Does replication work on mixed operating systems (for example, the master runs on Linux while slaves run on OS X and Windows)? 2887
A.13.14 Does replication work on mixed hardware architectures (for example, the master runs on a 64-bit machine while slaves run on 32-bit machines)? 2887

A.13.1 Must the slave be connected to the master all the time?

No, it does not. The slave can go down or stay disconnected for hours or even days, and then reconnect and catch up on updates. For example, you can set up a master/slave relationship over a dial-up link where the link is up only sporadically and for short periods of time. The implication of this is that, at any given time, the slave is not guaranteed to be in synchrony with the master unless you take some special measures.

To ensure that catchup can occur for a slave that has been disconnected, you must not remove binary log files from the master that contain information that has not yet been replicated to the slaves. Asynchronous replication can work only if the slave is able to continue reading the binary log from the point where it last read events.

A.13.2 Must I enable networking on my master and slave to enable replication?

Yes, networking must be enabled on the master and slave. If networking is not enabled, the slave cannot connect to the master and transfer the binary log. Check that the `skip-networking` option has not been enabled in the configuration file for either server.

A.13.3 How do I know how late a slave is compared to the master? In other words, how do I know the date of the last statement replicated by the slave?

Check the `Seconds_Behind_Master` column in the output from `SHOW SLAVE STATUS`. See Section 17.1.4.1, “Checking Replication Status”.

When the slave SQL thread executes an event read from the master, it modifies its own time to the event timestamp. (This is why `TIMESTAMP` is well replicated.) In the `Time` column in the output of `SHOW PROCESSLIST`, the number of seconds displayed for the slave SQL thread is the number of seconds between the timestamp of the last replicated event and the real time of the slave machine. You can use this to determine the date of the last replicated event. Note that if your slave has been disconnected from the master for one hour, and then reconnects, you may immediately see large `Time` values such as 3600 for the slave SQL thread in `SHOW PROCESSLIST`. This is because the slave is executing statements that are one hour old. See Section 17.2.1, “Replication Implementation Details”.

A.13.4 How do I force the master to block updates until the slave catches up?

Use the following procedure:

1. On the master, execute these statements:

```
mysql> FLUSH TABLES WITH READ LOCK;
mysql> SHOW MASTER STATUS;
```

   Record the replication coordinates (the current binary log file name and position) from the output of the `SHOW` statement.

2. On the slave, issue the following statement, where the arguments to the `MASTER_POS_WAIT()` function are the replication coordinate values obtained in the previous step:

```
mysql> SELECT MASTER_POS_WAIT('log_name', log_pos);
```

   The `SELECT` statement blocks until the slave reaches the specified log file and position. At that point, the slave is in synchrony with the master and the statement returns.

3. On the master, issue the following statement to enable the master to begin processing updates again:

```
mysql> UNLOCK TABLES;
```

A.13.5 What issues should I be aware of when setting up two-way replication?

MySQL replication currently does not support any locking protocol between master and slave to guarantee the atomicity of a distributed (cross-server) update. In other words, it is possible for client A to make an update to co-master 1, and in the meantime, before it propagates to co-master 2, client B could make an update to co-master 2 that makes the update of client A work

differently than it did on co-master 1. Thus, when the update of client A makes it to co-master 2, it produces tables that are different from what you have on co-master 1, even after all the updates from co-master 2 have also propagated. This means that you should not chain two servers together in a two-way replication relationship unless you are sure that your updates can safely happen in any order, or unless you take care of mis-ordered updates somehow in the client code.

You should also realize that two-way replication actually does not improve performance very much (if at all) as far as updates are concerned. Each server must do the same number of updates, just as you would have a single server do. The only difference is that there is a little less lock contention because the updates originating on another server are serialized in one slave thread. Even this benefit might be offset by network delays.

A.13.6. How can I use replication to improve performance of my system?

Set up one server as the master and direct all writes to it. Then configure as many slaves as you have the budget and rackspace for, and distribute the reads among the master and the slaves. You can also start the slaves with the `--skip-innodb`, `--low-priority-updates`, and `--delay-key-write=ALL` options to get speed improvements on the slave end. In this case, the slave uses nontransactional `MyISAM` tables instead of `InnoDB` tables to get more speed by eliminating transactional overhead.

A.13.7. What should I do to prepare client code in my own applications to use performance-enhancing replication?

See the guide to using replication as a scale-out solution, Section 17.3.3, “Using Replication for Scale-Out”.

A.13.8. When and how much can MySQL replication improve the performance of my system?

MySQL replication is most beneficial for a system that processes frequent reads and infrequent writes. In theory, by using a single-master/multiple-slave setup, you can scale the system by adding more slaves until you either run out of network bandwidth, or your update load grows to the point that the master cannot handle it.

To determine how many slaves you can use before the added benefits begin to level out, and how much you can improve performance of your site, you must know your query patterns, and determine empirically by benchmarking the relationship between the throughput for reads and writes on a typical master and a typical slave. The example here shows a rather simplified calculation of what you can get with replication for a hypothetical system. Let `reads` and `writes` denote the number of reads and writes per second, respectively.

Let's say that system load consists of 10% writes and 90% reads, and we have determined by benchmarking that `reads` is 1200 - 2 * `writes`. In other words, the system can do 1,200 reads per second with no writes, the average write is twice as slow as the average read, and the relationship is linear. Suppose that the master and each slave have the same capacity, and that we have one master and *N* slaves. Then we have for each server (master or slave):

`reads` = 1200 - 2 * `writes`

`reads` = 9 * `writes` / (*N* + 1) (reads are split, but writes replicated to all slaves)

9 * `writes` / (*N* + 1) + 2 * `writes` = 1200

`writes` = 1200 / (2 + 9/(*N* + 1))

The last equation indicates the maximum number of writes for *N* slaves, given a maximum possible read rate of 1,200 per second and a ratio of nine reads per write.

This analysis yields the following conclusions:

- If *N* = 0 (which means we have no replication), our system can handle about 1200/11 = 109 writes per second.
- If *N* = 1, we get up to 184 writes per second.
- If *N* = 8, we get up to 400 writes per second.
- If *N* = 17, we get up to 480 writes per second.
- Eventually, as *N* approaches infinity (and our budget negative infinity), we can get very close to 600 writes per second, increasing system throughput about 5.5 times. However, with only eight servers, we increase it nearly four times.

These computations assume infinite network bandwidth and neglect several other factors that could be significant on your system. In many cases, you may not be able to perform a computation similar to the one just shown that accurately predicts what will happen on your system if you add *N* replication slaves. However, answering the following questions should help you decide whether and by how much replication will improve the performance of your system:

- What is the read/write ratio on your system?
- How much more write load can one server handle if you reduce the reads?
- For how many slaves do you have bandwidth available on your network?

A.13.9. How can I use replication to provide redundancy or high availability?

How you implement redundancy is entirely dependent on your application and circumstances. High-availability solutions (with automatic failover) require active monitoring and either custom scripts or third party tools to provide the failover support from the original MySQL server to the slave.

To handle the process manually, you should be able to switch from a failed master to a pre-configured slave by altering your application to talk to the new server or by adjusting the DNS for the MySQL server from the failed server to the new server.

For more information and some example solutions, see Section 17.3.6, “Switching Masters During Failover”.

A.13.10. How do I tell whether a master server is using statement-based or row-based binary logging format?

Check the value of the `binlog_format` system variable:

```
mysql> SHOW VARIABLES LIKE 'binlog_format';
```

The value shown will be one of `STATEMENT`, `ROW`, or `MIXED`. For `MIXED` mode, statement-based logging is used by default but replication switches automatically to row-based logging under certain conditions, such as unsafe statements. For information about when this may occur, see Section 5.4.4.3, “Mixed Binary Logging Format”.

A.13.11. How do I tell a slave to use row-based replication?

Slaves automatically know which format to use.

A.13.12. How do I prevent `GRANT` and `REVOKE` statements from replicating to slave machines?

Start the server with the `--replicate-wild-ignore-table=mysql.%` option to ignore replication for tables in the `mysql` database.

A.13.13. Does replication work on mixed operating systems (for example, the master runs on Linux while slaves run on OS X and Windows)?

Yes.

A.13.14. Does replication work on mixed hardware architectures (for example, the master runs on a 64-bit machine while slaves run on 32-bit machines)?

Yes.

A.14 MySQL 5.5 FAQ: MySQL Enterprise Thread Pool

A.14.1 What is the Thread Pool and what problem does it solve? 2887
A.14.2 How does the Thread Pool limit and manage concurrent sessions and transactions for optimal performance and throughput? 2887
A.14.3 How is the Thread Pool different from the client side Connection Pool? 2887
A.14.4 When should I use the Thread Pool? 2888
A.14.5 Are there recommended Thread Pool configurations? 2888

A.14.1. What is the Thread Pool and what problem does it solve?

The MySQL Thread Pool is a MySQL server plugin that extends the default connection-handling capabilities of the MySQL server to limit the number of concurrently executing statements/queries and transactions to ensure that each has sufficient CPU and memory resources to fulfill its task. Commercial distributions of MySQL 5.5 include the Thread Pool plugin.

The default thread-handling model in MySQL Server executes statements using one thread per client connection. As more clients connect to the server and execute statements, overall performance degrades. The Thread Pool plugin provides an alternative thread-handling model designed to reduce overhead and improve performance. The Thread Pool plugin increases server performance by efficiently managing statement execution threads for large numbers of client connections, especially on modern multi-CPU/Core systems.

For more information, see Section 5.5.3, “MySQL Enterprise Thread Pool”.

A.14.2. How does the Thread Pool limit and manage concurrent sessions and transactions for optimal performance and throughput?

The Thread Pool uses a “divide and conquer” approach to limiting and balancing concurrency. Unlike the default connection handling of the MySQL Server, the Thread Pool separates connections and threads, so there is no fixed relationship between connections and the threads that execute statements received from those connections. The Thread Pool then manages client connections within configurable thread groups, where they are prioritized and queued based on the nature of the work they were submitted to accomplish.

For more information, see Section 5.5.3.3, “Thread Pool Operation”.

A.14.3. How is the Thread Pool different from the client side Connection Pool?

The MySQL Connection Pool operates on the client side to ensure that a MySQL client does not constantly connect to and disconnect from the MySQL server. It is designed to cache idle connections in the MySQL client for use by other users as they are needed. This minimizes the overhead and expense of establishing and tearing down connections as queries are submitted to the MySQL server. The MySQL Connection Pool has no visibility as to the query handling capabilities or load of the back-end MySQL server. By contrast, the Thread Pool operates on the MySQL server side and is designed to manage the execution of inbound concurrent connections and queries as they are received from the client connections accessing the back-end MySQL database. Because of the separation of duties, the MySQL Connection Pool and Thread Pool are orthogonal and can be used independent of each other.

MySQL Connection Pooling via the MySQL Connectors is covered in Chapter 23, *Connectors and APIs*.

A.14.4 When should I use the Thread Pool?

There are a few rules of thumb to consider for optimal Thread Pool use cases:

The MySQL `Threads_running` variable keeps track of the number of concurrent statements currently executing in the MySQL Server. If this variable consistently exceeds a region where the server won't operate optimally (usually going beyond 40 for InnoDB workloads), the Thread Pool will be beneficial, especially in extreme parallel overload situations.

If you are using the `innodb_thread_concurrency` to limit the number of concurrently executing statements, you will find the Thread Pool solves the same problem, only better, by assigning connections to thread groups, then queuing executions based on transactional content, user defined designations, and so forth.

Lastly, if your workload comprises mainly short queries, the Thread Pool will be beneficial.

To learn more, see Section 5.5.3.4, “Thread Pool Tuning”.

A.14.5 Are there recommended Thread Pool configurations?

The Thread Pool has a number of user case driven configuration parameters that affect its performance. To learn about these and tips on tuning, see Section 5.5.3.4, “Thread Pool Tuning”.

A.15 MySQL 5.5 FAQ: InnoDB Change Buffer

A.15.1 What types of operations modify secondary indexes and result in change buffering? 2888
A.15.2 What is the benefit of the `InnoDB` change buffer? 2888
A.15.3 Does the change buffer support other types of indexes? 2888
A.15.4 How much space does `InnoDB` use for the change buffer? 2888
A.15.5 How do I determine the current size of the change buffer? 2889
A.15.6 When does change buffer merging occur? 2889
A.15.7 When is the change buffer flushed? 2889
A.15.8 When should the change buffer be used? 2889
A.15.9 When should the change buffer not be used? 2889
A.15.10 Where can I find additional information about the change buffer? 2890

A.15.1 What types of operations modify secondary indexes and result in change buffering?

`INSERT`, `UPDATE`, and `DELETE` operations can modify secondary indexes. If an affected index page is not in the buffer pool, the changes can be buffered in the change buffer.

A.15.2 What is the benefit of the `InnoDB` change buffer?

Buffering secondary index changes when secondary index pages are not in the buffer pool avoids expensive random access I/O operations that would be required to immediately read in affected index pages from disk. Buffered changes can be applied later, in batches, as pages are read into the buffer pool by other read operations.

A.15.3 Does the change buffer support other types of indexes?

No. The change buffer only supports secondary indexes. Clustered indexes, full-text indexes, and spatial indexes are not supported. Full-text indexes have their own caching mechanism.

A.15.4 How much space does `InnoDB` use for the change buffer?

The maximum size of the on-disk change buffer in the system tablespace is 1/3 of the `InnoDB` buffer pool size. `InnoDB` does not buffer an operation if it would cause the on-disk change buffer to exceed this limit.

Change buffer pages are not required to persist in the buffer pool and may be evicted by LRU operations.

A.15.5. How do I determine the current size of the change buffer?

The current size of the change buffer is reported by `SHOW ENGINE INNODB STATUS \G`, under the `INSERT BUFFER AND ADAPTIVE HASH INDEX` heading. For example:

```
-------------------------------------
INSERT BUFFER AND ADAPTIVE HASH INDEX
-------------------------------------
Ibuf: size 1, free list len 0, seg size 2, 0 merges
```

Relevant data points include:

- `size`: The number of pages used within the change buffer. Change buffer size is equal to `seg size - (1 + free list len)`. The `1 +` value represents the change buffer header page.
- `seg size`: The size of the change buffer, in pages.

For information about monitoring change buffer status, see Section 14.7.2, “Change Buffer”.

A.15.6. When does change buffer merging occur?

- When a page is read into the buffer pool, buffered changes are merged upon completion of the read, before the page is made available.
- Change buffer merging is performed as a background task. The `innodb_io_capacity` parameter sets an upper limit on the I/O activity performed by `InnoDB` background tasks such as merging data from the change buffer.
- A change buffer merge is performed during crash recovery. Changes are applied from the change buffer (in the system tablespace) to leaf pages of secondary indexes as index pages are read into the buffer pool.
- The change buffer is fully durable and will survive a system crash. Upon restart, change buffer merge operations resume as part of normal operations.
- A full merge of the change buffer can be forced as part of a slow server shutdown using `--innodb-fast-shutdown=0`.

A.15.7. When is the change buffer flushed?

Updated pages are flushed by the same flushing mechanism that flushes the other pages that occupy the buffer pool.

A.15.8. When should the change buffer be used?

The change buffer is a feature designed to reduce random I/O to secondary indexes as indexes grow larger and no longer fit in the `InnoDB` buffer pool. Generally, the change buffer should be used when the entire data set does not fit into the buffer pool, when there is substantial DML activity that modifies secondary index pages, or when there are lots of secondary indexes that are regularly changed by DML activity.

A.15.9. When should the change buffer not be used?

You might consider disabling the change buffer if the entire data set fits within the `InnoDB` buffer pool, if you have relatively few secondary indexes, or if you are using solid-state storage, where random reads are about as fast as sequential reads. Before making configuration changes, it is recommended that you run tests using a representative workload to determine if disabling the change buffer provides any benefit.

A.15.10 Where can I find additional information about the change buffer?

The following sections and blog post provide additional information about the `InnoDB` change buffer:

- Section 14.7.2, “Change Buffer”
- Section 14.9.4, “Configuring InnoDB Change Buffering”
- MySQL 5.5: InnoDB Change Buffering

A.16 MySQL 5.5 FAQ: Virtualization Support

A.16.1 Is MySQL supported on virtualized environments such as Oracle VM, VMWare, Docker, Microsoft Hyper-V, or others? 2890

A.16.1 Is MySQL supported on virtualized environments such as Oracle VM, VMWare, Docker, Microsoft Hyper-V, or others?

MySQL is supported on virtualized environments, but is certified only for Oracle VM. Contact Oracle Support for more information.

Be aware of potential problems when using virtualization software. The usual ones are related to performance, performance degradations, slowness, or unpredictability of disk, I/O, network, and memory.

Appendix B Errors, Error Codes, and Common Problems

Table of Contents

B.1 Sources of Error Information 2891
B.2 Types of Error Values 2891
B.3 Server Error Codes and Messages 2892
B.4 Client Error Codes and Messages 2944
B.5 Problems and Common Errors 2948
B.5.1 How to Determine What Is Causing a Problem 2948
B.5.2 Common Errors When Using MySQL Programs 2949
B.5.3 Administration-Related Issues 2962
B.5.4 Query-Related Issues 2969
B.5.5 Optimizer-Related Issues 2977
B.5.6 Table Definition-Related Issues 2977
B.5.7 Known Issues in MySQL 2978

This appendix lists common problems and errors that may occur and potential resolutions, in addition to listing the errors that may appear when you call MySQL from any host language. The first section covers problems and resolutions. Detailed information on errors is provided: One list displays server error messages. Another list displays client program messages.

B.1 Sources of Error Information

There are several sources of error information in MySQL:

- Each SQL statement executed results in an error code, an SQLSTATE value, and an error message, as described in Section B.2, “Types of Error Values”. These errors are returned from the server side; see Section B.3, “Server Error Codes and Messages”.
- Errors can occur on the client side, usually involving problems communicating with the server; see Section B.4, “Client Error Codes and Messages”.
- SQL statement warning and error information is available through the `SHOW WARNINGS` and `SHOW ERRORS` statements. The `warning_count` system variable indicates the number of errors, warnings, and notes. The `error_count` system variable indicates the number of errors. Its value excludes warnings and notes.
- `SHOW SLAVE STATUS` statement output includes information about replication errors occurring on the slave side.
- `SHOW ENGINE INNODB STATUS` statement output includes information about the most recent foreign key error if a `CREATE TABLE` statement for an `InnoDB` table fails.
- The `perror` program provides information from the command line about error numbers. See Section 4.8.1, “`perror` — Explain Error Codes”.

Descriptions of server and client errors are provided later in this Appendix. For information about errors related to `InnoDB`, see Section 14.23.4, “InnoDB Error Handling”.

B.2 Types of Error Values

When an error occurs in MySQL, the server returns two types of error values:

- A MySQL-specific error code. This value is numeric. It is not portable to other database systems.
- An SQLSTATE value. The value is a five-character string (for example, `'42S02'`). The values are taken from ANSI SQL and ODBC and are more standardized.

A message string that provides a textual description of the error is also available.

When an error occurs, the MySQL error code, SQLSTATE value, and message string are available using C API functions:

- MySQL error code: Call `mysql_errno()`
- SQLSTATE value: Call `mysql_sqlstate()`
- Error message: Call `mysql_error()`

For prepared statements, the corresponding error functions are `mysql_stmt_errno()`, `mysql_stmt_sqlstate()`, and `mysql_stmt_error()`. All error functions are described in Section 23.8, “MySQL C API”.

The number of errors, warnings, and notes for the previous statement can be obtained by calling `mysql_warning_count()`. See Section 23.8.7.72, “mysql_warning_count()”.

The first two characters of an SQLSTATE value indicate the error class:

- Class = `'00'` indicates success.
- Class = `'01'` indicates a warning.
- Class = `'02'` indicates “not found.” This is relevant within the context of cursors and is used to control what happens when a cursor reaches the end of a data set. This condition also occurs for `SELECT ... INTO var_list` statements that retrieve no rows.
- Class > `'02'` indicates an exception.

B.3 Server Error Codes and Messages

MySQL programs have access to several types of error information when the server returns an error. For example, the `mysql` client program displays errors using the following format:

```
shell> SELECT * FROM no_such_table;
ERROR 1146 (42S02): Table 'test.no_such_table' doesn't exist
```

The message displayed contains three types of information:

- A numeric error code (`1146`). This number is MySQL-specific and is not portable to other database systems.
- A five-character SQLSTATE value (`'42S02'`). The values are taken from ANSI SQL and ODBC and are more standardized. Not all MySQL error numbers have corresponding SQLSTATE values. In these cases, `'HY000'` (general error) is used.
- A message string that provides a textual description of the error.

For error checking, use error codes, not error messages. Error messages do not change often, but it is possible. Also if the database administrator changes the language setting, that affects the language of error messages.

Error codes are stable across GA releases of a given MySQL series. Before a series reaches GA status, new codes may still be under development and subject to change.

Server error information comes from the following source files. For details about the way that error information is defined, see the MySQL Internals Manual.

- Error message information is listed in the `share/errmsg-utf8.txt` file. `%d` and `%s` represent numbers and strings, respectively, that are substituted into the Message values when they are displayed.

- The Error values listed in `share/errmsg-utf8.txt` are used to generate the definitions in the `include/mysqld_error.h` and `include/mysqld_ername.h` MySQL source files.
- The SQLSTATE values listed in `share/errmsg-utf8.txt` are used to generate the definitions in the `include/sql_state.h` MySQL source file.

Because updates are frequent, it is possible that those files will contain additional error information not listed here.

- Error: `1000` SQLSTATE: `HY000` (`ER_HASHCHK`)

  Message: hashchk

  Unused.

- Error: `1001` SQLSTATE: `HY000` (`ER_NISAMCHK`)

  Message: isamchk

  Unused.

- Error: `1002` SQLSTATE: `HY000` (`ER_NO`)

  Message: NO

  Used in the construction of other messages.

- Error: `1003` SQLSTATE: `HY000` (`ER_YES`)

  Message: YES

  Used in the construction of other messages.

  Extended `EXPLAIN` format generates Note messages. `ER_YES` is used in the `Code` column for these messages in subsequent `SHOW WARNINGS` output.

- Error: `1004` SQLSTATE: `HY000` (`ER_CANT_CREATE_FILE`)

  Message: Can't create file '%s' (errno: %d)

  Occurs for failure to create or copy a file needed for some operation.

  Possible causes: Permissions problem for source file; destination file already exists but is not writeable.

- Error: `1005` SQLSTATE: `HY000` (`ER_CANT_CREATE_TABLE`)

  Message: Can't create table '%s' (errno: %d)

  `InnoDB` reports this error when a table cannot be created. If the error message refers to error 150, table creation failed because a foreign key constraint was not correctly formed. If the error message refers to error −1, table creation probably failed because the table includes a column name that matched the name of an internal `InnoDB` table.

- Error: `1006` SQLSTATE: `HY000` (`ER_CANT_CREATE_DB`)

  Message: Can't create database '%s' (errno: %d)

- Error: `1007` SQLSTATE: `HY000` (`ER_DB_CREATE_EXISTS`)

  Message: Can't create database '%s'; database exists

  An attempt to create a database failed because the database already exists.

Drop the database first if you really want to replace an existing database, or add an `IF NOT EXISTS` clause to the `CREATE DATABASE` statement if to retain an existing database without having the statement produce an error.

- Error: `1008` SQLSTATE: `HY000` (`ER_DB_DROP_EXISTS`)

  Message: Can't drop database '%s'; database doesn't exist

- Error: `1009` SQLSTATE: `HY000` (`ER_DB_DROP_DELETE`)

  Message: Error dropping database (can't delete '%s', errno: %d)

- Error: `1010` SQLSTATE: `HY000` (`ER_DB_DROP_RMDIR`)

  Message: Error dropping database (can't rmdir '%s', errno: %d)

- Error: `1011` SQLSTATE: `HY000` (`ER_CANT_DELETE_FILE`)

  Message: Error on delete of '%s' (errno: %d)

- Error: `1012` SQLSTATE: `HY000` (`ER_CANT_FIND_SYSTEM_REC`)

  Message: Can't read record in system table

  Returned by `InnoDB` for attempts to access `InnoDB` `INFORMATION_SCHEMA` tables when `InnoDB` is unavailable.

- Error: `1013` SQLSTATE: `HY000` (`ER_CANT_GET_STAT`)

  Message: Can't get status of '%s' (errno: %d)

- Error: `1014` SQLSTATE: `HY000` (`ER_CANT_GET_WD`)

  Message: Can't get working directory (errno: %d)

- Error: `1015` SQLSTATE: `HY000` (`ER_CANT_LOCK`)

  Message: Can't lock file (errno: %d)

- Error: `1016` SQLSTATE: `HY000` (`ER_CANT_OPEN_FILE`)

  Message: Can't open file: '%s' (errno: %d)

  `InnoDB` reports this error when the table from the `InnoDB` data files cannot be found, even though the `.frm` file for the table exists. See Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”.

- Error: `1017` SQLSTATE: `HY000` (`ER_FILE_NOT_FOUND`)

  Message: Can't find file: '%s' (errno: %d)

- Error: `1018` SQLSTATE: `HY000` (`ER_CANT_READ_DIR`)

  Message: Can't read dir of '%s' (errno: %d)

- Error: `1019` SQLSTATE: `HY000` (`ER_CANT_SET_WD`)

  Message: Can't change dir to '%s' (errno: %d)

- Error: `1020` SQLSTATE: `HY000` (`ER_CHECKREAD`)

  Message: Record has changed since last read in table '%s'

- Error: 1021 SQLSTATE: HY000 (ER_DISK_FULL)

  Message: Disk full (%s); waiting for someone to free some space...

- Error: 1022 SQLSTATE: 23000 (ER_DUP_KEY)

  Message: Can't write; duplicate key in table '%s'

- Error: 1023 SQLSTATE: HY000 (ER_ERROR_ON_CLOSE)

  Message: Error on close of '%s' (errno: %d)

- Error: 1024 SQLSTATE: HY000 (ER_ERROR_ON_READ)

  Message: Error reading file '%s' (errno: %d)

- Error: 1025 SQLSTATE: HY000 (ER_ERROR_ON_RENAME)

  Message: Error on rename of '%s' to '%s' (errno: %d)

  InnoDB reports this error if you attempt to drop the last index that can enforce a particular referential constraint. As of MySQL 5.5, this error message is replaced by ERROR 1553.

- Error: 1026 SQLSTATE: HY000 (ER_ERROR_ON_WRITE)

  Message: Error writing file '%s' (errno: %d)

- Error: 1027 SQLSTATE: HY000 (ER_FILE_USED)

  Message: '%s' is locked against change

- Error: 1028 SQLSTATE: HY000 (ER_FILSORT_ABORT)

  Message: Sort aborted

- Error: 1029 SQLSTATE: HY000 (ER_FORM_NOT_FOUND)

  Message: View '%s' doesn't exist for '%s'

- Error: 1030 SQLSTATE: HY000 (ER_GET_ERRNO)

  Message: Got error %d from storage engine

  Check the %d value to see what the OS error means. For example, 28 indicates that you have run out of disk space.

- Error: 1031 SQLSTATE: HY000 (ER_ILLEGAL_HA)

  Message: Table storage engine for '%s' doesn't have this option

- Error: 1032 SQLSTATE: HY000 (ER_KEY_NOT_FOUND)

  Message: Can't find record in '%s'

- Error: 1033 SQLSTATE: HY000 (ER_NOT_FORM_FILE)

  Message: Incorrect information in file: '%s'

- Error: 1034 SQLSTATE: HY000 (ER_NOT_KEYFILE)

  Message: Incorrect key file for table '%s'; try to repair it

- Error: 1035 SQLSTATE: HY000 (ER_OLD_KEYFILE)

  Message: Old key file for table '%s'; repair it!

- Error: 1036 SQLSTATE: HY000 (ER_OPEN_AS_READONLY)

  Message: Table '%s' is read only

- Error: 1037 SQLSTATE: HY001 (ER_OUTOFMEMORY)

  Message: Out of memory; restart server and try again (needed %d bytes)

- Error: 1038 SQLSTATE: HY001 (ER_OUT_OF_SORTMEMORY)

  Message: Out of sort memory, consider increasing server sort buffer size

- Error: 1039 SQLSTATE: HY000 (ER_UNEXPECTED_EOF)

  Message: Unexpected EOF found when reading file '%s' (errno: %d)

- Error: 1040 SQLSTATE: 08004 (ER_CON_COUNT_ERROR)

  Message: Too many connections

- Error: 1041 SQLSTATE: HY000 (ER_OUT_OF_RESOURCES)

  Message: Out of memory; check if mysqld or some other process uses all available memory; if not, you may have to use 'ulimit' to allow mysqld to use more memory or you can add more swap space

- Error: 1042 SQLSTATE: 08S01 (ER_BAD_HOST_ERROR)

  Message: Can't get hostname for your address

- Error: 1043 SQLSTATE: 08S01 (ER_HANDSHAKE_ERROR)

  Message: Bad handshake

- Error: 1044 SQLSTATE: 42000 (ER_DBACCESS_DENIED_ERROR)

  Message: Access denied for user '%s'@'%s' to database '%s'

- Error: 1045 SQLSTATE: 28000 (ER_ACCESS_DENIED_ERROR)

  Message: Access denied for user '%s'@'%s' (using password: %s)

- Error: 1046 SQLSTATE: 3D000 (ER_NO_DB_ERROR)

  Message: No database selected

- Error: 1047 SQLSTATE: 08S01 (ER_UNKNOWN_COM_ERROR)

  Message: Unknown command

- Error: 1048 SQLSTATE: 23000 (ER_BAD_NULL_ERROR)

  Message: Column '%s' cannot be null

- Error: 1049 SQLSTATE: 42000 (ER_BAD_DB_ERROR)

  Message: Unknown database '%s'

- Error: 1050 SQLSTATE: 42S01 (ER_TABLE_EXISTS_ERROR)

  Message: Table '%s' already exists

- Error: 1051 SQLSTATE: 42S02 (ER_BAD_TABLE_ERROR)

  Message: Unknown table '%s'

- Error: 1052 SQLSTATE: 23000 (ER_NON_UNIQ_ERROR)

Message: Column '%s' in %s is ambiguous

```
%s = column name
%s = location of column (for example, "field list")
```

Likely cause: A column appears in a query without appropriate qualification, such as in a select list or ON clause.

Examples:

```
mysql> SELECT i FROM t INNER JOIN t AS t2;
ERROR 1052 (23000): Column 'i' in field list is ambiguous

mysql> SELECT * FROM t LEFT JOIN t AS t2 ON i = i;
ERROR 1052 (23000): Column 'i' in on clause is ambiguous
```

Resolution:

- Qualify the column with the appropriate table name:

  ```
  mysql> SELECT t2.i FROM t INNER JOIN t AS t2;
  ```

- Modify the query to avoid the need for qualification:

  ```
  mysql> SELECT * FROM t LEFT JOIN t AS t2 USING (i);
  ```

- Error: 1053 SQLSTATE: 08S01 (ER_SERVER_SHUTDOWN)

  Message: Server shutdown in progress

- Error: 1054 SQLSTATE: 42S22 (ER_BAD_FIELD_ERROR)

  Message: Unknown column '%s' in '%s'

- Error: 1055 SQLSTATE: 42000 (ER_WRONG_FIELD_WITH_GROUP)

  Message: '%s' isn't in GROUP BY

- Error: 1056 SQLSTATE: 42000 (ER_WRONG_GROUP_FIELD)

  Message: Can't group on '%s'

- Error: 1057 SQLSTATE: 42000 (ER_WRONG_SUM_SELECT)

  Message: Statement has sum functions and columns in same statement

- Error: 1058 SQLSTATE: 21S01 (ER_WRONG_VALUE_COUNT)

  Message: Column count doesn't match value count

- Error: 1059 SQLSTATE: 42000 (ER_TOO_LONG_IDENT)

  Message: Identifier name '%s' is too long

- Error: 1060 SQLSTATE: 42S21 (ER_DUP_FIELDNAME)

  Message: Duplicate column name '%s'

- Error: 1061 SQLSTATE: 42000 (ER_DUP_KEYNAME)

  Message: Duplicate key name '%s'

- Error: 1062 SQLSTATE: 23000 (ER_DUP_ENTRY)

  Message: Duplicate entry '%s' for key %d

  The message returned with this error uses the format string for ER_DUP_ENTRY_WITH_KEY_NAME.

- Error: 1063 SQLSTATE: 42000 (ER_WRONG_FIELD_SPEC)

  Message: Incorrect column specifier for column '%s'

- Error: 1064 SQLSTATE: 42000 (ER_PARSE_ERROR)

  Message: %s near '%s' at line %d

- Error: 1065 SQLSTATE: 42000 (ER_EMPTY_QUERY)

  Message: Query was empty

- Error: 1066 SQLSTATE: 42000 (ER_NONUNIQ_TABLE)

  Message: Not unique table/alias: '%s'

- Error: 1067 SQLSTATE: 42000 (ER_INVALID_DEFAULT)

  Message: Invalid default value for '%s'

- Error: 1068 SQLSTATE: 42000 (ER_MULTIPLE_PRI_KEY)

  Message: Multiple primary key defined

- Error: 1069 SQLSTATE: 42000 (ER_TOO_MANY_KEYS)

  Message: Too many keys specified; max %d keys allowed

- Error: 1070 SQLSTATE: 42000 (ER_TOO_MANY_KEY_PARTS)

  Message: Too many key parts specified; max %d parts allowed

- Error: 1071 SQLSTATE: 42000 (ER_TOO_LONG_KEY)

  Message: Specified key was too long; max key length is %d bytes

- Error: 1072 SQLSTATE: 42000 (ER_KEY_COLUMN_DOES_NOT_EXITS)

  Message: Key column '%s' doesn't exist in table

- Error: 1073 SQLSTATE: 42000 (ER_BLOB_USED_AS_KEY)

  Message: BLOB column '%s' can't be used in key specification with the used table type

- Error: 1074 SQLSTATE: 42000 (ER_TOO_BIG_FIELDLENGTH)

  Message: Column length too big for column '%s' (max = %lu); use BLOB or TEXT instead

- Error: 1075 SQLSTATE: 42000 (ER_WRONG_AUTO_KEY)

  Message: Incorrect table definition; there can be only one auto column and it must be defined as a key

- Error: 1076 SQLSTATE: HY000 (ER_READY)

  Message: %s: ready for connections. Version: '%s' socket: '%s' port: %d

- Error: 1077 SQLSTATE: HY000 (ER_NORMAL_SHUTDOWN)

Message: %s: Normal shutdown

- Error: 1078 SQLSTATE: HY000 (ER_GOT_SIGNAL)

  Message: %s: Got signal %d. Aborting!

- Error: 1079 SQLSTATE: HY000 (ER_SHUTDOWN_COMPLETE)

  Message: %s: Shutdown complete

- Error: 1080 SQLSTATE: 08S01 (ER_FORCING_CLOSE)

  Message: %s: Forcing close of thread %ld user: '%s'

- Error: 1081 SQLSTATE: 08S01 (ER_IPSOCK_ERROR)

  Message: Can't create IP socket

- Error: 1082 SQLSTATE: 42S12 (ER_NO_SUCH_INDEX)

  Message: Table '%s' has no index like the one used in CREATE INDEX; recreate the table

- Error: 1083 SQLSTATE: 42000 (ER_WRONG_FIELD_TERMINATORS)

  Message: Field separator argument is not what is expected; check the manual

- Error: 1084 SQLSTATE: 42000 (ER_BLOBS_AND_NO_TERMINATED)

  Message: You can't use fixed rowlength with BLOBs; please use 'fields terminated by'

- Error: 1085 SQLSTATE: HY000 (ER_TEXTFILE_NOT_READABLE)

  Message: The file '%s' must be in the database directory or be readable by all

- Error: 1086 SQLSTATE: HY000 (ER_FILE_EXISTS_ERROR)

  Message: File '%s' already exists

- Error: 1087 SQLSTATE: HY000 (ER_LOAD_INFO)

  Message: Records: %ld Deleted: %ld Skipped: %ld Warnings: %ld

- Error: 1088 SQLSTATE: HY000 (ER_ALTER_INFO)

  Message: Records: %ld Duplicates: %ld

- Error: 1089 SQLSTATE: HY000 (ER_WRONG_SUB_KEY)

  Message: Incorrect prefix key; the used key part isn't a string, the used length is longer than the key part, or the storage engine doesn't support unique prefix keys

- Error: 1090 SQLSTATE: 42000 (ER_CANT_REMOVE_ALL_FIELDS)

  Message: You can't delete all columns with ALTER TABLE; use DROP TABLE instead

- Error: 1091 SQLSTATE: 42000 (ER_CANT_DROP_FIELD_OR_KEY)

  Message: Can't DROP '%s'; check that column/key exists

- Error: 1092 SQLSTATE: HY000 (ER_INSERT_INFO)

  Message: Records: %ld Duplicates: %ld Warnings: %ld

- Error: 1093 SQLSTATE: HY000 (ER_UPDATE_TABLE_USED)

Message: You can't specify target table '%s' for update in FROM clause

This error occurs for attempts to select from and modify the same table within a single statement. See Section C.4, “Restrictions on Subqueries”.

- Error: 1094 SQLSTATE: HY000 (ER_NO_SUCH_THREAD)

  Message: Unknown thread id: %lu

- Error: 1095 SQLSTATE: HY000 (ER_KILL_DENIED_ERROR)

  Message: You are not owner of thread %lu

- Error: 1096 SQLSTATE: HY000 (ER_NO_TABLES_USED)

  Message: No tables used

- Error: 1097 SQLSTATE: HY000 (ER_TOO_BIG_SET)

  Message: Too many strings for column %s and SET

- Error: 1098 SQLSTATE: HY000 (ER_NO_UNIQUE_LOGFILE)

  Message: Can't generate a unique log-filename %s.(1-999)

- Error: 1099 SQLSTATE: HY000 (ER_TABLE_NOT_LOCKED_FOR_WRITE)

  Message: Table '%s' was locked with a READ lock and can't be updated

- Error: 1100 SQLSTATE: HY000 (ER_TABLE_NOT_LOCKED)

  Message: Table '%s' was not locked with LOCK TABLES

- Error: 1101 SQLSTATE: 42000 (ER_BLOB_CANT_HAVE_DEFAULT)

  Message: BLOB/TEXT column '%s' can't have a default value

- Error: 1102 SQLSTATE: 42000 (ER_WRONG_DB_NAME)

  Message: Incorrect database name '%s'

- Error: 1103 SQLSTATE: 42000 (ER_WRONG_TABLE_NAME)

  Message: Incorrect table name '%s'

- Error: 1104 SQLSTATE: 42000 (ER_TOO_BIG_SELECT)

  Message: The SELECT would examine more than MAX_JOIN_SIZE rows; check your WHERE and use SET SQL_BIG_SELECTS=1 or SET MAX_JOIN_SIZE=# if the SELECT is okay

- Error: 1105 SQLSTATE: HY000 (ER_UNKNOWN_ERROR)

  Message: Unknown error

- Error: 1106 SQLSTATE: 42000 (ER_UNKNOWN_PROCEDURE)

  Message: Unknown procedure '%s'

- Error: 1107 SQLSTATE: 42000 (ER_WRONG_PARAMCOUNT_TO_PROCEDURE)

  Message: Incorrect parameter count to procedure '%s'

- Error: 1108 SQLSTATE: HY000 (ER_WRONG_PARAMETERS_TO_PROCEDURE)

Message: Incorrect parameters to procedure '%s'

- Error: 1109 SQLSTATE: 42S02 (ER_UNKNOWN_TABLE)

  Message: Unknown table '%s' in %s

- Error: 1110 SQLSTATE: 42000 (ER_FIELD_SPECIFIED_TWICE)

  Message: Column '%s' specified twice

- Error: 1111 SQLSTATE: HY000 (ER_INVALID_GROUP_FUNC_USE)

  Message: Invalid use of group function

- Error: 1112 SQLSTATE: 42000 (ER_UNSUPPORTED_EXTENSION)

  Message: Table '%s' uses an extension that doesn't exist in this MySQL version

- Error: 1113 SQLSTATE: 42000 (ER_TABLE_MUST_HAVE_COLUMNS)

  Message: A table must have at least 1 column

- Error: 1114 SQLSTATE: HY000 (ER_RECORD_FILE_FULL)

  Message: The table '%s' is full

  InnoDB reports this error when the system tablespace runs out of free space. Reconfigure the system tablespace to add a new data file.

- Error: 1115 SQLSTATE: 42000 (ER_UNKNOWN_CHARACTER_SET)

  Message: Unknown character set: '%s'

- Error: 1116 SQLSTATE: HY000 (ER_TOO_MANY_TABLES)

  Message: Too many tables; MySQL can only use %d tables in a join

- Error: 1117 SQLSTATE: HY000 (ER_TOO_MANY_FIELDS)

  Message: Too many columns

- Error: 1118 SQLSTATE: 42000 (ER_TOO_BIG_ROWSIZE)

  Message: Row size too large. The maximum row size for the used table type, not counting BLOBs, is %ld. You have to change some columns to TEXT or BLOBs

- Error: 1119 SQLSTATE: HY000 (ER_STACK_OVERRUN)

  Message: Thread stack overrun: Used: %ld of a %ld stack. Use 'mysqld --thread_stack=#' to specify a bigger stack if needed

- Error: 1120 SQLSTATE: 42000 (ER_WRONG_OUTER_JOIN)

  Message: Cross dependency found in OUTER JOIN; examine your ON conditions

- Error: 1121 SQLSTATE: 42000 (ER_NULL_COLUMN_IN_INDEX)

  Message: Table handler doesn't support NULL in given index. Please change column '%s' to be NOT NULL or use another handler

- Error: 1122 SQLSTATE: HY000 (ER_CANT_FIND_UDF)

  Message: Can't load function '%s'

- Error: 1123 SQLSTATE: HY000 (ER_CANT_INITIALIZE_UDF)

  Message: Can't initialize function '%s'; %s

- Error: 1124 SQLSTATE: HY000 (ER_UDF_NO_PATHS)

  Message: No paths allowed for shared library

- Error: 1125 SQLSTATE: HY000 (ER_UDF_EXISTS)

  Message: Function '%s' already exists

- Error: 1126 SQLSTATE: HY000 (ER_CANT_OPEN_LIBRARY)

  Message: Can't open shared library '%s' (errno: %d %s)

- Error: 1127 SQLSTATE: HY000 (ER_CANT_FIND_DL_ENTRY)

  Message: Can't find symbol '%s' in library

- Error: 1128 SQLSTATE: HY000 (ER_FUNCTION_NOT_DEFINED)

  Message: Function '%s' is not defined

- Error: 1129 SQLSTATE: HY000 (ER_HOST_IS_BLOCKED)

  Message: Host '%s' is blocked because of many connection errors; unblock with 'mysqladmin flush-hosts'

- Error: 1130 SQLSTATE: HY000 (ER_HOST_NOT_PRIVILEGED)

  Message: Host '%s' is not allowed to connect to this MySQL server

- Error: 1131 SQLSTATE: 42000 (ER_PASSWORD_ANONYMOUS_USER)

  Message: You are using MySQL as an anonymous user and anonymous users are not allowed to change passwords

- Error: 1132 SQLSTATE: 42000 (ER_PASSWORD_NOT_ALLOWED)

  Message: You must have privileges to update tables in the mysql database to be able to change passwords for others

- Error: 1133 SQLSTATE: 42000 (ER_PASSWORD_NO_MATCH)

  Message: Can't find any matching row in the user table

- Error: 1134 SQLSTATE: HY000 (ER_UPDATE_INFO)

  Message: Rows matched: %ld Changed: %ld Warnings: %ld

- Error: 1135 SQLSTATE: HY000 (ER_CANT_CREATE_THREAD)

  Message: Can't create a new thread (errno %d); if you are not out of available memory, you can consult the manual for a possible OS-dependent bug

- Error: 1136 SQLSTATE: 21S01 (ER_WRONG_VALUE_COUNT_ON_ROW)

  Message: Column count doesn't match value count at row %ld

- Error: 1137 SQLSTATE: HY000 (ER_CANT_REOPEN_TABLE)

  Message: Can't reopen table: '%s'

- Error: 1138 SQLSTATE: 22004 (ER_INVALID_USE_OF_NULL)

Message: Invalid use of NULL value

- Error: 1139 SQLSTATE: 42000 (ER_REGEXP_ERROR)

  Message: Got error '%s' from regexp

- Error: 1140 SQLSTATE: 42000 (ER_MIX_OF_GROUP_FUNC_AND_FIELDS)

  Message: Mixing of GROUP columns (MIN(),MAX(),COUNT(),...) with no GROUP columns is illegal if there is no GROUP BY clause

- Error: 1141 SQLSTATE: 42000 (ER_NONEXISTING_GRANT)

  Message: There is no such grant defined for user '%s' on host '%s'

- Error: 1142 SQLSTATE: 42000 (ER_TABLEACCESS_DENIED_ERROR)

  Message: %s command denied to user '%s'@'%s' for table '%s'

- Error: 1143 SQLSTATE: 42000 (ER_COLUMNACCESS_DENIED_ERROR)

  Message: %s command denied to user '%s'@'%s' for column '%s' in table '%s'

- Error: 1144 SQLSTATE: 42000 (ER_ILLEGAL_GRANT_FOR_TABLE)

  Message: Illegal GRANT/REVOKE command; please consult the manual to see which privileges can be used

- Error: 1145 SQLSTATE: 42000 (ER_GRANT_WRONG_HOST_OR_USER)

  Message: The host or user argument to GRANT is too long

- Error: 1146 SQLSTATE: 42S02 (ER_NO_SUCH_TABLE)

  Message: Table '%s.%s' doesn't exist

- Error: 1147 SQLSTATE: 42000 (ER_NONEXISTING_TABLE_GRANT)

  Message: There is no such grant defined for user '%s' on host '%s' on table '%s'

- Error: 1148 SQLSTATE: 42000 (ER_NOT_ALLOWED_COMMAND)

  Message: The used command is not allowed with this MySQL version

- Error: 1149 SQLSTATE: 42000 (ER_SYNTAX_ERROR)

  Message: You have an error in your SQL syntax; check the manual that corresponds to your MySQL server version for the right syntax to use

- Error: 1150 SQLSTATE: HY000 (ER_DELAYED_CANT_CHANGE_LOCK)

  Message: Delayed insert thread couldn't get requested lock for table %s

- Error: 1151 SQLSTATE: HY000 (ER_TOO_MANY_DELAYED_THREADS)

  Message: Too many delayed threads in use

- Error: 1152 SQLSTATE: 08S01 (ER_ABORTING_CONNECTION)

  Message: Aborted connection %ld to db: '%s' user: '%s' (%s)

- Error: 1153 SQLSTATE: 08S01 (ER_NET_PACKET_TOO_LARGE)

  Message: Got a packet bigger than 'max_allowed_packet' bytes

- Error: 1154 SQLSTATE: 08S01 (ER_NET_READ_ERROR_FROM_PIPE)

  Message: Got a read error from the connection pipe

- Error: 1155 SQLSTATE: 08S01 (ER_NET_FCNTL_ERROR)

  Message: Got an error from fcntl()

- Error: 1156 SQLSTATE: 08S01 (ER_NET_PACKETS_OUT_OF_ORDER)

  Message: Got packets out of order

- Error: 1157 SQLSTATE: 08S01 (ER_NET_UNCOMPRESS_ERROR)

  Message: Couldn't uncompress communication packet

- Error: 1158 SQLSTATE: 08S01 (ER_NET_READ_ERROR)

  Message: Got an error reading communication packets

- Error: 1159 SQLSTATE: 08S01 (ER_NET_READ_INTERRUPTED)

  Message: Got timeout reading communication packets

- Error: 1160 SQLSTATE: 08S01 (ER_NET_ERROR_ON_WRITE)

  Message: Got an error writing communication packets

- Error: 1161 SQLSTATE: 08S01 (ER_NET_WRITE_INTERRUPTED)

  Message: Got timeout writing communication packets

- Error: 1162 SQLSTATE: 42000 (ER_TOO_LONG_STRING)

  Message: Result string is longer than 'max_allowed_packet' bytes

- Error: 1163 SQLSTATE: 42000 (ER_TABLE_CANT_HANDLE_BLOB)

  Message: The used table type doesn't support BLOB/TEXT columns

- Error: 1164 SQLSTATE: 42000 (ER_TABLE_CANT_HANDLE_AUTO_INCREMENT)

  Message: The used table type doesn't support AUTO_INCREMENT columns

- Error: 1165 SQLSTATE: HY000 (ER_DELAYED_INSERT_TABLE_LOCKED)

  Message: INSERT DELAYED can't be used with table '%s' because it is locked with LOCK TABLES

- Error: 1166 SQLSTATE: 42000 (ER_WRONG_COLUMN_NAME)

  Message: Incorrect column name '%s'

- Error: 1167 SQLSTATE: 42000 (ER_WRONG_KEY_COLUMN)

  Message: The used storage engine can't index column '%s'

- Error: 1168 SQLSTATE: HY000 (ER_WRONG_MRG_TABLE)

  Message: Unable to open underlying table which is differently defined or of non-MyISAM type or doesn't exist

- Error: 1169 SQLSTATE: 23000 (ER_DUP_UNIQUE)

  Message: Can't write, because of unique constraint, to table '%s'

- Error: 1170 SQLSTATE: 42000 (ER_BLOB_KEY_WITHOUT_LENGTH)

  Message: BLOB/TEXT column '%s' used in key specification without a key length

- Error: 1171 SQLSTATE: 42000 (ER_PRIMARY_CANT_HAVE_NULL)

  Message: All parts of a PRIMARY KEY must be NOT NULL; if you need NULL in a key, use UNIQUE instead

- Error: 1172 SQLSTATE: 42000 (ER_TOO_MANY_ROWS)

  Message: Result consisted of more than one row

- Error: 1173 SQLSTATE: 42000 (ER_REQUIRES_PRIMARY_KEY)

  Message: This table type requires a primary key

  InnoDB reports this error when you attempt to drop an implicit clustered index (the first UNIQUE NOT NULL index) if the table did not contain a PRIMARY KEY.

  InnoDB should no longer report this error as of MySQL 5.5. For tables without an explicit PRIMARY KEY, InnoDB creates an implicit clustered index using the first columns of the table that are declared UNIQUE and NOT NULL. When you drop such an index, InnoDB now automatically copies the table and rebuilds the index using a different UNIQUE NOT NULL group of columns or a system-generated key. Since this operation changes the primary key, it uses the slow method of copying the table and re-creating the index, rather than the Fast Index Creation technique from Section 14.16.3, “Implementation Details of Fast Index Creation”.

- Error: 1174 SQLSTATE: HY000 (ER_NO_RAID_COMPILED)

  Message: This version of MySQL is not compiled with RAID support

- Error: 1175 SQLSTATE: HY000 (ER_UPDATE_WITHOUT_KEY_IN_SAFE_MODE)

  Message: You are using safe update mode and you tried to update a table without a WHERE that uses a KEY column

- Error: 1176 SQLSTATE: 42000 (ER_KEY_DOES_NOT_EXITS)

  Message: Key '%s' doesn't exist in table '%s'

- Error: 1177 SQLSTATE: 42000 (ER_CHECK_NO_SUCH_TABLE)

  Message: Can't open table

- Error: 1178 SQLSTATE: 42000 (ER_CHECK_NOT_IMPLEMENTED)

  Message: The storage engine for the table doesn't support %s

- Error: 1179 SQLSTATE: 25000 (ER_CANT_DO_THIS_DURING_AN_TRANSACTION)

  Message: You are not allowed to execute this command in a transaction

- Error: 1180 SQLSTATE: HY000 (ER_ERROR_DURING_COMMIT)

  Message: Got error %d during COMMIT

- Error: 1181 SQLSTATE: HY000 (ER_ERROR_DURING_ROLLBACK)

  Message: Got error %d during ROLLBACK

- Error: 1182 SQLSTATE: HY000 (ER_ERROR_DURING_FLUSH_LOGS)

  Message: Got error %d during FLUSH_LOGS

- Error: 1183 SQLSTATE: HY000 (ER_ERROR_DURING_CHECKPOINT)

  Message: Got error %d during CHECKPOINT

- Error: 1184 SQLSTATE: 08S01 (ER_NEW_ABORTING_CONNECTION)

  Message: Aborted connection %ld to db: '%s' user: '%s' host: '%s' (%s)

- Error: 1185 SQLSTATE: HY000 (ER_DUMP_NOT_IMPLEMENTED)

  Message: The storage engine for the table does not support binary table dump

- Error: 1186 SQLSTATE: HY000 (ER_FLUSH_MASTER_BINLOG_CLOSED)

  Message: Binlog closed, cannot RESET MASTER

- Error: 1187 SQLSTATE: HY000 (ER_INDEX_REBUILD)

  Message: Failed rebuilding the index of dumped table '%s'

- Error: 1188 SQLSTATE: HY000 (ER_MASTER)

  Message: Error from master: '%s'

- Error: 1189 SQLSTATE: 08S01 (ER_MASTER_NET_READ)

  Message: Net error reading from master

- Error: 1190 SQLSTATE: 08S01 (ER_MASTER_NET_WRITE)

  Message: Net error writing to master

- Error: 1191 SQLSTATE: HY000 (ER_FT_MATCHING_KEY_NOT_FOUND)

  Message: Can't find FULLTEXT index matching the column list

- Error: 1192 SQLSTATE: HY000 (ER_LOCK_OR_ACTIVE_TRANSACTION)

  Message: Can't execute the given command because you have active locked tables or an active transaction

- Error: 1193 SQLSTATE: HY000 (ER_UNKNOWN_SYSTEM_VARIABLE)

  Message: Unknown system variable '%s'

- Error: 1194 SQLSTATE: HY000 (ER_CRASHED_ON_USAGE)

  Message: Table '%s' is marked as crashed and should be repaired

- Error: 1195 SQLSTATE: HY000 (ER_CRASHED_ON_REPAIR)

  Message: Table '%s' is marked as crashed and last (automatic?) repair failed

- Error: 1196 SQLSTATE: HY000 (ER_WARNING_NOT_COMPLETE_ROLLBACK)

  Message: Some non-transactional changed tables couldn't be rolled back

- Error: 1197 SQLSTATE: HY000 (ER_TRANS_CACHE_FULL)

  Message: Multi-statement transaction required more than 'max_binlog_cache_size' bytes of storage; increase this mysqld variable and try again

- Error: 1198 SQLSTATE: HY000 (ER_SLAVE_MUST_STOP)

  Message: This operation cannot be performed with a running slave; run STOP SLAVE first

- Error: 1199 SQLSTATE: HY000 (ER_SLAVE_NOT_RUNNING)

  Message: This operation requires a running slave; configure slave and do START SLAVE

- Error: 1200 SQLSTATE: HY000 (ER_BAD_SLAVE)

  Message: The server is not configured as slave; fix in config file or with CHANGE MASTER TO

- Error: 1201 SQLSTATE: HY000 (ER_MASTER_INFO)

  Message: Could not initialize master info structure; more error messages can be found in the MySQL error log

- Error: 1202 SQLSTATE: HY000 (ER_SLAVE_THREAD)

  Message: Could not create slave thread; check system resources

- Error: 1203 SQLSTATE: 42000 (ER_TOO_MANY_USER_CONNECTIONS)

  Message: User %s already has more than 'max_user_connections' active connections

- Error: 1204 SQLSTATE: HY000 (ER_SET_CONSTANTS_ONLY)

  Message: You may only use constant expressions with SET

- Error: 1205 SQLSTATE: HY000 (ER_LOCK_WAIT_TIMEOUT)

  Message: Lock wait timeout exceeded; try restarting transaction

  InnoDB reports this error when lock wait timeout expires. The statement that waited too long was rolled back (not the entire transaction). You can increase the value of the innodb_lock_wait_timeout configuration option if SQL statements should wait longer for other transactions to complete, or decrease it if too many long-running transactions are causing locking problems and reducing concurrency on a busy system.

- Error: 1206 SQLSTATE: HY000 (ER_LOCK_TABLE_FULL)

  Message: The total number of locks exceeds the lock table size

  InnoDB reports this error when the total number of locks exceeds the amount of memory devoted to managing locks. To avoid this error, increase the value of innodb_buffer_pool_size. Within an individual application, a workaround may be to break a large operation into smaller pieces. For example, if the error occurs for a large INSERT, perform several smaller INSERT operations.

- Error: 1207 SQLSTATE: 25000 (ER_READ_ONLY_TRANSACTION)

  Message: Update locks cannot be acquired during a READ UNCOMMITTED transaction

- Error: 1208 SQLSTATE: HY000 (ER_DROP_DB_WITH_READ_LOCK)

  Message: DROP DATABASE not allowed while thread is holding global read lock

- Error: 1209 SQLSTATE: HY000 (ER_CREATE_DB_WITH_READ_LOCK)

  Message: CREATE DATABASE not allowed while thread is holding global read lock

- Error: 1210 SQLSTATE: HY000 (ER_WRONG_ARGUMENTS)

  Message: Incorrect arguments to %s

- Error: 1211 SQLSTATE: 42000 (ER_NO_PERMISSION_TO_CREATE_USER)

  Message: '%s'@'%s' is not allowed to create new users

- Error: 1212 SQLSTATE: HY000 (ER_UNION_TABLES_IN_DIFFERENT_DIR)

  Message: Incorrect table definition; all MERGE tables must be in the same database

- Error: 1213 SQLSTATE: 40001 (ER_LOCK_DEADLOCK)

  Message: Deadlock found when trying to get lock; try restarting transaction

  InnoDB reports this error when a transaction encounters a deadlock and is automatically rolled back so that your application can take corrective action. To recover from this error, run all the operations in this transaction again. A deadlock occurs when requests for locks arrive in inconsistent order between transactions. The transaction that was rolled back released all its locks, and the other transaction can now get all the locks it requested. Thus, when you re-run the transaction that was rolled back, it might have to wait for other transactions to complete, but typically the deadlock does not recur. If you encounter frequent deadlocks, make the sequence of locking operations (LOCK TABLES, SELECT ... FOR UPDATE, and so on) consistent between the different transactions or applications that experience the issue. See Section 14.8.5, “Deadlocks in InnoDB” for details.

- Error: 1214 SQLSTATE: HY000 (ER_TABLE_CANT_HANDLE_FT)

  Message: The used table type doesn't support FULLTEXT indexes

- Error: 1215 SQLSTATE: HY000 (ER_CANNOT_ADD_FOREIGN)

  Message: Cannot add foreign key constraint

- Error: 1216 SQLSTATE: 23000 (ER_NO_REFERENCED_ROW)

  Message: Cannot add or update a child row: a foreign key constraint fails

  InnoDB reports this error when you try to add a row but there is no parent row, and a foreign key constraint fails. Add the parent row first.

- Error: 1217 SQLSTATE: 23000 (ER_ROW_IS_REFERENCED)

  Message: Cannot delete or update a parent row: a foreign key constraint fails

  InnoDB reports this error when you try to delete a parent row that has children, and a foreign key constraint fails. Delete the children first.

- Error: 1218 SQLSTATE: 08S01 (ER_CONNECT_TO_MASTER)

  Message: Error connecting to master: %s

- Error: 1219 SQLSTATE: HY000 (ER_QUERY_ON_MASTER)

  Message: Error running query on master: %s

- Error: 1220 SQLSTATE: HY000 (ER_ERROR_WHEN_EXECUTING_COMMAND)

  Message: Error when executing command %s: %s

- Error: 1221 SQLSTATE: HY000 (ER_WRONG_USAGE)

  Message: Incorrect usage of %s and %s

- Error: 1222 SQLSTATE: 21000 (ER_WRONG_NUMBER_OF_COLUMNS_IN_SELECT)

  Message: The used SELECT statements have a different number of columns

- Error: 1223 SQLSTATE: HY000 (ER_CANT_UPDATE_WITH_READLOCK)

  Message: Can't execute the query because you have a conflicting read lock

- Error: 1224 SQLSTATE: HY000 (ER_MIXING_NOT_ALLOWED)

  Message: Mixing of transactional and non-transactional tables is disabled
- Error: 1225 SQLSTATE: HY000 (ER_DUP_ARGUMENT)

  Message: Option '%s' used twice in statement
- Error: 1226 SQLSTATE: 42000 (ER_USER_LIMIT_REACHED)

  Message: User '%s' has exceeded the '%s' resource (current value: %ld)
- Error: 1227 SQLSTATE: 42000 (ER_SPECIFIC_ACCESS_DENIED_ERROR)

  Message: Access denied; you need (at least one of) the %s privilege(s) for this operation
- Error: 1228 SQLSTATE: HY000 (ER_LOCAL_VARIABLE)

  Message: Variable '%s' is a SESSION variable and can't be used with SET GLOBAL
- Error: 1229 SQLSTATE: HY000 (ER_GLOBAL_VARIABLE)

  Message: Variable '%s' is a GLOBAL variable and should be set with SET GLOBAL
- Error: 1230 SQLSTATE: 42000 (ER_NO_DEFAULT)

  Message: Variable '%s' doesn't have a default value
- Error: 1231 SQLSTATE: 42000 (ER_WRONG_VALUE_FOR_VAR)

  Message: Variable '%s' can't be set to the value of '%s'
- Error: 1232 SQLSTATE: 42000 (ER_WRONG_TYPE_FOR_VAR)

  Message: Incorrect argument type to variable '%s'
- Error: 1233 SQLSTATE: HY000 (ER_VAR_CANT_BE_READ)

  Message: Variable '%s' can only be set, not read
- Error: 1234 SQLSTATE: 42000 (ER_CANT_USE_OPTION_HERE)

  Message: Incorrect usage/placement of '%s'
- Error: 1235 SQLSTATE: 42000 (ER_NOT_SUPPORTED_YET)

  Message: This version of MySQL doesn't yet support '%s'
- Error: 1236 SQLSTATE: HY000 (ER_MASTER_FATAL_ERROR_READING_BINLOG)

  Message: Got fatal error %d from master when reading data from binary log: '%s'
- Error: 1237 SQLSTATE: HY000 (ER_SLAVE_IGNORED_TABLE)

  Message: Slave SQL thread ignored the query because of replicate-*-table rules
- Error: 1238 SQLSTATE: HY000 (ER_INCORRECT_GLOBAL_LOCAL_VAR)

  Message: Variable '%s' is a %s variable
- Error: 1239 SQLSTATE: 42000 (ER_WRONG_FK_DEF)

  Message: Incorrect foreign key definition for '%s': %s
- Error: 1240 SQLSTATE: HY000 (ER_KEY_REF_DO_NOT_MATCH_TABLE_REF)

Message: Key reference and table reference don't match

- Error: 1241 SQLSTATE: 21000 (ER_OPERAND_COLUMNS)

  Message: Operand should contain %d column(s)

- Error: 1242 SQLSTATE: 21000 (ER_SUBQUERY_NO_1_ROW)

  Message: Subquery returns more than 1 row

- Error: 1243 SQLSTATE: HY000 (ER_UNKNOWN_STMT_HANDLER)

  Message: Unknown prepared statement handler (%.*s) given to %s

- Error: 1244 SQLSTATE: HY000 (ER_CORRUPT_HELP_DB)

  Message: Help database is corrupt or does not exist

- Error: 1245 SQLSTATE: HY000 (ER_CYCLIC_REFERENCE)

  Message: Cyclic reference on subqueries

- Error: 1246 SQLSTATE: HY000 (ER_AUTO_CONVERT)

  Message: Converting column '%s' from %s to %s

- Error: 1247 SQLSTATE: 42S22 (ER_ILLEGAL_REFERENCE)

  Message: Reference '%s' not supported (%s)

- Error: 1248 SQLSTATE: 42000 (ER_DERIVED_MUST_HAVE_ALIAS)

  Message: Every derived table must have its own alias

- Error: 1249 SQLSTATE: 01000 (ER_SELECT_REDUCED)

  Message: Select %u was reduced during optimization

- Error: 1250 SQLSTATE: 42000 (ER_TABLENAME_NOT_ALLOWED_HERE)

  Message: Table '%s' from one of the SELECTs cannot be used in %s

- Error: 1251 SQLSTATE: 08004 (ER_NOT_SUPPORTED_AUTH_MODE)

  Message: Client does not support authentication protocol requested by server; consider upgrading MySQL client

- Error: 1252 SQLSTATE: 42000 (ER_SPATIAL_CANT_HAVE_NULL)

  Message: All parts of a SPATIAL index must be NOT NULL

- Error: 1253 SQLSTATE: 42000 (ER_COLLATION_CHARSET_MISMATCH)

  Message: COLLATION '%s' is not valid for CHARACTER SET '%s'

- Error: 1254 SQLSTATE: HY000 (ER_SLAVE_WAS_RUNNING)

  Message: Slave is already running

- Error: 1255 SQLSTATE: HY000 (ER_SLAVE_WAS_NOT_RUNNING)

  Message: Slave already has been stopped

- Error: 1256 SQLSTATE: HY000 (ER_TOO_BIG_FOR_UNCOMPRESS)

Message: Uncompressed data size too large; the maximum size is %d (probably, length of uncompressed data was corrupted)

- Error: 1257 SQLSTATE: HY000 (ER_ZLIB_Z_MEM_ERROR)

  Message: ZLIB: Not enough memory

- Error: 1258 SQLSTATE: HY000 (ER_ZLIB_Z_BUF_ERROR)

  Message: ZLIB: Not enough room in the output buffer (probably, length of uncompressed data was corrupted)

- Error: 1259 SQLSTATE: HY000 (ER_ZLIB_Z_DATA_ERROR)

  Message: ZLIB: Input data corrupted

- Error: 1260 SQLSTATE: HY000 (ER_CUT_VALUE_GROUP_CONCAT)

  Message: Row %u was cut by GROUP_CONCAT()

- Error: 1261 SQLSTATE: 01000 (ER_WARN_TOO_FEW_RECORDS)

  Message: Row %ld doesn't contain data for all columns

- Error: 1262 SQLSTATE: 01000 (ER_WARN_TOO_MANY_RECORDS)

  Message: Row %ld was truncated; it contained more data than there were input columns

- Error: 1263 SQLSTATE: 22004 (ER_WARN_NULL_TO_NOTNULL)

  Message: Column set to default value; NULL supplied to NOT NULL column '%s' at row %ld

- Error: 1264 SQLSTATE: 22003 (ER_WARN_DATA_OUT_OF_RANGE)

  Message: Out of range value for column '%s' at row %ld

- Error: 1265 SQLSTATE: 01000 (WARN_DATA_TRUNCATED)

  Message: Data truncated for column '%s' at row %ld

- Error: 1266 SQLSTATE: HY000 (ER_WARN_USING_OTHER_HANDLER)

  Message: Using storage engine %s for table '%s'

- Error: 1267 SQLSTATE: HY000 (ER_CANT_AGGREGATE_2COLLATIONS)

  Message: Illegal mix of collations (%s,%s) and (%s,%s) for operation '%s'

- Error: 1268 SQLSTATE: HY000 (ER_DROP_USER)

  Message: Cannot drop one or more of the requested users

- Error: 1269 SQLSTATE: HY000 (ER_REVOKE_GRANTS)

  Message: Can't revoke all privileges for one or more of the requested users

- Error: 1270 SQLSTATE: HY000 (ER_CANT_AGGREGATE_3COLLATIONS)

  Message: Illegal mix of collations (%s,%s), (%s,%s), (%s,%s) for operation '%s'

- Error: 1271 SQLSTATE: HY000 (ER_CANT_AGGREGATE_NCOLLATIONS)

  Message: Illegal mix of collations for operation '%s'

- Error: 1272 SQLSTATE: HY000 (ER_VARIABLE_IS_NOT_STRUCT)

  Message: Variable '%s' is not a variable component (can't be used as XXXX.variable_name)

- Error: 1273 SQLSTATE: HY000 (ER_UNKNOWN_COLLATION)

  Message: Unknown collation: '%s'

- Error: 1274 SQLSTATE: HY000 (ER_SLAVE_IGNORED_SSL_PARAMS)

  Message: SSL parameters in CHANGE MASTER are ignored because this MySQL slave was compiled without SSL support; they can be used later if MySQL slave with SSL is started

- Error: 1275 SQLSTATE: HY000 (ER_SERVER_IS_IN_SECURE_AUTH_MODE)

  Message: Server is running in --secure-auth mode, but '%s'@'%s' has a password in the old format; please change the password to the new format

- Error: 1276 SQLSTATE: HY000 (ER_WARN_FIELD_RESOLVED)

  Message: Field or reference '%s%s%s%s%s' of SELECT #%d was resolved in SELECT #%d

- Error: 1277 SQLSTATE: HY000 (ER_BAD_SLAVE_UNTIL_COND)

  Message: Incorrect parameter or combination of parameters for START SLAVE UNTIL

- Error: 1278 SQLSTATE: HY000 (ER_MISSING_SKIP_SLAVE)

  Message: It is recommended to use --skip-slave-start when doing step-by-step replication with START SLAVE UNTIL; otherwise, you will get problems if you get an unexpected slave's mysqld restart

- Error: 1279 SQLSTATE: HY000 (ER_UNTIL_COND_IGNORED)

  Message: SQL thread is not to be started so UNTIL options are ignored

- Error: 1280 SQLSTATE: 42000 (ER_WRONG_NAME_FOR_INDEX)

  Message: Incorrect index name '%s'

- Error: 1281 SQLSTATE: 42000 (ER_WRONG_NAME_FOR_CATALOG)

  Message: Incorrect catalog name '%s'

- Error: 1282 SQLSTATE: HY000 (ER_WARN_QC_RESIZE)

  Message: Query cache failed to set size %lu; new query cache size is %lu

- Error: 1283 SQLSTATE: HY000 (ER_BAD_FT_COLUMN)

  Message: Column '%s' cannot be part of FULLTEXT index

- Error: 1284 SQLSTATE: HY000 (ER_UNKNOWN_KEY_CACHE)

  Message: Unknown key cache '%s'

- Error: 1285 SQLSTATE: HY000 (ER_WARN_HOSTNAME_WONT_WORK)

  Message: MySQL is started in --skip-name-resolve mode; you must restart it without this switch for this grant to work

- Error: 1286 SQLSTATE: 42000 (ER_UNKNOWN_STORAGE_ENGINE)

  Message: Unknown storage engine '%s'

- Error: 1287 SQLSTATE: HY000 (ER_WARN_DEPRECATED_SYNTAX)

  Message: '%s' is deprecated and will be removed in a future release. Please use %s instead

- Error: 1288 SQLSTATE: HY000 (ER_NON_UPDATABLE_TABLE)

  Message: The target table %s of the %s is not updatable

- Error: 1289 SQLSTATE: HY000 (ER_FEATURE_DISABLED)

  Message: The '%s' feature is disabled; you need MySQL built with '%s' to have it working

- Error: 1290 SQLSTATE: HY000 (ER_OPTION_PREVENTS_STATEMENT)

  Message: The MySQL server is running with the %s option so it cannot execute this statement

- Error: 1291 SQLSTATE: HY000 (ER_DUPLICATED_VALUE_IN_TYPE)

  Message: Column '%s' has duplicated value '%s' in %s

- Error: 1292 SQLSTATE: 22007 (ER_TRUNCATED_WRONG_VALUE)

  Message: Truncated incorrect %s value: '%s'

- Error: 1293 SQLSTATE: HY000 (ER_TOO_MUCH_AUTO_TIMESTAMP_COLS)

  Message: Incorrect table definition; there can be only one TIMESTAMP column with CURRENT_TIMESTAMP in DEFAULT or ON UPDATE clause

- Error: 1294 SQLSTATE: HY000 (ER_INVALID_ON_UPDATE)

  Message: Invalid ON UPDATE clause for '%s' column

- Error: 1295 SQLSTATE: HY000 (ER_UNSUPPORTED_PS)

  Message: This command is not supported in the prepared statement protocol yet

- Error: 1296 SQLSTATE: HY000 (ER_GET_ERRMSG)

  Message: Got error %d '%s' from %s

- Error: 1297 SQLSTATE: HY000 (ER_GET_TEMPORARY_ERRMSG)

  Message: Got temporary error %d '%s' from %s

- Error: 1298 SQLSTATE: HY000 (ER_UNKNOWN_TIME_ZONE)

  Message: Unknown or incorrect time zone: '%s'

- Error: 1299 SQLSTATE: HY000 (ER_WARN_INVALID_TIMESTAMP)

  Message: Invalid TIMESTAMP value in column '%s' at row %ld

- Error: 1300 SQLSTATE: HY000 (ER_INVALID_CHARACTER_STRING)

  Message: Invalid %s character string: '%s'

- Error: 1301 SQLSTATE: HY000 (ER_WARN_ALLOWED_PACKET_OVERFLOWED)

  Message: Result of %s() was larger than max_allowed_packet (%ld) - truncated

- Error: 1302 SQLSTATE: HY000 (ER_CONFLICTING_DECLARATIONS)

  Message: Conflicting declarations: '%s%s' and '%s%s'

- Error: 1303 SQLSTATE: 2F003 (ER_SP_NO_RECURSIVE_CREATE)

  Message: Can't create a %s from within another stored routine

- Error: 1304 SQLSTATE: 42000 (ER_SP_ALREADY_EXISTS)

  Message: %s %s already exists

- Error: 1305 SQLSTATE: 42000 (ER_SP_DOES_NOT_EXIST)

  Message: %s %s does not exist

- Error: 1306 SQLSTATE: HY000 (ER_SP_DROP_FAILED)

  Message: Failed to DROP %s %s

- Error: 1307 SQLSTATE: HY000 (ER_SP_STORE_FAILED)

  Message: Failed to CREATE %s %s

- Error: 1308 SQLSTATE: 42000 (ER_SP_LILABEL_MISMATCH)

  Message: %s with no matching label: %s

- Error: 1309 SQLSTATE: 42000 (ER_SP_LABEL_REDEFINE)

  Message: Redefining label %s

- Error: 1310 SQLSTATE: 42000 (ER_SP_LABEL_MISMATCH)

  Message: End-label %s without match

- Error: 1311 SQLSTATE: 01000 (ER_SP_UNINIT_VAR)

  Message: Referring to uninitialized variable %s

- Error: 1312 SQLSTATE: 0A000 (ER_SP_BADSELECT)

  Message: PROCEDURE %s can't return a result set in the given context

- Error: 1313 SQLSTATE: 42000 (ER_SP_BADRETURN)

  Message: RETURN is only allowed in a FUNCTION

- Error: 1314 SQLSTATE: 0A000 (ER_SP_BADSTATEMENT)

  Message: %s is not allowed in stored procedures

- Error: 1315 SQLSTATE: 42000 (ER_UPDATE_LOG_DEPRECATED_IGNORED)

  Message: The update log is deprecated and replaced by the binary log; SET SQL_LOG_UPDATE has been ignored. This option will be removed in MySQL 5.6.

- Error: 1316 SQLSTATE: 42000 (ER_UPDATE_LOG_DEPRECATED_TRANSLATED)

  Message: The update log is deprecated and replaced by the binary log; SET SQL_LOG_UPDATE has been translated to SET SQL_LOG_BIN. This option will be removed in MySQL 5.6.

- Error: 1317 SQLSTATE: 70100 (ER_QUERY_INTERRUPTED)

  Message: Query execution was interrupted

- Error: 1318 SQLSTATE: 42000 (ER_SP_WRONG_NO_OF_ARGS)

  Message: Incorrect number of arguments for %s %s; expected %u, got %u

- Error: 1319 SQLSTATE: 42000 (ER_SP_COND_MISMATCH)

  Message: Undefined CONDITION: %s
- Error: 1320 SQLSTATE: 42000 (ER_SP_NORETURN)

  Message: No RETURN found in FUNCTION %s
- Error: 1321 SQLSTATE: 2F005 (ER_SP_NORETURNEND)

  Message: FUNCTION %s ended without RETURN
- Error: 1322 SQLSTATE: 42000 (ER_SP_BAD_CURSOR_QUERY)

  Message: Cursor statement must be a SELECT
- Error: 1323 SQLSTATE: 42000 (ER_SP_BAD_CURSOR_SELECT)

  Message: Cursor SELECT must not have INTO
- Error: 1324 SQLSTATE: 42000 (ER_SP_CURSOR_MISMATCH)

  Message: Undefined CURSOR: %s
- Error: 1325 SQLSTATE: 24000 (ER_SP_CURSOR_ALREADY_OPEN)

  Message: Cursor is already open
- Error: 1326 SQLSTATE: 24000 (ER_SP_CURSOR_NOT_OPEN)

  Message: Cursor is not open
- Error: 1327 SQLSTATE: 42000 (ER_SP_UNDECLARED_VAR)

  Message: Undeclared variable: %s
- Error: 1328 SQLSTATE: HY000 (ER_SP_WRONG_NO_OF_FETCH_ARGS)

  Message: Incorrect number of FETCH variables
- Error: 1329 SQLSTATE: 02000 (ER_SP_FETCH_NO_DATA)

  Message: No data - zero rows fetched, selected, or processed
- Error: 1330 SQLSTATE: 42000 (ER_SP_DUP_PARAM)

  Message: Duplicate parameter: %s
- Error: 1331 SQLSTATE: 42000 (ER_SP_DUP_VAR)

  Message: Duplicate variable: %s
- Error: 1332 SQLSTATE: 42000 (ER_SP_DUP_COND)

  Message: Duplicate condition: %s
- Error: 1333 SQLSTATE: 42000 (ER_SP_DUP_CURS)

  Message: Duplicate cursor: %s
- Error: 1334 SQLSTATE: HY000 (ER_SP_CANT_ALTER)

  Message: Failed to ALTER %s %s
- Error: 1335 SQLSTATE: 0A000 (ER_SP_SUBSELECT_NYI)

Message: Subquery value not supported

- Error: 1336 SQLSTATE: 0A000 (ER_STMT_NOT_ALLOWED_IN_SF_OR_TRG)

  Message: %s is not allowed in stored function or trigger

- Error: 1337 SQLSTATE: 42000 (ER_SP_VARCOND_AFTER_CURSHNDLR)

  Message: Variable or condition declaration after cursor or handler declaration

- Error: 1338 SQLSTATE: 42000 (ER_SP_CURSOR_AFTER_HANDLER)

  Message: Cursor declaration after handler declaration

- Error: 1339 SQLSTATE: 20000 (ER_SP_CASE_NOT_FOUND)

  Message: Case not found for CASE statement

- Error: 1340 SQLSTATE: HY000 (ER_FPARSER_TOO_BIG_FILE)

  Message: Configuration file '%s' is too big

- Error: 1341 SQLSTATE: HY000 (ER_FPARSER_BAD_HEADER)

  Message: Malformed file type header in file '%s'

- Error: 1342 SQLSTATE: HY000 (ER_FPARSER_EOF_IN_COMMENT)

  Message: Unexpected end of file while parsing comment '%s'

- Error: 1343 SQLSTATE: HY000 (ER_FPARSER_ERROR_IN_PARAMETER)

  Message: Error while parsing parameter '%s' (line: '%s')

- Error: 1344 SQLSTATE: HY000 (ER_FPARSER_EOF_IN_UNKNOWN_PARAMETER)

  Message: Unexpected end of file while skipping unknown parameter '%s'

- Error: 1345 SQLSTATE: HY000 (ER_VIEW_NO_EXPLAIN)

  Message: EXPLAIN/SHOW can not be issued; lacking privileges for underlying table

- Error: 1346 SQLSTATE: HY000 (ER_FRM_UNKNOWN_TYPE)

  Message: File '%s' has unknown type '%s' in its header

- Error: 1347 SQLSTATE: HY000 (ER_WRONG_OBJECT)

  Message: '%s.%s' is not %s

  The named object is incorrect for the type of operation attempted on it. It must be an object of the named type.

- Error: 1348 SQLSTATE: HY000 (ER_NONUPDATEABLE_COLUMN)

  Message: Column '%s' is not updatable

- Error: 1349 SQLSTATE: HY000 (ER_VIEW_SELECT_DERIVED)

  Message: View's SELECT contains a subquery in the FROM clause

- Error: 1350 SQLSTATE: HY000 (ER_VIEW_SELECT_CLAUSE)

  Message: View's SELECT contains a '%s' clause

- Error: 1351 SQLSTATE: HY000 (ER_VIEW_SELECT_VARIABLE)

  Message: View's SELECT contains a variable or parameter

- Error: 1352 SQLSTATE: HY000 (ER_VIEW_SELECT_TMPTABLE)

  Message: View's SELECT refers to a temporary table '%s'

- Error: 1353 SQLSTATE: HY000 (ER_VIEW_WRONG_LIST)

  Message: View's SELECT and view's field list have different column counts

- Error: 1354 SQLSTATE: HY000 (ER_WARN_VIEW_MERGE)

  Message: View merge algorithm can't be used here for now (assumed undefined algorithm)

- Error: 1355 SQLSTATE: HY000 (ER_WARN_VIEW_WITHOUT_KEY)

  Message: View being updated does not have complete key of underlying table in it

- Error: 1356 SQLSTATE: HY000 (ER_VIEW_INVALID)

  Message: View '%s.%s' references invalid table(s) or column(s) or function(s) or definer/invoker of view lack rights to use them

- Error: 1357 SQLSTATE: HY000 (ER_SP_NO_DROP_SP)

  Message: Can't drop or alter a %s from within another stored routine

- Error: 1358 SQLSTATE: HY000 (ER_SP_GOTO_IN_HNDLR)

  Message: GOTO is not allowed in a stored procedure handler

- Error: 1359 SQLSTATE: HY000 (ER_TRG_ALREADY_EXISTS)

  Message: Trigger already exists

- Error: 1360 SQLSTATE: HY000 (ER_TRG_DOES_NOT_EXIST)

  Message: Trigger does not exist

- Error: 1361 SQLSTATE: HY000 (ER_TRG_ON_VIEW_OR_TEMP_TABLE)

  Message: Trigger's '%s' is view or temporary table

- Error: 1362 SQLSTATE: HY000 (ER_TRG_CANT_CHANGE_ROW)

  Message: Updating of %s row is not allowed in %strigger

- Error: 1363 SQLSTATE: HY000 (ER_TRG_NO_SUCH_ROW_IN_TRG)

  Message: There is no %s row in %s trigger

- Error: 1364 SQLSTATE: HY000 (ER_NO_DEFAULT_FOR_FIELD)

  Message: Field '%s' doesn't have a default value

- Error: 1365 SQLSTATE: 22012 (ER_DIVISION_BY_ZERO)

  Message: Division by 0

- Error: 1366 SQLSTATE: HY000 (ER_TRUNCATED_WRONG_VALUE_FOR_FIELD)

  Message: Incorrect %s value: '%s' for column '%s' at row %ld

- Error: 1367 SQLSTATE: 22007 (ER_ILLEGAL_VALUE_FOR_TYPE)

  Message: Illegal %s '%s' value found during parsing
- Error: 1368 SQLSTATE: HY000 (ER_VIEW_NONUPD_CHECK)

  Message: CHECK OPTION on non-updatable view '%s.%s'
- Error: 1369 SQLSTATE: HY000 (ER_VIEW_CHECK_FAILED)

  Message: CHECK OPTION failed '%s.%s'
- Error: 1370 SQLSTATE: 42000 (ER_PROCACCESS_DENIED_ERROR)

  Message: %s command denied to user '%s'@'%s' for routine '%s'
- Error: 1371 SQLSTATE: HY000 (ER_RELAY_LOG_FAIL)

  Message: Failed purging old relay logs: %s
- Error: 1372 SQLSTATE: HY000 (ER_PASSWD_LENGTH)

  Message: Password hash should be a %d-digit hexadecimal number
- Error: 1373 SQLSTATE: HY000 (ER_UNKNOWN_TARGET_BINLOG)

  Message: Target log not found in binlog index
- Error: 1374 SQLSTATE: HY000 (ER_IO_ERR_LOG_INDEX_READ)

  Message: I/O error reading log index file
- Error: 1375 SQLSTATE: HY000 (ER_BINLOG_PURGE_PROHIBITED)

  Message: Server configuration does not permit binlog purge
- Error: 1376 SQLSTATE: HY000 (ER_FSEEK_FAIL)

  Message: Failed on fseek()
- Error: 1377 SQLSTATE: HY000 (ER_BINLOG_PURGE_FATAL_ERR)

  Message: Fatal error during log purge
- Error: 1378 SQLSTATE: HY000 (ER_LOG_IN_USE)

  Message: A purgeable log is in use, will not purge
- Error: 1379 SQLSTATE: HY000 (ER_LOG_PURGE_UNKNOWN_ERR)

  Message: Unknown error during log purge
- Error: 1380 SQLSTATE: HY000 (ER_RELAY_LOG_INIT)

  Message: Failed initializing relay log position: %s
- Error: 1381 SQLSTATE: HY000 (ER_NO_BINARY_LOGGING)

  Message: You are not using binary logging
- Error: 1382 SQLSTATE: HY000 (ER_RESERVED_SYNTAX)

  Message: The '%s' syntax is reserved for purposes internal to the MySQL server
- Error: 1383 SQLSTATE: HY000 (ER_WSAS_FAILED)

Message: WSAStartup Failed

- Error: 1384 SQLSTATE: HY000 (ER_DIFF_GROUPS_PROC)

  Message: Can't handle procedures with different groups yet

- Error: 1385 SQLSTATE: HY000 (ER_NO_GROUP_FOR_PROC)

  Message: Select must have a group with this procedure

- Error: 1386 SQLSTATE: HY000 (ER_ORDER_WITH_PROC)

  Message: Can't use ORDER clause with this procedure

- Error: 1387 SQLSTATE: HY000 (ER_LOGGING_PROHIBIT_CHANGING_OF)

  Message: Binary logging and replication forbid changing the global server %s

- Error: 1388 SQLSTATE: HY000 (ER_NO_FILE_MAPPING)

  Message: Can't map file: %s, errno: %d

- Error: 1389 SQLSTATE: HY000 (ER_WRONG_MAGIC)

  Message: Wrong magic in %s

- Error: 1390 SQLSTATE: HY000 (ER_PS_MANY_PARAM)

  Message: Prepared statement contains too many placeholders

- Error: 1391 SQLSTATE: HY000 (ER_KEY_PART_0)

  Message: Key part '%s' length cannot be 0

- Error: 1392 SQLSTATE: HY000 (ER_VIEW_CHECKSUM)

  Message: View text checksum failed

- Error: 1393 SQLSTATE: HY000 (ER_VIEW_MULTIUPDATE)

  Message: Can not modify more than one base table through a join view '%s.%s'

- Error: 1394 SQLSTATE: HY000 (ER_VIEW_NO_INSERT_FIELD_LIST)

  Message: Can not insert into join view '%s.%s' without fields list

- Error: 1395 SQLSTATE: HY000 (ER_VIEW_DELETE_MERGE_VIEW)

  Message: Can not delete from join view '%s.%s'

- Error: 1396 SQLSTATE: HY000 (ER_CANNOT_USER)

  Message: Operation %s failed for %s

- Error: 1397 SQLSTATE: XAE04 (ER_XAER_NOTA)

  Message: XAER_NOTA: Unknown XID

- Error: 1398 SQLSTATE: XAE05 (ER_XAER_INVAL)

  Message: XAER_INVAL: Invalid arguments (or unsupported command)

- Error: 1399 SQLSTATE: XAE07 (ER_XAER_RMFAIL)

Message: XAER_RMFAIL: The command cannot be executed when global transaction is in the %s state

- Error: 1400 SQLSTATE: XAE09 (ER_XAER_OUTSIDE)

  Message: XAER_OUTSIDE: Some work is done outside global transaction

- Error: 1401 SQLSTATE: XAE03 (ER_XAER_RMERR)

  Message: XAER_RMERR: Fatal error occurred in the transaction branch - check your data for consistency

- Error: 1402 SQLSTATE: XA100 (ER_XA_RBROLLBACK)

  Message: XA_RBROLLBACK: Transaction branch was rolled back

- Error: 1403 SQLSTATE: 42000 (ER_NONEXISTING_PROC_GRANT)

  Message: There is no such grant defined for user '%s' on host '%s' on routine '%s'

- Error: 1404 SQLSTATE: HY000 (ER_PROC_AUTO_GRANT_FAIL)

  Message: Failed to grant EXECUTE and ALTER ROUTINE privileges

- Error: 1405 SQLSTATE: HY000 (ER_PROC_AUTO_REVOKE_FAIL)

  Message: Failed to revoke all privileges to dropped routine

- Error: 1406 SQLSTATE: 22001 (ER_DATA_TOO_LONG)

  Message: Data too long for column '%s' at row %ld

- Error: 1407 SQLSTATE: 42000 (ER_SP_BAD_SQLSTATE)

  Message: Bad SQLSTATE: '%s'

- Error: 1408 SQLSTATE: HY000 (ER_STARTUP)

  Message: %s: ready for connections. Version: '%s' socket: '%s' port: %d %s

- Error: 1409 SQLSTATE: HY000 (ER_LOAD_FROM_FIXED_SIZE_ROWS_TO_VAR)

  Message: Can't load value from file with fixed size rows to variable

- Error: 1410 SQLSTATE: 42000 (ER_CANT_CREATE_USER_WITH_GRANT)

  Message: You are not allowed to create a user with GRANT

- Error: 1411 SQLSTATE: HY000 (ER_WRONG_VALUE_FOR_TYPE)

  Message: Incorrect %s value: '%s' for function %s

- Error: 1412 SQLSTATE: HY000 (ER_TABLE_DEF_CHANGED)

  Message: Table definition has changed, please retry transaction

- Error: 1413 SQLSTATE: 42000 (ER_SP_DUP_HANDLER)

  Message: Duplicate handler declared in the same block

- Error: 1414 SQLSTATE: 42000 (ER_SP_NOT_VAR_ARG)

  Message: OUT or INOUT argument %d for routine %s is not a variable or NEW pseudo-variable in BEFORE trigger

- Error: 1415 SQLSTATE: 0A000 (ER_SP_NO_RETSET)

  Message: Not allowed to return a result set from a %s

- Error: 1416 SQLSTATE: 22003 (ER_CANT_CREATE_GEOMETRY_OBJECT)

  Message: Cannot get geometry object from data you send to the GEOMETRY field

- Error: 1417 SQLSTATE: HY000 (ER_FAILED_ROUTINE_BREAK_BINLOG)

  Message: A routine failed and has neither NO SQL nor READS SQL DATA in its declaration and binary logging is enabled; if non-transactional tables were updated, the binary log will miss their changes

- Error: 1418 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_ROUTINE)

  Message: This function has none of DETERMINISTIC, NO SQL, or READS SQL DATA in its declaration and binary logging is enabled (you *might* want to use the less safe log_bin_trust_function_creators variable)

- Error: 1419 SQLSTATE: HY000 (ER_BINLOG_CREATE_ROUTINE_NEED_SUPER)

  Message: You do not have the SUPER privilege and binary logging is enabled (you *might* want to use the less safe log_bin_trust_function_creators variable)

- Error: 1420 SQLSTATE: HY000 (ER_EXEC_STMT_WITH_OPEN_CURSOR)

  Message: You can't execute a prepared statement which has an open cursor associated with it. Reset the statement to re-execute it.

- Error: 1421 SQLSTATE: HY000 (ER_STMT_HAS_NO_OPEN_CURSOR)

  Message: The statement (%lu) has no open cursor.

- Error: 1422 SQLSTATE: HY000 (ER_COMMIT_NOT_ALLOWED_IN_SF_OR_TRG)

  Message: Explicit or implicit commit is not allowed in stored function or trigger.

- Error: 1423 SQLSTATE: HY000 (ER_NO_DEFAULT_FOR_VIEW_FIELD)

  Message: Field of view '%s.%s' underlying table doesn't have a default value

- Error: 1424 SQLSTATE: HY000 (ER_SP_NO_RECURSION)

  Message: Recursive stored functions and triggers are not allowed.

- Error: 1425 SQLSTATE: 42000 (ER_TOO_BIG_SCALE)

  Message: Too big scale %d specified for column '%s'. Maximum is %lu.

- Error: 1426 SQLSTATE: 42000 (ER_TOO_BIG_PRECISION)

  Message: Too big precision %d specified for column '%s'. Maximum is %lu.

- Error: 1427 SQLSTATE: 42000 (ER_M_BIGGER_THAN_D)

  Message: For float(M,D), double(M,D) or decimal(M,D), M must be >= D (column '%s').

- Error: 1428 SQLSTATE: HY000 (ER_WRONG_LOCK_OF_SYSTEM_TABLE)

  Message: You can't combine write-locking of system tables with other tables or lock types

- Error: 1429 SQLSTATE: HY000 (ER_CONNECT_TO_FOREIGN_DATA_SOURCE)

  Message: Unable to connect to foreign data source: %s

- Error: 1430 SQLSTATE: HY000 (ER_QUERY_ON_FOREIGN_DATA_SOURCE)

  Message: There was a problem processing the query on the foreign data source. Data source error: %s

- Error: 1431 SQLSTATE: HY000 (ER_FOREIGN_DATA_SOURCE_DOESNT_EXIST)

  Message: The foreign data source you are trying to reference does not exist. Data source error: %s

- Error: 1432 SQLSTATE: HY000 (ER_FOREIGN_DATA_STRING_INVALID_CANT_CREATE)

  Message: Can't create federated table. The data source connection string '%s' is not in the correct format

- Error: 1433 SQLSTATE: HY000 (ER_FOREIGN_DATA_STRING_INVALID)

  Message: The data source connection string '%s' is not in the correct format

- Error: 1434 SQLSTATE: HY000 (ER_CANT_CREATE_FEDERATED_TABLE)

  Message: Can't create federated table. Foreign data src error: %s

- Error: 1435 SQLSTATE: HY000 (ER_TRG_IN_WRONG_SCHEMA)

  Message: Trigger in wrong schema

- Error: 1436 SQLSTATE: HY000 (ER_STACK_OVERRUN_NEED_MORE)

  Message: Thread stack overrun: %ld bytes used of a %ld byte stack, and %ld bytes needed. Use 'mysqld --thread_stack=#' to specify a bigger stack.

- Error: 1437 SQLSTATE: 42000 (ER_TOO_LONG_BODY)

  Message: Routine body for '%s' is too long

- Error: 1438 SQLSTATE: HY000 (ER_WARN_CANT_DROP_DEFAULT_KEYCACHE)

  Message: Cannot drop default keycache

- Error: 1439 SQLSTATE: 42000 (ER_TOO_BIG_DISPLAYWIDTH)

  Message: Display width out of range for column '%s' (max = %lu)

- Error: 1440 SQLSTATE: XAE08 (ER_XAER_DUPID)

  Message: XAER_DUPID: The XID already exists

- Error: 1441 SQLSTATE: 22008 (ER_DATETIME_FUNCTION_OVERFLOW)

  Message: Datetime function: %s field overflow

- Error: 1442 SQLSTATE: HY000 (ER_CANT_UPDATE_USED_TABLE_IN_SF_OR_TRG)

  Message: Can't update table '%s' in stored function/trigger because it is already used by statement which invoked this stored function/trigger.

- Error: 1443 SQLSTATE: HY000 (ER_VIEW_PREVENT_UPDATE)

  Message: The definition of table '%s' prevents operation %s on table '%s'.

- Error: 1444 SQLSTATE: HY000 (ER_PS_NO_RECURSION)

  Message: The prepared statement contains a stored routine call that refers to that same statement. It's not allowed to execute a prepared statement in such a recursive manner

- Error: 1445 SQLSTATE: HY000 (ER_SP_CANT_SET_AUTOCOMMIT)

  Message: Not allowed to set autocommit from a stored function or trigger

- Error: 1446 SQLSTATE: HY000 (ER_MALFORMED_DEFINER)

  Message: Definer is not fully qualified

- Error: 1447 SQLSTATE: HY000 (ER_VIEW_FRM_NO_USER)

  Message: View '%s'.'%s' has no definer information (old table format). Current user is used as definer. Please recreate the view!

- Error: 1448 SQLSTATE: HY000 (ER_VIEW_OTHER_USER)

  Message: You need the SUPER privilege for creation view with '%s'@'%s' definer

- Error: 1449 SQLSTATE: HY000 (ER_NO_SUCH_USER)

  Message: The user specified as a definer ('%s'@'%s') does not exist

- Error: 1450 SQLSTATE: HY000 (ER_FORBID_SCHEMA_CHANGE)

  Message: Changing schema from '%s' to '%s' is not allowed.

- Error: 1451 SQLSTATE: 23000 (ER_ROW_IS_REFERENCED_2)

  Message: Cannot delete or update a parent row: a foreign key constraint fails (%s)

- Error: 1452 SQLSTATE: 23000 (ER_NO_REFERENCED_ROW_2)

  Message: Cannot add or update a child row: a foreign key constraint fails (%s)

- Error: 1453 SQLSTATE: 42000 (ER_SP_BAD_VAR_SHADOW)

  Message: Variable '%s' must be quoted with `...`, or renamed

- Error: 1454 SQLSTATE: HY000 (ER_TRG_NO_DEFINER)

  Message: No definer attribute for trigger '%s'.'%s'. The trigger will be activated under the authorization of the invoker, which may have insufficient privileges. Please recreate the trigger.

- Error: 1455 SQLSTATE: HY000 (ER_OLD_FILE_FORMAT)

  Message: '%s' has an old format, you should re-create the '%s' object(s)

- Error: 1456 SQLSTATE: HY000 (ER_SP_RECURSION_LIMIT)

  Message: Recursive limit %d (as set by the max_sp_recursion_depth variable) was exceeded for routine %s

- Error: 1457 SQLSTATE: HY000 (ER_SP_PROC_TABLE_CORRUPT)

  Message: Failed to load routine %s. The table mysql.proc is missing, corrupt, or contains bad data (internal code %d)

- Error: 1458 SQLSTATE: 42000 (ER_SP_WRONG_NAME)

  Message: Incorrect routine name '%s'

- Error: 1459 SQLSTATE: HY000 (ER_TABLE_NEEDS_UPGRADE)

  Message: Table upgrade required. Please do "REPAIR TABLE `%s`" or dump/reload to fix it!

- Error: 1460 SQLSTATE: 42000 (ER_SP_NO_AGGREGATE)

  Message: AGGREGATE is not supported for stored functions

- Error: 1461 SQLSTATE: 42000 (ER_MAX_PREPARED_STMT_COUNT_REACHED)

  Message: Can't create more than max_prepared_stmt_count statements (current value: %lu)

- Error: 1462 SQLSTATE: HY000 (ER_VIEW_RECURSIVE)

  Message: `%s`.`%s` contains view recursion

- Error: 1463 SQLSTATE: 42000 (ER_NON_GROUPING_FIELD_USED)

  Message: Non-grouping field '%s' is used in %s clause

- Error: 1464 SQLSTATE: HY000 (ER_TABLE_CANT_HANDLE_SPKEYS)

  Message: The used table type doesn't support SPATIAL indexes

- Error: 1465 SQLSTATE: HY000 (ER_NO_TRIGGERS_ON_SYSTEM_SCHEMA)

  Message: Triggers can not be created on system tables

- Error: 1466 SQLSTATE: HY000 (ER_REMOVED_SPACES)

  Message: Leading spaces are removed from name '%s'

- Error: 1467 SQLSTATE: HY000 (ER_AUTOINC_READ_FAILED)

  Message: Failed to read auto-increment value from storage engine

- Error: 1468 SQLSTATE: HY000 (ER_USERNAME)

  Message: user name

- Error: 1469 SQLSTATE: HY000 (ER_HOSTNAME)

  Message: host name

- Error: 1470 SQLSTATE: HY000 (ER_WRONG_STRING_LENGTH)

  Message: String '%s' is too long for %s (should be no longer than %d)

- Error: 1471 SQLSTATE: HY000 (ER_NON_INSERTABLE_TABLE)

  Message: The target table %s of the %s is not insertable-into

- Error: 1472 SQLSTATE: HY000 (ER_ADMIN_WRONG_MRG_TABLE)

  Message: Table '%s' is differently defined or of non-MyISAM type or doesn't exist

- Error: 1473 SQLSTATE: HY000 (ER_TOO_HIGH_LEVEL_OF_NESTING_FOR_SELECT)

  Message: Too high level of nesting for select

- Error: 1474 SQLSTATE: HY000 (ER_NAME_BECOMES_EMPTY)

  Message: Name '%s' has become ''

- Error: 1475 SQLSTATE: HY000 (ER_AMBIGUOUS_FIELD_TERM)

  Message: First character of the FIELDS TERMINATED string is ambiguous; please use non-optional and non-empty FIELDS ENCLOSED BY

- Error: 1476 SQLSTATE: HY000 (ER_FOREIGN_SERVER_EXISTS)

  Message: The foreign server, %s, you are trying to create already exists.

- Error: 1477 SQLSTATE: HY000 (ER_FOREIGN_SERVER_DOESNT_EXIST)

  Message: The foreign server name you are trying to reference does not exist. Data source error: %s

- Error: 1478 SQLSTATE: HY000 (ER_ILLEGAL_HA_CREATE_OPTION)

  Message: Table storage engine '%s' does not support the create option '%s'

- Error: 1479 SQLSTATE: HY000 (ER_PARTITION_REQUIRES_VALUES_ERROR)

  Message: Syntax error: %s PARTITIONING requires definition of VALUES %s for each partition

- Error: 1480 SQLSTATE: HY000 (ER_PARTITION_WRONG_VALUES_ERROR)

  Message: Only %s PARTITIONING can use VALUES %s in partition definition

- Error: 1481 SQLSTATE: HY000 (ER_PARTITION_MAXVALUE_ERROR)

  Message: MAXVALUE can only be used in last partition definition

- Error: 1482 SQLSTATE: HY000 (ER_PARTITION_SUBPARTITION_ERROR)

  Message: Subpartitions can only be hash partitions and by key

- Error: 1483 SQLSTATE: HY000 (ER_PARTITION_SUBPART_MIX_ERROR)

  Message: Must define subpartitions on all partitions if on one partition

- Error: 1484 SQLSTATE: HY000 (ER_PARTITION_WRONG_NO_PART_ERROR)

  Message: Wrong number of partitions defined, mismatch with previous setting

- Error: 1485 SQLSTATE: HY000 (ER_PARTITION_WRONG_NO_SUBPART_ERROR)

  Message: Wrong number of subpartitions defined, mismatch with previous setting

- Error: 1486 SQLSTATE: HY000 (ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR)

  Message: Constant/Random expression in (sub)partitioning function is not allowed

  In 5.5.1: ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR was renamed to ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR.

  ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR was removed after 5.5.0.

- Error: 1486 SQLSTATE: HY000 (ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR)

  Message: Constant, random or timezone-dependent expressions in (sub)partitioning function are not allowed

  In 5.5.1: ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR was renamed to ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR.

  ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR was added in 5.5.1.

- Error: 1487 SQLSTATE: HY000 (ER_NO_CONST_EXPR_IN_RANGE_OR_LIST_ERROR)

  Message: Expression in RANGE/LIST VALUES must be constant

- Error: 1488 SQLSTATE: HY000 (ER_FIELD_NOT_FOUND_PART_ERROR)

Message: Field in list of fields for partition function not found in table

- Error: 1489 SQLSTATE: HY000 (ER_LIST_OF_FIELDS_ONLY_IN_HASH_ERROR)

  Message: List of fields is only allowed in KEY partitions

- Error: 1490 SQLSTATE: HY000 (ER_INCONSISTENT_PARTITION_INFO_ERROR)

  Message: The partition info in the frm file is not consistent with what can be written into the frm file

- Error: 1491 SQLSTATE: HY000 (ER_PARTITION_FUNC_NOT_ALLOWED_ERROR)

  Message: The %s function returns the wrong type

- Error: 1492 SQLSTATE: HY000 (ER_PARTITIONS_MUST_BE_DEFINED_ERROR)

  Message: For %s partitions each partition must be defined

- Error: 1493 SQLSTATE: HY000 (ER_RANGE_NOT_INCREASING_ERROR)

  Message: VALUES LESS THAN value must be strictly increasing for each partition

- Error: 1494 SQLSTATE: HY000 (ER_INCONSISTENT_TYPE_OF_FUNCTIONS_ERROR)

  Message: VALUES value must be of same type as partition function

- Error: 1495 SQLSTATE: HY000 (ER_MULTIPLE_DEF_CONST_IN_LIST_PART_ERROR)

  Message: Multiple definition of same constant in list partitioning

- Error: 1496 SQLSTATE: HY000 (ER_PARTITION_ENTRY_ERROR)

  Message: Partitioning can not be used stand-alone in query

- Error: 1497 SQLSTATE: HY000 (ER_MIX_HANDLER_ERROR)

  Message: The mix of handlers in the partitions is not allowed in this version of MySQL

- Error: 1498 SQLSTATE: HY000 (ER_PARTITION_NOT_DEFINED_ERROR)

  Message: For the partitioned engine it is necessary to define all %s

- Error: 1499 SQLSTATE: HY000 (ER_TOO_MANY_PARTITIONS_ERROR)

  Message: Too many partitions (including subpartitions) were defined

- Error: 1500 SQLSTATE: HY000 (ER_SUBPARTITION_ERROR)

  Message: It is only possible to mix RANGE/LIST partitioning with HASH/KEY partitioning for subpartitioning

- Error: 1501 SQLSTATE: HY000 (ER_CANT_CREATE_HANDLER_FILE)

  Message: Failed to create specific handler file

- Error: 1502 SQLSTATE: HY000 (ER_BLOB_FIELD_IN_PART_FUNC_ERROR)

  Message: A BLOB field is not allowed in partition function

- Error: 1503 SQLSTATE: HY000 (ER_UNIQUE_KEY_NEED_ALL_FIELDS_IN_PF)

  Message: A %s must include all columns in the table's partitioning function

- Error: 1504 SQLSTATE: HY000 (ER_NO_PARTS_ERROR)

Message: Number of %s = 0 is not an allowed value

- Error: 1505 SQLSTATE: HY000 (ER_PARTITION_MGMT_ON_NONPARTITIONED)

  Message: Partition management on a not partitioned table is not possible

- Error: 1506 SQLSTATE: HY000 (ER_FOREIGN_KEY_ON_PARTITIONED)

  Message: Foreign key clause is not yet supported in conjunction with partitioning

- Error: 1507 SQLSTATE: HY000 (ER_DROP_PARTITION_NON_EXISTENT)

  Message: Error in list of partitions to %s

- Error: 1508 SQLSTATE: HY000 (ER_DROP_LAST_PARTITION)

  Message: Cannot remove all partitions, use DROP TABLE instead

- Error: 1509 SQLSTATE: HY000 (ER_COALESCE_ONLY_ON_HASH_PARTITION)

  Message: COALESCE PARTITION can only be used on HASH/KEY partitions

- Error: 1510 SQLSTATE: HY000 (ER_REORG_HASH_ONLY_ON_SAME_NO)

  Message: REORGANIZE PARTITION can only be used to reorganize partitions not to change their numbers

- Error: 1511 SQLSTATE: HY000 (ER_REORG_NO_PARAM_ERROR)

  Message: REORGANIZE PARTITION without parameters can only be used on auto-partitioned tables using HASH PARTITIONs

- Error: 1512 SQLSTATE: HY000 (ER_ONLY_ON_RANGE_LIST_PARTITION)

  Message: %s PARTITION can only be used on RANGE/LIST partitions

- Error: 1513 SQLSTATE: HY000 (ER_ADD_PARTITION_SUBPART_ERROR)

  Message: Trying to Add partition(s) with wrong number of subpartitions

- Error: 1514 SQLSTATE: HY000 (ER_ADD_PARTITION_NO_NEW_PARTITION)

  Message: At least one partition must be added

- Error: 1515 SQLSTATE: HY000 (ER_COALESCE_PARTITION_NO_PARTITION)

  Message: At least one partition must be coalesced

- Error: 1516 SQLSTATE: HY000 (ER_REORG_PARTITION_NOT_EXIST)

  Message: More partitions to reorganize than there are partitions

- Error: 1517 SQLSTATE: HY000 (ER_SAME_NAME_PARTITION)

  Message: Duplicate partition name %s

- Error: 1518 SQLSTATE: HY000 (ER_NO_BINLOG_ERROR)

  Message: It is not allowed to shut off binlog on this command

- Error: 1519 SQLSTATE: HY000 (ER_CONSECUTIVE_REORG_PARTITIONS)

  Message: When reorganizing a set of partitions they must be in consecutive order

- Error: 1520 SQLSTATE: HY000 (ER_REORG_OUTSIDE_RANGE)

  Message: Reorganize of range partitions cannot change total ranges except for last partition where it can extend the range

- Error: 1521 SQLSTATE: HY000 (ER_PARTITION_FUNCTION_FAILURE)

  Message: Partition function not supported in this version for this handler

- Error: 1522 SQLSTATE: HY000 (ER_PART_STATE_ERROR)

  Message: Partition state cannot be defined from CREATE/ALTER TABLE

- Error: 1523 SQLSTATE: HY000 (ER_LIMITED_PART_RANGE)

  Message: The %s handler only supports 32 bit integers in VALUES

- Error: 1524 SQLSTATE: HY000 (ER_PLUGIN_IS_NOT_LOADED)

  Message: Plugin '%s' is not loaded

- Error: 1525 SQLSTATE: HY000 (ER_WRONG_VALUE)

  Message: Incorrect %s value: '%s'

- Error: 1526 SQLSTATE: HY000 (ER_NO_PARTITION_FOR_GIVEN_VALUE)

  Message: Table has no partition for value %s

- Error: 1527 SQLSTATE: HY000 (ER_FILEGROUP_OPTION_ONLY_ONCE)

  Message: It is not allowed to specify %s more than once

- Error: 1528 SQLSTATE: HY000 (ER_CREATE_FILEGROUP_FAILED)

  Message: Failed to create %s

- Error: 1529 SQLSTATE: HY000 (ER_DROP_FILEGROUP_FAILED)

  Message: Failed to drop %s

- Error: 1530 SQLSTATE: HY000 (ER_TABLESPACE_AUTO_EXTEND_ERROR)

  Message: The handler doesn't support autoextend of tablespaces

- Error: 1531 SQLSTATE: HY000 (ER_WRONG_SIZE_NUMBER)

  Message: A size parameter was incorrectly specified, either number or on the form 10M

- Error: 1532 SQLSTATE: HY000 (ER_SIZE_OVERFLOW_ERROR)

  Message: The size number was correct but we don't allow the digit part to be more than 2 billion

- Error: 1533 SQLSTATE: HY000 (ER_ALTER_FILEGROUP_FAILED)

  Message: Failed to alter: %s

- Error: 1534 SQLSTATE: HY000 (ER_BINLOG_ROW_LOGGING_FAILED)

  Message: Writing one row to the row-based binary log failed

- Error: 1535 SQLSTATE: HY000 (ER_BINLOG_ROW_WRONG_TABLE_DEF)

  Message: Table definition on master and slave does not match: %s

- Error: 1536 SQLSTATE: HY000 (ER_BINLOG_ROW_RBR_TO_SBR)

  Message: Slave running with --log-slave-updates must use row-based binary logging to be able to replicate row-based binary log events

- Error: 1537 SQLSTATE: HY000 (ER_EVENT_ALREADY_EXISTS)

  Message: Event '%s' already exists

- Error: 1538 SQLSTATE: HY000 (ER_EVENT_STORE_FAILED)

  Message: Failed to store event %s. Error code %d from storage engine.

- Error: 1539 SQLSTATE: HY000 (ER_EVENT_DOES_NOT_EXIST)

  Message: Unknown event '%s'

- Error: 1540 SQLSTATE: HY000 (ER_EVENT_CANT_ALTER)

  Message: Failed to alter event '%s'

- Error: 1541 SQLSTATE: HY000 (ER_EVENT_DROP_FAILED)

  Message: Failed to drop %s

- Error: 1542 SQLSTATE: HY000 (ER_EVENT_INTERVAL_NOT_POSITIVE_OR_TOO_BIG)

  Message: INTERVAL is either not positive or too big

- Error: 1543 SQLSTATE: HY000 (ER_EVENT_ENDS_BEFORE_STARTS)

  Message: ENDS is either invalid or before STARTS

- Error: 1544 SQLSTATE: HY000 (ER_EVENT_EXEC_TIME_IN_THE_PAST)

  Message: Event execution time is in the past. Event has been disabled

- Error: 1545 SQLSTATE: HY000 (ER_EVENT_OPEN_TABLE_FAILED)

  Message: Failed to open mysql.event

- Error: 1546 SQLSTATE: HY000 (ER_EVENT_NEITHER_M_EXPR_NOR_M_AT)

  Message: No datetime expression provided

- Error: 1547 SQLSTATE: HY000 (ER_COL_COUNT_DOESNT_MATCH_CORRUPTED)

  Message: Column count of mysql.%s is wrong. Expected %d, found %d. The table is probably corrupted

- Error: 1548 SQLSTATE: HY000 (ER_CANNOT_LOAD_FROM_TABLE)

  Message: Cannot load from mysql.%s. The table is probably corrupted

- Error: 1549 SQLSTATE: HY000 (ER_EVENT_CANNOT_DELETE)

  Message: Failed to delete the event from mysql.event

- Error: 1550 SQLSTATE: HY000 (ER_EVENT_COMPILE_ERROR)

  Message: Error during compilation of event's body

- Error: 1551 SQLSTATE: HY000 (ER_EVENT_SAME_NAME)

  Message: Same old and new event name

- Error: 1552 SQLSTATE: HY000 (ER_EVENT_DATA_TOO_LONG)

  Message: Data for column '%s' too long

- Error: 1553 SQLSTATE: HY000 (ER_DROP_INDEX_FK)

  Message: Cannot drop index '%s': needed in a foreign key constraint

  InnoDB reports this error when you attempt to drop the last index that can enforce a particular referential constraint.

  For optimal performance with DML statements, InnoDB requires an index to exist on foreign key columns, so that UPDATE and DELETE operations on a parent table can easily check whether corresponding rows exist in the child table. MySQL creates or drops such indexes automatically when needed, as a side-effect of CREATE TABLE, CREATE INDEX, and ALTER TABLE statements.

  When you drop an index, InnoDB checks if the index is used for checking a foreign key constraint. It is still OK to drop the index if there is another index that can be used to enforce the same constraint. InnoDB prevents you from dropping the last index that can enforce a particular referential constraint.

- Error: 1554 SQLSTATE: HY000 (ER_WARN_DEPRECATED_SYNTAX_WITH_VER)

  Message: The syntax '%s' is deprecated and will be removed in MySQL %s. Please use %s instead

- Error: 1555 SQLSTATE: HY000 (ER_CANT_WRITE_LOCK_LOG_TABLE)

  Message: You can't write-lock a log table. Only read access is possible

- Error: 1556 SQLSTATE: HY000 (ER_CANT_LOCK_LOG_TABLE)

  Message: You can't use locks with log tables.

- Error: 1557 SQLSTATE: 23000 (ER_FOREIGN_DUPLICATE_KEY)

  Message: Upholding foreign key constraints for table '%s', entry '%s', key %d would lead to a duplicate entry

- Error: 1558 SQLSTATE: HY000 (ER_COL_COUNT_DOESNT_MATCH_PLEASE_UPDATE)

  Message: Column count of mysql.%s is wrong. Expected %d, found %d. Created with MySQL %d, now running %d. Please use mysql_upgrade to fix this error.

- Error: 1559 SQLSTATE: HY000 (ER_TEMP_TABLE_PREVENTS_SWITCH_OUT_OF_RBR)

  Message: Cannot switch out of the row-based binary log format when the session has open temporary tables

- Error: 1560 SQLSTATE: HY000 (ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_FORMAT)

  Message: Cannot change the binary logging format inside a stored function or trigger

- Error: 1561 SQLSTATE: HY000 (ER_NDB_CANT_SWITCH_BINLOG_FORMAT)

  Message: The NDB cluster engine does not support changing the binlog format on the fly yet

- Error: 1562 SQLSTATE: HY000 (ER_PARTITION_NO_TEMPORARY)

  Message: Cannot create temporary table with partitions

- Error: 1563 SQLSTATE: HY000 (ER_PARTITION_CONST_DOMAIN_ERROR)

  Message: Partition constant is out of partition function domain

- Error: 1564 SQLSTATE: HY000 (ER_PARTITION_FUNCTION_IS_NOT_ALLOWED)

Message: This partition function is not allowed

- Error: 1565 SQLSTATE: HY000 (ER_DDL_LOG_ERROR)

  Message: Error in DDL log

- Error: 1566 SQLSTATE: HY000 (ER_NULL_IN_VALUES_LESS_THAN)

  Message: Not allowed to use NULL value in VALUES LESS THAN

- Error: 1567 SQLSTATE: HY000 (ER_WRONG_PARTITION_NAME)

  Message: Incorrect partition name

- Error: 1568 SQLSTATE: 25001 (ER_CANT_CHANGE_TX_ISOLATION)

  Message: Transaction isolation level can't be changed while a transaction is in progress

- Error: 1569 SQLSTATE: HY000 (ER_DUP_ENTRY_AUTOINCREMENT_CASE)

  Message: ALTER TABLE causes auto_increment resequencing, resulting in duplicate entry '%s' for key '%s'

- Error: 1570 SQLSTATE: HY000 (ER_EVENT_MODIFY_QUEUE_ERROR)

  Message: Internal scheduler error %d

- Error: 1571 SQLSTATE: HY000 (ER_EVENT_SET_VAR_ERROR)

  Message: Error during starting/stopping of the scheduler. Error code %u

- Error: 1572 SQLSTATE: HY000 (ER_PARTITION_MERGE_ERROR)

  Message: Engine cannot be used in partitioned tables

- Error: 1573 SQLSTATE: HY000 (ER_CANT_ACTIVATE_LOG)

  Message: Cannot activate '%s' log

- Error: 1574 SQLSTATE: HY000 (ER_RBR_NOT_AVAILABLE)

  Message: The server was not built with row-based replication

- Error: 1575 SQLSTATE: HY000 (ER_BASE64_DECODE_ERROR)

  Message: Decoding of base64 string failed

- Error: 1576 SQLSTATE: HY000 (ER_EVENT_RECURSION_FORBIDDEN)

  Message: Recursion of EVENT DDL statements is forbidden when body is present

- Error: 1577 SQLSTATE: HY000 (ER_EVENTS_DB_ERROR)

  Message: Cannot proceed because system tables used by Event Scheduler were found damaged at server start

  To address this issue, try running `mysql_upgrade`.

- Error: 1578 SQLSTATE: HY000 (ER_ONLY_INTEGERS_ALLOWED)

  Message: Only integers allowed as number here

- Error: 1579 SQLSTATE: HY000 (ER_UNSUPORTED_LOG_ENGINE)

Message: This storage engine cannot be used for log tables"

- Error: 1580 SQLSTATE: HY000 (ER_BAD_LOG_STATEMENT)

  Message: You cannot '%s' a log table if logging is enabled

- Error: 1581 SQLSTATE: HY000 (ER_CANT_RENAME_LOG_TABLE)

  Message: Cannot rename '%s'. When logging enabled, rename to/from log table must rename two tables: the log table to an archive table and another table back to '%s'

- Error: 1582 SQLSTATE: 42000 (ER_WRONG_PARAMCOUNT_TO_NATIVE_FCT)

  Message: Incorrect parameter count in the call to native function '%s'

- Error: 1583 SQLSTATE: 42000 (ER_WRONG_PARAMETERS_TO_NATIVE_FCT)

  Message: Incorrect parameters in the call to native function '%s'

- Error: 1584 SQLSTATE: 42000 (ER_WRONG_PARAMETERS_TO_STORED_FCT)

  Message: Incorrect parameters in the call to stored function '%s'

- Error: 1585 SQLSTATE: HY000 (ER_NATIVE_FCT_NAME_COLLISION)

  Message: This function '%s' has the same name as a native function

- Error: 1586 SQLSTATE: 23000 (ER_DUP_ENTRY_WITH_KEY_NAME)

  Message: Duplicate entry '%s' for key '%s'

  The format string for this error is also used with ER_DUP_ENTRY.

- Error: 1587 SQLSTATE: HY000 (ER_BINLOG_PURGE_EMFILE)

  Message: Too many files opened, please execute the command again

- Error: 1588 SQLSTATE: HY000 (ER_EVENT_CANNOT_CREATE_IN_THE_PAST)

  Message: Event execution time is in the past and ON COMPLETION NOT PRESERVE is set. The event was dropped immediately after creation.

- Error: 1589 SQLSTATE: HY000 (ER_EVENT_CANNOT_ALTER_IN_THE_PAST)

  Message: Event execution time is in the past and ON COMPLETION NOT PRESERVE is set. The event was dropped immediately after creation.

- Error: 1590 SQLSTATE: HY000 (ER_SLAVE_INCIDENT)

  Message: The incident %s occured on the master. Message: %s

- Error: 1591 SQLSTATE: HY000 (ER_NO_PARTITION_FOR_GIVEN_VALUE_SILENT)

  Message: Table has no partition for some existing values

- Error: 1592 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_STATEMENT)

  Message: Unsafe statement written to the binary log using statement format since BINLOG_FORMAT = STATEMENT. %s

- Error: 1593 SQLSTATE: HY000 (ER_SLAVE_FATAL_ERROR)

  Message: Fatal error: %s

- Error: 1594 SQLSTATE: HY000 (ER_SLAVE_RELAY_LOG_READ_FAILURE)

  Message: Relay log read failure: %s
- Error: 1595 SQLSTATE: HY000 (ER_SLAVE_RELAY_LOG_WRITE_FAILURE)

  Message: Relay log write failure: %s
- Error: 1596 SQLSTATE: HY000 (ER_SLAVE_CREATE_EVENT_FAILURE)

  Message: Failed to create %s
- Error: 1597 SQLSTATE: HY000 (ER_SLAVE_MASTER_COM_FAILURE)

  Message: Master command %s failed: %s
- Error: 1598 SQLSTATE: HY000 (ER_BINLOG_LOGGING_IMPOSSIBLE)

  Message: Binary logging not possible. Message: %s
- Error: 1599 SQLSTATE: HY000 (ER_VIEW_NO_CREATION_CTX)

  Message: View `%s`.`%s` has no creation context
- Error: 1600 SQLSTATE: HY000 (ER_VIEW_INVALID_CREATION_CTX)

  Message: Creation context of view `%s`.`%s' is invalid
- Error: 1601 SQLSTATE: HY000 (ER_SR_INVALID_CREATION_CTX)

  Message: Creation context of stored routine `%s`.`%s` is invalid
- Error: 1602 SQLSTATE: HY000 (ER_TRG_CORRUPTED_FILE)

  Message: Corrupted TRG file for table `%s`.`%s`
- Error: 1603 SQLSTATE: HY000 (ER_TRG_NO_CREATION_CTX)

  Message: Triggers for table `%s`.`%s` have no creation context
- Error: 1604 SQLSTATE: HY000 (ER_TRG_INVALID_CREATION_CTX)

  Message: Trigger creation context of table `%s`.`%s` is invalid
- Error: 1605 SQLSTATE: HY000 (ER_EVENT_INVALID_CREATION_CTX)

  Message: Creation context of event `%s`.`%s` is invalid
- Error: 1606 SQLSTATE: HY000 (ER_TRG_CANT_OPEN_TABLE)

  Message: Cannot open table for trigger `%s`.`%s`
- Error: 1607 SQLSTATE: HY000 (ER_CANT_CREATE_SROUTINE)

  Message: Cannot create stored routine `%s`. Check warnings
- Error: 1608 SQLSTATE: HY000 (ER_SLAVE_AMBIGOUS_EXEC_MODE)

  Message: Ambiguous slave modes combination. %s

  In 5.5.3: ER_SLAVE_AMBIGOUS_EXEC_MODE was renamed to ER_NEVER_USED.

  ER_SLAVE_AMBIGOUS_EXEC_MODE was removed after 5.5.2.
- Error: 1608 SQLSTATE: HY000 (ER_NEVER_USED)

Message: Ambiguous slave modes combination. %s

In 5.5.3: `ER_SLAVE_AMBIGOUS_EXEC_MODE` was renamed to `ER_NEVER_USED`.

`ER_NEVER_USED` was added in 5.5.3.

- Error: `1609` SQLSTATE: `HY000` (`ER_NO_FORMAT_DESCRIPTION_EVENT_BEFORE_BINLOG_STATEMENT`)

  Message: The BINLOG statement of type `%s` was not preceded by a format description BINLOG statement.

- Error: `1610` SQLSTATE: `HY000` (`ER_SLAVE_CORRUPT_EVENT`)

  Message: Corrupted replication event was detected

- Error: `1611` SQLSTATE: `HY000` (`ER_LOAD_DATA_INVALID_COLUMN`)

  Message: Invalid column reference (%s) in LOAD DATA

- Error: `1612` SQLSTATE: `HY000` (`ER_LOG_PURGE_NO_FILE`)

  Message: Being purged log %s was not found

- Error: `1613` SQLSTATE: `XA106` (`ER_XA_RBTIMEOUT`)

  Message: XA_RBTIMEOUT: Transaction branch was rolled back: took too long

- Error: `1614` SQLSTATE: `XA102` (`ER_XA_RBDEADLOCK`)

  Message: XA_RBDEADLOCK: Transaction branch was rolled back: deadlock was detected

- Error: `1615` SQLSTATE: `HY000` (`ER_NEED_REPREPARE`)

  Message: Prepared statement needs to be re-prepared

- Error: `1616` SQLSTATE: `HY000` (`ER_DELAYED_NOT_SUPPORTED`)

  Message: DELAYED option not supported for table '%s'

- Error: `1617` SQLSTATE: `HY000` (`WARN_NO_MASTER_INFO`)

  Message: The master info structure does not exist

- Error: `1618` SQLSTATE: `HY000` (`WARN_OPTION_IGNORED`)

  Message: <%s> option ignored

- Error: `1619` SQLSTATE: `HY000` (`WARN_PLUGIN_DELETE_BUILTIN`)

  Message: Built-in plugins cannot be deleted

- Error: `1620` SQLSTATE: `HY000` (`WARN_PLUGIN_BUSY`)

  Message: Plugin is busy and will be uninstalled on shutdown

- Error: `1621` SQLSTATE: `HY000` (`ER_VARIABLE_IS_READONLY`)

  Message: %s variable '%s' is read-only. Use SET %s to assign the value

- Error: `1622` SQLSTATE: `HY000` (`ER_WARN_ENGINE_TRANSACTION_ROLLBACK`)

  Message: Storage engine %s does not support rollback for this statement. Transaction rolled back and must be restarted

- Error: 1623 SQLSTATE: HY000 (ER_SLAVE_HEARTBEAT_FAILURE)

  Message: Unexpected master's heartbeat data: %s

- Error: 1624 SQLSTATE: HY000 (ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE)

  Message: The requested value for the heartbeat period is either negative or exceeds the maximum allowed (%s seconds).

- Error: 1625 SQLSTATE: HY000 (ER_NDB_REPLICATION_SCHEMA_ERROR)

  Message: Bad schema for mysql.ndb_replication table. Message: %s

- Error: 1626 SQLSTATE: HY000 (ER_CONFLICT_FN_PARSE_ERROR)

  Message: Error in parsing conflict function. Message: %s

- Error: 1627 SQLSTATE: HY000 (ER_EXCEPTIONS_WRITE_ERROR)

  Message: Write to exceptions table failed. Message: %s"

- Error: 1628 SQLSTATE: HY000 (ER_TOO_LONG_TABLE_COMMENT)

  Message: Comment for table '%s' is too long (max = %lu)

- Error: 1629 SQLSTATE: HY000 (ER_TOO_LONG_FIELD_COMMENT)

  Message: Comment for field '%s' is too long (max = %lu)

- Error: 1630 SQLSTATE: 42000 (ER_FUNC_INEXISTENT_NAME_COLLISION)

  Message: FUNCTION %s does not exist. Check the 'Function Name Parsing and Resolution' section in the Reference Manual

- Error: 1631 SQLSTATE: HY000 (ER_DATABASE_NAME)

  Message: Database

- Error: 1632 SQLSTATE: HY000 (ER_TABLE_NAME)

  Message: Table

- Error: 1633 SQLSTATE: HY000 (ER_PARTITION_NAME)

  Message: Partition

- Error: 1634 SQLSTATE: HY000 (ER_SUBPARTITION_NAME)

  Message: Subpartition

- Error: 1635 SQLSTATE: HY000 (ER_TEMPORARY_NAME)

  Message: Temporary

- Error: 1636 SQLSTATE: HY000 (ER_RENAMED_NAME)

  Message: Renamed

- Error: 1637 SQLSTATE: HY000 (ER_TOO_MANY_CONCURRENT_TRXS)

  Message: Too many active concurrent transactions

- Error: 1638 SQLSTATE: HY000 (WARN_NON_ASCII_SEPARATOR_NOT_IMPLEMENTED)

  Message: Non-ASCII separator arguments are not fully supported

- Error: 1639 SQLSTATE: HY000 (ER_DEBUG_SYNC_TIMEOUT)

  Message: debug sync point wait timed out
- Error: 1640 SQLSTATE: HY000 (ER_DEBUG_SYNC_HIT_LIMIT)

  Message: debug sync point hit limit reached
- Error: 1641 SQLSTATE: 42000 (ER_DUP_SIGNAL_SET)

  Message: Duplicate condition information item '%s'
- Error: 1642 SQLSTATE: 01000 (ER_SIGNAL_WARN)

  Message: Unhandled user-defined warning condition
- Error: 1643 SQLSTATE: 02000 (ER_SIGNAL_NOT_FOUND)

  Message: Unhandled user-defined not found condition
- Error: 1644 SQLSTATE: HY000 (ER_SIGNAL_EXCEPTION)

  Message: Unhandled user-defined exception condition
- Error: 1645 SQLSTATE: 0K000 (ER_RESIGNAL_WITHOUT_ACTIVE_HANDLER)

  Message: RESIGNAL when handler not active
- Error: 1646 SQLSTATE: HY000 (ER_SIGNAL_BAD_CONDITION_TYPE)

  Message: SIGNAL/RESIGNAL can only use a CONDITION defined with SQLSTATE
- Error: 1647 SQLSTATE: HY000 (WARN_COND_ITEM_TRUNCATED)

  Message: Data truncated for condition item '%s'
- Error: 1648 SQLSTATE: HY000 (ER_COND_ITEM_TOO_LONG)

  Message: Data too long for condition item '%s'
- Error: 1649 SQLSTATE: HY000 (ER_UNKNOWN_LOCALE)

  Message: Unknown locale: '%s'
- Error: 1650 SQLSTATE: HY000 (ER_SLAVE_IGNORE_SERVER_IDS)

  Message: The requested server id %d clashes with the slave startup option --replicate-same-server-id
- Error: 1651 SQLSTATE: HY000 (ER_QUERY_CACHE_DISABLED)

  Message: Query cache is disabled; restart the server with query_cache_type=1 to enable it
- Error: 1652 SQLSTATE: HY000 (ER_SAME_NAME_PARTITION_FIELD)

  Message: Duplicate partition field name '%s'
- Error: 1653 SQLSTATE: HY000 (ER_PARTITION_COLUMN_LIST_ERROR)

  Message: Inconsistency in usage of column lists for partitioning
- Error: 1654 SQLSTATE: HY000 (ER_WRONG_TYPE_COLUMN_VALUE_ERROR)

  Message: Partition column values of incorrect type
- Error: 1655 SQLSTATE: HY000 (ER_TOO_MANY_PARTITION_FUNC_FIELDS_ERROR)

Message: Too many fields in '%s'

- Error: 1656 SQLSTATE: HY000 (ER_MAXVALUE_IN_VALUES_IN)

  Message: Cannot use MAXVALUE as value in VALUES IN

- Error: 1657 SQLSTATE: HY000 (ER_TOO_MANY_VALUES_ERROR)

  Message: Cannot have more than one value for this type of %s partitioning

- Error: 1658 SQLSTATE: HY000 (ER_ROW_SINGLE_PARTITION_FIELD_ERROR)

  Message: Row expressions in VALUES IN only allowed for multi-field column partitioning

- Error: 1659 SQLSTATE: HY000 (ER_FIELD_TYPE_NOT_ALLOWED_AS_PARTITION_FIELD)

  Message: Field '%s' is of a not allowed type for this type of partitioning

- Error: 1660 SQLSTATE: HY000 (ER_PARTITION_FIELDS_TOO_LONG)

  Message: The total length of the partitioning fields is too large

- Error: 1661 SQLSTATE: HY000 (ER_BINLOG_ROW_ENGINE_AND_STMT_ENGINE)

  Message: Cannot execute statement: impossible to write to binary log since both row-incapable engines and statement-incapable engines are involved.

  ER_BINLOG_ROW_ENGINE_AND_STMT_ENGINE was added in 5.5.3.

- Error: 1662 SQLSTATE: HY000 (ER_BINLOG_ROW_MODE_AND_STMT_ENGINE)

  Message: Cannot execute statement: impossible to write to binary log since BINLOG_FORMAT = ROW and at least one table uses a storage engine limited to statement-based logging.

  ER_BINLOG_ROW_MODE_AND_STMT_ENGINE was added in 5.5.3.

- Error: 1663 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_AND_STMT_ENGINE)

  Message: Cannot execute statement: impossible to write to binary log since statement is unsafe, storage engine is limited to statement-based logging, and BINLOG_FORMAT = MIXED. %s

  ER_BINLOG_UNSAFE_AND_STMT_ENGINE was added in 5.5.3.

- Error: 1664 SQLSTATE: HY000 (ER_BINLOG_ROW_INJECTION_AND_STMT_ENGINE)

  Message: Cannot execute statement: impossible to write to binary log since statement is in row format and at least one table uses a storage engine limited to statement-based logging.

  ER_BINLOG_ROW_INJECTION_AND_STMT_ENGINE was added in 5.5.3.

- Error: 1665 SQLSTATE: HY000 (ER_BINLOG_STMT_MODE_AND_ROW_ENGINE)

  Message: Cannot execute statement: impossible to write to binary log since BINLOG_FORMAT = STATEMENT and at least one table uses a storage engine limited to row-based logging.%s

  ER_BINLOG_STMT_MODE_AND_ROW_ENGINE was added in 5.5.3.

- Error: 1666 SQLSTATE: HY000 (ER_BINLOG_ROW_INJECTION_AND_STMT_MODE)

  Message: Cannot execute statement: impossible to write to binary log since statement is in row format and BINLOG_FORMAT = STATEMENT.

  ER_BINLOG_ROW_INJECTION_AND_STMT_MODE was added in 5.5.3.

- Error: 1667 SQLSTATE: HY000 (ER_BINLOG_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE)

  Message: Cannot execute statement: impossible to write to binary log since more than one engine is involved and at least one engine is self-logging.

  ER_BINLOG_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE was added in 5.5.3.

- Error: 1668 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_LIMIT)

  Message: The statement is unsafe because it uses a LIMIT clause. This is unsafe because the set of rows included cannot be predicted.

  ER_BINLOG_UNSAFE_LIMIT was added in 5.5.3.

- Error: 1669 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_INSERT_DELAYED)

  Message: The statement is unsafe because it uses INSERT DELAYED. This is unsafe because the times when rows are inserted cannot be predicted.

  ER_BINLOG_UNSAFE_INSERT_DELAYED was added in 5.5.3.

- Error: 1670 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_SYSTEM_TABLE)

  Message: The statement is unsafe because it uses the general log, slow query log, or performance_schema table(s). This is unsafe because system tables may differ on slaves.

  ER_BINLOG_UNSAFE_SYSTEM_TABLE was added in 5.5.3.

- Error: 1671 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_AUTOINC_COLUMNS)

  Message: Statement is unsafe because it invokes a trigger or a stored function that inserts into an AUTO_INCREMENT column. Inserted values cannot be logged correctly.

  ER_BINLOG_UNSAFE_AUTOINC_COLUMNS was added in 5.5.3.

- Error: 1672 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_UDF)

  Message: Statement is unsafe because it uses a UDF which may not return the same value on the slave.

  ER_BINLOG_UNSAFE_UDF was added in 5.5.3.

- Error: 1673 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_SYSTEM_VARIABLE)

  Message: Statement is unsafe because it uses a system variable that may have a different value on the slave.

  ER_BINLOG_UNSAFE_SYSTEM_VARIABLE was added in 5.5.3.

- Error: 1674 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_SYSTEM_FUNCTION)

  Message: Statement is unsafe because it uses a system function that may return a different value on the slave.

  ER_BINLOG_UNSAFE_SYSTEM_FUNCTION was added in 5.5.3.

- Error: 1675 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_NONTRANS_AFTER_TRANS)

  Message: Statement is unsafe because it accesses a non-transactional table after accessing a transactional table within the same transaction.

  ER_BINLOG_UNSAFE_NONTRANS_AFTER_TRANS was added in 5.5.3.

- Error: 1676 SQLSTATE: HY000 (ER_MESSAGE_AND_STATEMENT)

  Message: %s Statement: %s

  ER_MESSAGE_AND_STATEMENT was added in 5.5.3.

- Error: 1677 SQLSTATE: HY000 (ER_SLAVE_CONVERSION_FAILED)

  Message: Column %d of table '%s.%s' cannot be converted from type '%s' to type '%s'

  ER_SLAVE_CONVERSION_FAILED was added in 5.5.3.

- Error: 1678 SQLSTATE: HY000 (ER_SLAVE_CANT_CREATE_CONVERSION)

  Message: Can't create conversion table for table '%s.%s'

  ER_SLAVE_CANT_CREATE_CONVERSION was added in 5.5.3.

- Error: 1679 SQLSTATE: HY000 (ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_FORMAT)

  Message: Cannot modify @@session.binlog_format inside a transaction

  ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_FORMAT was added in 5.5.3.

- Error: 1680 SQLSTATE: HY000 (ER_PATH_LENGTH)

  Message: The path specified for %s is too long.

  ER_PATH_LENGTH was added in 5.5.3.

- Error: 1681 SQLSTATE: HY000 (ER_WARN_DEPRECATED_SYNTAX_NO_REPLACEMENT)

  Message: '%s' is deprecated and will be removed in a future release.

  ER_WARN_DEPRECATED_SYNTAX_NO_REPLACEMENT was added in 5.5.3.

- Error: 1682 SQLSTATE: HY000 (ER_WRONG_NATIVE_TABLE_STRUCTURE)

  Message: Native table '%s'.'%s' has the wrong structure

  ER_WRONG_NATIVE_TABLE_STRUCTURE was added in 5.5.3.

- Error: 1683 SQLSTATE: HY000 (ER_WRONG_PERFSCHEMA_USAGE)

  Message: Invalid performance_schema usage.

  ER_WRONG_PERFSCHEMA_USAGE was added in 5.5.3.

- Error: 1684 SQLSTATE: HY000 (ER_WARN_I_S_SKIPPED_TABLE)

  Message: Table '%s'.'%s' was skipped since its definition is being modified by concurrent DDL statement

  ER_WARN_I_S_SKIPPED_TABLE was added in 5.5.3.

- Error: 1685 SQLSTATE: HY000 (ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_DIRECT)

  Message: Cannot modify @@session.binlog_direct_non_transactional_updates inside a transaction

  ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_DIRECT was added in 5.5.3.

- Error: 1686 SQLSTATE: HY000 (ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_DIRECT)

Message: Cannot change the binlog direct flag inside a stored function or trigger

`ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_DIRECT` was added in 5.5.3.

- Error: `1687` SQLSTATE: `42000` (`ER_SPATIAL_MUST_HAVE_GEOM_COL`)

  Message: A SPATIAL index may only contain a geometrical type column

  `ER_SPATIAL_MUST_HAVE_GEOM_COL` was added in 5.5.2.

- Error: `1688` SQLSTATE: `HY000` (`ER_TOO_LONG_INDEX_COMMENT`)

  Message: Comment for index '%s' is too long (max = %lu)

  `ER_TOO_LONG_INDEX_COMMENT` was added in 5.5.3.

- Error: `1689` SQLSTATE: `HY000` (`ER_LOCK_ABORTED`)

  Message: Wait on a lock was aborted due to a pending exclusive lock

  `ER_LOCK_ABORTED` was added in 5.5.4.

- Error: `1690` SQLSTATE: `22003` (`ER_DATA_OUT_OF_RANGE`)

  Message: %s value is out of range in '%s'

  `ER_DATA_OUT_OF_RANGE` was added in 5.5.5.

- Error: `1691` SQLSTATE: `HY000` (`ER_WRONG_SPVAR_TYPE_IN_LIMIT`)

  Message: A variable of a non-integer based type in LIMIT clause

  `ER_WRONG_SPVAR_TYPE_IN_LIMIT` was added in 5.5.5.

- Error: `1692` SQLSTATE: `HY000` (`ER_BINLOG_UNSAFE_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE`)

  Message: Mixing self-logging and non-self-logging engines in a statement is unsafe.

  `ER_BINLOG_UNSAFE_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE` was added in 5.5.5.

- Error: `1693` SQLSTATE: `HY000` (`ER_BINLOG_UNSAFE_MIXED_STATEMENT`)

  Message: Statement accesses nontransactional table as well as transactional or temporary table, and writes to any of them.

  `ER_BINLOG_UNSAFE_MIXED_STATEMENT` was added in 5.5.5.

- Error: `1694` SQLSTATE: `HY000` (`ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_SQL_LOG_BIN`)

  Message: Cannot modify @@session.sql_log_bin inside a transaction

  `ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_SQL_LOG_BIN` was added in 5.5.5.

- Error: `1695` SQLSTATE: `HY000` (`ER_STORED_FUNCTION_PREVENTS_SWITCH_SQL_LOG_BIN`)

  Message: Cannot change the sql_log_bin inside a stored function or trigger

  `ER_STORED_FUNCTION_PREVENTS_SWITCH_SQL_LOG_BIN` was added in 5.5.5.

- Error: `1696` SQLSTATE: `HY000` (`ER_FAILED_READ_FROM_PAR_FILE`)

Message: Failed to read from the .par file

`ER_FAILED_READ_FROM_PAR_FILE` was added in 5.5.5.

- Error: `1697` SQLSTATE: `HY000` (`ER_VALUES_IS_NOT_INT_TYPE_ERROR`)

  Message: VALUES value for partition '%s' must have type INT

  `ER_VALUES_IS_NOT_INT_TYPE_ERROR` was added in 5.5.7.

- Error: `1698` SQLSTATE: `28000` (`ER_ACCESS_DENIED_NO_PASSWORD_ERROR`)

  Message: Access denied for user '%s'@'%s'

  `ER_ACCESS_DENIED_NO_PASSWORD_ERROR` was added in 5.5.7.

- Error: `1699` SQLSTATE: `HY000` (`ER_SET_PASSWORD_AUTH_PLUGIN`)

  Message: SET PASSWORD has no significance for users authenticating via plugins

  `ER_SET_PASSWORD_AUTH_PLUGIN` was added in 5.5.7.

- Error: `1700` SQLSTATE: `HY000` (`ER_GRANT_PLUGIN_USER_EXISTS`)

  Message: GRANT with IDENTIFIED WITH is illegal because the user %-.*s already exists

  `ER_GRANT_PLUGIN_USER_EXISTS` was added in 5.5.7.

- Error: `1701` SQLSTATE: `42000` (`ER_TRUNCATE_ILLEGAL_FK`)

  Message: Cannot truncate a table referenced in a foreign key constraint (%s)

  `ER_TRUNCATE_ILLEGAL_FK` was added in 5.5.7.

- Error: `1702` SQLSTATE: `HY000` (`ER_PLUGIN_IS_PERMANENT`)

  Message: Plugin '%s' is force_plus_permanent and can not be unloaded

  `ER_PLUGIN_IS_PERMANENT` was added in 5.5.7.

- Error: `1703` SQLSTATE: `HY000` (`ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MIN`)

  Message: The requested value for the heartbeat period is less than 1 millisecond. The value is reset to 0, meaning that heartbeating will effectively be disabled.

  `ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MIN` was added in 5.5.7.

- Error: `1704` SQLSTATE: `HY000` (`ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MAX`)

  Message: The requested value for the heartbeat period exceeds the value of `slave_net_timeout' seconds. A sensible value for the period should be less than the timeout.

  `ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MAX` was added in 5.5.7.

- Error: `1705` SQLSTATE: `HY000` (`ER_STMT_CACHE_FULL`)

  Message: Multi-row statements required more than 'max_binlog_stmt_cache_size' bytes of storage; increase this mysqld variable and try again

  `ER_STMT_CACHE_FULL` was added in 5.5.9.

- Error: `1706` SQLSTATE: `HY000` (`ER_MULTI_UPDATE_KEY_CONFLICT`)

Message: Primary key/partition key update is not allowed since the table is updated both as '%s' and '%s'.

`ER_MULTI_UPDATE_KEY_CONFLICT` was added in 5.5.11.

- Error: `1707` SQLSTATE: `HY000` (`ER_TABLE_NEEDS_REBUILD`)

  Message: Table rebuild required. Please do "ALTER TABLE `%s` FORCE" or dump/reload to fix it!

  `ER_TABLE_NEEDS_REBUILD` was added in 5.5.11.

- Error: `1708` SQLSTATE: `HY000` (`WARN_OPTION_BELOW_LIMIT`)

  Message: The value of '%s' should be no less than the value of '%s'

  `WARN_OPTION_BELOW_LIMIT` was added in 5.5.12.

- Error: `1709` SQLSTATE: `HY000` (`ER_INDEX_COLUMN_TOO_LONG`)

  Message: Index column size too large. The maximum column size is %lu bytes.

  `ER_INDEX_COLUMN_TOO_LONG` was added in 5.5.14.

- Error: `1710` SQLSTATE: `HY000` (`ER_ERROR_IN_TRIGGER_BODY`)

  Message: Trigger '%s' has an error in its body: '%s'

  `ER_ERROR_IN_TRIGGER_BODY` was added in 5.5.15.

- Error: `1711` SQLSTATE: `HY000` (`ER_ERROR_IN_UNKNOWN_TRIGGER_BODY`)

  Message: Unknown trigger has an error in its body: '%s'

  `ER_ERROR_IN_UNKNOWN_TRIGGER_BODY` was added in 5.5.15.

- Error: `1712` SQLSTATE: `HY000` (`ER_INDEX_CORRUPT`)

  Message: Index %s is corrupted

  `ER_INDEX_CORRUPT` was added in 5.5.17.

- Error: `1713` SQLSTATE: `HY000` (`ER_UNDO_RECORD_TOO_BIG`)

  Message: Undo log record is too big.

  `ER_UNDO_RECORD_TOO_BIG` was added in 5.5.17.

- Error: `1714` SQLSTATE: `HY000` (`ER_BINLOG_UNSAFE_INSERT_IGNORE_SELECT`)

  Message: INSERT IGNORE... SELECT is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are ignored. This order cannot be predicted and may differ on master and the slave.

  `ER_BINLOG_UNSAFE_INSERT_IGNORE_SELECT` was added in 5.5.18.

- Error: `1715` SQLSTATE: `HY000` (`ER_BINLOG_UNSAFE_INSERT_SELECT_UPDATE`)

  Message: INSERT... SELECT... ON DUPLICATE KEY UPDATE is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are updated. This order cannot be predicted and may differ on master and the slave.

  `ER_BINLOG_UNSAFE_INSERT_SELECT_UPDATE` was added in 5.5.18.

- Error: 1716 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_REPLACE_SELECT)

  Message: REPLACE... SELECT is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are replaced. This order cannot be predicted and may differ on master and the slave.

  ER_BINLOG_UNSAFE_REPLACE_SELECT was added in 5.5.18.

- Error: 1717 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_CREATE_IGNORE_SELECT)

  Message: CREATE... IGNORE SELECT is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are ignored. This order cannot be predicted and may differ on master and the slave.

  ER_BINLOG_UNSAFE_CREATE_IGNORE_SELECT was added in 5.5.18.

- Error: 1718 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_CREATE_REPLACE_SELECT)

  Message: CREATE... REPLACE SELECT is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are replaced. This order cannot be predicted and may differ on master and the slave.

  ER_BINLOG_UNSAFE_CREATE_REPLACE_SELECT was added in 5.5.18.

- Error: 1719 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_UPDATE_IGNORE)

  Message: UPDATE IGNORE is unsafe because the order in which rows are updated determines which (if any) rows are ignored. This order cannot be predicted and may differ on master and the slave.

  ER_BINLOG_UNSAFE_UPDATE_IGNORE was added in 5.5.18.

- Error: 1720 SQLSTATE: HY000 (ER_PLUGIN_NO_UNINSTALL)

  Message: Plugin '%s' is marked as not dynamically uninstallable. You have to stop the server to uninstall it.

  ER_PLUGIN_NO_UNINSTALL was added in 5.5.16.

- Error: 1721 SQLSTATE: HY000 (ER_PLUGIN_NO_INSTALL)

  Message: Plugin '%s' is marked as not dynamically installable. You have to stop the server to install it.

  ER_PLUGIN_NO_INSTALL was added in 5.5.16.

- Error: 1722 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_WRITE_AUTOINC_SELECT)

  Message: Statements writing to a table with an auto-increment column after selecting from another table are unsafe because the order in which rows are retrieved determines what (if any) rows will be written. This order cannot be predicted and may differ on master and the slave.

  ER_BINLOG_UNSAFE_WRITE_AUTOINC_SELECT was added in 5.5.22.

- Error: 1723 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_CREATE_SELECT_AUTOINC)

  Message: CREATE TABLE... SELECT... on a table with an auto-increment column is unsafe because the order in which rows are retrieved by the SELECT determines which (if any) rows are inserted. This order cannot be predicted and may differ on master and the slave.

  ER_BINLOG_UNSAFE_CREATE_SELECT_AUTOINC was added in 5.5.22.

- Error: 1724 SQLSTATE: HY000 (ER_BINLOG_UNSAFE_INSERT_TWO_KEYS)

Message: INSERT... ON DUPLICATE KEY UPDATE on a table with more than one UNIQUE KEY is unsafe

`ER_BINLOG_UNSAFE_INSERT_TWO_KEYS` was added in 5.5.24.

- Error: `1725` SQLSTATE: `HY000` (`ER_TABLE_IN_FK_CHECK`)

  Message: Table is being used in foreign key check.

  `ER_TABLE_IN_FK_CHECK` was added in 5.5.24.

- Error: `1726` SQLSTATE: `HY000` (`ER_UNSUPPORTED_ENGINE`)

  Message: Storage engine '%s' does not support system tables. [%s.%s]

  `ER_UNSUPPORTED_ENGINE` was added in 5.5.24.

- Error: `1727` SQLSTATE: `HY000` (`ER_BINLOG_UNSAFE_AUTOINC_NOT_FIRST`)

  Message: INSERT into autoincrement field which is not the first part in the composed primary key is unsafe.

  `ER_BINLOG_UNSAFE_AUTOINC_NOT_FIRST` was added in 5.5.25.

B.4 Client Error Codes and Messages

Client error information comes from the following source files:

- The Error values and the symbols in parentheses correspond to definitions in the `include/errmsg.h` MySQL source file.
- The Message values correspond to the error messages that are listed in the `libmysql/errmsg.c` file. `%d` and `%s` represent numbers and strings, respectively, that are substituted into the messages when they are displayed.

Because updates are frequent, it is possible that those files will contain additional error information not listed here.

- Error: `2000` (`CR_UNKNOWN_ERROR`)

  Message: Unknown MySQL error

- Error: `2001` (`CR_SOCKET_CREATE_ERROR`)

  Message: Can't create UNIX socket (%d)

- Error: `2002` (`CR_CONNECTION_ERROR`)

  Message: Can't connect to local MySQL server through socket '%s' (%d)

- Error: `2003` (`CR_CONN_HOST_ERROR`)

  Message: Can't connect to MySQL server on '%s' (%d)

- Error: `2004` (`CR_IPSOCK_ERROR`)

  Message: Can't create TCP/IP socket (%d)

- Error: `2005` (`CR_UNKNOWN_HOST`)

  Message: Unknown MySQL server host '%s' (%d)

- Error: 2006 (CR_SERVER_GONE_ERROR)

  Message: MySQL server has gone away
- Error: 2007 (CR_VERSION_ERROR)

  Message: Protocol mismatch; server version = %d, client version = %d
- Error: 2008 (CR_OUT_OF_MEMORY)

  Message: MySQL client ran out of memory
- Error: 2009 (CR_WRONG_HOST_INFO)

  Message: Wrong host info
- Error: 2010 (CR_LOCALHOST_CONNECTION)

  Message: Localhost via UNIX socket
- Error: 2011 (CR_TCP_CONNECTION)

  Message: %s via TCP/IP
- Error: 2012 (CR_SERVER_HANDSHAKE_ERR)

  Message: Error in server handshake
- Error: 2013 (CR_SERVER_LOST)

  Message: Lost connection to MySQL server during query
- Error: 2014 (CR_COMMANDS_OUT_OF_SYNC)

  Message: Commands out of sync; you can't run this command now
- Error: 2015 (CR_NAMEDPIPE_CONNECTION)

  Message: Named pipe: %s
- Error: 2016 (CR_NAMEDPIPEWAIT_ERROR)

  Message: Can't wait for named pipe to host: %s pipe: %s (%lu)
- Error: 2017 (CR_NAMEDPIPEOPEN_ERROR)

  Message: Can't open named pipe to host: %s pipe: %s (%lu)
- Error: 2018 (CR_NAMEDPIPESETSTATE_ERROR)

  Message: Can't set state of named pipe to host: %s pipe: %s (%lu)
- Error: 2019 (CR_CANT_READ_CHARSET)

  Message: Can't initialize character set %s (path: %s)
- Error: 2020 (CR_NET_PACKET_TOO_LARGE)

  Message: Got packet bigger than 'max_allowed_packet' bytes
- Error: 2021 (CR_EMBEDDED_CONNECTION)

  Message: Embedded server
- Error: 2022 (CR_PROBE_SLAVE_STATUS)

Message: Error on SHOW SLAVE STATUS:

- Error: 2023 (CR_PROBE_SLAVE_HOSTS)

  Message: Error on SHOW SLAVE HOSTS:

- Error: 2024 (CR_PROBE_SLAVE_CONNECT)

  Message: Error connecting to slave:

- Error: 2025 (CR_PROBE_MASTER_CONNECT)

  Message: Error connecting to master:

- Error: 2026 (CR_SSL_CONNECTION_ERROR)

  Message: SSL connection error: %s

- Error: 2027 (CR_MALFORMED_PACKET)

  Message: Malformed packet

- Error: 2028 (CR_WRONG_LICENSE)

  Message: This client library is licensed only for use with MySQL servers having '%s' license

- Error: 2029 (CR_NULL_POINTER)

  Message: Invalid use of null pointer

- Error: 2030 (CR_NO_PREPARE_STMT)

  Message: Statement not prepared

- Error: 2031 (CR_PARAMS_NOT_BOUND)

  Message: No data supplied for parameters in prepared statement

- Error: 2032 (CR_DATA_TRUNCATED)

  Message: Data truncated

- Error: 2033 (CR_NO_PARAMETERS_EXISTS)

  Message: No parameters exist in the statement

- Error: 2034 (CR_INVALID_PARAMETER_NO)

  Message: Invalid parameter number

  The column number for `mysql_stmt_fetch_column()` was invalid.

  The parameter number for `mysql_stmt_send_long_data()` was invalid.

- Error: 2035 (CR_INVALID_BUFFER_USE)

  Message: Can't send long data for non-string/non-binary data types (parameter: %d)

- Error: 2036 (CR_UNSUPPORTED_PARAM_TYPE)

  Message: Using unsupported buffer type: %d (parameter: %d)

- Error: 2037 (CR_SHARED_MEMORY_CONNECTION)

Message: Shared memory: %s

- Error: 2038 (CR_SHARED_MEMORY_CONNECT_REQUEST_ERROR)

  Message: Can't open shared memory; client could not create request event (%lu)

- Error: 2039 (CR_SHARED_MEMORY_CONNECT_ANSWER_ERROR)

  Message: Can't open shared memory; no answer event received from server (%lu)

- Error: 2040 (CR_SHARED_MEMORY_CONNECT_FILE_MAP_ERROR)

  Message: Can't open shared memory; server could not allocate file mapping (%lu)

- Error: 2041 (CR_SHARED_MEMORY_CONNECT_MAP_ERROR)

  Message: Can't open shared memory; server could not get pointer to file mapping (%lu)

- Error: 2042 (CR_SHARED_MEMORY_FILE_MAP_ERROR)

  Message: Can't open shared memory; client could not allocate file mapping (%lu)

- Error: 2043 (CR_SHARED_MEMORY_MAP_ERROR)

  Message: Can't open shared memory; client could not get pointer to file mapping (%lu)

- Error: 2044 (CR_SHARED_MEMORY_EVENT_ERROR)

  Message: Can't open shared memory; client could not create %s event (%lu)

- Error: 2045 (CR_SHARED_MEMORY_CONNECT_ABANDONED_ERROR)

  Message: Can't open shared memory; no answer from server (%lu)

- Error: 2046 (CR_SHARED_MEMORY_CONNECT_SET_ERROR)

  Message: Can't open shared memory; cannot send request event to server (%lu)

- Error: 2047 (CR_CONN_UNKNOW_PROTOCOL)

  Message: Wrong or unknown protocol

- Error: 2048 (CR_INVALID_CONN_HANDLE)

  Message: Invalid connection handle

- Error: 2049 (CR_SECURE_AUTH)

  Message: Connection using old (pre-4.1.1) authentication protocol refused (client option 'secure_auth' enabled)

- Error: 2050 (CR_FETCH_CANCELED)

  Message: Row retrieval was canceled by mysql_stmt_close() call

- Error: 2051 (CR_NO_DATA)

  Message: Attempt to read column without prior row fetch

- Error: 2052 (CR_NO_STMT_METADATA)

  Message: Prepared statement contains no metadata

- Error: 2053 (CR_NO_RESULT_SET)

Message: Attempt to read a row while there is no result set associated with the statement

- Error: 2054 (CR_NOT_IMPLEMENTED)

  Message: This feature is not implemented yet

- Error: 2055 (CR_SERVER_LOST_EXTENDED)

  Message: Lost connection to MySQL server at '%s', system error: %d

- Error: 2056 (CR_STMT_CLOSED)

  Message: Statement closed indirectly because of a preceeding %s() call

- Error: 2057 (CR_NEW_STMT_METADATA)

  Message: The number of columns in the result set differs from the number of bound buffers. You must reset the statement, rebind the result set columns, and execute the statement again

- Error: 2058 (CR_ALREADY_CONNECTED)

  Message: This handle is already connected. Use a separate handle for each connection.

- Error: 2059 (CR_AUTH_PLUGIN_CANNOT_LOAD)

  Message: Authentication plugin '%s' cannot be loaded: %s

  CR_AUTH_PLUGIN_CANNOT_LOAD was added in 5.5.7.

B.5 Problems and Common Errors

This section lists some common problems and error messages that you may encounter. It describes how to determine the causes of the problems and what to do to solve them.

B.5.1 How to Determine What Is Causing a Problem

When you run into a problem, the first thing you should do is to find out which program or piece of equipment is causing it:

- If you have one of the following symptoms, then it is probably a hardware problems (such as memory, motherboard, CPU, or hard disk) or kernel problem:
  - The keyboard does not work. This can normally be checked by pressing the Caps Lock key. If the Caps Lock light does not change, you have to replace your keyboard. (Before doing this, you should try to restart your computer and check all cables to the keyboard.)
  - The mouse pointer does not move.
  - The machine does not answer to a remote machine's pings.
  - Other programs that are not related to MySQL do not behave correctly.
  - Your system restarted unexpectedly. (A faulty user-level program should never be able to take down your system.)

  In this case, you should start by checking all your cables and run some diagnostic tool to check your hardware! You should also check whether there are any patches, updates, or service packs for your operating system that could likely solve your problem. Check also that all your libraries (such as glibc) are up to date.

  It is always good to use a machine with ECC memory to discover memory problems early.

- If your keyboard is locked up, you may be able to recover by logging in to your machine from another machine and executing `kbd_mode -a`.
- Please examine your system log file (`/var/log/messages` or similar) for reasons for your problem. If you think the problem is in MySQL, you should also examine MySQL's log files. See Section 5.4, “MySQL Server Logs”.
- If you do not think you have hardware problems, you should try to find out which program is causing problems. Try using `top`, `ps`, Task Manager, or some similar program, to check which program is taking all CPU or is locking the machine.
- Use `top`, `df`, or a similar program to check whether you are out of memory, disk space, file descriptors, or some other critical resource.
- If the problem is some runaway process, you can always try to kill it. If it does not want to die, there is probably a bug in the operating system.

If after you have examined all other possibilities and you have concluded that the MySQL server or a MySQL client is causing the problem, it is time to create a bug report for our mailing list or our support team. In the bug report, try to give a very detailed description of how the system is behaving and what you think is happening. You should also state why you think that MySQL is causing the problem. Take into consideration all the situations in this chapter. State any problems exactly how they appear when you examine your system. Use the “copy and paste” method for any output and error messages from programs and log files.

Try to describe in detail which program is not working and all symptoms you see. We have in the past received many bug reports that state only “the system does not work.” This provides us with no information about what could be the problem.

If a program fails, it is always useful to know the following information:

- Has the program in question made a segmentation fault (did it dump core)?
- Is the program taking up all available CPU time? Check with `top`. Let the program run for a while, it may simply be evaluating something computationally intensive.
- If the `mysqld` server is causing problems, can you get any response from it with `mysqladmin -u root ping` or `mysqladmin -u root processlist`?
- What does a client program say when you try to connect to the MySQL server? (Try with `mysql`, for example.) Does the client jam? Do you get any output from the program?

When sending a bug report, you should follow the outline described in Section 1.6, “How to Report Bugs or Problems”.

B.5.2 Common Errors When Using MySQL Programs

This section lists some errors that users frequently encounter when running MySQL programs. Although the problems show up when you try to run client programs, the solutions to many of the problems involves changing the configuration of the MySQL server.

B.5.2.1 Access denied

An `Access denied` error can have many causes. Often the problem is related to the MySQL accounts that the server permits client programs to use when connecting. See Section 6.2, “The MySQL Access Privilege System”, and Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”.

B.5.2.2 Can't connect to [local] MySQL server

A MySQL client on Unix can connect to the `mysqld` server in two different ways: By using a Unix socket file to connect through a file in the file system (default `/tmp/mysql.sock`), or by using TCP/IP,

which connects through a port number. A Unix socket file connection is faster than TCP/IP, but can be used only when connecting to a server on the same computer. A Unix socket file is used if you do not specify a host name or if you specify the special host name `localhost`.

If the MySQL server is running on Windows, you can connect using TCP/IP. If the server is started with the `--enable-named-pipe` option, you can also connect with named pipes if you run the client on the host where the server is running. The name of the named pipe is `MySQL` by default. If you do not give a host name when connecting to `mysqld`, a MySQL client first tries to connect to the named pipe. If that does not work, it connects to the TCP/IP port. You can force the use of named pipes on Windows by using `.` as the host name.

The error (2002) `Can't connect to ...` normally means that there is no MySQL server running on the system or that you are using an incorrect Unix socket file name or TCP/IP port number when trying to connect to the server. You should also check that the TCP/IP port you are using has not been blocked by a firewall or port blocking service.

The error (2003) `Can't connect to MySQL server on 'server' (10061)` indicates that the network connection has been refused. You should check that there is a MySQL server running, that it has network connections enabled, and that the network port you specified is the one configured on the server.

Start by checking whether there is a process named `mysqld` running on your server host. (Use `ps xa | grep mysqld` on Unix or the Task Manager on Windows.) If there is no such process, you should start the server. See Section 2.10.2, “Starting the Server”.

If a `mysqld` process is running, you can check it by trying the following commands. The port number or Unix socket file name might be different in your setup. `host_ip` represents the IP address of the machine where the server is running.

```
shell> mysqladmin version
shell> mysqladmin variables
shell> mysqladmin -h `hostname` version variables
shell> mysqladmin -h `hostname` --port=3306 version
shell> mysqladmin -h host_ip version
shell> mysqladmin --protocol=SOCKET --socket=/tmp/mysql.sock version
```

Note the use of backticks rather than forward quotation marks with the `hostname` command; these cause the output of `hostname` (that is, the current host name) to be substituted into the `mysqladmin` command. If you have no `hostname` command or are running on Windows, you can manually type the host name of your machine (without backticks) following the `-h` option. You can also try `-h 127.0.0.1` to connect with TCP/IP to the local host.

Make sure that the server has not been configured to ignore network connections or (if you are attempting to connect remotely) that it has not been configured to listen only locally on its network interfaces. If the server was started with `--skip-networking`, it will not accept TCP/IP connections at all. If the server was started with `--bind-address=127.0.0.1`, it will listen for TCP/IP connections only locally on the loopback interface and will not accept remote connections.

Check to make sure that there is no firewall blocking access to MySQL. Your firewall may be configured on the basis of the application being executed, or the port number used by MySQL for communication (3306 by default). Under Linux or Unix, check your IP tables (or similar) configuration to ensure that the port has not been blocked. Under Windows, applications such as ZoneAlarm or the Windows XP personal firewall may need to be configured not to block the MySQL port.

Here are some reasons the `Can't connect to local MySQL server` error might occur:

- `mysqld` is not running on the local host. Check your operating system's process list to ensure the `mysqld` process is present.
- You're running a MySQL server on Windows with many TCP/IP connections to it. If you're experiencing that quite often your clients get that error, you can find a workaround here: Connection to MySQL Server Failing on Windows.

- Someone has removed the Unix socket file that `mysqld` uses (`/tmp/mysql.sock` by default). For example, you might have a `cron` job that removes old files from the `/tmp` directory. You can always run `mysqladmin version` to check whether the Unix socket file that `mysqladmin` is trying to use really exists. The fix in this case is to change the `cron` job to not remove `mysql.sock` or to place the socket file somewhere else. See Section B.5.3.6, “How to Protect or Change the MySQL Unix Socket File”.
- You have started the `mysqld` server with the `--socket=/path/to/socket` option, but forgotten to tell client programs the new name of the socket file. If you change the socket path name for the server, you must also notify the MySQL clients. You can do this by providing the same `--socket` option when you run client programs. You also need to ensure that clients have permission to access the `mysql.sock` file. To find out where the socket file is, you can do:

  ```
  shell> netstat -ln | grep mysql
  ```

  See Section B.5.3.6, “How to Protect or Change the MySQL Unix Socket File”.
- You are using Linux and one server thread has died (dumped core). In this case, you must kill the other `mysqld` threads (for example, with `kill` or with the `mysql_zap` script) before you can restart the MySQL server. See Section B.5.3.3, “What to Do If MySQL Keeps Crashing”.
- The server or client program might not have the proper access privileges for the directory that holds the Unix socket file or the socket file itself. In this case, you must either change the access privileges for the directory or socket file so that the server and clients can access them, or restart `mysqld` with a `--socket` option that specifies a socket file name in a directory where the server can create it and where client programs can access it.

If you get the error message `Can't connect to MySQL server on some_host`, you can try the following things to find out what the problem is:

- Check whether the server is running on that host by executing `telnet some_host 3306` and pressing the Enter key a couple of times. (3306 is the default MySQL port number. Change the value if your server is listening to a different port.) If there is a MySQL server running and listening to the port, you should get a response that includes the server's version number. If you get an error such as `telnet: Unable to connect to remote host: Connection refused`, then there is no server running on the given port.
- If the server is running on the local host, try using `mysqladmin -h localhost variables` to connect using the Unix socket file. Verify the TCP/IP port number that the server is configured to listen to (it is the value of the `port` variable.)
- If you are running under Linux and Security-Enhanced Linux (SELinux) is enabled, make sure you have disabled SELinux protection for the `mysqld` process.

Connection to MySQL Server Failing on Windows

When you're running a MySQL server on Windows with many TCP/IP connections to it, and you're experiencing that quite often your clients get a `Can't connect to MySQL server` error, the reason might be that Windows does not allow for enough ephemeral (short-lived) ports to serve those connections.

The purpose of `TIME_WAIT` is to keep a connection accepting packets even after the connection has been closed. This is because Internet routing can cause a packet to take a slow route to its destination and it may arrive after both sides have agreed to close. If the port is in use for a new connection, that packet from the old connection could break the protocol or compromise personal information from the original connection. The `TIME_WAIT` delay prevents this by ensuring that the port cannot be reused until after some time has been permitted for those delayed packets to arrive.

It is safe to reduce `TIME_WAIT` greatly on LAN connections because there is little chance of packets arriving at very long delays, as they could through the Internet with its comparatively large distances and latencies.

Windows permits ephemeral (short-lived) TCP ports to the user. After any port is closed it will remain in a `TIME_WAIT` status for 120 seconds. The port will not be available again until this time expires. The default range of port numbers depends on the version of Windows, with a more limited number of ports in older versions:

- Windows through Server 2003: Ports in range 1025–5000
- Windows Vista, Server 2008, and newer: Ports in range 49152–65535

With a small stack of available TCP ports (5000) and a high number of TCP ports being open and closed over a short period of time along with the `TIME_WAIT` status you have a good chance for running out of ports. There are two ways to address this problem:

- Reduce the number of TCP ports consumed quickly by investigating connection pooling or persistent connections where possible
- Tune some settings in the Windows registry (see below)

Important

The following procedure involves modifying the Windows registry. Before you modify the registry, make sure to back it up and make sure that you understand how to restore it if a problem occurs. For information about how to back up, restore, and edit the registry, view the following article in the Microsoft Knowledge Base: http://support.microsoft.com/kb/256986/EN-US/.

1. Start Registry Editor (`Regedt32.exe`).
2. Locate the following key in the registry:

   ```
   HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\Tcpip\Parameters
   ```

3. On the `Edit` menu, click `Add Value`, and then add the following registry value:

   ```
   Value Name: MaxUserPort
   Data Type: REG_DWORD
   Value: 65534
   ```

   This sets the number of ephemeral ports available to any user. The valid range is between 5000 and 65534 (decimal). The default value is 0x1388 (5000 decimal).

4. On the `Edit` menu, click `Add Value`, and then add the following registry value:

   ```
   Value Name: TcpTimedWaitDelay
   Data Type: REG_DWORD
   Value: 30
   ```

   This sets the number of seconds to hold a TCP port connection in `TIME_WAIT` state before closing. The valid range is between 30 and 300 decimal, although you may wish to check with Microsoft for the latest permitted values. The default value is 0x78 (120 decimal).

5. Quit Registry Editor.
6. Reboot the machine.

Note: Undoing the above should be as simple as deleting the registry entries you've created.

B.5.2.3 Lost connection to MySQL server

There are three likely causes for this error message.

Usually it indicates network connectivity trouble and you should check the condition of your network if this error occurs frequently. If the error message includes “during query,” this is probably the case you are experiencing.

Sometimes the “during query” form happens when millions of rows are being sent as part of one or more queries. If you know that this is happening, you should try increasing `net_read_timeout` from its default of 30 seconds to 60 seconds or longer, sufficient for the data transfer to complete.

More rarely, it can happen when the client is attempting the initial connection to the server. In this case, if your `connect_timeout` value is set to only a few seconds, you may be able to resolve the problem by increasing it to ten seconds, perhaps more if you have a very long distance or slow connection. You can determine whether you are experiencing this more uncommon cause by using `SHOW GLOBAL STATUS LIKE 'Aborted_connects'`. It will increase by one for each initial connection attempt that the server aborts. You may see “reading authorization packet” as part of the error message; if so, that also suggests that this is the solution that you need.

If the cause is none of those just described, you may be experiencing a problem with `BLOB` values that are larger than `max_allowed_packet`, which can cause this error with some clients. Sometime you may see an `ER_NET_PACKET_TOO_LARGE` error, and that confirms that you need to increase `max_allowed_packet`.

B.5.2.4 Client does not support authentication protocol

The current implementation of the authentication protocol uses a password hashing algorithm that is incompatible with that used by older (pre-4.1) clients. Attempts to connect to a 4.1 or higher server with an older client may fail with the following message:

```
shell> mysql
Client does not support authentication protocol requested
by server; consider upgrading MySQL client
```

To deal with this problem, the preferred solution is to upgrade all client programs to use a 4.1.1 or higher client library. If that is not possible, use one of the following approaches:

- To connect to the server with a pre-4.1 client program, use an account that still has a pre-4.1-style password.
- Reset the password to pre-4.1 style for each user that needs to use a pre-4.1 client program. This can be done using the `SET PASSWORD` statement and the `OLD_PASSWORD()` function:

  ```
  mysql> SET PASSWORD FOR
      -> 'some_user'@'some_host' = OLD_PASSWORD('new_password');
  ```

  Substitute the password you want to use for “*new_password*” in the preceding example. MySQL cannot tell you what the original password was, so you'll need to pick a new one.
- Tell the server to use the older password hashing algorithm by default:

  1. Start `mysqld` with the `old_passwords` system variable set to 1.
  2. Assign an old-format password to each account that has had its password updated to the longer 4.1 format. You can identify these accounts with the following query:

     ```
     mysql> SELECT Host, User, Password FROM mysql.user
         -> WHERE LENGTH(Password) > 16;
     ```

     For each account record displayed by the query, use the `Host` and `User` values and assign a password using one of the methods described previously.

The `Client does not support authentication protocol` error also can occur if multiple versions of MySQL are installed but client programs are dynamically linked and link to an older

library. Make sure that clients use the most recent library version with which they are compatible. The procedure to do this will depend on your system.

Note

The PHP `mysql` extension does not support the authentication protocol in MySQL 4.1.1 and higher. This is true regardless of the PHP version being used. If you wish to use the `mysql` extension with MySQL 4.1 or higher, you may need to follow one of the options discussed above for configuring MySQL to work with old clients. The `mysqli` extension (stands for "MySQL, Improved"; added in PHP 5) is compatible with the improved password hashing employed in MySQL 4.1 and higher, and no special configuration of MySQL need be done to use this MySQL client library. For more information about the `mysqli` extension, see http://php.net/mysqli.

For additional background on password hashing and authentication, see Section 6.1.2.4, “Password Hashing in MySQL”.

B.5.2.5 Password Fails When Entered Interactively

MySQL client programs prompt for a password when invoked with a `--password` or `-p` option that has no following password value:

```
shell> mysql -u user_name -p
Enter password:
```

On some systems, you may find that your password works when specified in an option file or on the command line, but not when you enter it interactively at the `Enter password:` prompt. This occurs when the library provided by the system to read passwords limits password values to a small number of characters (typically eight). That is a problem with the system library, not with MySQL. To work around it, change your MySQL password to a value that is eight or fewer characters long, or put your password in an option file.

B.5.2.6 Host 'host_name' is blocked

If the following error occurs, it means that `mysqld` has received many connection requests from the given host that were interrupted in the middle:

```
Host 'host_name' is blocked because of many connection errors.
Unblock with 'mysqladmin flush-hosts'
```

The value of the `max_connect_errors` system variable determines how many successive interrupted connection requests are permitted. (See Section 5.1.5, “Server System Variables”.) After `max_connect_errors` failed requests without a successful connection, `mysqld` assumes that something is wrong (for example, that someone is trying to break in), and blocks the host from further connections until you issue a `FLUSH HOSTS` statement or execute a `mysqladmin flush-hosts` command.

By default, `mysqld` blocks a host after 10 connection errors. You can adjust the value by setting `max_connect_errors` at server startup:

```
shell> mysqld_safe --max_connect_errors=10000 &
```

The value can also be set at runtime:

```
mysql> SET GLOBAL max_connect_errors=10000;
```

If you get the `Host 'host_name' is blocked` error message for a given host, you should first verify that there is nothing wrong with TCP/IP connections from that host. If you are having network problems, it does you no good to increase the value of the `max_connect_errors` variable.

B.5.2.7 Too many connections

If you get a `Too many connections` error when you try to connect to the `mysqld` server, this means that all available connections are in use by other clients.

The number of connections permitted is controlled by the `max_connections` system variable. The default value is 151 to improve performance when MySQL is used with the Apache Web server. (Previously, the default was 100.) If you need to support more connections, you should set a larger value for this variable.

`mysqld` actually permits `max_connections+1` clients to connect. The extra connection is reserved for use by accounts that have the `SUPER` privilege. By granting the `SUPER` privilege to administrators and not to normal users (who should not need it), an administrator who also has the `PROCESS` privilege can connect to the server and use `SHOW PROCESSLIST` to diagnose problems even if the maximum number of unprivileged clients are connected. See Section 13.7.5.30, “SHOW PROCESSLIST Syntax”.

The maximum number of connections MySQL supports depends on the quality of the thread library on a given platform, the amount of RAM available, how much RAM is used for each connection, the workload from each connection, and the desired response time. Linux or Solaris should be able to support at least 500 to 1000 simultaneous connections routinely and as many as 10,000 connections if you have many gigabytes of RAM available and the workload from each is low or the response time target undemanding. Windows is limited to (open tables × 2 + open connections) < 2048 due to the Posix compatibility layer used on that platform.

Increasing `open-files-limit` may be necessary. Also see Section 2.5, “Installing MySQL on Linux”, for how to raise the operating system limit on how many handles can be used by MySQL.

B.5.2.8 Out of memory

If you issue a query using the `mysql` client program and receive an error like the following one, it means that `mysql` does not have enough memory to store the entire query result:

```
mysql: Out of memory at line 42, 'malloc.c'
mysql: needed 8136 byte (8k), memory in use: 12481367 bytes (12189k)
ERROR 2008: MySQL client ran out of memory
```

To remedy the problem, first check whether your query is correct. Is it reasonable that it should return so many rows? If not, correct the query and try again. Otherwise, you can invoke `mysql` with the `--quick` option. This causes it to use the `mysql_use_result()` C API function to retrieve the result set, which places less of a load on the client (but more on the server).

B.5.2.9 MySQL server has gone away

This section also covers the related `Lost connection to server during query` error.

The most common reason for the `MySQL server has gone away` error is that the server timed out and closed the connection. In this case, you normally get one of the following error codes (which one you get is operating system-dependent).

Error Code	Description
`CR_SERVER_GONE_ERROR`	The client couldn't send a question to the server.
`CR_SERVER_LOST`	The client didn't get an error when writing to the server, but it didn't get a full answer (or any answer) to the question.

By default, the server closes the connection after eight hours if nothing has happened. You can change the time limit by setting the `wait_timeout` variable when you start `mysqld`. See Section 5.1.5, “Server System Variables”.

If you have a script, you just have to issue the query again for the client to do an automatic reconnection. This assumes that you have automatic reconnection in the client enabled (which is the default for the `mysql` command-line client).

Some other common reasons for the `MySQL server has gone away` error are:

- You (or the db administrator) has killed the running thread with a `KILL` statement or a `mysqladmin kill` command.
- You tried to run a query after closing the connection to the server. This indicates a logic error in the application that should be corrected.
- A client application running on a different host does not have the necessary privileges to connect to the MySQL server from that host.
- You got a timeout from the TCP/IP connection on the client side. This may happen if you have been using the commands: `mysql_options(..., MYSQL_OPT_READ_TIMEOUT,...)` or `mysql_options(..., MYSQL_OPT_WRITE_TIMEOUT,...)`. In this case increasing the timeout may help solve the problem.
- You have encountered a timeout on the server side and the automatic reconnection in the client is disabled (the `reconnect` flag in the `MYSQL` structure is equal to 0).
- You are using a Windows client and the server had dropped the connection (probably because `wait_timeout` expired) before the command was issued.

  The problem on Windows is that in some cases MySQL does not get an error from the OS when writing to the TCP/IP connection to the server, but instead gets the error when trying to read the answer from the connection.

  The solution to this is to either do a `mysql_ping()` on the connection if there has been a long time since the last query (this is what Connector/ODBC does) or set `wait_timeout` on the `mysqld` server so high that it in practice never times out.
- You can also get these errors if you send a query to the server that is incorrect or too large. If `mysqld` receives a packet that is too large or out of order, it assumes that something has gone wrong with the client and closes the connection. If you need big queries (for example, if you are working with big `BLOB` columns), you can increase the query limit by setting the server's `max_allowed_packet` variable, which has a default value of 1MB. You may also need to increase the maximum packet size on the client end. More information on setting the packet size is given in Section B.5.2.10, “Packet Too Large”.

  An `INSERT` or `REPLACE` statement that inserts a great many rows can also cause these sorts of errors. Either one of these statements sends a single request to the server irrespective of the number of rows to be inserted; thus, you can often avoid the error by reducing the number of rows sent per `INSERT` or `REPLACE`.
- It is also possible to see this error if host name lookups fail (for example, if the DNS server on which your server or network relies goes down). This is because MySQL is dependent on the host system for name resolution, but has no way of knowing whether it is working—from MySQL's point of view the problem is indistinguishable from any other network timeout.

  You may also see the `MySQL server has gone away` error if MySQL is started with the `--skip-networking` option.

  Another networking issue that can cause this error occurs if the MySQL port (default 3306) is blocked by your firewall, thus preventing any connections at all to the MySQL server.
- You can also encounter this error with applications that fork child processes, all of which try to use the same connection to the MySQL server. This can be avoided by using a separate connection for each child process.

- You have encountered a bug where the server died while executing the query.

You can check whether the MySQL server died and restarted by executing `mysqladmin version` and examining the server's uptime. If the client connection was broken because `mysqld` crashed and restarted, you should concentrate on finding the reason for the crash. Start by checking whether issuing the query again kills the server again. See Section B.5.3.3, “What to Do If MySQL Keeps Crashing”.

You can get more information about the lost connections by starting `mysqld` with the `--log-warnings=2` option. This logs some of the disconnected errors in the `hostname.err` file. See Section 5.4.2, “The Error Log”.

If you want to create a bug report regarding this problem, be sure that you include the following information:

- Indicate whether the MySQL server died. You can find information about this in the server error log. See Section B.5.3.3, “What to Do If MySQL Keeps Crashing”.
- If a specific query kills `mysqld` and the tables involved were checked with `CHECK TABLE` before you ran the query, can you provide a reproducible test case? See Section 24.5, “Debugging and Porting MySQL”.
- What is the value of the `wait_timeout` system variable in the MySQL server? (`mysqladmin variables` gives you the value of this variable.)
- Have you tried to run `mysqld` with the general query log enabled to determine whether the problem query appears in the log? (See Section 5.4.3, “The General Query Log”.)

See also Section B.5.2.11, “Communication Errors and Aborted Connections”, and Section 1.6, “How to Report Bugs or Problems”.

B.5.2.10 Packet Too Large

A communication packet is a single SQL statement sent to the MySQL server, a single row that is sent to the client, or a binary log event sent from a master replication server to a slave.

The largest possible packet that can be transmitted to or from a MySQL 5.5 server or client is 1GB.

When a MySQL client or the `mysqld` server receives a packet bigger than `max_allowed_packet` bytes, it issues an `ER_NET_PACKET_TOO_LARGE` error and closes the connection. With some clients, you may also get a `Lost connection to MySQL server during query` error if the communication packet is too large.

Both the client and the server have their own `max_allowed_packet` variable, so if you want to handle big packets, you must increase this variable both in the client and in the server.

If you are using the `mysql` client program, its default `max_allowed_packet` variable is 16MB. To set a larger value, start `mysql` like this:

```
shell> mysql --max_allowed_packet=32M
```

That sets the packet size to 32MB.

The server's default `max_allowed_packet` value is 1MB. You can increase this if the server needs to handle big queries (for example, if you are working with big `BLOB` columns). For example, to set the variable to 16MB, start the server like this:

```
shell> mysqld --max_allowed_packet=16M
```

You can also use an option file to set `max_allowed_packet`. For example, to set the size for the server to 16MB, add the following lines in an option file:

```
[mysqld]
max_allowed_packet=16M
```

It is safe to increase the value of this variable because the extra memory is allocated only when needed. For example, `mysqld` allocates more memory only when you issue a long query or when `mysqld` must return a large result row. The small default value of the variable is a precaution to catch incorrect packets between the client and server and also to ensure that you do not run out of memory by using large packets accidentally.

You can also get strange problems with large packets if you are using large `BLOB` values but have not given `mysqld` access to enough memory to handle the query. If you suspect this is the case, try adding `ulimit -d 256000` to the beginning of the `mysqld_safe` script and restarting `mysqld`.

B.5.2.11 Communication Errors and Aborted Connections

If connection problems occur such as communication errors or aborted connections, use these sources of information to diagnose problems:

- The error log. See Section 5.4.2, “The Error Log”.
- The general query log. See Section 5.4.3, “The General Query Log”.
- The `Aborted_xxx` status variables. See Section 5.1.7, “Server Status Variables”.

If you start the server with the `--log-warnings` option, you might find messages like this in your error log:

```
Aborted connection 854 to db: 'employees' user: 'josh'
```

If a client is unable even to connect, the server increments the `Aborted_connects` status variable. Unsuccessful connection attempts can occur for the following reasons:

- A client attempts to access a database but has no privileges for it.
- A client uses an incorrect password.
- A connection packet does not contain the right information.
- It takes more than `connect_timeout` seconds to obtain a connect packet. See Section 5.1.5, “Server System Variables”.

If these kinds of things happen, it might indicate that someone is trying to break into your server! If the general query log is enabled, messages for these types of problems are logged to it.

If a client successfully connects but later disconnects improperly or is terminated, the server increments the `Aborted_clients` status variable, and logs an `Aborted connection` message to the error log. The cause can be any of the following:

- The client program did not call `mysql_close()` before exiting.
- The client had been sleeping more than `wait_timeout` or `interactive_timeout` seconds without issuing any requests to the server. See Section 5.1.5, “Server System Variables”.
- The client program ended abruptly in the middle of a data transfer.

Other reasons for problems with aborted connections or aborted clients:

- The `max_allowed_packet` variable value is too small or queries require more memory than you have allocated for `mysqld`. See Section B.5.2.10, “Packet Too Large”.

- Use of Ethernet protocol with Linux, both half and full duplex. Some Linux Ethernet drivers have this bug. You should test for this bug by transferring a huge file using FTP between the client and server machines. If a transfer goes in burst-pause-burst-pause mode, you are experiencing a Linux duplex syndrome. Switch the duplex mode for both your network card and hub/switch to either full duplex or to half duplex and test the results to determine the best setting.
- A problem with the thread library that causes interrupts on reads.
- Badly configured TCP/IP.
- Faulty Ethernets, hubs, switches, cables, and so forth. This can be diagnosed properly only by replacing hardware.

See also Section B.5.2.9, “MySQL server has gone away”.

B.5.2.12 The table is full

If a table-full error occurs, it may be that the disk is full or that the table has reached its maximum size. The effective maximum table size for MySQL databases is usually determined by operating system constraints on file sizes, not by MySQL internal limits. See Section C.10.3, “Limits on Table Size”.

This error can occur sometimes for NDB Cluster tables even when there appears to be more than sufficient data memory available. See the documentation for the `DataMemory` NDB Cluster data node configuration parameter, as well as Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”, for more information.

B.5.2.13 Can't create/write to file

If you get an error of the following type for some queries, it means that MySQL cannot create a temporary file for the result set in the temporary directory:

```
Can't create/write to file '\\sqla3fe_0.ism'.
```

The preceding error is a typical message for Windows; the Unix message is similar.

One fix is to start `mysqld` with the `--tmpdir` option or to add the option to the `[mysqld]` section of your option file. For example, to specify a directory of `C:\temp`, use these lines:

```
[mysqld]
tmpdir=C:/temp
```

The `C:\temp` directory must exist and have sufficient space for the MySQL server to write to. See Section 4.2.6, “Using Option Files”.

Another cause of this error can be permissions issues. Make sure that the MySQL server can write to the `tmpdir` directory.

Check also the error code that you get with `perror`. One reason the server cannot write to a table is that the file system is full:

```
shell> perror 28
OS error code  28:  No space left on device
```

If you get an error of the following type during startup, it indicates that the file system or directory used for storing data files is write protected. Provided that the write error is to a test file, the error is not serious and can be safely ignored.

```
Can't create test file /usr/local/mysql/data/master.lower-test
```

B.5.2.14 Commands out of sync

If you get `Commands out of sync; you can't run this command now` in your client code, you are calling client functions in the wrong order.

This can happen, for example, if you are using `mysql_use_result()` and try to execute a new query before you have called `mysql_free_result()`. It can also happen if you try to execute two queries that return data without calling `mysql_use_result()` or `mysql_store_result()` in between.

B.5.2.15 Ignoring user

If you get the following error, it means that when `mysqld` was started or when it reloaded the grant tables, it found an account in the `user` table that had an invalid password.

`Found wrong password for user 'some_user'@'some_host'; ignoring user`

As a result, the account is simply ignored by the permission system.

The following list indicates possible causes of and fixes for this problem:

- You may be running a new version of `mysqld` with an old `user` table. Check whether the `Password` column of that table is shorter than 16 characters. If so, correct this condition by running `mysql_upgrade`.
- The account has an old password (eight characters long). Update the account in the `user` table to have a new password.
- You have specified a password in the `user` table without using the `PASSWORD()` function. Use `mysql` to update the account in the `user` table with a new password, making sure to use the `PASSWORD()` function:

```
mysql> UPDATE user SET Password=PASSWORD('new_password')
    -> WHERE User='some_user' AND Host='some_host';
```

B.5.2.16 Table 'tbl_name' doesn't exist

If you get either of the following errors, it usually means that no table exists in the default database with the given name:

```
Table 'tbl_name' doesn't exist
Can't find file: 'tbl_name' (errno: 2)
```

In some cases, it may be that the table does exist but that you are referring to it incorrectly:

- Because MySQL uses directories and files to store databases and tables, database and table names are case sensitive if they are located on a file system that has case-sensitive file names.
- Even for file systems that are not case sensitive, such as on Windows, all references to a given table within a query must use the same lettercase.

You can check which tables are in the default database with `SHOW TABLES`. See Section 13.7.5, “SHOW Syntax”.

B.5.2.17 Can't initialize character set

You might see an error like this if you have character set problems:

```
MySQL Connection Failed: Can't initialize character set charset_name
```

This error can have any of the following causes:

- The character set is a multibyte character set and you have no support for the character set in the client. In this case, you need to recompile the client by running `CMake` with the `-DDEFAULT_CHARSET=charset_name` or `-DWITH_EXTRA_CHARSETS=charset_name` option. See Section 2.9.4, “MySQL Source-Configuration Options”.

  All standard MySQL binaries are compiled with `-DWITH_EXTRA_CHARSETS=all`, which enables support for all multibyte character sets. See Section 2.9.4, “MySQL Source-Configuration Options”.

- The character set is a simple character set that is not compiled into `mysqld`, and the character set definition files are not in the place where the client expects to find them.

  In this case, you need to use one of the following methods to solve the problem:

  - Recompile the client with support for the character set. See Section 2.9.4, “MySQL Source-Configuration Options”.
  - Specify to the client the directory where the character set definition files are located. For many clients, you can do this with the `--character-sets-dir` option.
  - Copy the character definition files to the path where the client expects them to be.

B.5.2.18 File Not Found and Similar Errors

If you get `ERROR 'file_name' not found (errno: 23)`, `Can't open file: file_name (errno: 24)`, or any other error with `errno 23` or `errno 24` from MySQL, it means that you have not allocated enough file descriptors for the MySQL server. You can use the `perror` utility to get a description of what the error number means:

```
shell> perror 23
OS error code  23:  File table overflow
shell> perror 24
OS error code  24:  Too many open files
shell> perror 11
OS error code  11:  Resource temporarily unavailable
```

The problem here is that `mysqld` is trying to keep open too many files simultaneously. You can either tell `mysqld` not to open so many files at once or increase the number of file descriptors available to `mysqld`.

To tell `mysqld` to keep open fewer files at a time, you can make the table cache smaller by reducing the value of the `table_open_cache` system variable (the default value is 64). This may not entirely prevent running out of file descriptors because in some circumstances the server may attempt to extend the cache size temporarily, as described in Section 8.4.3.1, “How MySQL Opens and Closes Tables”. Reducing the value of `max_connections` also reduces the number of open files (the default value is 100).

To change the number of file descriptors available to `mysqld`, you can use the `--open-files-limit` option to `mysqld_safe` or set the `open_files_limit` system variable. See Section 5.1.5, “Server System Variables”. The easiest way to set these values is to add an option to your option file. See Section 4.2.6, “Using Option Files”. If you have an old version of `mysqld` that does not support setting the open files limit, you can edit the `mysqld_safe` script. There is a commented-out line `ulimit -n 256` in the script. You can remove the `#` character to uncomment this line, and change the number `256` to set the number of file descriptors to be made available to `mysqld`.

`--open-files-limit` and `ulimit` can increase the number of file descriptors, but only up to the limit imposed by the operating system. There is also a “hard” limit that can be overridden only if you start `mysqld_safe` or `mysqld` as `root` (just remember that you also need to start the server with the `--user` option in this case so that it does not continue to run as `root` after it starts up). If you need to

increase the operating system limit on the number of file descriptors available to each process, consult the documentation for your system.

Note

If you run the `tcsh` shell, `ulimit` does not work! `tcsh` also reports incorrect values when you ask for the current limits. In this case, you should start `mysqld_safe` using `sh`.

B.5.2.19 Table-Corruption Issues

If you have started `mysqld` with `--myisam-recover-options`, MySQL automatically checks and tries to repair `MyISAM` tables if they are marked as 'not closed properly' or 'crashed'. If this happens, MySQL writes an entry in the `hostname.err` file `'Warning: Checking table ...'` which is followed by `Warning: Repairing table` if the table needs to be repaired. If you get a lot of these errors, without `mysqld` having died unexpectedly just before, then something is wrong and needs to be investigated further.

As of MySQL 5.5.3, when the server detects `MyISAM` table corruption, it writes additional information to the error log, such as the name and line number of the source file, and the list of threads accessing the table. Example: `Got an error from thread_id=1, mi_dynrec.c:368`. This is useful information to include in bug reports.

See also Section 5.1.4, “Server Command Options”, and Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”.

B.5.3 Administration-Related Issues

B.5.3.1 Problems with File Permissions

If you have problems with file permissions, the `UMASK` or `UMASK_DIR` environment variable might be set incorrectly when `mysqld` starts. For example, MySQL might issue the following error message when you create a table:

```
ERROR: Can't find file: 'path/with/filename.frm' (Errcode: 13)
```

The default `UMASK` and `UMASK_DIR` values are `0660` and `0700`, respectively. MySQL assumes that the value for `UMASK` or `UMASK_DIR` is in octal if it starts with a zero. For example, setting `UMASK=0600` is equivalent to `UMASK=384` because 0600 octal is 384 decimal.

To change the default `UMASK` value, start `mysqld_safe` as follows:

```
shell> UMASK=384  # = 600 in octal
shell> export UMASK
shell> mysqld_safe &
```

By default, MySQL creates database directories with an access permission value of `0700`. To modify this behavior, set the `UMASK_DIR` variable. If you set its value, new directories are created with the combined `UMASK` and `UMASK_DIR` values. For example, to give group access to all new directories, start `mysqld_safe` as follows:

```
shell> UMASK_DIR=504  # = 770 in octal
shell> export UMASK_DIR
shell> mysqld_safe &
```

For additional details, see Section 4.9, “MySQL Program Environment Variables”.

B.5.3.2 How to Reset the Root Password

If you have never assigned a `root` password for MySQL, the server does not require a password at all for connecting as `root`. However, this is insecure. For instructions on assigning passwords, see Section 2.10.4, “Securing the Initial MySQL Accounts”.

If you know the `root` password and want to change it, see Section 13.7.1.6, “SET PASSWORD Syntax”.

If you assigned a `root` password previously but have forgotten it, you can assign a new password. The following sections provide instructions for Windows and Unix and Unix-like systems, as well as generic instructions that apply to any system.

Resetting the Root Password: Windows Systems

On Windows, use the following procedure to reset the password for the MySQL `'root'@'localhost'` account. To change the password for a `root` account with a different host name part, modify the instructions to use that host name.

1. Log on to your system as Administrator.
2. Stop the MySQL server if it is running. For a server that is running as a Windows service, go to the Services manager: From the **Start** menu, select **Control Panel**, then **Administrative Tools**, then **Services**. Find the MySQL service in the list and stop it.

   If your server is not running as a service, you may need to use the Task Manager to force it to stop.
3. Create a text file containing the following statement on a single line. Replace the password with the password that you want to use.

   ```
   SET PASSWORD FOR 'root'@'localhost' = PASSWORD('MyNewPass');
   ```
4. Save the file. This example assumes that you name the file `C:\mysql-init.txt`.
5. Open a console window to get to the command prompt: From the **Start** menu, select **Run**, then enter `cmd` as the command to be run.
6. Start the MySQL server with the special `--init-file` option (notice that the backslash in the option value is doubled):

   ```
   C:\> cd "C:\Program Files\MySQL\MySQL Server 5.5\bin"
   C:\> mysqld --init-file=C:\\mysql-init.txt
   ```

   If you installed MySQL to a different location, adjust the `cd` command accordingly.

   The server executes the contents of the file named by the `--init-file` option at startup, changing the `'root'@'localhost'` account password.

   To have server output to appear in the console window rather than in a log file, add the `--console` option to the `mysqld` command.

   If you installed MySQL using the MySQL Installation Wizard, you may need to specify a `--defaults-file` option. For example:

   ```
   C:\> mysqld
           --defaults-file="C:\\ProgramData\\MySQL\\MySQL Server 5.5\\my.ini"
           --init-file=C:\\mysql-init.txt
   ```

   The appropriate `--defaults-file` setting can be found using the Services Manager: From the **Start** menu, select **Control Panel**, then **Administrative Tools**, then **Services**. Find the MySQL service in the list, right-click it, and choose the `Properties` option. The `Path to executable` field contains the `--defaults-file` setting.

7. After the server has started successfully, delete `C:\mysql-init.txt`.

You should now be able to connect to the MySQL server as `root` using the new password. Stop the MySQL server and restart it normally. If you run the server as a service, start it from the Windows Services window. If you start the server manually, use whatever command you normally use.

Resetting the Root Password: Unix and Unix-Like Systems

On Unix, use the following procedure to reset the password for the MySQL `'root'@'localhost'` account. To change the password for a `root` account with a different host name part, modify the instructions to use that host name.

The instructions assume that you will start the MySQL server from the Unix login account that you normally use for running it. For example, if you run the server using the `mysql` login account, you should log in as `mysql` before using the instructions. Alternatively, you can log in as `root`, but in this case you *must* start `mysqld` with the `--user=mysql` option. If you start the server as `root` without using `--user=mysql`, the server may create `root`-owned files in the data directory, such as log files, and these may cause permission-related problems for future server startups. If that happens, you will need to either change the ownership of the files to `mysql` or remove them.

1. Log on to your system as the Unix user that the MySQL server runs as (for example, `mysql`).
2. Stop the MySQL server if it is running. Locate the `.pid` file that contains the server's process ID. The exact location and name of this file depend on your distribution, host name, and configuration. Common locations are `/var/lib/mysql/`, `/var/run/mysqld/`, and `/usr/local/mysql/data/`. Generally, the file name has an extension of `.pid` and begins with either `mysqld` or your system's host name.

   Stop the MySQL server by sending a normal `kill` (not `kill -9`) to the `mysqld` process. Use the actual path name of the `.pid` file in the following command:

   ```
   shell> kill `cat /mysql-data-directory/host_name.pid`
   ```

   Use backticks (not forward quotation marks) with the `cat` command. These cause the output of `cat` to be substituted into the `kill` command.
3. Create a text file containing the following statement on a single line. Replace the password with the password that you want to use.

   ```
   SET PASSWORD FOR 'root'@'localhost' = PASSWORD('MyNewPass');
   ```
4. Save the file. This example assumes that you name the file `/home/me/mysql-init`. The file contains the password, so do not save it where it can be read by other users. If you are not logged in as `mysql` (the user the server runs as), make sure that the file has permissions that permit `mysql` to read it.
5. Start the MySQL server with the special `--init-file` option:

   ```
   shell> mysqld --init-file=/home/me/mysql-init &
   ```

   The server executes the contents of the file named by the `--init-file` option at startup, changing the `'root'@'localhost'` account password.

   Other options may be necessary as well, depending on how you normally start your server. For example, `--defaults-file` may be needed before `--init-file`.
6. After the server has started successfully, delete `/home/me/mysql-init`.

You should now be able to connect to the MySQL server as `root` using the new password. Stop the server and restart it normally.

Resetting the Root Password: Generic Instructions

The preceding sections provide password-resetting instructions specifically for Windows and Unix and Unix-like systems. Alternatively, on any platform, you can reset the password using the `mysql` client (but this approach is less secure):

1. Stop the MySQL server if necessary, then restart it with the `--skip-grant-tables` option. This enables anyone to connect without a password and with all privileges, and disables account-management statements such as `SET PASSWORD`. Because this is insecure, you might want to use `--skip-grant-tables` in conjunction with `--skip-networking` to prevent remote clients from connecting.

2. Connect to the MySQL server using the `mysql` client; no password is necessary because the server was started with `--skip-grant-tables`:

   ```
   shell> mysql
   ```

3. In the `mysql` client, tell the server to reload the grant tables so that account-management statements work:

   ```
   mysql> FLUSH PRIVILEGES;
   ```

   Then change the `'root'@'localhost'` account password. Replace the password with the password that you want to use. To change the password for a `root` account with a different host name part, modify the instructions to use that host name.

   ```
   mysql> SET PASSWORD FOR 'root'@'localhost' = PASSWORD('MyNewPass');
   ```

You should now be able to connect to the MySQL server as `root` using the new password. Stop the server and restart it normally (without the `--skip-grant-tables` and `--skip-networking` options).

B.5.3.3 What to Do If MySQL Keeps Crashing

Each MySQL version is tested on many platforms before it is released. This does not mean that there are no bugs in MySQL, but if there are bugs, they should be very few and can be hard to find. If you have a problem, it always helps if you try to find out exactly what crashes your system, because you have a much better chance of getting the problem fixed quickly.

First, you should try to find out whether the problem is that the `mysqld` server dies or whether your problem has to do with your client. You can check how long your `mysqld` server has been up by executing `mysqladmin version`. If `mysqld` has died and restarted, you may find the reason by looking in the server's error log. See Section 5.4.2, “The Error Log”.

On some systems, you can find in the error log a stack trace of where `mysqld` died that you can resolve with the `resolve_stack_dump` program. See Section 24.5, “Debugging and Porting MySQL”. Note that the variable values written in the error log may not always be 100% correct.

Many server crashes are caused by corrupted data files or index files. MySQL updates the files on disk with the `write()` system call after every SQL statement and before the client is notified about the result. (This is not true if you are running with `--delay-key-write`, in which case data files are written but not index files.) This means that data file contents are safe even if `mysqld` crashes, because the operating system ensures that the unflushed data is written to disk. You can force MySQL to flush everything to disk after every SQL statement by starting `mysqld` with the `--flush` option.

The preceding means that normally you should not get corrupted tables unless one of the following happens:

- The MySQL server or the server host was killed in the middle of an update.

- You have found a bug in `mysqld` that caused it to die in the middle of an update.
- Some external program is manipulating data files or index files at the same time as `mysqld` without locking the table properly.
- You are running many `mysqld` servers using the same data directory on a system that does not support good file system locks (normally handled by the `lockd` lock manager), or you are running multiple servers with external locking disabled.
- You have a crashed data file or index file that contains very corrupt data that confused `mysqld`.
- You have found a bug in the data storage code. This isn't likely, but it is at least possible. In this case, you can try to change the storage engine to another engine by using `ALTER TABLE` on a repaired copy of the table.

Because it is very difficult to know why something is crashing, first try to check whether things that work for others crash for you. Please try the following things:

- Stop the `mysqld` server with `mysqladmin shutdown`, run `myisamchk --silent --force */*.MYI` from the data directory to check all `MyISAM` tables, and restart `mysqld`. This ensures that you are running from a clean state. See Chapter 5, *MySQL Server Administration*.
- Start `mysqld` with the general query log enabled (see Section 5.4.3, “The General Query Log”). Then try to determine from the information written to the log whether some specific query kills the server. About 95% of all bugs are related to a particular query. Normally, this is one of the last queries in the log file just before the server restarts. See Section 5.4.3, “The General Query Log”. If you can repeatedly kill MySQL with a specific query, even when you have checked all tables just before issuing it, then you have been able to locate the bug and should submit a bug report for it. See Section 1.6, “How to Report Bugs or Problems”.
- Try to make a test case that we can use to repeat the problem. See Section 24.5, “Debugging and Porting MySQL”.
- Try the `fork_big.pl` script. (It is located in the `tests` directory of source distributions.)
- If you configure MySQL for debugging, it is much easier to gather information about possible errors if something goes wrong. Reconfigure MySQL with the `-DWITH_DEBUG=1` option to `CMake` and then recompile. See Section 24.5, “Debugging and Porting MySQL”.
- Make sure that you have applied the latest patches for your operating system.
- Use the `--skip-external-locking` option to `mysqld`. On some systems, the `lockd` lock manager does not work properly; the `--skip-external-locking` option tells `mysqld` not to use external locking. (This means that you cannot run two `mysqld` servers on the same data directory and that you must be careful if you use `myisamchk`. Nevertheless, it may be instructive to try the option as a test.)
- Have you tried `mysqladmin -u root processlist` when `mysqld` appears to be running but not responding? Sometimes `mysqld` is not comatose even though you might think so. The problem may be that all connections are in use, or there may be some internal lock problem. `mysqladmin -u root processlist` usually is able to make a connection even in these cases, and can provide useful information about the current number of connections and their status.
- Run the command `mysqladmin -i 5 status` or `mysqladmin -i 5 -r status` in a separate window to produce statistics while you run your other queries.
- Try the following:

  1. Start `mysqld` from `gdb` (or another debugger). See Section 24.5, “Debugging and Porting MySQL”.
  2. Run your test scripts.

3. Print the backtrace and the local variables at the three lowest levels. In `gdb`, you can do this with the following commands when `mysqld` has crashed inside `gdb`:

```
backtrace
info local
up
info local
up
info local
```

   With `gdb`, you can also examine which threads exist with `info threads` and switch to a specific thread with `thread N`, where *`N`* is the thread ID.

- Try to simulate your application with a Perl script to force MySQL to crash or misbehave.
- Send a normal bug report. See Section 1.6, “How to Report Bugs or Problems”. Be even more detailed than usual. Because MySQL works for many people, it may be that the crash results from something that exists only on your computer (for example, an error that is related to your particular system libraries).
- If you have a problem with tables containing dynamic-length rows and you are using only `VARCHAR` columns (not `BLOB` or `TEXT` columns), you can try to change all `VARCHAR` to `CHAR` with `ALTER TABLE`. This forces MySQL to use fixed-size rows. Fixed-size rows take a little extra space, but are much more tolerant to corruption.

  The current dynamic row code has been in use for several years with very few problems, but dynamic-length rows are by nature more prone to errors, so it may be a good idea to try this strategy to see whether it helps.
- Do not rule out your server hardware when diagnosing problems. Defective hardware can be the cause of data corruption. Particular attention should be paid to your memory and disk subsystems when troubleshooting hardware.

B.5.3.4 How MySQL Handles a Full Disk

This section describes how MySQL responds to disk-full errors (such as “no space left on device”), and to quota-exceeded errors (such as “write failed” or “user block limit reached”).

This section is relevant for writes to `MyISAM` tables. It also applies for writes to binary log files and binary log index file, except that references to “row” and “record” should be understood to mean “event.”

When a disk-full condition occurs, MySQL does the following:

- It checks once every minute to see whether there is enough space to write the current row. If there is enough space, it continues as if nothing had happened.
- Every 10 minutes it writes an entry to the log file, warning about the disk-full condition.

To alleviate the problem, you can take the following actions:

- To continue, you only have to free enough disk space to insert all records.
- To abort the thread, you must use `mysqladmin kill`. The thread is aborted the next time it checks the disk (in one minute).
- Other threads might be waiting for the table that caused the disk-full condition. If you have several “locked” threads, killing the one thread that is waiting on the disk-full condition enables the other threads to continue.

Exceptions to the preceding behavior are when you use `REPAIR TABLE` or `OPTIMIZE TABLE` or when the indexes are created in a batch after `LOAD DATA INFILE` or after an `ALTER TABLE`

statement. All of these statements may create large temporary files that, if left to themselves, would cause big problems for the rest of the system. If the disk becomes full while MySQL is doing any of these operations, it removes the big temporary files and mark the table as crashed. The exception is that for `ALTER TABLE`, the old table is left unchanged.

B.5.3.5 Where MySQL Stores Temporary Files

On Unix, MySQL uses the value of the `TMPDIR` environment variable as the path name of the directory in which to store temporary files. If `TMPDIR` is not set, MySQL uses the system default, which is usually `/tmp`, `/var/tmp`, or `/usr/tmp`.

On Windows, MySQL checks in order the values of the `TMPDIR`, `TEMP`, and `TMP` environment variables. For the first one found to be set, MySQL uses it and does not check those remaining. If none of `TMPDIR`, `TEMP`, or `TMP` are set, MySQL uses the Windows system default, which is usually `C:\windows\temp\`.

If the file system containing your temporary file directory is too small, you can use the `mysqld --tmpdir` option to specify a directory in a file system where you have enough space. On replication slaves, you can use `--slave-load-tmpdir` to specify a separate directory for holding temporary files when replicating `LOAD DATA INFILE` statements.

The `--tmpdir` option can be set to a list of several paths that are used in round-robin fashion. Paths should be separated by colon characters (`:`) on Unix and semicolon characters (`;`) on Windows.

Note

To spread the load effectively, these paths should be located on different *physical* disks, not different partitions of the same disk.

If the MySQL server is acting as a replication slave, you should be sure to set `--slave-load-tmpdir` not to point to a directory that is on a memory-based file system or to a directory that is cleared when the server host restarts. A replication slave needs some of its temporary files to survive a machine restart so that it can replicate temporary tables or `LOAD DATA INFILE` operations. If files in the slave temporary file directory are lost when the server restarts, replication fails.

MySQL arranges that temporary files are removed if `mysqld` is terminated. On platforms that support it (such as Unix), this is done by unlinking the file after opening it. The disadvantage of this is that the name does not appear in directory listings and you do not see a big temporary file that fills up the file system in which the temporary file directory is located. (In such cases, `lsof +L1` may be helpful in identifying large files associated with `mysqld`.)

When sorting (`ORDER BY` or `GROUP BY`), MySQL normally uses one or two temporary files. The maximum disk space required is determined by the following expression:

```
(length of what is sorted + sizeof(row pointer))
* number of matched rows
* 2
```

The row pointer size is usually four bytes, but may grow in the future for really big tables.

For some `SELECT` queries, MySQL also creates temporary SQL tables. These are not hidden and have names of the form `SQL_*`.

`ALTER TABLE` creates a temporary copy of the original table in the same directory as the original table.

B.5.3.6 How to Protect or Change the MySQL Unix Socket File

The default location for the Unix socket file that the server uses for communication with local clients is `/tmp/mysql.sock`. (For some distribution formats, the directory might be different, such as `/var/lib/mysql` for RPMs.)

On some versions of Unix, anyone can delete files in the `/tmp` directory or other similar directories used for temporary files. If the socket file is located in such a directory on your system, this might cause problems.

On most versions of Unix, you can protect your `/tmp` directory so that files can be deleted only by their owners or the superuser (`root`). To do this, set the `sticky` bit on the `/tmp` directory by logging in as `root` and using the following command:

```
shell> chmod +t /tmp
```

You can check whether the `sticky` bit is set by executing `ls -ld /tmp`. If the last permission character is `t`, the bit is set.

Another approach is to change the place where the server creates the Unix socket file. If you do this, you should also let client programs know the new location of the file. You can specify the file location in several ways:

- Specify the path in a global or local option file. For example, put the following lines in `/etc/my.cnf`:

  ```
  [mysqld]
  socket=/path/to/socket

  [client]
  socket=/path/to/socket
  ```

  See Section 4.2.6, “Using Option Files”.

- Specify a `--socket` option on the command line to `mysqld_safe` and when you run client programs.

- Set the `MYSQL_UNIX_PORT` environment variable to the path of the Unix socket file.

- Recompile MySQL from source to use a different default Unix socket file location. Define the path to the file with the `MYSQL_UNIX_ADDR` option when you run `CMake`. See Section 2.9.4, “MySQL Source-Configuration Options”.

You can test whether the new socket location works by attempting to connect to the server with this command:

```
shell> mysqladmin --socket=/path/to/socket version
```

B.5.3.7 Time Zone Problems

If you have a problem with `SELECT NOW()` returning values in UTC and not your local time, you have to tell the server your current time zone. The same applies if `UNIX_TIMESTAMP()` returns the wrong value. This should be done for the environment in which the server runs; for example, in `mysqld_safe` or `mysql.server`. See Section 4.9, “MySQL Program Environment Variables”.

You can set the time zone for the server with the `--timezone=`*`timezone_name`* option to `mysqld_safe`. You can also set it by setting the `TZ` environment variable before you start `mysqld`.

The permissible values for `--timezone` or `TZ` are system dependent. Consult your operating system documentation to see what values are acceptable.

B.5.4 Query-Related Issues

B.5.4.1 Case Sensitivity in String Searches

For nonbinary strings (`CHAR`, `VARCHAR`, `TEXT`), string searches use the collation of the comparison operands. For binary strings (`BINARY`, `VARBINARY`, `BLOB`), comparisons use the numeric values of the bytes in the operands; this means that for alphabetic characters, comparisons will be case sensitive.

A comparison between a nonbinary string and binary string is treated as a comparison of binary strings.

Simple comparison operations (`>=, >, =, <, <=`, sorting, and grouping) are based on each character's "sort value." Characters with the same sort value are treated as the same character. For example, if `e` and `é` have the same sort value in a given collation, they compare as equal.

The default character set and collation are `latin1` and `latin1_swedish_ci`, so nonbinary string comparisons are case insensitive by default. This means that if you search with *`col_name`* `LIKE 'a%'`, you get all column values that start with `A` or `a`. To make this search case sensitive, make sure that one of the operands has a case sensitive or binary collation. For example, if you are comparing a column and a string that both have the `latin1` character set, you can use the `COLLATE` operator to cause either operand to have the `latin1_general_cs` or `latin1_bin` collation:

```
col_name COLLATE latin1_general_cs LIKE 'a%'
col_name LIKE 'a%' COLLATE latin1_general_cs
col_name COLLATE latin1_bin LIKE 'a%'
col_name LIKE 'a%' COLLATE latin1_bin
```

If you want a column always to be treated in case-sensitive fashion, declare it with a case sensitive or binary collation. See Section 13.1.17, "CREATE TABLE Syntax".

To cause a case-sensitive comparison of nonbinary strings to be case insensitive, use `COLLATE` to name a case-insensitive collation. The strings in the following example normally are case sensitive, but `COLLATE` changes the comparison to be case insensitive:

```
mysql> SET @s1 = 'MySQL' COLLATE latin1_bin,
    ->     @s2 = 'mysql' COLLATE latin1_bin;
mysql> SELECT @s1 = @s2;
+-----------+
| @s1 = @s2 |
+-----------+
|         0 |
+-----------+
mysql> SELECT @s1 COLLATE latin1_swedish_ci = @s2;
+-------------------------------------+
| @s1 COLLATE latin1_swedish_ci = @s2 |
+-------------------------------------+
|                                   1 |
+-------------------------------------+
```

A binary string is case sensitive in comparisons. To compare the string as case insensitive, convert it to a nonbinary string and use `COLLATE` to name a case-insensitive collation:

```
mysql> SET @s = BINARY 'MySQL';
mysql> SELECT @s = 'mysql';
+--------------+
| @s = 'mysql' |
+--------------+
|            0 |
+--------------+
mysql> SELECT CONVERT(@s USING latin1) COLLATE latin1_swedish_ci = 'mysql';
+-------------------------------------------------------------+
| CONVERT(@s USING latin1) COLLATE latin1_swedish_ci = 'mysql' |
+-------------------------------------------------------------+
|                                                           1 |
+-------------------------------------------------------------+
```

To determine whether a value will compare as a nonbinary or binary string, use the `COLLATION()` function. This example shows that `VERSION()` returns a string that has a case-insensitive collation, so comparisons are case insensitive:

```
mysql> SELECT COLLATION(VERSION());
+----------------------+
```

```
| COLLATION(VERSION()) |
+----------------------+
| utf8_general_ci      |
+----------------------+
```

For binary strings, the collation value is `binary`, so comparisons will be case sensitive. One context in which you will see `binary` is for compression functions, which return binary strings as a general rule: string:

```
mysql> SELECT COLLATION(COMPRESS('x'));
+--------------------------+
| COLLATION(COMPRESS('x')) |
+--------------------------+
| binary                   |
+--------------------------+
```

B.5.4.2 Problems Using DATE Columns

The format of a `DATE` value is `'YYYY-MM-DD'`. According to standard SQL, no other format is permitted. You should use this format in `UPDATE` expressions and in the `WHERE` clause of `SELECT` statements. For example:

```
SELECT * FROM t1 WHERE date >= '2003-05-05';
```

As a convenience, MySQL automatically converts a date to a number if the date is used in a numeric context and vice versa. MySQL also permits a “relaxed” string format when updating and in a `WHERE` clause that compares a date to a `DATE`, `DATETIME`, or `TIMESTAMP` column. “Relaxed” format means that any punctuation character may be used as the separator between parts. For example, `'2004-08-15'` and `'2004#08#15'` are equivalent. MySQL can also convert a string containing no separators (such as `'20040815'`), provided it makes sense as a date.

When you compare a `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP` to a constant string with the `<`, `<=`, `=`, `>=`, `>`, or `BETWEEN` operators, MySQL normally converts the string to an internal long integer for faster comparison (and also for a bit more “relaxed” string checking). However, this conversion is subject to the following exceptions:

- When you compare two columns
- When you compare a `DATE`, `TIME`, `DATETIME`, or `TIMESTAMP` column to an expression
- When you use any comparison method other than those just listed, such as `IN` or `STRCMP()`.

For those exceptions, the comparison is done by converting the objects to strings and performing a string comparison.

To be on the safe side, assume that strings are compared as strings and use the appropriate string functions if you want to compare a temporal value to a string.

The special “zero” date `'0000-00-00'` can be stored and retrieved as `'0000-00-00'`. When a `'0000-00-00'` date is used through Connector/ODBC, it is automatically converted to `NULL` because ODBC cannot handle that kind of date.

Because MySQL performs the conversions just described, the following statements work (assume that `idate` is a `DATE` column):

```
INSERT INTO t1 (idate) VALUES (19970505);
INSERT INTO t1 (idate) VALUES ('19970505');
INSERT INTO t1 (idate) VALUES ('97-05-05');
INSERT INTO t1 (idate) VALUES ('1997.05.05');
INSERT INTO t1 (idate) VALUES ('1997 05 05');
INSERT INTO t1 (idate) VALUES ('0000-00-00');
```

```
SELECT idate FROM t1 WHERE idate >= '1997-05-05';
SELECT idate FROM t1 WHERE idate >= 19970505;
SELECT MOD(idate,100) FROM t1 WHERE idate >= 19970505;
SELECT idate FROM t1 WHERE idate >= '19970505';
```

However, the following statement does not work:

```
SELECT idate FROM t1 WHERE STRCMP(idate,'20030505')=0;
```

`STRCMP()` is a string function, so it converts `idate` to a string in `'YYYY-MM-DD'` format and performs a string comparison. It does not convert `'20030505'` to the date `'2003-05-05'` and perform a date comparison.

If you enable the `ALLOW_INVALID_DATES` SQL mode, MySQL permits you to store dates that are given only limited checking: MySQL requires only that the day is in the range from 1 to 31 and the month is in the range from 1 to 12. This makes MySQL very convenient for Web applications where you obtain year, month, and day in three different fields and you want to store exactly what the user inserted (without date validation).

MySQL permits you to store dates where the day or month and day are zero. This is convenient if you want to store a birthdate in a `DATE` column and you know only part of the date. To disallow zero month or day parts in dates, enable the `NO_ZERO_IN_DATE` SQL mode.

MySQL permits you to store a “zero” value of `'0000-00-00'` as a “dummy date.” This is in some cases more convenient than using `NULL` values. If a date to be stored in a `DATE` column cannot be converted to any reasonable value, MySQL stores `'0000-00-00'`. To disallow `'0000-00-00'`, enable the `NO_ZERO_DATE` SQL mode.

To have MySQL check all dates and accept only legal dates (unless overridden by `IGNORE`), set the `sql_mode` system variable to `"NO_ZERO_IN_DATE,NO_ZERO_DATE"`.

B.5.4.3 Problems with NULL Values

The concept of the `NULL` value is a common source of confusion for newcomers to SQL, who often think that `NULL` is the same thing as an empty string `''`. This is not the case. For example, the following statements are completely different:

```
mysql> INSERT INTO my_table (phone) VALUES (NULL);
mysql> INSERT INTO my_table (phone) VALUES ('');
```

Both statements insert a value into the `phone` column, but the first inserts a `NULL` value and the second inserts an empty string. The meaning of the first can be regarded as “phone number is not known” and the meaning of the second can be regarded as “the person is known to have no phone, and thus no phone number.”

To help with `NULL` handling, you can use the `IS NULL` and `IS NOT NULL` operators and the `IFNULL()` function.

In SQL, the `NULL` value is never true in comparison to any other value, even `NULL`. An expression that contains `NULL` always produces a `NULL` value unless otherwise indicated in the documentation for the operators and functions involved in the expression. All columns in the following example return `NULL`:

```
mysql> SELECT NULL, 1+NULL, CONCAT('Invisible',NULL);
```

To search for column values that are `NULL`, you cannot use an `expr = NULL` test. The following statement returns no rows, because `expr = NULL` is never true for any expression:

```
```

```
mysql> SELECT * FROM my_table WHERE phone = NULL;
```

To look for `NULL` values, you must use the `IS NULL` test. The following statements show how to find the `NULL` phone number and the empty phone number:

```
mysql> SELECT * FROM my_table WHERE phone IS NULL;
mysql> SELECT * FROM my_table WHERE phone = '';
```

See Section 3.3.4.6, “Working with NULL Values”, for additional information and examples.

You can add an index on a column that can have `NULL` values if you are using the `MyISAM`, `InnoDB`, or `MEMORY` storage engine. Otherwise, you must declare an indexed column `NOT NULL`, and you cannot insert `NULL` into the column.

When reading data with `LOAD DATA INFILE`, empty or missing columns are updated with `''`. To load a `NULL` value into a column, use `\N` in the data file. The literal word `NULL` may also be used under some circumstances. See Section 13.2.6, “LOAD DATA INFILE Syntax”.

When using `DISTINCT`, `GROUP BY`, or `ORDER BY`, all `NULL` values are regarded as equal.

When using `ORDER BY`, `NULL` values are presented first, or last if you specify `DESC` to sort in descending order.

Aggregate (summary) functions such as `COUNT()`, `MIN()`, and `SUM()` ignore `NULL` values. The exception to this is `COUNT(*)`, which counts rows and not individual column values. For example, the following statement produces two counts. The first is a count of the number of rows in the table, and the second is a count of the number of non-`NULL` values in the `age` column:

```
mysql> SELECT COUNT(*), COUNT(age) FROM person;
```

For some data types, MySQL handles `NULL` values specially. If you insert `NULL` into a `TIMESTAMP` column, the current date and time is inserted. If you insert `NULL` into an integer or floating-point column that has the `AUTO_INCREMENT` attribute, the next number in the sequence is inserted.

B.5.4.4 Problems with Column Aliases

An alias can be used in a query select list to give a column a different name. You can use the alias in `GROUP BY`, `ORDER BY`, or `HAVING` clauses to refer to the column:

```
SELECT SQRT(a*b) AS root FROM tbl_name
  GROUP BY root HAVING root > 0;
SELECT id, COUNT(*) AS cnt FROM tbl_name
  GROUP BY id HAVING cnt > 0;
SELECT id AS 'Customer identity' FROM tbl_name;
```

Standard SQL disallows references to column aliases in a `WHERE` clause. This restriction is imposed because when the `WHERE` clause is evaluated, the column value may not yet have been determined. For example, the following query is illegal:

```
SELECT id, COUNT(*) AS cnt FROM tbl_name
  WHERE cnt > 0 GROUP BY id;
```

The `WHERE` clause determines which rows should be included in the `GROUP BY` clause, but it refers to the alias of a column value that is not known until after the rows have been selected, and grouped by the `GROUP BY`.

In the select list of a query, a quoted column alias can be specified using identifier or string quoting characters:

```
SELECT 1 AS `one`, 2 AS 'two';
```

Elsewhere in the statement, quoted references to the alias must use identifier quoting or the reference is treated as a string literal. For example, this statement groups by the values in column `id`, referenced using the alias `` `a` ``:

```
SELECT id AS 'a', COUNT(*) AS cnt FROM tbl_name
  GROUP BY `a`;
```

But this statement groups by the literal string `'a'` and will not work as expected:

```
SELECT id AS 'a', COUNT(*) AS cnt FROM tbl_name
  GROUP BY 'a';
```

B.5.4.5 Rollback Failure for Nontransactional Tables

If you receive the following message when trying to perform a `ROLLBACK`, it means that one or more of the tables you used in the transaction do not support transactions:

```
Warning: Some non-transactional changed tables couldn't be rolled back
```

These nontransactional tables are not affected by the `ROLLBACK` statement.

If you were not deliberately mixing transactional and nontransactional tables within the transaction, the most likely cause for this message is that a table you thought was transactional actually is not. This can happen if you try to create a table using a transactional storage engine that is not supported by your `mysqld` server (or that was disabled with a startup option). If `mysqld` does not support a storage engine, it instead creates the table as a `MyISAM` table, which is nontransactional.

You can check the storage engine for a table by using either of these statements:

```
SHOW TABLE STATUS LIKE 'tbl_name';
SHOW CREATE TABLE tbl_name;
```

See Section 13.7.5.37, “SHOW TABLE STATUS Syntax”, and Section 13.7.5.12, “SHOW CREATE TABLE Syntax”.

You can check which storage engines your `mysqld` server supports by using this statement:

```
SHOW ENGINES;
```

You can also use the following statement, and check the value of the variable that is associated with the storage engine in which you are interested:

```
SHOW VARIABLES LIKE 'have_%';
```

For example, to determine whether the `InnoDB` storage engine is available, check the value of the `have_innodb` variable.

See Section 13.7.5.17, “SHOW ENGINES Syntax”, and Section 13.7.5.40, “SHOW VARIABLES Syntax”.

B.5.4.6 Deleting Rows from Related Tables

If the total length of the `DELETE` statement for `related_table` is more than 1MB (the default value of the `max_allowed_packet` system variable), you should split it into smaller parts and execute

multiple `DELETE` statements. You probably get the fastest `DELETE` by specifying only 100 to 1,000 `related_column` values per statement if the `related_column` is indexed. If the `related_column` isn't indexed, the speed is independent of the number of arguments in the `IN` clause.

B.5.4.7 Solving Problems with No Matching Rows

If you have a complicated query that uses many tables but that returns no rows, you should use the following procedure to find out what is wrong:

1. Test the query with `EXPLAIN` to check whether you can find something that is obviously wrong. See Section 13.8.2, “EXPLAIN Syntax”.

2. Select only those columns that are used in the `WHERE` clause.

3. Remove one table at a time from the query until it returns some rows. If the tables are large, it is a good idea to use `LIMIT 10` with the query.

4. Issue a `SELECT` for the column that should have matched a row against the table that was last removed from the query.

5. If you are comparing `FLOAT` or `DOUBLE` columns with numbers that have decimals, you cannot use equality (`=`) comparisons. This problem is common in most computer languages because not all floating-point values can be stored with exact precision. In some cases, changing the `FLOAT` to a `DOUBLE` fixes this. See Section B.5.4.8, “Problems with Floating-Point Values”.

6. If you still cannot figure out what is wrong, create a minimal test that can be run with `mysql test < query.sql` that shows your problems. You can create a test file by dumping the tables with `mysqldump --quick db_name tbl_name_1 ... tbl_name_n > query.sql`. Open the file in an editor, remove some insert lines (if there are more than needed to demonstrate the problem), and add your `SELECT` statement at the end of the file.

   Verify that the test file demonstrates the problem by executing these commands:

   ```
   shell> mysqladmin create test2
   shell> mysql test2 < query.sql
   ```

   Attach the test file to a bug report, which you can file using the instructions in Section 1.6, “How to Report Bugs or Problems”.

B.5.4.8 Problems with Floating-Point Values

Floating-point numbers sometimes cause confusion because they are approximate and not stored as exact values. A floating-point value as written in an SQL statement may not be the same as the value represented internally. Attempts to treat floating-point values as exact in comparisons may lead to problems. They are also subject to platform or implementation dependencies. The `FLOAT` and `DOUBLE` data types are subject to these issues. For `DECIMAL` columns, MySQL performs operations with a precision of 65 decimal digits, which should solve most common inaccuracy problems.

The following example uses `DOUBLE` to demonstrate how calculations that are done using floating-point operations are subject to floating-point error.

```
mysql> CREATE TABLE t1 (i INT, d1 DOUBLE, d2 DOUBLE);
mysql> INSERT INTO t1 VALUES (1, 101.40, 21.40), (1, -80.00, 0.00),
    -> (2, 0.00, 0.00), (2, -13.20, 0.00), (2, 59.60, 46.40),
    -> (2, 30.40, 30.40), (3, 37.00, 7.40), (3, -29.60, 0.00),
    -> (4, 60.00, 15.40), (4, -10.60, 0.00), (4, -34.00, 0.00),
    -> (5, 33.00, 0.00), (5, -25.80, 0.00), (5, 0.00, 7.20),
    -> (6, 0.00, 0.00), (6, -51.40, 0.00);

mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b
    -> FROM t1 GROUP BY i HAVING a <> b;
```

```
+------+-------+------+
| i    | a     | b    |
+------+-------+------+
|    1 |  21.4 | 21.4 |
|    2 |  76.8 | 76.8 |
|    3 |   7.4 |  7.4 |
|    4 |  15.4 | 15.4 |
|    5 |   7.2 |  7.2 |
|    6 | -51.4 |    0 |
+------+-------+------+
```

The result is correct. Although the first five records look like they should not satisfy the comparison (the values of `a` and `b` do not appear to be different), they may do so because the difference between the numbers shows up around the tenth decimal or so, depending on factors such as computer architecture or the compiler version or optimization level. For example, different CPUs may evaluate floating-point numbers differently.

If columns `d1` and `d2` had been defined as `DECIMAL` rather than `DOUBLE`, the result of the `SELECT` query would have contained only one row—the last one shown above.

The correct way to do floating-point number comparison is to first decide on an acceptable tolerance for differences between the numbers and then do the comparison against the tolerance value. For example, if we agree that floating-point numbers should be regarded the same if they are same within a precision of one in ten thousand (0.0001), the comparison should be written to find differences larger than the tolerance value:

```
mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b FROM t1
    -> GROUP BY i HAVING ABS(a - b) > 0.0001;
+------+-------+------+
| i    | a     | b    |
+------+-------+------+
|    6 | -51.4 |    0 |
+------+-------+------+
1 row in set (0.00 sec)
```

Conversely, to get rows where the numbers are the same, the test should find differences within the tolerance value:

```
mysql> SELECT i, SUM(d1) AS a, SUM(d2) AS b FROM t1
    -> GROUP BY i HAVING ABS(a - b) <= 0.0001;
+------+------+------+
| i    | a    | b    |
+------+------+------+
|    1 | 21.4 | 21.4 |
|    2 | 76.8 | 76.8 |
|    3 |  7.4 |  7.4 |
|    4 | 15.4 | 15.4 |
|    5 |  7.2 |  7.2 |
+------+------+------+
5 rows in set (0.03 sec)
```

Floating-point values are subject to platform or implementation dependencies. Suppose that you execute the following statements:

```
CREATE TABLE t1(c1 FLOAT(53,0), c2 FLOAT(53,0));
INSERT INTO t1 VALUES('1e+52','-1e+52');
SELECT * FROM t1;
```

On some platforms, the `SELECT` statement returns `inf` and `-inf`. On others, it returns `0` and `-0`.

An implication of the preceding issues is that if you attempt to create a replication slave by dumping table contents with `mysqldump` on the master and reloading the dump file into the slave, tables containing floating-point columns might differ between the two hosts.

B.5.5 Optimizer-Related Issues

MySQL uses a cost-based optimizer to determine the best way to resolve a query. In many cases, MySQL can calculate the best possible query plan, but sometimes MySQL does not have enough information about the data at hand and has to make “educated” guesses about the data.

For the cases when MySQL does not do the "right" thing, tools that you have available to help MySQL are:

- Use the `EXPLAIN` statement to get information about how MySQL processes a query. To use it, just add the keyword `EXPLAIN` to the front of your `SELECT` statement:

  ```
  mysql> EXPLAIN SELECT * FROM t1, t2 WHERE t1.i = t2.i;
  ```

  `EXPLAIN` is discussed in more detail in Section 13.8.2, “EXPLAIN Syntax”.

- Use `ANALYZE TABLE tbl_name` to update the key distributions for the scanned table. See Section 13.7.2.1, “ANALYZE TABLE Syntax”.

- Use `FORCE INDEX` for the scanned table to tell MySQL that table scans are very expensive compared to using the given index:

  ```
  SELECT * FROM t1, t2 FORCE INDEX (index_for_column)
  WHERE t1.col_name=t2.col_name;
  ```

  `USE INDEX` and `IGNORE INDEX` may also be useful. See Section 8.9.3, “Index Hints”.

- Global and table-level `STRAIGHT_JOIN`. See Section 13.2.9, “SELECT Syntax”.

- You can tune global or thread-specific system variables. For example, start `mysqld` with the `--max-seeks-for-key=1000` option or use `SET max_seeks_for_key=1000` to tell the optimizer to assume that no key scan causes more than 1,000 key seeks. See Section 5.1.5, “Server System Variables”.

B.5.6 Table Definition-Related Issues

B.5.6.1 Problems with ALTER TABLE

If you get a duplicate-key error when using `ALTER TABLE` to change the character set or collation of a character column, the cause is either that the new column collation maps two keys to the same value or that the table is corrupted. In the latter case, you should run `REPAIR TABLE` on the table. `REPAIR TABLE` works for `MyISAM`, `ARCHIVE`, and `CSV` tables.

If `ALTER TABLE` dies with the following error, the problem may be that MySQL crashed during an earlier `ALTER TABLE` operation and there is an old table named `A-xxx` or `B-xxx` lying around:

```
Error on rename of './database/name.frm'
to './database/B-xxx.frm' (Errcode: 17)
```

In this case, go to the MySQL data directory and delete all files that have names starting with `A-` or `B-`. (You may want to move them elsewhere instead of deleting them.)

`ALTER TABLE` works in the following way:

- Create a new table named `A-xxx` with the requested structural changes.
- Copy all rows from the original table to `A-xxx`.
- Rename the original table to `B-xxx`.
- Rename `A-xxx` to your original table name.

- Delete `B-xxx`.

If something goes wrong with the renaming operation, MySQL tries to undo the changes. If something goes seriously wrong (although this shouldn't happen), MySQL may leave the old table as `B-xxx`. A simple rename of the table files at the system level should get your data back.

If you use `ALTER TABLE` on a transactional table or if you are using Windows, `ALTER TABLE` unlocks the table if you had done a `LOCK TABLE` on it. This is done because `InnoDB` and these operating systems cannot drop a table that is in use.

B.5.6.2 TEMPORARY Table Problems

Temporary tables created with `CREATE TEMPORARY TABLE` have the following limitations:

- `TEMPORARY` tables are supported only by the `InnoDB`, `MEMORY`, `MyISAM`, and `MERGE` storage engines.
- Temporary tables are not supported for NDB Cluster.
- The `SHOW TABLES` statement does not list `TEMPORARY` tables.
- You cannot use `RENAME TABLE` to rename a `TEMPORARY` table. However, you can use `ALTER TABLE` instead:

```
ALTER TABLE old_name RENAME new_name;
```

- You cannot refer to a `TEMPORARY` table more than once in the same query. For example, the following does not work:

```
SELECT * FROM temp_table JOIN temp_table AS t2;
```

  The statement produces this error:

```
ERROR 1137: Can't reopen table: 'temp_table'
```

- The `Can't reopen table` error also occurs if you refer to a temporary table multiple times in a stored function under different aliases, even if the references occur in different statements within the function.
- There are known issues in using temporary tables with replication. See Section 17.4.1.31, “Replication and Temporary Tables”, for more information.

B.5.7 Known Issues in MySQL

This section lists known issues in recent versions of MySQL.

For information about platform-specific issues, see the installation and porting instructions in Section 2.1, “General Installation Guidance”, and Section 24.5, “Debugging and Porting MySQL”.

The following problems are known:

- Subquery optimization for `IN` is not as effective as for `=`.
- Even if you use `lower_case_table_names=2` (which enables MySQL to remember the case used for databases and table names), MySQL does not remember the case used for database names for the function `DATABASE()` or within the various logs (on case-insensitive systems).
- Dropping a `FOREIGN KEY` constraint does not work in replication because the constraint may have another name on the slave.
- `REPLACE` (and `LOAD DATA` with the `REPLACE` option) does not trigger `ON DELETE CASCADE`.

- `DISTINCT` with `ORDER BY` does not work inside `GROUP_CONCAT()` if you do not use all and only those columns that are in the `DISTINCT` list.
- When inserting a big integer value (between 2^{63} and $2^{64}-1$) into a decimal or string column, it is inserted as a negative value because the number is evaluated in a signed integer context.
- `ANALYZE TABLE`, `OPTIMIZE TABLE`, and `REPAIR TABLE` may cause problems on tables for which you are using `INSERT DELAYED`.
- With statement-based binary logging, the master writes the executed queries to the binary log. This is a very fast, compact, and efficient logging method that works perfectly in most cases. However, it is possible for the data on the master and slave to become different if a query is designed in such a way that the data modification is nondeterministic (generally not a recommended practice, even outside of replication).

  For example:

  - `CREATE TABLE ... SELECT` or `INSERT ... SELECT` statements that insert zero or `NULL` values into an `AUTO_INCREMENT` column.
  - `DELETE` if you are deleting rows from a table that has foreign keys with `ON DELETE CASCADE` properties.
  - `REPLACE ... SELECT`, `INSERT IGNORE ... SELECT` if you have duplicate key values in the inserted data.

  If and only if the preceding queries have no `ORDER BY` clause guaranteeing a deterministic order.

  For example, for `INSERT ... SELECT` with no `ORDER BY`, the `SELECT` may return rows in a different order (which results in a row having different ranks, hence getting a different number in the `AUTO_INCREMENT` column), depending on the choices made by the optimizers on the master and slave.

  A query is optimized differently on the master and slave only if:

  - The table is stored using a different storage engine on the master than on the slave. (It is possible to use different storage engines on the master and slave. For example, you can use `InnoDB` on the master, but `MyISAM` on the slave if the slave has less available disk space.)
  - MySQL buffer sizes (`key_buffer_size`, and so on) are different on the master and slave.
  - The master and slave run different MySQL versions, and the optimizer code differs between these versions.

  This problem may also affect database restoration using `mysqlbinlog|mysql`.

  The easiest way to avoid this problem is to add an `ORDER BY` clause to the aforementioned nondeterministic queries to ensure that the rows are always stored or modified in the same order. Using row-based or mixed logging format also avoids the problem.
- Log file names are based on the server host name if you do not specify a file name with the startup option. To retain the same log file names if you change your host name to something else, you must explicitly use options such as `--log-bin=`*`old_host_name`*`-bin`. See Section 5.1.4, “Server Command Options”. Alternatively, rename the old files to reflect your host name change. If these are binary logs, you must edit the binary log index file and fix the binary log file names there as well. (The same is true for the relay logs on a slave server.)
- `mysqlbinlog` does not delete temporary files left after a `LOAD DATA INFILE` statement. See Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”.
- `RENAME` does not work with `TEMPORARY` tables or tables used in a `MERGE` table.

- When using `SET CHARACTER SET`, you cannot use translated characters in database, table, and column names.
- You cannot use `_` or `%` with `ESCAPE` in `LIKE ... ESCAPE`.
- The server uses only the first `max_sort_length` bytes when comparing data values. This means that values cannot reliably be used in `GROUP BY`, `ORDER BY`, or `DISTINCT` if they differ only after the first `max_sort_length` bytes. To work around this, increase the variable value. The default value of `max_sort_length` is 1024 and can be changed at server startup time or at runtime.
- Numeric calculations are done with `BIGINT` or `DOUBLE` (both are normally 64 bits long). Which precision you get depends on the function. The general rule is that bit functions are performed with `BIGINT` precision, `IF()` and `ELT()` with `BIGINT` or `DOUBLE` precision, and the rest with `DOUBLE` precision. You should try to avoid using unsigned long long values if they resolve to be larger than 63 bits (9223372036854775807) for anything other than bit fields.
- You can have up to 255 `ENUM` and `SET` columns in one table.
- In `MIN()`, `MAX()`, and other aggregate functions, MySQL currently compares `ENUM` and `SET` columns by their string value rather than by the string's relative position in the set.
- In an `UPDATE` statement, columns are updated from left to right. If you refer to an updated column, you get the updated value instead of the original value. For example, the following statement increments `KEY` by `2`, **not** `1`:

```
mysql> UPDATE tbl_name SET KEY=KEY+1,KEY=KEY+1;
```

- You can refer to multiple temporary tables in the same query, but you cannot refer to any given temporary table more than once. For example, the following does not work:

```
mysql> SELECT * FROM temp_table, temp_table AS t2;
ERROR 1137: Can't reopen table: 'temp_table'
```

- The optimizer may handle `DISTINCT` differently when you are using “hidden” columns in a join than when you are not. In a join, hidden columns are counted as part of the result (even if they are not shown), whereas in normal queries, hidden columns do not participate in the `DISTINCT` comparison.

  An example of this is:

```
SELECT DISTINCT mp3id FROM band_downloads
       WHERE userid = 9 ORDER BY id DESC;
```

  and

```
SELECT DISTINCT band_downloads.mp3id
       FROM band_downloads,band_mp3
       WHERE band_downloads.userid = 9
       AND band_mp3.id = band_downloads.mp3id
       ORDER BY band_downloads.id DESC;
```

  In the second case, you may get two identical rows in the result set (because the values in the hidden `id` column may differ).

  Note that this happens only for queries that do not have the `ORDER BY` columns in the result.
- If you execute a `PROCEDURE` on a query that returns an empty set, in some cases the `PROCEDURE` does not transform the columns.
- Creation of a table of type `MERGE` does not check whether the underlying tables are compatible types.

- If you use `ALTER TABLE` to add a `UNIQUE` index to a table used in a `MERGE` table and then add a normal index on the `MERGE` table, the key order is different for the tables if there was an old, non-`UNIQUE` key in the table. This is because `ALTER TABLE` puts `UNIQUE` indexes before normal indexes to be able to detect duplicate keys as early as possible.

Appendix C Restrictions and Limits

Table of Contents

C.1 Restrictions on Stored Programs 2983
C.2 Restrictions on Condition Handling 2987
C.3 Restrictions on Server-Side Cursors 2987
C.4 Restrictions on Subqueries 2987
C.5 Restrictions on Views 2989
C.6 Restrictions on XA Transactions 2990
C.7 Restrictions on Character Sets 2991
C.8 Restrictions on Performance Schema 2991
C.9 Restrictions on Pluggable Authentication 2992
C.10 Limits in MySQL 2993
C.10.1 Limits on Joins 2993
C.10.2 Limits on Number of Databases and Tables 2993
C.10.3 Limits on Table Size 2994
C.10.4 Limits on Table Column Count and Row Size 2995
C.10.5 Limits Imposed by .frm File Structure 2998
C.10.6 Windows Platform Limitations 2998

The discussion here describes restrictions that apply to the use of MySQL features such as subqueries or views.

C.1 Restrictions on Stored Programs

These restrictions apply to the features described in Chapter 20, *Stored Programs and Views*.

Some of the restrictions noted here apply to all stored routines; that is, both to stored procedures and stored functions. There are also some restrictions specific to stored functions but not to stored procedures.

The restrictions for stored functions also apply to triggers. There are also some restrictions specific to triggers.

The restrictions for stored procedures also apply to the `DO` clause of Event Scheduler event definitions. There are also some restrictions specific to events.

SQL Statements Not Permitted in Stored Routines

Stored routines cannot contain arbitrary SQL statements. The following statements are not permitted:

- The locking statements `LOCK TABLES` and `UNLOCK TABLES`.
- `ALTER VIEW`.
- `LOAD DATA` and `LOAD TABLE`.
- SQL prepared statements (`PREPARE`, `EXECUTE`, `DEALLOCATE PREPARE`) can be used in stored procedures, but not stored functions or triggers. Thus, stored functions and triggers cannot use dynamic SQL (where you construct statements as strings and then execute them).
- Generally, statements not permitted in SQL prepared statements are also not permitted in stored programs. For a list of statements supported as prepared statements, see Section 13.5, “Prepared SQL Statement Syntax”. Exceptions are `SIGNAL` and `RESIGNAL`, which are not permissible as prepared statements but are permitted in stored programs.
- Because local variables are in scope only during stored program execution, references to them are not permitted in prepared statements created within a stored program. Prepared statement

scope is the current session, not the stored program, so the statement could be executed after the program ends, at which point the variables would no longer be in scope. For example, `SELECT ... INTO local_var` cannot be used as a prepared statement. This restriction also applies to stored procedure and function parameters. See Section 13.5.1, “PREPARE Syntax”.

- Inserts cannot be delayed. `INSERT DELAYED` syntax is accepted, but the statement is handled as a normal `INSERT`.
- Within all stored programs (stored procedures and functions, triggers, and events), the parser treats `BEGIN [WORK]` as the beginning of a `BEGIN ... END` block. To begin a transaction in this context, use `START TRANSACTION` instead.

Restrictions for Stored Functions

The following additional statements or operations are not permitted within stored functions. They are permitted within stored procedures, except stored procedures that are invoked from within a stored function or trigger. For example, if you use `FLUSH` in a stored procedure, that stored procedure cannot be called from a stored function or trigger.

- Statements that perform explicit or implicit commit or rollback. Support for these statements is not required by the SQL standard, which states that each DBMS vendor may decide whether to permit them.
- Statements that return a result set. This includes `SELECT` statements that do not have an `INTO var_list` clause and other statements such as `SHOW`, `EXPLAIN`, and `CHECK TABLE`. A function can process a result set either with `SELECT ... INTO var_list` or by using a cursor and `FETCH` statements. See Section 13.2.9.1, “SELECT ... INTO Syntax”, and Section 13.6.6, “Cursors”.
- `FLUSH` statements.
- Stored functions cannot be used recursively.
- A stored function or trigger cannot modify a table that is already being used (for reading or writing) by the statement that invoked the function or trigger.
- If you refer to a temporary table multiple times in a stored function under different aliases, a `Can't reopen table: 'tbl_name'` error occurs, even if the references occur in different statements within the function.
- `HANDLER ... READ` statements that invoke stored functions can cause replication errors. As of MySQL 5.5.7, such statements are disallowed.

Restrictions for Triggers

For triggers, the following additional restrictions apply:

- Triggers are not activated by foreign key actions.
- When using row-based replication, triggers on the slave are not activated by statements originating on the master. The triggers on the slave are activated when using statement-based replication. For more information, see Section 17.4.1.36, “Replication and Triggers”.
- The `RETURN` statement is not permitted in triggers, which cannot return a value. To exit a trigger immediately, use the `LEAVE` statement.
- Triggers are not permitted on tables in the `mysql` database. Nor are they permitted on `INFORMATION_SCHEMA` or `performance_schema` tables. Those tables are actually views and triggers are not permitted on views.
- The trigger cache does not detect when metadata of the underlying objects has changed. If a trigger uses a table and the table has changed since the trigger was loaded into the cache, the trigger operates using the outdated metadata.

Name Conflicts within Stored Routines

The same identifier might be used for a routine parameter, a local variable, and a table column. Also, the same local variable name can be used in nested blocks. For example:

```
CREATE PROCEDURE p (i INT)
BEGIN
  DECLARE i INT DEFAULT 0;
  SELECT i FROM t;
  BEGIN
    DECLARE i INT DEFAULT 1;
    SELECT i FROM t;
  END;
END;
```

In such cases, the identifier is ambiguous and the following precedence rules apply:

- A local variable takes precedence over a routine parameter or table column.
- A routine parameter takes precedence over a table column.
- A local variable in an inner block takes precedence over a local variable in an outer block.

The behavior that variables take precedence over table columns is nonstandard.

Replication Considerations

Use of stored routines can cause replication problems. This issue is discussed further in Section 20.7, “Binary Logging of Stored Programs”.

The `--replicate-wild-do-table=db_name.tbl_name` option applies to tables, views, and triggers. It does not apply to stored procedures and functions, or events. To filter statements operating on the latter objects, use one or more of the `--replicate-*-db` options.

Debugging Considerations

There are no stored routine debugging facilities.

Unsupported Syntax from the SQL:2003 Standard

The MySQL stored routine syntax is based on the SQL:2003 standard. The following items from that standard are not currently supported:

- `UNDO` handlers
- `FOR` loops

Concurrency Considerations

To prevent problems of interaction between sessions, when a client issues a statement, the server uses a snapshot of routines and triggers available for execution of the statement. That is, the server calculates a list of procedures, functions, and triggers that may be used during execution of the statement, loads them, and then proceeds to execute the statement. While the statement executes, it does not see changes to routines performed by other sessions.

For maximum concurrency, stored functions should minimize their side-effects; in particular, updating a table within a stored function can reduce concurrent operations on that table. A stored function acquires table locks before executing, to avoid inconsistency in the binary log due to mismatch of the order in which statements execute and when they appear in the log. When statement-based binary logging is used, statements that invoke a function are recorded rather than the statements executed within the function. Consequently, stored functions that update the same underlying tables do not execute in parallel. In contrast, stored procedures do not acquire table-level locks. All statements

executed within stored procedures are written to the binary log, even for statement-based binary logging. See Section 20.7, “Binary Logging of Stored Programs”.

Event Scheduler Restrictions

The following limitations are specific to the Event Scheduler:

- Event names are handled in case-insensitive fashion. For example, you cannot have two events in the same database with the names `anEvent` and `AnEvent`.
- An event may not be created, altered, or dropped by a stored routine, trigger, or another event. An event also may not create, alter, or drop stored routines or triggers. (Bug #16409, Bug #18896)
- As of MySQL 5.5.8, DDL statements on events are prohibited while a `LOCK TABLES` statement is in effect.
- Event timings using the intervals `YEAR`, `QUARTER`, `MONTH`, and `YEAR_MONTH` are resolved in months; those using any other interval are resolved in seconds. There is no way to cause events scheduled to occur at the same second to execute in a given order. In addition—due to rounding, the nature of threaded applications, and the fact that a nonzero length of time is required to create events and to signal their execution—events may be delayed by as much as 1 or 2 seconds. However, the time shown in the `INFORMATION_SCHEMA.EVENTS` table's `LAST_EXECUTED` column or the `mysql.event` table's `last_executed` column is always accurate to within one second of the actual event execution time. (See also Bug #16522.)
- Each execution of the statements contained in the body of an event takes place in a new connection; thus, these statements has no effect in a given user session on the server's statement counts such as `Com_select` and `Com_insert` that are displayed by `SHOW STATUS`. However, such counts *are* updated in the global scope. (Bug #16422)
- Events do not support times later than the end of the Unix Epoch; this is approximately the beginning of the year 2038. Such dates are specifically not permitted by the Event Scheduler. (Bug #16396)
- References to stored functions, user-defined functions, and tables in the `ON SCHEDULE` clauses of `CREATE EVENT` and `ALTER EVENT` statements are not supported. These sorts of references are not permitted. (See Bug #22830 for more information.)

Stored routines and triggers in NDB Cluster. Stored procedures, stored functions, and triggers are all supported by tables using the `NDB` storage engine; however, it is important to keep in mind that they do *not* propagate automatically between MySQL Servers acting as Cluster SQL nodes. This is because of the following:

- Stored routine definitions are kept in tables in the `mysql` system database using the `MyISAM` storage engine, and so do not participate in clustering.
- The `.TRN` and `.TRG` files containing trigger definitions are not read by the `NDB` storage engine, and are not copied between Cluster nodes.

Any stored routine or trigger that interacts with NDB Cluster tables must be re-created by running the appropriate `CREATE PROCEDURE`, `CREATE FUNCTION`, or `CREATE TRIGGER` statements on each MySQL Server that participates in the cluster where you wish to use the stored routine or trigger. Similarly, any changes to existing stored routines or triggers must be carried out explicitly on all Cluster SQL nodes, using the appropriate `ALTER` or `DROP` statements on each MySQL Server accessing the cluster.

Warning

Do *not* attempt to work around the issue described in the first item mentioned previously by converting any `mysql` database tables to use the `NDB` storage engine. *Altering the system tables in the `mysql` database is not supported* and is very likely to produce undesirable results.

C.2 Restrictions on Condition Handling

`SIGNAL` and `RESIGNAL` are not permissible as prepared statements. For example, this statement is invalid:

```
PREPARE stmt1 FROM 'SIGNAL SQLSTATE "02000"';
```

`SQLSTATE` values in class `'04'` are not treated specially. They are handled the same as other exceptions.

C.3 Restrictions on Server-Side Cursors

Server-side cursors are implemented in the C API using the `mysql_stmt_attr_set()` function. The same implementation is used for cursors in stored routines. A server-side cursor enables a result set to be generated on the server side, but not transferred to the client except for those rows that the client requests. For example, if a client executes a query but is only interested in the first row, the remaining rows are not transferred.

In MySQL, a server-side cursor is materialized into an internal temporary table. Initially, this is a `MEMORY` table, but is converted to a `MyISAM` table when its size exceeds the minimum value of the `max_heap_table_size` and `tmp_table_size` system variables. The same restrictions apply to internal temporary tables created to hold the result set for a cursor as for other uses of internal temporary tables. See Section 8.4.4, “Internal Temporary Table Use in MySQL”. One limitation of the implementation is that for a large result set, retrieving its rows through a cursor might be slow.

Cursors are read only; you cannot use a cursor to update rows.

`UPDATE WHERE CURRENT OF` and `DELETE WHERE CURRENT OF` are not implemented, because updatable cursors are not supported.

Cursors are nonholdable (not held open after a commit).

Cursors are asensitive.

Cursors are nonscrollable.

Cursors are not named. The statement handler acts as the cursor ID.

You can have open only a single cursor per prepared statement. If you need several cursors, you must prepare several statements.

You cannot use a cursor for a statement that generates a result set if the statement is not supported in prepared mode. This includes statements such as `CHECK TABLE`, `HANDLER READ`, and `SHOW BINLOG EVENTS`.

C.4 Restrictions on Subqueries

- Subquery optimization for `IN` is not as effective as for the `=` operator or for the `IN(value_list)` operator.

  A typical case for poor `IN` subquery performance is when the subquery returns a small number of rows but the outer query returns a large number of rows to be compared to the subquery result.

  The problem is that, for a statement that uses an `IN` subquery, the optimizer rewrites it as a correlated subquery. Consider the following statement that uses an uncorrelated subquery:

  ```
  SELECT ... FROM t1 WHERE t1.a IN (SELECT b FROM t2);
  ```

  The optimizer rewrites the statement to a correlated subquery:

```
SELECT ... FROM t1 WHERE EXISTS (SELECT 1 FROM t2 WHERE t2.b = t1.a);
```

If the inner and outer queries return *M* and *N* rows, respectively, the execution time becomes on the order of O(*M*×*N*), rather than O(*M*+*N*) as it would be for an uncorrelated subquery.

An implication is that an `IN` subquery can be much slower than a query written using an `IN(value_list)` operator that lists the same values that the subquery would return.

- In general, you cannot modify a table and select from the same table in a subquery. For example, this limitation applies to statements of the following forms:

```
DELETE FROM t WHERE ... (SELECT ... FROM t ...);
UPDATE t ... WHERE col = (SELECT ... FROM t ...);
{INSERT|REPLACE} INTO t (SELECT ... FROM t ...);
```

Exception: The preceding prohibition does not apply if for the modified table you are using a derived table (subquery in the `FROM` clause) and that derived table is materialized rather than merged into the outer query. Example:

```
UPDATE t ... WHERE col = (SELECT * FROM (SELECT ... FROM t...) AS _t ...);
```

Here the result from the derived table is materialized as a temporary table, so the relevant rows in `t` have already been selected by the time the update to `t` takes place.

- Row comparison operations are only partially supported:
  - For *expr* `[NOT] IN` *subquery*, *expr* can be an *n*-tuple (specified using row constructor syntax) and the subquery can return rows of *n*-tuples. The permitted syntax is therefore more specifically expressed as *row_constructor* `[NOT] IN` *table_subquery*
  - For *expr op* `{ALL|ANY|SOME}` *subquery*, *expr* must be a scalar value and the subquery must be a column subquery; it cannot return multiple-column rows.

  In other words, for a subquery that returns rows of *n*-tuples, this is supported:

```
(expr_1, ..., expr_n) [NOT] IN table_subquery
```

But this is not supported:

```
(expr_1, ..., expr_n) op {ALL|ANY|SOME} subquery
```

The reason for supporting row comparisons for `IN` but not for the others is that `IN` is implemented by rewriting it as a sequence of `=` comparisons and `AND` operations. This approach cannot be used for `ALL`, `ANY`, or `SOME`.

- Subqueries in the `FROM` clause cannot be correlated subqueries. They are materialized in whole (evaluated to produce a result set) before evaluating the outer query, so they cannot be evaluated per row of the outer query.
- MySQL does not support `LIMIT` in subqueries for certain subquery operators:

```
mysql> SELECT * FROM t1
    ->   WHERE s1 IN (SELECT s2 FROM t2 ORDER BY s1 LIMIT 1);
ERROR 1235 (42000): This version of MySQL doesn't yet support
 'LIMIT & IN/ALL/ANY/SOME subquery'
```

- The optimizer is more mature for joins than for subqueries, so in many cases a statement that uses a subquery can be executed more efficiently if you rewrite it as a join.

An exception occurs for the case where an `IN` subquery can be rewritten as a `SELECT DISTINCT` join. Example:

```
SELECT col FROM t1 WHERE id_col IN (SELECT id_col2 FROM t2 WHERE condition);
```

That statement can be rewritten as follows:

```
SELECT DISTINCT col FROM t1, t2 WHERE t1.id_col = t2.id_col AND condition;
```

But in this case, the join requires an extra `DISTINCT` operation and is not more efficient than the subquery.

- MySQL permits a subquery to refer to a stored function that has data-modifying side effects such as inserting rows into a table. For example, if `f()` inserts rows, the following query can modify data:

```
SELECT ... WHERE x IN (SELECT f() ...);
```

This behavior is an extension to the SQL standard. In MySQL, it can produce indeterminate results because `f()` might be executed a different number of times for different executions of a given query depending on how the optimizer chooses to handle it.

For statement-based or mixed-format replication, one implication of this indeterminism is that such a query can produce different results on the master and its slaves.

C.5 Restrictions on Views

View processing is not optimized:

- It is not possible to create an index on a view.
- Indexes can be used for views processed using the merge algorithm. However, a view that is processed with the temptable algorithm is unable to take advantage of indexes on its underlying tables (although indexes can be used during generation of the temporary tables).

Subqueries cannot be used in the `FROM` clause of a view.

There is a general principle that you cannot modify a table and select from the same table in a subquery. See Section C.4, “Restrictions on Subqueries”.

The same principle also applies if you select from a view that selects from the table, if the view selects from the table in a subquery and the view is evaluated using the merge algorithm. Example:

```
CREATE VIEW v1 AS
SELECT * FROM t2 WHERE EXISTS (SELECT 1 FROM t1 WHERE t1.a = t2.a);

UPDATE t1, v2 SET t1.a = 1 WHERE t1.b = v2.b;
```

If the view is evaluated using a temporary table, you *can* select from the table in the view subquery and still modify that table in the outer query. In this case the view will be stored in a temporary table and thus you are not really selecting from the table in a subquery and modifying it “at the same time.” (This is another reason you might wish to force MySQL to use the temptable algorithm by specifying `ALGORITHM = TEMPTABLE` in the view definition.)

You can use `DROP TABLE` or `ALTER TABLE` to drop or alter a table that is used in a view definition. No warning results from the `DROP` or `ALTER` operation, even though this invalidates the view. Instead, an error occurs later, when the view is used. `CHECK TABLE` can be used to check for views that have been invalidated by `DROP` or `ALTER` operations.

A view definition is “frozen” by certain statements. If a statement prepared by PREPARE refers to a view, the view definition seen each time the statement is executed later will be the definition of the view at the time it was prepared. This is true even if the view definition is changed after the statement is prepared and before it is executed. In the following example, the result returned by the EXECUTE statement is a random number, not the current date and time:

```
CREATE VIEW v AS SELECT RAND();
PREPARE s FROM 'SELECT * FROM v';
ALTER VIEW v AS SELECT NOW();
EXECUTE s;
```

With regard to view updatability, the overall goal for views is that if any view is theoretically updatable, it should be updatable in practice. MySQL as quickly as possible. Many theoretically updatable views can be updated now, but limitations still exist. For details, see Section 20.5.3, “Updatable and Insertable Views”.

There exists a shortcoming with the current implementation of views. If a user is granted the basic privileges necessary to create a view (the CREATE VIEW and SELECT privileges), that user will be unable to call SHOW CREATE VIEW on that object unless the user is also granted the SHOW VIEW privilege.

That shortcoming can lead to problems backing up a database with mysqldump, which may fail due to insufficient privileges. This problem is described in Bug #22062.

The workaround to the problem is for the administrator to manually grant the SHOW VIEW privilege to users who are granted CREATE VIEW, since MySQL doesn't grant it implicitly when views are created.

Views do not have indexes, so index hints do not apply. Use of index hints when selecting from a view is not permitted.

SHOW CREATE VIEW displays view definitions using an AS *alias_name* clause for each column. If a column is created from an expression, the default alias is the expression text, which can be quite long. Aliases for column names in CREATE VIEW statements are checked against the maximum column length of 64 characters (not the maximum alias length of 256 characters). As a result, views created from the output of SHOW CREATE VIEW fail if any column alias exceeds 64 characters. This can cause problems in the following circumstances for views with too-long aliases:

- View definitions fail to replicate to newer slaves that enforce the column-length restriction.
- Dump files created with mysqldump cannot be loaded into servers that enforce the column-length restriction.

A workaround for either problem is to modify each problematic view definition to use aliases that provide shorter column names. Then the view will replicate properly, and can be dumped and reloaded without causing an error. To modify the definition, drop and create the view again with DROP VIEW and CREATE VIEW, or replace the definition with CREATE OR REPLACE VIEW.

For problems that occur when reloading view definitions in dump files, another workaround is to edit the dump file to modify its CREATE VIEW statements. However, this does not change the original view definitions, which may cause problems for subsequent dump operations.

C.6 Restrictions on XA Transactions

XA transaction support is limited to the InnoDB storage engine.

For “external XA,” a MySQL server acts as a Resource Manager and client programs act as Transaction Managers. For “Internal XA”, storage engines within a MySQL server act as RMs, and the server itself acts as a TM. Internal XA support is limited by the capabilities of individual storage engines. Internal XA is required for handling XA transactions that involve more than one storage

engine. The implementation of internal XA requires that a storage engine support two-phase commit at the table handler level, and currently this is true only for `InnoDB`.

For `XA START`, the `JOIN` and `RESUME` clauses are not supported.

For `XA END`, the `SUSPEND [FOR MIGRATE]` clause is not supported.

The requirement that the *`bqual`* part of the *`xid`* value be different for each XA transaction within a global transaction is a limitation of the current MySQL XA implementation. It is not part of the XA specification.

If an XA transaction has reached the `PREPARED` state and the MySQL server is killed (for example, with `kill -9` on Unix) or shuts down abnormally, the transaction can be continued after the server restarts. However, if the client reconnects and commits the transaction, the transaction will be absent from the binary log even though it has been committed. This means the data and the binary log have gone out of synchrony. An implication is that XA cannot be used safely together with replication.

It is possible that the server will roll back a pending XA transaction, even one that has reached the `PREPARED` state. This happens if a client connection terminates and the server continues to run, or if clients are connected and the server shuts down gracefully. (In the latter case, the server marks each connection to be terminated, and then rolls back the `PREPARED` XA transaction associated with it.) It should be possible to commit or roll back a `PREPARED` XA transaction, but this cannot be done without changes to the binary logging mechanism.

`FLUSH TABLES WITH READ LOCK` is not compatible with XA transactions.

C.7 Restrictions on Character Sets

- Identifiers are stored in `mysql` database tables (`user`, `db`, and so forth) using `utf8`, but identifiers can contain only characters in the Basic Multilingual Plane (BMP). Supplementary characters are not permitted in identifiers.
- The `ucs2`, `utf16`, and `utf32` character sets have the following restrictions:
  - They cannot be used as a client character set, which means that they do not work for `SET NAMES` or `SET CHARACTER SET`. (See Section 10.1.4, “Connection Character Sets and Collations”.)
  - It is currently not possible to use `LOAD DATA INFILE` to load data files that use these character sets.
  - `FULLTEXT` indexes cannot be created on a column that uses any of these character sets. However, you can perform `IN BOOLEAN MODE` searches on the column without an index.
  - The use of `ENCRYPT()` with these character sets is not recommended because the underlying system call expects a string terminated by a zero byte.
- The `REGEXP` and `RLIKE` operators work in byte-wise fashion, so they are not multibyte safe and may produce unexpected results with multibyte character sets. In addition, these operators compare characters by their byte values and accented characters may not compare as equal even if a given collation treats them as equal.

C.8 Restrictions on Performance Schema

The Performance Schema avoids using mutexes to collect or produce data, so there are no guarantees of consistency and results can sometimes be incorrect. Event values in `performance_schema` tables are nondeterministic and nonrepeatable.

If you save event information in another table, you should not assume that the original events will still be available later. For example, if you select events from a `performance_schema` table into a temporary table, intending to join that table with the original table later, there might be no matches.

`mysqldump` and `BACKUP DATABASE` ignore tables in the `performance_schema` database.

Tables in the `performance_schema` database cannot be locked with `LOCK TABLES`, except the `setup_xxx` tables.

Tables in the `performance_schema` database cannot be indexed.

Results for queries that refer to tables in the `performance_schema` database are not saved in the query cache.

Tables in the `performance_schema` database are not replicated.

The Performance Schema is not available in `libmysqld`, the embedded server.

The types of timers might vary per platform. The `performance_timers` table shows which event timers are available. If the values in this table for a given timer name are `NULL`, that timer is not supported on your platform.

Instruments that apply to storage engines might not be implemented for all storage engines. Instrumentation of each third-party engine is the responsibility of the engine maintainer.

C.9 Restrictions on Pluggable Authentication

The first part of this section describes general restrictions on the applicability of the pluggable authentication framework described at Section 6.3.6, “Pluggable Authentication”. The second part describes how third-party connector developers can determine the extent to which a connector can take advantage of pluggable authentication capabilities and what steps to take to become more compliant.

The term “native authentication” used here refers to authentication against passwords stored in the `Password` column of the `mysql.user` table. This is the same authentication method provided by MySQL servers older than 5.5.7, before pluggable authentication was implemented. It remains the default method in 5.5.7 and up, although now it is implemented using plugins. “Windows native authentication” refers to authentication using the credentials of a user who has already logged in to Windows, as implemented by the Windows Native Authentication plugin (“Windows plugin” for short).

General Pluggable Authentication Restrictions

- **Connector/C, Connector/C++:** Clients that use these connectors can connect to the server only through accounts that use native authentication.

  Exception: A connector supports pluggable authentication if it was built to link to `libmysqlclient` dynamically (rather than statically) and it loads the current version of `libmysqlclient` if that version is installed, or if the connector is recompiled from source to link against the current `libmysqlclient`.

- **Connector/Net:** Clients that use Connector/Net can connect to the server through accounts that use native authentication or the Windows plugin.

- **Connector/PHP:** Clients that use this connector can connect to the server only through accounts that use native authentication, when compiled using the MySQL native driver for PHP (`mysqlnd`).

- **Windows native authentication:** Connecting through an account that uses the Windows plugin requires Windows Domain setup. Without it, NTLM authentication is used and then only local connections are possible; that is, the client and server must run on the same computer.

- **Proxy users:** Proxy user support is available to the extent that clients can connect through accounts authenticated with plugins that implement proxy user capability (that is, plugins that can return a user name different from that of the connecting user). For example, the native authentication plugins do not support proxy users, whereas the PAM and Windows plugins do.

- **Replication:** Before MySQL 5.5.17, replication slaves can connect to the master server only through master accounts that use native authentication. As of 5.5.17 (or 5.5.19 for Windows native authentication), replication slaves can also connect through master accounts that use nonnative authentication if the required client-side plugin is available. If the plugin is built into `libmysqlclient`, it is available by default. Otherwise, the plugin must be installed on the slave side in the directory named by the slave `plugin_dir` system variable.
- **`FEDERATED` tables:** A `FEDERATED` table can access the remote table only through accounts on the remote server that use native authentication.

Pluggable Authentication and Third-Party Connectors

Third-party connector developers can use the following guidelines to determine readiness of a connector to take advantage of pluggable authentication capabilities and what steps to take to become more compliant:

- An existing connector to which no changes have been made uses native authentication and clients that use the connector can connect to the server only through accounts that use native authentication. *However, you should test the connector against a recent version of the server to verify that such connections still work without problem.*

  Exception: A connector might work with pluggable authentication without any changes if it links to `libmysqlclient` dynamically (rather than statically) and it loads the current version of `libmysqlclient` if that version is installed.

- To take advantage of pluggable authentication capabilities, a connector that is `libmysqlclient`-based should be relinked against the current version of `libmysqlclient`. This enables the connector to support connections though accounts that require client-side plugins now built into `libmysqlclient` (such as the cleartext plugin needed for PAM authentication and the Windows plugin needed for Windows native authentication). Linking with a current `libmysqlclient` also enables the connector to access client-side plugins installed in the default MySQL plugin directory (typically the directory named by the default value of the local server's `plugin_dir` system variable).

  If a connector links to `libmysqlclient` dynamically, it must be ensured that the newer version of `libmysqlclient` is installed on the client host and that the connector loads it at runtime.

- Another way for a connector to support a given authentication method is to implement it directly in the client/server protocol. Connector/Net uses this approach to provide support for Windows native authentication.

- If a connector should be able to load client-side plugins from a directory different from the default plugin directory, it must implement some means for client users to specify the directory. Possibilities for this include a command-line option or environment variable from which the connector can obtain the directory name. Standard MySQL client programs such as `mysql` and `mysqladmin` implement a `--plugin-dir` option. See also Section 23.8.14, “C API Client Plugin Functions”.

- Proxy user support by a connector depends, as described earlier in this section, on whether the authentication methods that it supports permit proxy users.

C.10 Limits in MySQL

This section lists current limits in MySQL 5.5.

C.10.1 Limits on Joins

The maximum number of tables that can be referenced in a single join is 61. This also applies to the number of tables that can be referenced in the definition of a view.

C.10.2 Limits on Number of Databases and Tables

MySQL has no limit on the number of databases. The underlying file system may have a limit on the number of directories.

MySQL has no limit on the number of tables. The underlying file system may have a limit on the number of files that represent tables. Individual storage engines may impose engine-specific constraints. `InnoDB` permits up to 4 billion tables.

C.10.3 Limits on Table Size

The effective maximum table size for MySQL databases is usually determined by operating system constraints on file sizes, not by MySQL internal limits. For up-to-date information operating system file size limits, refer to the documentation specific to your operating system.

Windows users, please note that FAT and VFAT (FAT32) are *not* considered suitable for production use with MySQL. Use NTFS instead.

If you encounter a full-table error, there are several reasons why it might have occurred:

- The disk might be full.
- You are using `InnoDB` tables and have run out of room in an `InnoDB` tablespace file. The maximum tablespace size is four billion pages (64TB), which is also the maximum size for a table. See Section 14.11.1.7, “Limits on InnoDB Tables”.

  Generally, partitioning of tables into multiple tablespace files is recommended for tables larger than 1TB in size.
- You have hit an operating system file size limit. For example, you are using `MyISAM` tables on an operating system that supports files only up to 2GB in size and you have hit this limit for the data file or index file.
- You are using a `MyISAM` table and the space required for the table exceeds what is permitted by the internal pointer size. `MyISAM` permits data and index files to grow up to 256TB by default, but this limit can be changed up to the maximum permissible size of 65,536TB ($256^7 - 1$ bytes).

  If you need a `MyISAM` table that is larger than the default limit and your operating system supports large files, the `CREATE TABLE` statement supports `AVG_ROW_LENGTH` and `MAX_ROWS` options. See Section 13.1.17, “CREATE TABLE Syntax”. The server uses these options to determine how large a table to permit.

  If the pointer size is too small for an existing table, you can change the options with `ALTER TABLE` to increase a table's maximum permissible size. See Section 13.1.7, “ALTER TABLE Syntax”.

  ```
  ALTER TABLE tbl_name MAX_ROWS=1000000000 AVG_ROW_LENGTH=nnn;
  ```

  You have to specify `AVG_ROW_LENGTH` only for tables with `BLOB` or `TEXT` columns; in this case, MySQL can't optimize the space required based only on the number of rows.

  To change the default size limit for `MyISAM` tables, set the `myisam_data_pointer_size`, which sets the number of bytes used for internal row pointers. The value is used to set the pointer size for new tables if you do not specify the `MAX_ROWS` option. The value of `myisam_data_pointer_size` can be from 2 to 7. A value of 4 permits tables up to 4GB; a value of 6 permits tables up to 256TB.

  You can check the maximum data and index sizes by using this statement:

  ```
  SHOW TABLE STATUS FROM db_name LIKE 'tbl_name';
  ```

  You also can use `myisamchk -dv /path/to/table-index-file`. See Section 13.7.5, “SHOW Syntax”, or Section 4.6.3, “`myisamchk` — MyISAM Table-Maintenance Utility”.

  Other ways to work around file-size limits for `MyISAM` tables are as follows:

  - If your large table is read only, you can use `myisampack` to compress it. `myisampack` usually compresses a table by at least 50%, so you can have, in effect, much bigger tables. `myisampack` also can merge multiple tables into a single table. See Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”.
  - MySQL includes a `MERGE` library that enables you to handle a collection of `MyISAM` tables that have identical structure as a single `MERGE` table. See Section 15.8, “The MERGE Storage Engine”.
- You are using the `NDB` storage engine, in which case you need to increase the values for the `DataMemory` and `IndexMemory` configuration parameters in your `config.ini` file. See Section 18.3.2.1, “NDB Cluster Data Node Configuration Parameters”.
- You are using the `MEMORY` (`HEAP`) storage engine; in this case you need to increase the value of the `max_heap_table_size` system variable. See Section 5.1.5, “Server System Variables”.

C.10.4 Limits on Table Column Count and Row Size

Column Count Limits

MySQL has hard limit of 4096 columns per table, but the effective maximum may be less for a given table. The exact column limit depends on several factors:

- The maximum row size for a table constrains the number (and possibly size) of columns because the total length of all columns cannot exceed this size. See Row Size Limits.
- The storage requirements of individual columns constrain the number of columns that fit within a given maximum row size. Storage requirements for some data types depend on factors such as storage engine, storage format, and character set. See Section 11.7, “Data Type Storage Requirements”.
- Storage engines may impose additional restrictions that limit table column count. For example, `InnoDB` has a limit of 1000 columns per table. See Section 14.11.1.7, “Limits on InnoDB Tables”. For information about other storage engines, see Chapter 15, *Alternative Storage Engines*.
- Each table has an `.frm` file that contains the table definition. The definition affects the content of this file in ways that may affect the number of columns permitted in the table. See Section C.10.5, “Limits Imposed by .frm File Structure”.

Row Size Limits

The maximum row size for a given table is determined by several factors:

- The internal representation of a MySQL table has a maximum row size limit of 65,535 bytes, even if the storage engine is capable of supporting larger rows. `BLOB` and `TEXT` columns only contribute 9 to 12 bytes toward the row size limit because their contents are stored separately from the rest of the row.
- The maximum row size for an `InnoDB` table, which applies to data stored locally within a database page, is slightly less than half a page. For example, the maximum row size is slightly less than 8KB for the default 16KB `InnoDB` page size. See Section 14.11.1.7, “Limits on InnoDB Tables”.

  If a row containing variable-length columns exceeds the `InnoDB` maximum row size, `InnoDB` selects variable-length columns for external off-page storage until the row fits within the `InnoDB` row size limit. The amount of data stored locally for variable-length columns that are stored off-page differs by row format. For more information, see Section 14.14, “InnoDB Row Storage and Row Formats”.
- Different storage formats use different amounts of page header and trailer data, which affects the amount of storage available for rows.
  - For information about `InnoDB` row formats, see Section 14.14, “InnoDB Row Storage and Row Formats”, and Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table”.

- For information about MyISAM storage formats, see Section 15.3.3, “MyISAM Table Storage Formats”.

Row Size Limit Examples

- The MySQL maximum row size limit of 65,535 bytes is demonstrated in the following InnoDB and MyISAM examples. The limit is enforced regardless of storage engine, even though the storage engine may be capable of supporting larger rows.

```
mysql> CREATE TABLE t (a VARCHAR(10000), b VARCHAR(10000),
       c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
       f VARCHAR(10000), g VARCHAR(6000)) ENGINE=InnoDB CHARACTER SET latin1;
ERROR 1118 (42000): Row size too large. The maximum row size for the used
table type, not counting BLOBs, is 65535. You have to change some columns
to TEXT or BLOBs
```

```
mysql> CREATE TABLE t (a VARCHAR(10000), b VARCHAR(10000),
       c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
       f VARCHAR(10000), g VARCHAR(6000)) ENGINE=MyISAM CHARACTER SET latin1;
ERROR 1118 (42000): Row size too large. The maximum row size for the used
table type, not counting BLOBs, is 65535. You have to change some columns
to TEXT or BLOBs
```

In the following MyISAM example, changing a column to TEXT avoids the 65,535-byte row size limit and permits the operation to succeed because BLOB and TEXT columns only contribute 9 to 12 bytes toward the row size.

```
mysql> CREATE TABLE t (a VARCHAR(10000), b VARCHAR(10000),
       c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
       f VARCHAR(10000), g TEXT(6000)) ENGINE=MyISAM CHARACTER SET latin1;
Query OK, 0 rows affected (0.02 sec)
```

The operation succeeds for an InnoDB table because changing a column to TEXT avoids the MySQL 65,535-byte row size limit, and InnoDB off-page storage of variable-length columns avoids the InnoDB row size limit.

```
mysql> CREATE TABLE t (a VARCHAR(10000), b VARCHAR(10000),
       c VARCHAR(10000), d VARCHAR(10000), e VARCHAR(10000),
       f VARCHAR(10000), g TEXT(6000)) ENGINE=InnoDB CHARACTER SET latin1;
Query OK, 0 rows affected (0.02 sec)
```

- Storage for variable-length columns includes length bytes, which are counted toward the row size. For example, a VARCHAR(255) CHARACTER SET utf8mb3 column takes two bytes to store the length of the value, so each value can take up to 767 bytes.

  The statement to create table t1 succeeds because the columns require 32,765 + 2 bytes and 32,766 + 2 bytes, which falls within the maximum row size of 65,535 bytes:

```
mysql> CREATE TABLE t1
       (c1 VARCHAR(32765) NOT NULL, c2 VARCHAR(32766) NOT NULL)
       ENGINE = InnoDB CHARACTER SET latin1;
Query OK, 0 rows affected (0.02 sec)
```

  The statement to create table t2 fails because, although the column length is within the maximum length of 65,535 bytes, two additional bytes are required to record the length, which causes the row size to exceed 65,535 bytes:

```
mysql> CREATE TABLE t2
       (c1 VARCHAR(65535) NOT NULL)
       ENGINE = InnoDB CHARACTER SET latin1;
```

```
ERROR 1118 (42000): Row size too large. The maximum row size for the
used table type, not counting BLOBs, is 65535. You have to change some
columns to TEXT or BLOBs
```

Reducing the column length to 65,533 or less permits the statement to succeed.

```
mysql> CREATE TABLE t2
       (c1 VARCHAR(65533) NOT NULL)
       ENGINE = InnoDB CHARACTER SET latin1;
Query OK, 0 rows affected (0.01 sec)
```

- For `MyISAM` tables, `NULL` columns require additional space in the row to record whether their values are `NULL`. Each `NULL` column takes one bit extra, rounded up to the nearest byte.

  The statement to create table `t3` fails because `MyISAM` requires space for `NULL` columns in addition to the space required for variable-length column length bytes, causing the row size to exceed 65,535 bytes:

  ```
  mysql> CREATE TABLE t3
         (c1 VARCHAR(32765) NULL, c2 VARCHAR(32766) NULL)
         ENGINE = MyISAM CHARACTER SET latin1;
  ERROR 1118 (42000): Row size too large. The maximum row size for the
  used table type, not counting BLOBs, is 65535. You have to change some
  columns to TEXT or BLOBs
  ```

  For information about `InnoDB` `NULL` column storage, see Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table”.

- `InnoDB` restricts row size (for data stored locally within the database page) to slightly less than half a database page. For example, the maximum row size is slightly less than 8KB for the 16KB `InnoDB` page size.

  The statement to create table `t4` fails because the defined columns exceed the row size limit for a 16KB `InnoDB` page.

  Note

  `innodb_strict_mode` is enabled in the following example to ensure that `InnoDB` returns an error if the defined columns exceed the `InnoDB` row size limit. When `innodb_strict_mode` is disabled (the default), creating a table that uses `REDUNDANT` or `COMPACT` row format succeeds with a warning if the `InnoDB` row size limit is exceeded.

  `DYNAMIC` and `COMPRESSED` row formats are more restrictive in this regard. Creating a table that uses `DYNAMIC` or `COMRESSED` row format fails with an error if the `InnoDB` row size limit is exceeded, regardless of the `innodb_strict_mode` setting.

  ```
  mysql> SET SESSION innodb_strict_mode=1;
  mysql> CREATE TABLE t4 (
         c1 CHAR(255),c2 CHAR(255),c3 CHAR(255),
         c4 CHAR(255),c5 CHAR(255),c6 CHAR(255),
         c7 CHAR(255),c8 CHAR(255),c9 CHAR(255),
         c10 CHAR(255),c11 CHAR(255),c12 CHAR(255),
         c13 CHAR(255),c14 CHAR(255),c15 CHAR(255),
         c16 CHAR(255),c17 CHAR(255),c18 CHAR(255),
         c19 CHAR(255),c20 CHAR(255),c21 CHAR(255),
         c22 CHAR(255),c23 CHAR(255),c24 CHAR(255),
         c25 CHAR(255),c26 CHAR(255),c27 CHAR(255),
         c28 CHAR(255),c29 CHAR(255),c30 CHAR(255),
         c31 CHAR(255),c32 CHAR(255),c33 CHAR(255)
         ) ENGINE=InnoDB ROW_FORMAT=COMPACT DEFAULT CHARSET latin1;
  ERROR 1118 (42000): Row size too large (> 8126). Changing some columns to TEXT or BLOB or using
  ```

```
ROW_FORMAT=DYNAMIC or ROW_FORMAT=COMPRESSED may help. In current row format, BLOB prefix of 768
bytes is stored inline.
```

C.10.5 Limits Imposed by .frm File Structure

Each table has an `.frm` file that contains the table definition. The server uses the following expression to check some of the table information stored in the file against an upper limit of 64KB:

```
if (info_length+(ulong) create_fields.elements*FCOMP+288+
    n_length+int_length+com_length > 65535L || int_count > 255)
```

The portion of the information stored in the `.frm` file that is checked against the expression cannot grow beyond the 64KB limit, so if the table definition reaches this size, no more columns can be added.

The relevant factors in the expression are:

- `info_length` is space needed for “screens.” This is related to MySQL's Unireg heritage.
- `create_fields.elements` is the number of columns.
- `FCOMP` is 17.
- `n_length` is the total length of all column names, including one byte per name as a separator.
- `int_length` is related to the list of values for `ENUM` and `SET` columns. In this context, “int” does not mean “integer.” It means “interval,” a term that refers collectively to `ENUM` and `SET` columns.
- `int_count` is the number of unique `ENUM` and `SET` definitions.
- `com_length` is the total length of column comments.

The expression just described has several implications for permitted table definitions:

- Using long column names can reduce the maximum number of columns, as can the inclusion of `ENUM` or `SET` columns, or use of column comments.
- A table can have no more than 255 unique `ENUM` and `SET` definitions. Columns with identical element lists are considered the same against this limt. For example, if a table contains these two columns, they count as one (not two) toward this limit because the definitions are identical:

  ```
  e1 ENUM('a','b','c')
  e2 ENUM('a','b','c')
  ```

- The sum of the length of element names in the unique `ENUM` and `SET` definitions counts toward the 64KB limit, so although the theoretical limit on number of elements in a given `ENUM` column is 65,535, the practical limit is less than 3000.

C.10.6 Windows Platform Limitations

The following limitations apply to use of MySQL on the Windows platform:

- **Process memory**

  On Windows 32-bit platforms, it is not possible by default to use more than 2GB of RAM within a single process, including MySQL. This is because the physical address limit on Windows 32-bit is 4GB and the default setting within Windows is to split the virtual address space between kernel (2GB) and user/applications (2GB).

  Some versions of Windows have a boot time setting to enable larger applications by reducing the kernel application. Alternatively, to use more than 2GB, use a 64-bit version of Windows.

- **File system aliases**

  When using `MyISAM` tables, you cannot use aliases within Windows link to the data files on another volume and then link back to the main MySQL `datadir` location.

  This facility is often used to move the data and index files to a RAID or other fast solution, while retaining the main `.frm` files in the default data directory configured with the `datadir` option.

- **Limited number of ports**

  Windows systems have about 4,000 ports available for client connections, and after a connection on a port closes, it takes two to four minutes before the port can be reused. In situations where clients connect to and disconnect from the server at a high rate, it is possible for all available ports to be used up before closed ports become available again. If this happens, the MySQL server appears to be unresponsive even though it is running. Ports may be used by other applications running on the machine as well, in which case the number of ports available to MySQL is lower.

  For more information about this problem, see http://support.microsoft.com/default.aspx?scid=kb;en-us;196271.

- **`DATA DIRECTORY` and `INDEX DIRECTORY`**

  The `DATA DIRECTORY` and `INDEX DIRECTORY` options for `CREATE TABLE` are ignored on Windows, because MySQL does not support Windows symbolic links. These options also are ignored on systems that have a nonfunctional `realpath()` call.

- **`DROP DATABASE`**

  You cannot drop a database that is in use by another session.

- **Case-insensitive names**

  File names are not case sensitive on Windows, so MySQL database and table names are also not case sensitive on Windows. The only restriction is that database and table names must be specified using the same case throughout a given statement. See Section 9.2.2, “Identifier Case Sensitivity”.

- **Directory and file names**

  On Windows, MySQL Server supports only directory and file names that are compatible with the current ANSI code pages. For example, the following Japanese directory name will not work in the Western locale (code page 1252):

```
datadir="C:/私たちのプロジェクトのデータ"
```

  The same limitation applies to directory and file names referred to in SQL statements, such as the data file path name in `LOAD DATA INFILE`.

- **The `\` path name separator character**

  Path name components in Windows are separated by the `\` character, which is also the escape character in MySQL. If you are using `LOAD DATA INFILE` or `SELECT ... INTO OUTFILE`, use Unix-style file names with `/` characters:

```
mysql> LOAD DATA INFILE 'C:/tmp/skr.txt' INTO TABLE skr;
mysql> SELECT * INTO OUTFILE 'C:/tmp/skr.txt' FROM skr;
```

  Alternatively, you must double the `\` character:

```
mysql> LOAD DATA INFILE 'C:\\tmp\\skr.txt' INTO TABLE skr;
mysql> SELECT * INTO OUTFILE 'C:\\tmp\\skr.txt' FROM skr;
```

- **Problems with pipes**

  Pipes do not work reliably from the Windows command-line prompt. If the pipe includes the character `^Z` / `CHAR(24)`, Windows thinks that it has encountered end-of-file and aborts the program.

  This is mainly a problem when you try to apply a binary log as follows:

```
C:\> mysqlbinlog binary_log_file | mysql --user=root
```

  If you have a problem applying the log and suspect that it is because of a `^Z` / `CHAR(24)` character, you can use the following workaround:

```
C:\> mysqlbinlog binary_log_file --result-file=/tmp/bin.sql
C:\> mysql --user=root --execute "source /tmp/bin.sql"
```

  The latter command also can be used to reliably read in any SQL file that may contain binary data.

Appendix D Indexes

Table of Contents

General Index 3001
C Function Index 3190
Command Index 3205
Function Index 3244
INFORMATION_SCHEMA Index 3273
Join Types Index 3281
Operator Index 3283
Option Index 3290
Privileges Index 3373
SQL Modes Index 3382
Statement/Syntax Index 3385
Status Variable Index 3453
System Variable Index 3472
Transaction Isolation Level Index 3512

General Index

Symbols

! (logical NOT), 1159
!= (not equal), 1155
", 974
#mysql50 identifier prefix, 975, 981
%, 1188
% (modulo), 1193
% (wildcard character), 966
& (bitwise AND), 1251
&& (logical AND), 1160
() (parentheses), 1153
(Control+Z) \Z, 966, 1415
* (multiplication), 1188
+ (addition), 1187
- (subtraction), 1187
- (unary minus), 1187
--password option, 700
-? option (NDB Cluster programs), 2311
-c option (NDB Cluster programs), 2311
-c option (ndb_mgmd) (OBSOLETE), 2244
-d option (ndb_index_stat), 2270
-d option (ndb_mgmd), 2245
-e option (ndb_mgm), 2250
-f option (ndb_mgmd), 2244
-l option (ndbinfo_select_all), 2240
-n option (ndbd), 2236
-n option (ndbmtd), 2236
-p option, 700
-P option (ndb_mgmd), 2246
-V option (NDB Cluster programs), 2312
.my.cnf file, 258, 261, 263, 678, 700, 732
.mysql_history file, 312, 701
.pid (process ID) file, 827
/ (division), 1188

/etc/passwd, 708, 1435
:= (assignment operator), 1161
:= (assignment), 1006
< (less than), 1155
<< (left shift), 245, 1251
<= (less than or equal), 1155
<=> (equal to), 1154
<> (not equal), 1155
= (assignment operator), 1161
= (assignment), 1006
= (equal), 1154
> (greater than), 1155
>= (greater than or equal), 1155
>> (right shift), 1251
[api] (NDB Cluster), 2084
[computer] (NDB Cluster), 2087
[mgm] (NDB Cluster), 2082
[mysqld] (NDB Cluster), 2084
[ndbd default] (NDB Cluster), 2067
[ndbd] (NDB Cluster), 2067
[ndb_mgmd] (NDB Cluster), 2082
[sci] (NDB Cluster), 2087
[shm] (NDB Cluster), 2087
[tcp] (NDB Cluster), 2087
\" (double quote), 966
\' (single quote), 966
\. (mysql client command), 240, 314
\0 (ASCII NUL), 966, 1415
\b (backspace), 966, 1415
\n (linefeed), 966, 1415
\n (newline), 966, 1415
\N (NULL), 1415
\r (carriage return), 966, 1415
\t (tab), 966, 1415
\Z (Control+Z) ASCII 26, 966, 1415
\\ (escape), 966
^ (bitwise XOR), 1251
_ (wildcard character), 967
_ai collation sufffix, 1020
_as collation sufffix, 1020
_bin collation sufffix, 1020, 1038
_ci collation sufffix, 1020
_cs collation sufffix, 1020
_rowid, 1338, 1355, 1355
`, 974
| (bitwise OR), 1250
|| (logical OR), 1160
~ (invert bits), 1251

A

abort-on-error option
    ndb_move_data, 2274
abort-slave-event-count option
    mysqld, 1916
aborted clients, 2958
aborted connection, 2958
ABS(), 1189
access control, 726

access denied errors, 2949
access privileges, 713
account names, 724
accounts
  adding privileges, 738
  anonymous user, 190
  default, 190
  root, 190
ACID, 1600, 1608, 3515
ACLs, 713
ACOS(), 1189
activating plugins, 661
ActiveState Perl, 213
adaptive flushing, 3515
adaptive hash index, 1612, 3515
add-drop-database option
  mysqldump, 337
add-drop-table option
  mysqldump, 337
add-drop-trigger option
  mysqldump, 337
add-locks option
  mysqldump, 337
ADDDATE(), 1200
adding
  character sets, 1062
  native functions, 2827
  new account privileges, 738
  new functions, 2817
  new user privileges, 738
  new users, 186
  user-defined functions, 2818
addition (+), 1187
ADDTIME(), 1200
addtodest option
  mysqlhotcopy, 412
administration
  server, 317
administration of NDB Cluster, 2249
administrative programs, 252
AES_DECRYPT(), 1253
AES_ENCRYPT(), 1253
After create
  thread state, 953
age
  calculating, 229
AHI, 3516
AIO, 3516
alias names
  case sensitivity, 978
aliases
  for expressions, 1289
  for tables, 1430
  in GROUP BY clauses, 1289
  names, 974
  on expressions, 1429
ALL, 1446
  SELECT modifier, 1433

ALL join type
  optimizer, 909
all-databases option
  mysqlcheck, 327
  mysqldump, 338
all-in-1 option
  mysqlcheck, 327
all-tablespaces option
  mysqldump, 338
allocating local table
  thread state, 959
allow-keywords option
  mysqldump, 338
allow-suspicious-udfs option
  mysqld, 457
allowold option
  mysqlhotcopy, 412
ALLOW_INVALID_DATES SQL mode, 624
ALTER COLUMN, 1315
ALTER DATABASE, 1304
ALTER EVENT, 1305
  and replication, 1992
ALTER FUNCTION, 1307
ALTER LOGFILE GROUP, 1307
  (see also NDB Cluster Disk Data)
ALTER PROCEDURE, 1308
ALTER SCHEMA, 1304
ALTER SERVER, 1309
ALTER TABLE, 1309, 1316, 2977
  ROW_FORMAT, 1696
ALTER TABLESPACE, 1330
  (see also NDB Cluster Disk Data)
ALTER VIEW, 1331
altering
  database, 1304
  schema, 1304
ANALYSE()
  PROCEDURE, 888
analyze option
  myisamchk, 377
  mysqlcheck, 327
ANALYZE TABLE
  and partitioning, 2495
ANALYZE TABLE statement, 1527
Analyzing
  thread state, 954
AND
  bitwise, 1251
  logical, 1160
anonymous user, 190, 190, 726, 728
ANSI mode
  running, 25
ansi option
  mysqld, 457
ANSI SQL mode, 623, 628
ANSI_QUOTES SQL mode, 624
answering questions
  etiquette, 19

Antelope, 3516
Antelope file format, 1691, 1697, 1716
ANY, 1446
Apache, 248
API node (NDB Cluster)
  defined, 2014
API nodes (see SQL nodes)
APIs, 2643
  list of, 39
  Perl, 2766
append option
  ndb_restore, 2284
application programming interface (API), 3516
apply, 3516
apply-slave-statements option
  mysqldump, 338
apply_status table (OBSOLETE), 2426
  (see also NDB Cluster replication)
approximate-value literals, 1294
approximate-value numeric literals, 968, 1295
Arbitration, 2150
ArbitrationDelay, 2119, 2174
ArbitrationRank, 2119, 2173
ArbitrationTimeout, 2150
arbitrator_validity_detail
  ndbinfo table, 2358
arbitrator_validity_summary
  ndbinfo table, 2359
ARCHIVE storage engine, 1781, 1801
Area(), 1276
argument processing, 2822
arithmetic expressions, 1187
arithmetic functions, 1250
arithmetic operators, 1250
.ARM file, 3515
.ARZ file, 3515
AS, 1430, 1436
AsBinary(), 1272
ASCII(), 1165
ASIN(), 1190
assignment operator
  :=, 1161
  =, 1161
assignment operators, 1160
AsText(), 1272
asynchronous I/O, 1650, 3516
asynchronous replication (see NDB Cluster replication)
ATAN(), 1190
ATAN2(), 1190
atomic, 3516
atomic DDL, 3516
atomic instruction, 3517
attackers
  security against, 707
attribute demotion
  replication, 1985
attribute promotion
  replication, 1985

audit plugins, 2773
audit-log option
  mysqld, 800
audit_log plugin, 784
  installing, 786
  startup failure, 798
audit_log_buffer_size system variable, 801
audit_log_file system variable, 801
audit_log_flush system variable, 802
audit_log_format system variable, 802
audit_log_policy system variable, 803
audit_log_rotate_on_size system variable, 803
audit_log_strategy system variable, 804
authentication plugin
  authentication_pam, 768
  authentication_windows, 776
  authentication_windows_client, 776
  auth_socket, 781
  auth_test_plugin, 782
  mysql_clear_password, 767
  mysql_native_password, 765
  mysql_old_password, 766
  test_plugin_server, 782
authentication plugins, 2774
authentication_pam authentication plugin, 768
AUTHENTICATION_PAM_LOG environment variable, 776
authentication_windows authentication plugin, 776
authentication_windows_client authentication plugin, 776
authentication_windows_log_level system variable, 501
authentication_windows_use_principal_name system variable, 501
auth_socket authentication plugin, 781
auth_test_plugin authentication plugin, 782
auto-generate-sql option
  mysqlslap, 362
auto-generate-sql-add-autoincrement option
  mysqlslap, 362
auto-generate-sql-execute-number option
  mysqlslap, 363
auto-generate-sql-guid-primary option
  mysqlslap, 363
auto-generate-sql-load-type option
  mysqlslap, 363
auto-generate-sql-secondary-indexes option
  mysqlslap, 363
auto-generate-sql-unique-query-number option
  mysqlslap, 363
auto-generate-sql-unique-write-number option
  mysqlslap, 363
auto-generate-sql-write-number option
  mysqlslap, 363
auto-inc lock, 1615
auto-increment, 1669, 1669, 1675, 3517
auto-increment locking, 3517
auto-rehash option
  mysql, 299
auto-repair option
  mysqlcheck, 327
auto-vertical-output option

mysql, 299
autocommit, 3517
autocommit mode, 1622
autocommit system variable, 502
automatic_sp_privileges system variable, 503
AutoReconnect
API and SQL nodes, 2175
AUTO_INCREMENT, 246, 1092
and NULL values, 2973
and replication, 1980
auto_increment_increment system variable, 1913
auto_increment_offset system variable, 1915
availability, 3517
AVG(), 1281
AVG(DISTINCT), 1281

B

B-tree, 3517
B-tree indexes, 883, 1680
background threads
master, 1644, 1651
read, 1649
write, 1649
backslash
escape character, 965
backspace (\b), 966, 1415
backticks, 3518
backup, 3518
BACKUP Events (NDB Cluster), 2334
backup identifiers
native backup and restore, 2321
backup option
myisamchk, 376
myisampack, 387
BackupDataBufferSize, 2155, 2323
BackupDataDir, 2125
backupid option
ndb_restore, 2284
BackupLogBufferSize, 2156, 2323
BackupMaxWriteSize, 2157, 2323
BackupMemory, 2156, 2323
BackupReportFrequency, 2156
backups, 805, 2842
databases and tables, 331, 411
in NDB Cluster, 2280, 2319, 2319, 2320, 2323
in NDB Cluster replication, 2434
InnoDB, 1770
with mysqldump, 814
backups, troubleshooting
in NDB Cluster, 2323
BackupWriteSize, 2157, 2323
backup_path option
ndb_restore, 2284
back_log system variable, 503
Barracuda, 3518
Barracuda file format, 1681, 1691, 1696, 1716
base64-output option
mysqlbinlog, 397

basedir option
  mysql.server, 279
  mysqld, 458
  mysqld_safe, 274
  mysql_install_db, 286
  mysql_plugin, 288
  mysql_upgrade, 293
basedir system variable, 503
batch mode, 239
batch option
  mysql, 299
batch SQL files, 295
BatchByteSize, 2174
batched updates (NDB Cluster Replication), 2430
BatchSize, 2174
BatchSizePerLocalScan, 2133
BEGIN, 1458, 1486
  labels, 1487
  XA transactions, 1470
BENCHMARK(), 1259
benchmarks, 949, 950
beta, 3518
BETWEEN ... AND, 1156
big-tables option
  mysqld, 458
big5, 2871
BIGINT data type, 1085
big_tables system variable, 504
BIN(), 1166
BINARY, 1237
binary collation, 1038
BINARY data type, 1090, 1108
binary distributions
  installing, 59
binary log, 645, 3518
  event groups, 1479
binary logging
  and NDB Cluster, 2033
binary-as-hex option
  mysql, 299
bind-address option
  mysql, 299
  mysqladmin, 321
  mysqlbinlog, 398
  mysqlcheck, 327
  mysqld, 458
  mysqldump, 338
  mysqlimport, 352
  mysqlshow, 357
bind-address option (ndb_mgmd), 2243
binlog, 3519
Binlog Dump
  thread command, 951
BINLOG statement, 1585
  mysqlbinlog output, 406
binlog-do-db option
  mysqld, 1938
binlog-format option

mysqld, 459
binlog-ignore-db option
mysqld, 1940
binlog-row-event-max-size option
mysqld, 1936
binlog_cache_size system variable, 1941
binlog_direct_non_transactional_updates system variable, 1942
binlog_format
BLACKHOLE, 1981
binlog_format system variable, 1943
NDB Cluster, 1943, 1944
binlog_index table (OBSOLETE) (see NDB Cluster replication)
binlog_stmt_cache_size system variable, 1944
BIT data type, 1084
bit functions, 1250
example, 245
bit operators, 1250
bit-value literal introducer, 972
bit-value literals, 972
BIT_AND(), 1281
BIT_COUNT, 245
BIT_COUNT(), 1251
BIT_LENGTH(), 1166
BIT_OR, 245
BIT_OR(), 1281
BIT_XOR(), 1282
BLACKHOLE
binlog_format, 1981
replication, 1981
BLACKHOLE storage engine, 1781, 1802
blind query expansion, 3519
BLOB
size, 1135
BLOB columns
default values, 1109
indexing, 879, 1353
inserting binary data, 967
BLOB data type, 1091, 1109
blob-info option
ndb_desc, 2265
Block Nested-Loop join algorithm, 842
block-search option
myisamchk, 377
blocks
ndbinfo table, 2359
BOOL data type, 1084
BOOLEAN data type, 1084
boolean literals, 973
boolean options, 261
bootstrap option
mysqld, 459
bottleneck, 3519
bounce, 3519
brackets
square, 1084
brief option
mysqlaccess, 393
buddy allocator, 1742, 3519

buffer, 3519
buffer pool, 921, 1638, 1642, 1643, 1644, 3519
  and compressed tables, 1688
  monitoring, 1644
buffer pool instance, 3520
buffer sizes, 921, 1638
  client, 2643
bugs
  known, 2978
  NDB Cluster
    reporting, 2267
  reporting, 2, 20
bugs database, 20
bugs.mysql.com, 20
builddir option
  mysql_install_db, 286
BuildIndexThreads, 2158
building
  client programs, 2655
BUILD_CONFIG option
  CMake, 171
built-in, 3520
bulk loading
  for InnoDB tables, 893
  for MyISAM tables, 900
bulk_insert_buffer_size system variable, 504
business rules, 3520

C

C API, 2643
  data structures, 2659
  data types, 2652
  example programs, 2655
  functions, 2664
  linking problems, 2657
C prepared statement API
  data structures, 2718
  functions, 2723, 2724
  type codes, 2722
C++, 2646
C:\my.cnf file, 678
cache, 3520
CACHE INDEX
  and partitioning, 2505
CACHE INDEX statement, 1585
caches
  clearing, 1587
calculating
  aggregate value for a set of rows, 1280
  cardinality, 1561
  dates, 229
calendar, 1218
CALL, 1394
calling sequences for aggregate functions
  UDF, 2821
calling sequences for simple functions
  UDF, 2820
can't create/write to file, 2959

Can't reopen table
  error message, 2978
cardinality, 865, 3520
carriage return (\r), 966, 1415
CASE, 1162, 1489
case sensitivity
  access checking, 723
  account names, 724
  in identifiers, 978
  in names, 978
  in searches, 2969
  in string comparisons, 1176
  of database names, 26
  of replication filtering options, 1956
  of table names, 26
CAST, 1238
cast functions, 1233
cast operators, 1233
casts, 1149, 1153, 1233
CC environment variable, 180, 423
CEIL(), 1190
CEILING(), 1190
Centroid(), 1276
.cfg file, 3520
cflags option
  mysql_config, 418
change buffer, 1611, 3521
  monitoring, 1611
change buffering, 3521
  disabling, 1647
CHANGE MASTER TO, 1475
  in NDB Cluster, 2428
Change user
  thread command, 951
changes to privileges, 730
changing
  column, 1314
  field, 1314
  socket location, 279, 2969
  table, 1309, 1316, 2977
Changing master
  thread state, 963
CHAR data type, 1089, 1106
CHAR VARYING data type, 1090
CHAR(), 1166
CHARACTER data type, 1089
character set introducer, 1026
character set repertoire, 1045
character sets, 1013
  adding, 1062
  and replication, 1981
  Asian, 1057
  Baltic, 1057
  binary, 1061
  Central European, 1055
  Cyrillic, 1057
  Middle East, 1056
  repertoire, 1016

restrictions, 2991
South European, 1056
Unicode, 1050
West European, 1054
CHARACTER VARYING data type, 1090
character-set-client-handshake option
mysqld, 460
character-set-filesystem option
mysqld, 460
character-set-server option
mysqld, 460
character-sets-dir option
myisamchk, 376
myisampack, 387
mysql, 299
mysqladmin, 322
mysqlbinlog, 398
mysqlcheck, 328
mysqld, 460
mysqldump, 338
mysqlimport, 352
mysqlshow, 357
mysql_upgrade, 293
ndb_move_data, 2274
character-sets-dir option (NDB Cluster programs), 2310, 2310
characters
multibyte, 1065
CHARACTER_LENGTH(), 1167
CHARACTER_SETS
INFORMATION_SCHEMA table, 2548
character_sets_dir system variable, 506
character_set_client system variable, 504
character_set_connection system variable, 505
character_set_database system variable, 505
character_set_filesystem system variable, 505
character_set_results system variable, 506
character_set_server system variable, 506
character_set_system system variable, 506
charset command
mysql, 307
charset option
comp_err, 284
CHARSET(), 1259
CHAR_LENGTH(), 1166
check option
myisamchk, 375
mysqlcheck, 328
check options
myisamchk, 375
CHECK TABLE
and partitioning, 2495
CHECK TABLE statement, 1528
check-only-changed option
myisamchk, 375
mysqlcheck, 328
check-orphans option
ndb_blob_tool, 2251
check-upgrade option

mysqlcheck, 328
checking
tables for errors, 824
Checking master version
thread state, 961
checking permissions
thread state, 954
checking privileges on cached query
thread state, 960
checking query cache for query
thread state, 961
Checking table
thread state, 954
checkpoint, 3521
CHECKPOINT Events (NDB Cluster), 2331
checkpoint option
mysqlhotcopy, 412
Checksum, 2224, 2230
checksum, 3521
Checksum (NDB Cluster), 2228
checksum errors, 157
CHECKSUM TABLE
and replication, 1981
CHECKSUM TABLE statement, 1531
child table, 3522
Chinese, Japanese, Korean character sets
frequently asked questions, 2871
choosing
a MySQL version, 43
data types, 1136
chroot option
mysqld, 460
mysqlhotcopy, 412
circular replication
in NDB Cluster, 2419, 2440, 2444
CJK (Chinese, Japanese, Korean)
Access, PHP, etc., 2871
availability of specific characters, 2871
big5, 2871
character sets available, 2871
characters displayed as question marks, 2871
CJKV, 2871
collations, 2871, 2871
conversion problems with Japanese character sets, 2871
data truncation, 2871
Database and table names, 2871
documentation in Chinese, 2871
documentation in Japanese, 2871
documentation in Korean, 2871
FAQ, 2871
gb2312, gbk, 2871
Japanese character sets, 2871
Korean character set, 2871
LIKE and FULLTEXT, 2871
MySQL 4.0 behavior, 2871
ORDER BY treatment, 2871, 2871
problems with Access, PHP, etc., 2871
problems with Big5 character sets (Chinese), 2871

problems with data truncation, 2871
problems with euckr character set (Korean), 2871
problems with GB character sets (Chinese), 2871
problems with LIKE and FULLTEXT, 2871
problems with Yen sign (Japanese), 2871
rejected characters, 2871
sort order problems, 2871, 2871
sorting problems, 2871, 2871
testing availability of characters, 2871
Unicode collations, 2871
Vietnamese, 2871
Yen sign, 2871
clean page, 3522
clean shutdown, 636, 3522
cleaning up
thread state, 954
clear command
mysql, 307
Clearing
thread state, 964
clearing
caches, 1587
client, 3522
client connection threads, 947
client programs, 251
building, 2655
client tools, 2643
clients
debugging, 2837
threaded, 2658
cloning tables, 1370
CLOSE, 1494
Close stmt
thread command, 952
closing
tables, 888
closing tables
thread state, 954
cluster database (OBSOLETE) (see NDB Cluster replication)
cluster logs, 2327, 2329
cluster.binlog_index table (OBSOLETE) (see NDB Cluster replication)
clustered index, 3522
InnoDB, 1680
Clustering (see NDB Cluster)
CLUSTERLOG commands (NDB Cluster), 2329
CLUSTERLOG STATISTICS command (NDB Cluster), 2334
cluster_operations
ndbinfo table, 2360
cluster_replication database (OBSOLETE) (see NDB Cluster replication)
cluster_transactions
ndbinfo table, 2361
CMake
BUILD_CONFIG option, 171
CMAKE_BUILD_TYPE option, 171
CMAKE_CXX_FLAGS option, 177
CMAKE_C_FLAGS option, 177
CMAKE_INSTALL_PREFIX option, 171
COMPILATION_COMMENT option, 174

CPACK_MONOLITHIC_INSTALL option, 171
DEFAULT_CHARSET option, 174
DEFAULT_COLLATION option, 174
ENABLED_LOCAL_INFILE option, 175
ENABLED_PROFILING option, 175
ENABLE_DEBUG_SYNC option, 174
ENABLE_DOWNLOADS option, 175
ENABLE_DTRACE option, 175
ENABLE_GCOV option, 175
IGNORE_AIO_CHECK option, 175
INSTALL_BINDIR option, 172
INSTALL_DOCDIR option, 172
INSTALL_DOCREADMEDIR option, 172
INSTALL_INCLUDEDIR option, 172
INSTALL_INFODIR option, 172
INSTALL_LAYOUT option, 172
INSTALL_LIBDIR option, 172
INSTALL_MANDIR option, 172
INSTALL_MYSQLSHAREDIR option, 172
INSTALL_MYSQLTESTDIR option, 172
INSTALL_PLUGINDIR option, 172
INSTALL_SBINDIR option, 172
INSTALL_SCRIPTDIR option, 173
INSTALL_SECURE_FILE_PRIVDIR option, 173
INSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR option, 173
INSTALL_SHAREDIR option, 173
INSTALL_SQLBENCHDIR option, 173
INSTALL_SUPPORTFILESDIR option, 173
MEMCACHED_HOME option, 178
MYSQL_DATADIR option, 173
MYSQL_MAINTAINER_MODE option, 175
MYSQL_PROJECT_NAME option, 176
MYSQL_TCP_PORT option, 176
MYSQL_UNIX_ADDR option, 176
ODBC_INCLUDES option, 173
ODBC_LIB_DIR option, 173
options, 167
running after prior invocation, 164, 179
SYSCONFDIR option, 173
TMPDIR option, 173
VERSION file, 181
WITHOUT_SERVER option, 177
WITH_ASAN option, 176
WITH_BUNDLED_LIBEVENT option, 178
WITH_BUNDLED_MEMCACHED option, 178
WITH_CLASSPATH option, 179
WITH_DEBUG option, 176
WITH_EMBEDDED_SERVER option, 176
WITH_EMBEDDED_SHARED_LIBRARY option, 176
WITH_ERROR_INSERT option, 179
WITH_EXTRA_CHARSETS option, 176
WITH_LIBEDIT option, 176
WITH_LIBWRAP option, 176
WITH_NDBCLUSTER option, 179
WITH_NDBCLUSTER_STORAGE_ENGINE option, 179
WITH_NDBMTD option, 179
WITH_NDB_BINLOG option, 179
WITH_NDB_DEBUG option, 179

WITH_NDB_JAVA option, 179
WITH_NDB_PORT option, 179
WITH_NDB_TEST option, 179
WITH_READLINE option, 177
WITH_SSL option, 177
WITH_UNIT_TESTS option, 177
WITH_UNIXODBC option, 177
WITH_VALGRIND option, 177
WITH_ZLIB option, 177
CMakeCache.txt file, 179
CMAKE_BUILD_TYPE option
CMake, 171
CMAKE_CXX_FLAGS option
CMake, 177
CMAKE_C_FLAGS option
CMake, 177
CMAKE_INSTALL_PREFIX option
CMake, 171
COALESCE(), 1157
coercibility
collation, 1036
COERCIBILITY(), 1259
cold backup, 3522
collating
strings, 1065
collation
adding, 1066
coercibility, 1036
INFORMATION_SCHEMA, 1041
modifying, 1066
COLLATION(), 1260
collation-server option
mysqld, 461
collations
Asian, 1058
Baltic, 1057
binary, 1038, 1061
Central European, 1055
Cyrillic, 1057
Middle East, 1056
naming conventions, 1019
PAD SPACE, 1039, 1107
South European, 1056
Unicode, 1050
West European, 1054
_ai suffix, 1020
_as suffix, 1020
_bin suffix, 1020, 1038
_ci suffix, 1020
_ss suffix, 1020
COLLATIONS
INFORMATION_SCHEMA table, 2549
COLLATION_CHARACTER_SET_APPLICABILITY
INFORMATION_SCHEMA table, 2549
collation_connection system variable, 507
collation_database system variable, 507
collation_server system variable, 507
column, 3522

changing, 1314
types, 1083
column alias
problems, 2973
quoting, 975, 2973
column comments, 1354
column format, 1354
column index, 3523
column names
case sensitivity, 978
column prefix, 3523
column storage, 1354
column-names option
mysql, 299
column-type-info option
mysql, 299
columns
displaying, 355
indexes, 879
names, 974
other types, 1136
selecting, 227
storage requirements, 1132
COLUMNS
INFORMATION_SCHEMA table, 2550
columns option
mysqlimport, 352
columns partitioning, 2468
columns per table
maximum, 2995
columns_priv table
system table, 638, 719
COLUMN_PRIVILEGES
INFORMATION_SCHEMA table, 2550
comma-separated values data, reading, 1413, 1436
command option precedence, 259
command options
mysql, 296
mysqladmin, 320
mysqld, 456
command options (NDB Cluster)
mysqld, 2178
ndbd, 2233
ndbinfo_select_all, 2240
ndb_mgm, 2249
ndb_mgmd, 2242
command syntax, 4
command-line history
mysql, 312
command-line options (NDB Cluster), 2309
command-line tool, 81, 295
commands
for binary distribution, 60
commands out of sync, 2960
comment syntax, 1011
comments
adding, 1011
starting, 30

comments option
  mysql, 299
  mysqldump, 338
COMMIT, 1458
  XA transactions, 1470
commit, 3523
commit option
  mysqlaccess, 393
  mysqlslap, 363
Committing events to binlog
  thread state, 963
compact option
  mysqldump, 338
compact row format, 1697, 3523
comparison operators, 1153
comparisons
  access checking, 723
  account names, 724
compatibility
  between MySQL versions, 199
  with mSQL, 1179
  with ODBC, 567, 977, 1087, 1149, 1156, 1354, 1438
  with Oracle, 27, 1284, 1314, 1594
  with PostgreSQL, 28
  with standard SQL, 24
compatible option
  mysqldump, 338
COMPILATION_COMMENT option
  CMake, 174
compiling
  optimizing, 938
  problems, 179
  user-defined functions, 2825
compiling clients
  on Unix, 2655
  on Windows, 2656
complete-insert option
  mysqldump, 338
completion_type system variable, 507
composite index, 3523
composite partitioning, 2480
compound statements, 1486
compress option
  mysql, 300
  mysqladmin, 322
  mysqlcheck, 328
  mysqldump, 339
  mysqlimport, 352
  mysqlshow, 357
  mysqlslap, 363
  mysql_upgrade, 293
COMPRESS(), 1254
compressed backup, 3523
compressed row format, 1696, 3523
compressed table, 3524
compressed tables, 386, 1793
CompressedBackup, 2142
CompressedLCP, 2142

compression, 1681, 3524
  algorithms, 1686
  application and schema design, 1684
  BLOBs, VARCHAR and TEXT, 1688
  buffer pool considerations, 1688
  compressed page size, 1685
  configuration characteristics, 1685
  data and indexes, 1687
  data characteristics, 1683
  enabling for a table, 1681
  implementation, 1686
  information schema, 1742, 1742
  KEY_BLOCK_SIZE, 1685
  log file format, 1689
  modification log, 1687
  monitoring, 1685
  overflow pages, 1688
  overview, 1681
  tuning, 1682
  workload characteristics, 1685
compression failure, 3524
comp_err, 251, 283
  charset option, 284
  debug option, 284
  debug-info option, 284
  header_file option, 284
  help option, 284
  in_file option, 284
  name_file option, 284
  out_dir option, 284
  out_file option, 284
  statefile option, 284
  version option, 284
CONCAT(), 1167
concatenation
  string, 965, 1167
CONCAT_WS(), 1167
concurrency, 1600, 3524
  of commits, 1713
  of threads, 1738
  tickets, 1714
concurrency option
  mysqlslap, 363
concurrent inserts, 933, 936
concurrent_insert system variable, 508
Conditions, 1496
conditions, 1557, 1582
cond_instances table
  performance_schema, 2624
config-cache option (ndb_mgmd), 2243
config-file option
  mysqld_multi, 281
  my_print_defaults, 420
  ndb_config, 2255
config-file option (ndb_mgmd), 2244
config.ini (NDB Cluster), 2055, 2108, 2109, 2248
configdir option (ndb_mgmd), 2243
configinfo option

ndb_config, 2254
configuration
NDB Cluster, 2066
server, 426
configuration file, 3525
configuration files, 732
configure option
MySQLInstallerConsole, 82
configuring backups
in NDB Cluster, 2323
configuring NDB Cluster, 2038, 2064, 2248, 2324
Configuring NDB Cluster (concepts), 2014
config_from_node option
ndb_config, 2255
config_params
ndbinfo table, 2362
conflict detection status variables
NDB Cluster Replication, 2449
conflict resolution
and ndb_replication system table, 2446
enabling, 2446
in NDB Cluster Replication, 2444
mysqld startup options, 2445
Connect
thread command, 952
connect command
mysql, 307
CONNECT command (NDB Cluster), 2316
connect option
ndb_restore, 2285
Connect Out
thread command, 952
connect-delay option (ndbd), 2237
connect-delay option (ndbmtd), 2237
connect-retries option (ndbd), 2237
connect-retries option (ndbmtd), 2237
connect-string option (NDB Cluster programs), 2311
ConnectBackoffMaxTime, 2177
ConnectCheckIntervalDelay, 2146
connecting
remotely with SSH, 765
to the server, 217, 255
verification, 726
Connecting to master
thread state, 961
connection
aborted, 2958
CONNECTION Events (NDB Cluster), 2330
connection string (see NDB Cluster)
connection-timeout option (ndb_error_reporter), 2268
ConnectionMap, 2172
connections option
ndb_config, 2255
CONNECTION_ID(), 1260
Connector/C, 2643, 2646
Connector/C++, 2643, 2646
Connector/J, 2643, 2646
Connector/Net, 2643, 2647

Connector/ODBC, 2643, 2647
Connector/Python, 2643, 2647
Connectors, 2643
connect_timeout system variable, 509
connect_timeout variable, 306, 324
consistent read, 3525
consistent reads, 1623
console option
  mysqld, 461
const table
  optimizer, 907, 1433
constant table, 834
constraint, 3525
constraints, 30
  foreign keys, 1374
Contains(), 1280
contributing companies
  list of, 40
contributors
  list of, 33
control flow functions, 1162
Control+C
  statement termination, 296, 304
CONV(), 1191
conventions
  syntax, 2
  typographical, 2
CONVERT, 1238
CONVERT TO, 1317
converting HEAP to MyISAM
  thread state, 954
CONVERT_TZ(), 1200
copy option
  mysqlaccess, 393
copy to tmp table
  thread state, 954
copying databases, 211
copying tables, 1371
Copying to group table
  thread state, 954
Copying to tmp table
  thread state, 954
Copying to tmp table on disk
  thread state, 954
core-file option
  mysqld, 461
core-file option (NDB Cluster programs), 2311
core-file-size option
  mysqld_safe, 274
correct-checksum option
  myisamchk, 376
correlated subqueries, 1448
corruption, 1776
  InnoDB, 1771
COS(), 1191
COT(), 1191
count option
  myisam_ftdump, 368

mysqladmin, 322
mysqlshow, 357
COUNT(), 1282
COUNT(DISTINCT), 1282
counter, 3525
counters
ndbinfo table, 2362
counting
table rows, 235
covering index, 3525
CPACK_MONOLITHIC_INSTALL option
CMake, 171
CPU-bound, 3526
crash, 2829, 3526
recovery, 823
repeated, 2965
replication, 1997
crash recovery, 3526
InnoDB, 1772
crash-me, 950
crash-me program, 949
CrashOnCorruptedTuple, 2141
CRC32(), 1191
CREATE ... IF NOT EXISTS
and replication, 1981
CREATE DATABASE, 1331
Create DB
thread command, 952
CREATE EVENT, 1332
and replication, 1992
CREATE FUNCTION, 1342
CREATE FUNCTION statement, 1536
CREATE INDEX, 1337, 1701
CREATE LOGFILE GROUP, 1341
(see also NDB Cluster Disk Data)
CREATE NODEGROUP command (NDB Cluster), 2318
create option
mysqlslap, 363
CREATE PROCEDURE, 1342
CREATE SCHEMA, 1331
CREATE SERVER, 1348
CREATE TABLE, 1349
DIRECTORY options
and replication, 1988
KEY_BLOCK_SIZE, 1685
options for table compression, 1681
ROW_FORMAT, 1696
statement retention, 1369
table definition, 1369
CREATE TABLE ... SELECT
and replication, 1981
CREATE TABLESPACE, 1379
(see also NDB Cluster Disk Data)
CREATE TRIGGER, 1381
CREATE USER statement, 741, 1510
CREATE VIEW, 1383
create-options option
mysqldump, 339

create-schema option
  mysqlslap, 363
creating
  bug reports, 20
  database, 1331
  databases, 221
  default startup options, 261
  function, 1536
  schema, 1331
  tables, 223
Creating delayed handler
  thread state, 959
Creating index
  thread state, 954
Creating sort index
  thread state, 954
creating table
  thread state, 954
Creating tmp table
  thread state, 954
creating user accounts, 1510
CROSS JOIN, 1436
cross-bootstrap option
  mysql_install_db, 286
Crosses(), 1278
CRUD, 3526
CR_ALREADY_CONNECTED error code, 2948
CR_AUTH_PLUGIN_CANNOT_LOAD error code, 2948
CR_CANT_READ_CHARSET error code, 2945
CR_COMMANDS_OUT_OF_SYNC error code, 2945
CR_CONNECTION_ERROR error code, 2944
CR_CONN_HOST_ERROR error code, 2944
CR_CONN_UNKNOW_PROTOCOL error code, 2947
CR_DATA_TRUNCATED error code, 2946
CR_EMBEDDED_CONNECTION error code, 2945
CR_FETCH_CANCELED error code, 2947
CR_INVALID_BUFFER_USE error code, 2946
CR_INVALID_CONN_HANDLE error code, 2947
CR_INVALID_PARAMETER_NO error code, 2946
CR_IPSOCK_ERROR error code, 2944
CR_LOCALHOST_CONNECTION error code, 2945
CR_MALFORMED_PACKET error code, 2946
CR_NAMEDPIPEOPEN_ERROR error code, 2945
CR_NAMEDPIPESETSTATE_ERROR error code, 2945
CR_NAMEDPIPEWAIT_ERROR error code, 2945
CR_NAMEDPIPE_CONNECTION error code, 2945
CR_NET_PACKET_TOO_LARGE error code, 2945
CR_NEW_STMT_METADATA error code, 2948
CR_NOT_IMPLEMENTED error code, 2948
CR_NO_DATA error code, 2947
CR_NO_PARAMETERS_EXISTS error code, 2946
CR_NO_PREPARE_STMT error code, 2946
CR_NO_RESULT_SET error code, 2947
CR_NO_STMT_METADATA error code, 2947
CR_NULL_POINTER error code, 2946
CR_OUT_OF_MEMORY error code, 2945
CR_PARAMS_NOT_BOUND error code, 2946
CR_PROBE_MASTER_CONNECT error code, 2946

CR_PROBE_SLAVE_CONNECT error code, 2946
CR_PROBE_SLAVE_HOSTS error code, 2946
CR_PROBE_SLAVE_STATUS error code, 2945
CR_SECURE_AUTH error code, 2947
CR_SERVER_GONE_ERROR, 2955
CR_SERVER_GONE_ERROR error code, 2945
CR_SERVER_HANDSHAKE_ERR error code, 2945
CR_SERVER_LOST error code, 2945
CR_SERVER_LOST_ERROR, 2955
CR_SERVER_LOST_EXTENDED error code, 2948
CR_SHARED_MEMORY_CONNECTION error code, 2946
CR_SHARED_MEMORY_CONNECT_ABANDONED_ERROR error code, 2947
CR_SHARED_MEMORY_CONNECT_ANSWER_ERROR error code, 2947
CR_SHARED_MEMORY_CONNECT_FILE_MAP_ERROR error code, 2947
CR_SHARED_MEMORY_CONNECT_MAP_ERROR error code, 2947
CR_SHARED_MEMORY_CONNECT_REQUEST_ERROR error code, 2947
CR_SHARED_MEMORY_CONNECT_SET_ERROR error code, 2947
CR_SHARED_MEMORY_EVENT_ERROR error code, 2947
CR_SHARED_MEMORY_FILE_MAP_ERROR error code, 2947
CR_SHARED_MEMORY_MAP_ERROR error code, 2947
CR_SOCKET_CREATE_ERROR error code, 2944
CR_SSL_CONNECTION_ERROR error code, 2946
CR_STMT_CLOSED error code, 2948
CR_TCP_CONNECTION error code, 2945
CR_UNKNOWN_ERROR error code, 2944
CR_UNKNOWN_HOST error code, 2944
CR_UNSUPPORTED_PARAM_TYPE error code, 2946
CR_VERSION_ERROR error code, 2945
CR_WRONG_HOST_INFO error code, 2945
CR_WRONG_LICENSE error code, 2946
CSV data, reading, 1413, 1436
csv option
  mysqlslap, 363
CSV storage engine, 1781, 1799
CURDATE(), 1200
CURRENT_DATE, 1201
CURRENT_TIME, 1201
CURRENT_TIMESTAMP, 1201
CURRENT_USER(), 1260
cursor, 3526
Cursors, 1494
CURTIME(), 1201
CXX environment variable, 180, 423

D

Daemon
  thread command, 952
daemon option (ndb_mgmd), 2245
daemon plugins, 2773
data
  importing, 314, 350
  loading into tables, 224
  retrieving, 225
  size, 885
data dictionary, 1656, 3526
DATA DIRECTORY
  and replication, 1988
data directory, 3527

data files, 3527
data node (NDB Cluster)
  defined, 2014
data nodes
  memory allocation, 2159
data nodes (NDB Cluster), 2233, 2240
Data on disk (NDB Cluster)
  and INFORMATION_SCHEMA.FILES table, 2586
data structures
  C API, 2659
  C prepared statement API, 2718
Data truncation with CJK characters, 2871
data type
  BIGINT, 1085
  BINARY, 1090, 1108
  BIT, 1084
  BLOB, 1091, 1109
  BOOL, 1084, 1136
  BOOLEAN, 1084, 1136
  CHAR, 1089, 1106
  CHAR VARYING, 1090
  CHARACTER, 1089
  CHARACTER VARYING, 1090
  DATE, 1087, 1097
  DATETIME, 1087, 1097
  DEC, 1086
  DECIMAL, 1086, 1294
  DOUBLE, 1086
  DOUBLE PRECISION, 1087
  ENUM, 1091, 1110
  FIXED, 1086
  FLOAT, 1086, 1086, 1087
  GEOMETRY, 1117
  GEOMETRYCOLLECTION, 1117
  INT, 1085
  INTEGER, 1085
  LINESTRING, 1117
  LONG, 1109
  LONGBLOB, 1091
  LONGTEXT, 1091
  MEDIUMBLOB, 1091
  MEDIUMINT, 1085
  MEDIUMTEXT, 1091
  MULTILINESTRING, 1117
  MULTIPOINT, 1117
  MULTIPOLYGON, 1117
  NATIONAL CHAR, 1089
  NATIONAL VARCHAR, 1090
  NCHAR, 1089
  NUMERIC, 1086
  NVARCHAR, 1090
  POINT, 1117
  POLYGON, 1117
  REAL, 1087
  SET, 1091, 1113
  SMALLINT, 1085
  TEXT, 1091, 1109
  TIME, 1088, 1099

TIMESTAMP, 1087, 1097
TINYBLOB, 1090
TINYINT, 1084
TINYTEXT, 1090
VARBINARY, 1090, 1108
VARCHAR, 1090, 1106
VARCHARACTER, 1090
YEAR, 1088, 1099
data types, 1083
C API, 2652
overview, 1084
data warehouse, 3527
data-file-length option
myisamchk, 376
database, 3527
altering, 1304
creating, 1331
deleting, 1387
renaming, 1392
Database information
obtaining, 1543
database metadata, 2545
database names
case sensitivity, 26, 978
database objects
metadata, 1018
database option
mysql, 300
mysqlbinlog, 398
ndb_blob_tool, 2251
ndb_desc, 2265
ndb_move_data, 2274
ndb_show_tables, 2303
database option (ndb_index_stat), 2270
DATABASE(), 1261
databases
backups, 805
copying, 211
creating, 221, 1331
defined, 4
displaying, 355
dumping, 331, 411
information about, 238
names, 974
replicating, 1881
selecting, 222
symbolic links, 940
using, 221
databases option
mysqlcheck, 328
mysqldump, 339
DataDir, 2120, 2124
datadir option
mysql.server, 279
mysqld, 461
mysqld_safe, 274
mysql_install_db, 286
mysql_plugin, 288

mysql_upgrade, 293
datadir system variable, 509
DataMemory, 2125
DATE, 2971
date and time functions, 1197
Date and Time types, 1096
date calculations, 229
DATE columns
problems, 2971
DATE data type, 1087, 1097
date data types
storage requirements, 1134
date literals, 968
date values
problems, 1098
DATE(), 1201
DATEDIFF(), 1201
dates
used with partitioning, 2460
used with partitioning (examples), 2463, 2476, 2480, 2499
DATETIME data type, 1087, 1097
datetime_format system variable, 509
DATE_ADD(), 1201
date_format system variable, 509
DATE_FORMAT(), 1204
DATE_SUB(), 1201, 1205
DAY(), 1205
DAYNAME(), 1205
DAYOFMONTH(), 1205
DAYOFWEEK(), 1205
DAYOFYEAR(), 1205
db option
mysqlaccess, 393
db table
sorting, 729
system table, 190, 638, 719
DB2 SQL mode, 629
DBI interface, 2766
DBI->quote, 967
DBI->trace, 2833
DBI/DBD interface, 2766
DBI_TRACE environment variable, 423, 2833
DBI_USER environment variable, 423
DBUG package, 2837
DCL, 1513, 1524, 3527
DDL, 1304, 3527
DDL log, 659
deadlock, 932, 1627, 1630, 1631, 1632, 1632, 1730, 3528
deadlock detection, 3528
DEALLOCATE PREPARE, 1481, 1485
Debug
thread command, 952
debug option
comp_err, 284
myisamchk, 372
myisampack, 387
mysql, 300
mysqlaccess, 393

mysqladmin, 322
mysqlbinlog, 399
mysqlcheck, 328
mysqld, 461
mysqldump, 339
mysqldumpslow, 410
mysqlhotcopy, 412
mysqlimport, 352
mysqlshow, 357
mysqlslap, 364
mysql_upgrade, 293
my_print_defaults, 420
debug option (NDB Cluster programs), 2311
debug system variable, 509
debug-check option
mysql, 300
mysqladmin, 322
mysqlbinlog, 399
mysqlcheck, 328
mysqldump, 339
mysqlimport, 352
mysqlshow, 357
mysqlslap, 364
mysql_upgrade, 293
debug-info option
comp_err, 284
mysql, 300
mysqladmin, 322
mysqlbinlog, 399
mysqlcheck, 328
mysqldump, 339
mysqlimport, 352
mysqlshow, 357
mysqlslap, 364
mysql_upgrade, 293
debug-sync-timeout option
mysqld, 462
debugging
client, 2837
server, 2829
debugging support, 167
debug_sync system variable, 510
DEC data type, 1086
decimal arithmetic, 1294
DECIMAL data type, 1086, 1294
decimal point, 1084
DECLARE, 1487
DECODE(), 1254
decode_bits myisamchk variable, 373
DEFAULT
constraint, 31
default
privileges, 190
default accounts, 190
default host name, 255
default installation location, 59
default options, 261
default proxy user, 747

DEFAULT value clause, 1131, 1353
default values, 1131, 1353, 1401
  BLOB and TEXT columns, 1109
  explicit, 1131
  implicit, 1131
  suppression, 31
DEFAULT(), 1289
default-auth option
  mysql, 300
  mysqladmin, 322
  mysqlbinlog, 399
  mysqlcheck, 329
  mysqldump, 339
  mysqlimport, 352
  mysqlshow, 358
  mysqlslap, 364
  mysql_upgrade, 293
default-character-set option
  mysql, 300
  mysqladmin, 322
  mysqlcheck, 328
  mysqld, 462
  mysqldump, 339
  mysqlimport, 352
  mysqlshow, 357
  mysql_upgrade, 293
default-collation option
  mysqld, 462
default-storage-engine option
  mysqld, 463
default-time-zone option
  mysqld, 463
DefaultHashMapSize, 2133, 2176
DefaultOperationRedoProblemAction
  API and SQL nodes, 2175
defaults
  embedded, 2649
defaults-extra-file option, 266, 286
  myisamchk, 372
  mysql, 300
  mysqladmin, 322
  mysqlbinlog, 399
  mysqlcheck, 328
  mysqld, 463
  mysqldump, 339
  mysqld_multi, 281
  mysqld_safe, 274
  mysqlimport, 352
  mysqlshow, 358
  mysqlslap, 364
  mysql_upgrade, 293
  my_print_defaults, 420
  NDB client programs, 2311
defaults-file option, 266, 286
  myisamchk, 373
  mysql, 300
  mysqladmin, 322
  mysqlbinlog, 399

mysqlcheck, 328
mysqld, 463
mysqldump, 339
mysqld_multi, 281
mysqld_safe, 274
mysqlimport, 352
mysqlshow, 358
mysqlslap, 364
mysql_upgrade, 293
my_print_defaults, 420
NDB client programs, 2311
defaults-group-suffix option, 267
myisamchk, 373
mysql, 300
mysqladmin, 322
mysqlbinlog, 399
mysqlcheck, 329
mysqld, 464
mysqldump, 339
mysqlimport, 352
mysqlshow, 358
mysqlslap, 364
mysql_upgrade, 294
my_print_defaults, 420
DEFAULT_CHARSET option
CMake, 174
DEFAULT_COLLATION option
CMake, 174
default_storage_engine system variable, 511
default_week_format system variable, 511
DEFINER privileges, 1560, 2536
DEGREES(), 1191
delay option (ndbinfo_select_all), 2240
delay-key-write option
mysqld, 464, 1790
DELAYED, 1407
INSERT modifier, 1403
when ignored, 1403
Delayed insert
thread command, 952
delayed inserts
thread states, 959
delayed-insert option
mysqldump, 340
delayed_insert_limit, 1409
delayed_insert_limit system variable, 512
delayed_insert_timeout system variable, 513
delayed_queue_size system variable, 513
delay_key_write system variable, 512
DELETE, 1395
and NDB Cluster, 2028
delete, 3528
delete buffering, 3528
delete option
mysqlimport, 353
delete option (ndb_index_stat), 2271
delete-master-logs option
mysqldump, 340

delete-orphans option
  ndb_blob_tool, 2251
deleting
  database, 1387
  foreign key, 1317, 1377
  function, 1537
  index, 1316, 1388
  primary key, 1315
  rows, 2974
  schema, 1387
  table, 1390
  user, 739, 1513
  users, 739, 1513
deleting from main table
  thread state, 955
deleting from reference tables
  thread state, 955
deletion
  mysql.sock, 2968
delimiter command
  mysql, 307
delimiter option
  mysql, 301
  mysqlslap, 364
  ndb_select_all, 2300
denormalized, 3528
deprecated features in MySQL 5.5, 9
derived tables, 1449
des-key-file option
  mysqld, 464
DESC, 1593
descending index, 3528
descending option
  ndb_select_all, 2300
DESCRIBE, 238, 1593
description option
  myisamchk, 377
design
  issues, 2978
DES_DECRYPT(), 1254
DES_ENCRYPT(), 1254
detach option
  mysqlslap, 364
development of NDB Cluster, 2020
development source tree, 166
dictionary collation, German, 1015, 1055, 1055
digits, 1084
Dimension(), 1272
directory structure
  default, 59
dirty page, 1644, 1709, 3528
dirty read, 3528
disable named command
  mysql, 301
--disable option prefix, 261
disable-indexes option
  ndb_restore, 2285
disable-keys option

mysqldump, 340
disable-log-bin option
mysqlbinlog, 399
DISCARD TABLESPACE, 1318, 1658
discard_or_import_tablespace
thread state, 955
disconnect-slave-event-count option
mysqld, 1916
disconnecting
from the server, 217
Disjoint(), 1280
Disk Data tables (NDB Cluster) (see NDB Cluster Disk Data)
disk failure
InnoDB, 1771
disk full, 2967
disk I/O, 895
disk option
ndb_select_all, 2301
disk performance, 939
disk-based, 3529
disk-bound, 3529
DiskCheckpointSpeed, 2149
DiskCheckpointSpeedInRestart, 2150
DiskIOThreadPool, 2165, 2168
Diskless, 2141
diskpagebuffer
ndbinfo table, 2363
DiskPageBufferEntries, 2164
DiskPageBufferMemory, 2164, 2168
disks
splitting data across, 942
DiskSyncSize, 2149
display size, 1084
display triggers, 1580
display width, 1084
displaying
database information, 355
information
Cardinality, 1561
Collation, 1561
SHOW, 1543, 1546, 1579
SHOW statement, 1560, 1562
table status, 1577
DISTINCT, 228, 860
AVG(), 1281
COUNT(), 1282
MAX(), 1283
MIN(), 1283
SELECT modifier, 1433
SUM(), 1284
DISTINCTROW
SELECT modifier, 1433
distributed privileges (NDB Cluster), 2401
and NDB API applications, 2404
DIV, 1188
division (/), 1188
div_precision_increment system variable, 513
DML, 3529

DELETE statement, 1395
INSERT statement, 1400
UPDATE statement, 1455
DNS, 948
DO, 1398
DocBook XML
documentation source format, 2
document id, 3529
Documentation
in Chinese, 2871
in Japanese, 2871
in Korean, 2871
Documenters
list of, 38
dont_ignore_systab_0 option
ndb_restore, 2285
DOUBLE data type, 1086
DOUBLE PRECISION data type, 1087
double quote (\"), 966
doublewrite buffer, 1698, 3529
downgrades
NDB Cluster, 2062, 2325
downgrading, 195, 205, 1608
downloading, 45
drop, 3529
DROP ... IF EXISTS
and replication, 1989
DROP DATABASE, 1387
Drop DB
thread command, 952
DROP EVENT, 1388
DROP FOREIGN KEY, 1317, 1377
DROP FUNCTION, 1389
DROP FUNCTION statement, 1537
DROP INDEX, 1316, 1388, 1701
DROP LOGFILE GROUP, 1389
(see also NDB Cluster Disk Data)
DROP NODEGROUP command (NDB Cluster), 2318
DROP PREPARE, 1485
DROP PRIMARY KEY, 1315
DROP PROCEDURE, 1389
DROP SCHEMA, 1387
DROP SERVER, 1390
DROP TABLE, 1390
and NDB Cluster, 2028
DROP TABLESPACE, 1391
(see also NDB Cluster Disk Data)
DROP TRIGGER, 1391
DROP USER statement, 1513
DROP VIEW, 1391
drop-source option
ndb_move_data, 2274
dropping
user, 739, 1513
dry-scp option (ndb_error_reporter), 2268
dryrun option
mysqlhotcopy, 412
DTrace, 678

and memcached, 1833
DUAL, 1429
dump option
myisam_ftdump, 368
ndb_redo_log_reader, 2278
dump option (ndb_index_stat), 2271
dump-date option
mysqldump, 340
dump-file option
ndb_blob_tool, 2251
dump-slave option
mysqldump, 340
DUMPFILE, 1436
dumping
databases and tables, 331, 411
DYLD_LIBRARY_PATH environment variable, 2659
dynamic row format, 1696, 3529
dynamic table characteristics, 1792

E

early adopter, 3530
edit command
mysql, 308
ego command
mysql, 308
Eiffel Wrapper, 2768
ELT(), 1167
email lists, 17
embedded MySQL server library, 2647
embedded option
mysql_config, 418
embedded-libs option
mysql_config, 418
--enable option prefix, 261
enable-cleartext-plugin option
mysql, 301
mysqladmin, 322
mysqlcheck, 329
mysqldump, 341
mysqlimport, 353
mysqlshow, 358
mysqlslap, 364
enable-named-pipe option
mysqld, 464
enable-pstack option
mysqld, 465
ENABLED_LOCAL_INFILE option
CMake, 175
ENABLED_PROFILING option
CMake, 175
ENABLE_DEBUG_SYNC option
CMake, 174
ENABLE_DOWNLOADS option
CMake, 175
ENABLE_DTRACE option
CMake, 175
ENABLE_GCOV option
CMake, 175

ENCODE(), 1255
ENCRYPT(), 1255
encrypted connections, 751
  command options, 754
encryption, 751
encryption functions, 1252
end
  thread state, 955
END, 1486
EndPoint(), 1274
engine option
  mysqlslap, 364
ENGINES
  INFORMATION_SCHEMA table, 2551
engine_condition_pushdown system variable, 514
ENTER SINGLE USER MODE command (NDB Cluster), 2317
entering
  queries, 218
enterprise components
  MySQL Enterprise Audit, 784, 2843
  MySQL Enterprise Backup, 2842
  MySQL Enterprise Encryption, 2843
  MySQL Enterprise Firewall, 2843
  MySQL Enterprise Monitor, 2841
  MySQL Enterprise Security, 768, 776, 2842
  MySQL Enterprise Thread Pool, 665, 2844
ENUM
  size, 1136
ENUM data type, 1091, 1110
Envelope(), 1273
environment variable
  AUTHENTICATION_PAM_LOG, 776
  CC, 180, 423
  CXX, 180, 423
  DBI_TRACE, 423, 2833
  DBI_USER, 423
  DYLD_LIBRARY_PATH, 2659
  HOME, 312, 423
  LD_LIBRARY_PATH, 214, 2659
  LD_RUN_PATH, 214, 423
  LIBMYSQL_ENABLE_CLEARTEXT_PLUGIN, 423
  LIBMYSQL_PLUGINS, 2753
  MYSQL_DEBUG, 254, 423, 2837
  MYSQL_GROUP_SUFFIX, 423
  MYSQL_HISTFILE, 312, 423
  MYSQL_HOME, 423
  MYSQL_HOST, 258, 423
  MYSQL_PS1, 423
  MYSQL_PWD, 254, 258, 423
  MYSQL_TCP_PORT, 254, 423, 677, 678
  MYSQL_UNIX_PORT, 185, 254, 423, 677, 678
  PATH, 119, 125, 188, 255, 423
  TMPDIR, 185, 254, 423, 2968
  TZ, 423, 2969
  UMASK, 423, 2962
  UMASK_DIR, 423, 2962
  USER, 258, 423
environment variables, 254, 271, 732

list of, 423
equal (=), 1154
Equals(), 1280
eq_ref join type
optimizer, 907
Errcode, 421
errno, 421
Error
thread command, 952
error code
CR_ALREADY_CONNECTED, 2948
CR_AUTH_PLUGIN_CANNOT_LOAD, 2948
CR_CANT_READ_CHARSET, 2945
CR_COMMANDS_OUT_OF_SYNC, 2945
CR_CONNECTION_ERROR, 2944
CR_CONN_HOST_ERROR, 2944
CR_CONN_UNKNOW_PROTOCOL, 2947
CR_DATA_TRUNCATED, 2946
CR_EMBEDDED_CONNECTION, 2945
CR_FETCH_CANCELED, 2947
CR_INVALID_BUFFER_USE, 2946
CR_INVALID_CONN_HANDLE, 2947
CR_INVALID_PARAMETER_NO, 2946
CR_IPSOCK_ERROR, 2944
CR_LOCALHOST_CONNECTION, 2945
CR_MALFORMED_PACKET, 2946
CR_NAMEDPIPEOPEN_ERROR, 2945
CR_NAMEDPIPESETSTATE_ERROR, 2945
CR_NAMEDPIPEWAIT_ERROR, 2945
CR_NAMEDPIPE_CONNECTION, 2945
CR_NET_PACKET_TOO_LARGE, 2945
CR_NEW_STMT_METADATA, 2948
CR_NOT_IMPLEMENTED, 2948
CR_NO_DATA, 2947
CR_NO_PARAMETERS_EXISTS, 2946
CR_NO_PREPARE_STMT, 2946
CR_NO_RESULT_SET, 2947
CR_NO_STMT_METADATA, 2947
CR_NULL_POINTER, 2946
CR_OUT_OF_MEMORY, 2945
CR_PARAMS_NOT_BOUND, 2946
CR_PROBE_MASTER_CONNECT, 2946
CR_PROBE_SLAVE_CONNECT, 2946
CR_PROBE_SLAVE_HOSTS, 2946
CR_PROBE_SLAVE_STATUS, 2945
CR_SECURE_AUTH, 2947
CR_SERVER_GONE_ERROR, 2945
CR_SERVER_HANDSHAKE_ERR, 2945
CR_SERVER_LOST, 2945
CR_SERVER_LOST_EXTENDED, 2948
CR_SHARED_MEMORY_CONNECTION, 2946
CR_SHARED_MEMORY_CONNECT_ABANDONED_ERROR, 2947
CR_SHARED_MEMORY_CONNECT_ANSWER_ERROR, 2947
CR_SHARED_MEMORY_CONNECT_FILE_MAP_ERROR, 2947
CR_SHARED_MEMORY_CONNECT_MAP_ERROR, 2947
CR_SHARED_MEMORY_CONNECT_REQUEST_ERROR, 2947
CR_SHARED_MEMORY_CONNECT_SET_ERROR, 2947
CR_SHARED_MEMORY_EVENT_ERROR, 2947

CR_SHARED_MEMORY_FILE_MAP_ERROR, 2947
CR_SHARED_MEMORY_MAP_ERROR, 2947
CR_SOCKET_CREATE_ERROR, 2944
CR_SSL_CONNECTION_ERROR, 2946
CR_STMT_CLOSED, 2948
CR_TCP_CONNECTION, 2945
CR_UNKNOWN_ERROR, 2944
CR_UNKNOWN_HOST, 2944
CR_UNSUPPORTED_PARAM_TYPE, 2946
CR_VERSION_ERROR, 2945
CR_WRONG_HOST_INFO, 2945
CR_WRONG_LICENSE, 2946
ER_ABORTING_CONNECTION, 2903
ER_ACCESS_DENIED_ERROR, 2896
ER_ACCESS_DENIED_NO_PASSWORD_ERROR, 2941
ER_ADD_PARTITION_NO_NEW_PARTITION, 2927
ER_ADD_PARTITION_SUBPART_ERROR, 2927
ER_ADMIN_WRONG_MRG_TABLE, 2924
ER_ALTER_FILEGROUP_FAILED, 2928
ER_ALTER_INFO, 2899
ER_AMBIGUOUS_FIELD_TERM, 2924
ER_AUTOINC_READ_FAILED, 2924
ER_AUTO_CONVERT, 2910
ER_BAD_DB_ERROR, 2896
ER_BAD_FIELD_ERROR, 2897
ER_BAD_FT_COLUMN, 2912
ER_BAD_HOST_ERROR, 2896
ER_BAD_LOG_STATEMENT, 2932
ER_BAD_NULL_ERROR, 2896
ER_BAD_SLAVE, 2907
ER_BAD_SLAVE_UNTIL_COND, 2912
ER_BAD_TABLE_ERROR, 2896
ER_BASE64_DECODE_ERROR, 2931
ER_BINLOG_CREATE_ROUTINE_NEED_SUPER, 2921
ER_BINLOG_LOGGING_IMPOSSIBLE, 2933
ER_BINLOG_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE, 2938
ER_BINLOG_PURGE_EMFILE, 2932
ER_BINLOG_PURGE_FATAL_ERR, 2918
ER_BINLOG_PURGE_PROHIBITED, 2918
ER_BINLOG_ROW_ENGINE_AND_STMT_ENGINE, 2937
ER_BINLOG_ROW_INJECTION_AND_STMT_ENGINE, 2937
ER_BINLOG_ROW_INJECTION_AND_STMT_MODE, 2937
ER_BINLOG_ROW_LOGGING_FAILED, 2928
ER_BINLOG_ROW_MODE_AND_STMT_ENGINE, 2937
ER_BINLOG_ROW_RBR_TO_SBR, 2929
ER_BINLOG_ROW_WRONG_TABLE_DEF, 2928
ER_BINLOG_STMT_MODE_AND_ROW_ENGINE, 2937
ER_BINLOG_UNSAFE_AND_STMT_ENGINE, 2937
ER_BINLOG_UNSAFE_AUTOINC_COLUMNS, 2938
ER_BINLOG_UNSAFE_AUTOINC_NOT_FIRST, 2944
ER_BINLOG_UNSAFE_CREATE_IGNORE_SELECT, 2943
ER_BINLOG_UNSAFE_CREATE_REPLACE_SELECT, 2943
ER_BINLOG_UNSAFE_CREATE_SELECT_AUTOINC, 2943
ER_BINLOG_UNSAFE_INSERT_DELAYED, 2938
ER_BINLOG_UNSAFE_INSERT_IGNORE_SELECT, 2942
ER_BINLOG_UNSAFE_INSERT_SELECT_UPDATE, 2942
ER_BINLOG_UNSAFE_INSERT_TWO_KEYS, 2943
ER_BINLOG_UNSAFE_LIMIT, 2938

ER_BINLOG_UNSAFE_MIXED_STATEMENT, 2940
ER_BINLOG_UNSAFE_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE, 2940
ER_BINLOG_UNSAFE_NONTRANS_AFTER_TRANS, 2938
ER_BINLOG_UNSAFE_REPLACE_SELECT, 2943
ER_BINLOG_UNSAFE_ROUTINE, 2921
ER_BINLOG_UNSAFE_STATEMENT, 2932
ER_BINLOG_UNSAFE_SYSTEM_FUNCTION, 2938
ER_BINLOG_UNSAFE_SYSTEM_TABLE, 2938
ER_BINLOG_UNSAFE_SYSTEM_VARIABLE, 2938
ER_BINLOG_UNSAFE_UDF, 2938
ER_BINLOG_UNSAFE_UPDATE_IGNORE, 2943
ER_BINLOG_UNSAFE_WRITE_AUTOINC_SELECT, 2943
ER_BLOBS_AND_NO_TERMINATED, 2899
ER_BLOB_CANT_HAVE_DEFAULT, 2900
ER_BLOB_FIELD_IN_PART_FUNC_ERROR, 2926
ER_BLOB_KEY_WITHOUT_LENGTH, 2905
ER_BLOB_USED_AS_KEY, 2898
ER_CANNOT_ADD_FOREIGN, 2908
ER_CANNOT_LOAD_FROM_TABLE, 2929
ER_CANNOT_USER, 2919
ER_CANT_ACTIVATE_LOG, 2931
ER_CANT_AGGREGATE_2COLLATIONS, 2911
ER_CANT_AGGREGATE_3COLLATIONS, 2911
ER_CANT_AGGREGATE_NCOLLATIONS, 2911
ER_CANT_CHANGE_TX_ISOLATION, 2931
ER_CANT_CREATE_DB, 2893
ER_CANT_CREATE_FEDERATED_TABLE, 2922
ER_CANT_CREATE_FILE, 2893
ER_CANT_CREATE_GEOMETRY_OBJECT, 2921
ER_CANT_CREATE_HANDLER_FILE, 2926
ER_CANT_CREATE_SROUTINE, 2933
ER_CANT_CREATE_TABLE, 2893
ER_CANT_CREATE_THREAD, 2902
ER_CANT_CREATE_USER_WITH_GRANT, 2920
ER_CANT_DELETE_FILE, 2894
ER_CANT_DO_THIS_DURING_AN_TRANSACTION, 2905
ER_CANT_DROP_FIELD_OR_KEY, 2899
ER_CANT_FIND_DL_ENTRY, 2902
ER_CANT_FIND_SYSTEM_REC, 2894
ER_CANT_FIND_UDF, 2901
ER_CANT_GET_STAT, 2894
ER_CANT_GET_WD, 2894
ER_CANT_INITIALIZE_UDF, 2902
ER_CANT_LOCK, 2894
ER_CANT_LOCK_LOG_TABLE, 2930
ER_CANT_OPEN_FILE, 2894
ER_CANT_OPEN_LIBRARY, 2902
ER_CANT_READ_DIR, 2894
ER_CANT_REMOVE_ALL_FIELDS, 2899
ER_CANT_RENAME_LOG_TABLE, 2932
ER_CANT_REOPEN_TABLE, 2902
ER_CANT_SET_WD, 2894
ER_CANT_UPDATE_USED_TABLE_IN_SF_OR_TRG, 2922
ER_CANT_UPDATE_WITH_READLOCK, 2908
ER_CANT_USE_OPTION_HERE, 2909
ER_CANT_WRITE_LOCK_LOG_TABLE, 2930
ER_CHECKREAD, 2894
ER_CHECK_NOT_IMPLEMENTED, 2905

ER_CHECK_NO_SUCH_TABLE, 2905
ER_COALESCE_ONLY_ON_HASH_PARTITION, 2927
ER_COALESCE_PARTITION_NO_PARTITION, 2927
ER_COLLATION_CHARSET_MISMATCH, 2910
ER_COLUMNACCESS_DENIED_ERROR, 2903
ER_COL_COUNT_DOESNT_MATCH_CORRUPTED, 2929
ER_COL_COUNT_DOESNT_MATCH_PLEASE_UPDATE, 2930
ER_COMMIT_NOT_ALLOWED_IN_SF_OR_TRG, 2921
ER_COND_ITEM_TOO_LONG, 2936
ER_CONFLICTING_DECLARATIONS, 2913
ER_CONFLICT_FN_PARSE_ERROR, 2935
ER_CONNECT_TO_FOREIGN_DATA_SOURCE, 2921
ER_CONNECT_TO_MASTER, 2908
ER_CONSECUTIVE_REORG_PARTITIONS, 2927
ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR, 2925
ER_CON_COUNT_ERROR, 2896
ER_CORRUPT_HELP_DB, 2910
ER_CRASHED_ON_REPAIR, 2906
ER_CRASHED_ON_USAGE, 2906
ER_CREATE_DB_WITH_READ_LOCK, 2907
ER_CREATE_FILEGROUP_FAILED, 2928
ER_CUT_VALUE_GROUP_CONCAT, 2911
ER_CYCLIC_REFERENCE, 2910
ER_DATABASE_NAME, 2935
ER_DATA_OUT_OF_RANGE, 2940
ER_DATA_TOO_LONG, 2920
ER_DATETIME_FUNCTION_OVERFLOW, 2922
ER_DBACCESS_DENIED_ERROR, 2896
ER_DB_CREATE_EXISTS, 2893
ER_DB_DROP_DELETE, 2894
ER_DB_DROP_EXISTS, 2894
ER_DB_DROP_RMDIR, 2894
ER_DDL_LOG_ERROR, 2931
ER_DEBUG_SYNC_HIT_LIMIT, 2936
ER_DEBUG_SYNC_TIMEOUT, 2936
ER_DELAYED_CANT_CHANGE_LOCK, 2903
ER_DELAYED_INSERT_TABLE_LOCKED, 2904
ER_DELAYED_NOT_SUPPORTED, 2934
ER_DERIVED_MUST_HAVE_ALIAS, 2910
ER_DIFF_GROUPS_PROC, 2919
ER_DISK_FULL, 2895
ER_DIVISION_BY_ZERO, 2917
ER_DROP_DB_WITH_READ_LOCK, 2907
ER_DROP_FILEGROUP_FAILED, 2928
ER_DROP_INDEX_FK, 2930
ER_DROP_LAST_PARTITION, 2927
ER_DROP_PARTITION_NON_EXISTENT, 2927
ER_DROP_USER, 2911
ER_DUMP_NOT_IMPLEMENTED, 2906
ER_DUPLICATED_VALUE_IN_TYPE, 2913
ER_DUP_ARGUMENT, 2909
ER_DUP_ENTRY, 2898
ER_DUP_ENTRY_AUTOINCREMENT_CASE, 2931
ER_DUP_ENTRY_WITH_KEY_NAME, 2932
ER_DUP_FIELDNAME, 2897
ER_DUP_KEY, 2895
ER_DUP_KEYNAME, 2897
ER_DUP_SIGNAL_SET, 2936

ER_DUP_UNIQUE, 2904
ER_EMPTY_QUERY, 2898
ER_ERROR_DURING_CHECKPOINT, 2906
ER_ERROR_DURING_COMMIT, 2905
ER_ERROR_DURING_FLUSH_LOGS, 2905
ER_ERROR_DURING_ROLLBACK, 2905
ER_ERROR_IN_TRIGGER_BODY, 2942
ER_ERROR_IN_UNKNOWN_TRIGGER_BODY, 2942
ER_ERROR_ON_CLOSE, 2895
ER_ERROR_ON_READ, 2895
ER_ERROR_ON_RENAME, 2895
ER_ERROR_ON_WRITE, 2895
ER_ERROR_WHEN_EXECUTING_COMMAND, 2908
ER_EVENTS_DB_ERROR, 2931
ER_EVENT_ALREADY_EXISTS, 2929
ER_EVENT_CANNOT_ALTER_IN_THE_PAST, 2932
ER_EVENT_CANNOT_CREATE_IN_THE_PAST, 2932
ER_EVENT_CANNOT_DELETE, 2929
ER_EVENT_CANT_ALTER, 2929
ER_EVENT_COMPILE_ERROR, 2929
ER_EVENT_DATA_TOO_LONG, 2930
ER_EVENT_DOES_NOT_EXIST, 2929
ER_EVENT_DROP_FAILED, 2929
ER_EVENT_ENDS_BEFORE_STARTS, 2929
ER_EVENT_EXEC_TIME_IN_THE_PAST, 2929
ER_EVENT_INTERVAL_NOT_POSITIVE_OR_TOO_BIG, 2929
ER_EVENT_INVALID_CREATION_CTX, 2933
ER_EVENT_MODIFY_QUEUE_ERROR, 2931
ER_EVENT_NEITHER_M_EXPR_NOR_M_AT, 2929
ER_EVENT_OPEN_TABLE_FAILED, 2929
ER_EVENT_RECURSION_FORBIDDEN, 2931
ER_EVENT_SAME_NAME, 2929
ER_EVENT_SET_VAR_ERROR, 2931
ER_EVENT_STORE_FAILED, 2929
ER_EXCEPTIONS_WRITE_ERROR, 2935
ER_EXEC_STMT_WITH_OPEN_CURSOR, 2921
ER_FAILED_READ_FROM_PAR_FILE, 2940
ER_FAILED_ROUTINE_BREAK_BINLOG, 2921
ER_FEATURE_DISABLED, 2913
ER_FIELD_NOT_FOUND_PART_ERROR, 2925
ER_FIELD_SPECIFIED_TWICE, 2901
ER_FIELD_TYPE_NOT_ALLOWED_AS_PARTITION_FIELD, 2937
ER_FILEGROUP_OPTION_ONLY_ONCE, 2928
ER_FILE_EXISTS_ERROR, 2899
ER_FILE_NOT_FOUND, 2894
ER_FILE_USED, 2895
ER_FILSORT_ABORT, 2895
ER_FLUSH_MASTER_BINLOG_CLOSED, 2906
ER_FORBID_SCHEMA_CHANGE, 2923
ER_FORCING_CLOSE, 2899
ER_FOREIGN_DATA_SOURCE_DOESNT_EXIST, 2922
ER_FOREIGN_DATA_STRING_INVALID, 2922
ER_FOREIGN_DATA_STRING_INVALID_CANT_CREATE, 2922
ER_FOREIGN_DUPLICATE_KEY, 2930
ER_FOREIGN_KEY_ON_PARTITIONED, 2927
ER_FOREIGN_SERVER_DOESNT_EXIST, 2925
ER_FOREIGN_SERVER_EXISTS, 2925
ER_FORM_NOT_FOUND, 2895

ER_FPARSER_BAD_HEADER, 2916
ER_FPARSER_EOF_IN_COMMENT, 2916
ER_FPARSER_EOF_IN_UNKNOWN_PARAMETER, 2916
ER_FPARSER_ERROR_IN_PARAMETER, 2916
ER_FPARSER_TOO_BIG_FILE, 2916
ER_FRM_UNKNOWN_TYPE, 2916
ER_FSEEK_FAIL, 2918
ER_FT_MATCHING_KEY_NOT_FOUND, 2906
ER_FUNCTION_NOT_DEFINED, 2902
ER_FUNC_INEXISTENT_NAME_COLLISION, 2935
ER_GET_ERRMSG, 2913
ER_GET_ERRNO, 2895
ER_GET_TEMPORARY_ERRMSG, 2913
ER_GLOBAL_VARIABLE, 2909
ER_GOT_SIGNAL, 2899
ER_GRANT_PLUGIN_USER_EXISTS, 2941
ER_GRANT_WRONG_HOST_OR_USER, 2903
ER_HANDSHAKE_ERROR, 2896
ER_HASHCHK, 2893
ER_HOSTNAME, 2924
ER_HOST_IS_BLOCKED, 2902
ER_HOST_NOT_PRIVILEGED, 2902
ER_ILLEGAL_GRANT_FOR_TABLE, 2903
ER_ILLEGAL_HA, 2895
ER_ILLEGAL_HA_CREATE_OPTION, 2925
ER_ILLEGAL_REFERENCE, 2910
ER_ILLEGAL_VALUE_FOR_TYPE, 2918
ER_INCONSISTENT_PARTITION_INFO_ERROR, 2926
ER_INCONSISTENT_TYPE_OF_FUNCTIONS_ERROR, 2926
ER_INCORRECT_GLOBAL_LOCAL_VAR, 2909
ER_INDEX_COLUMN_TOO_LONG, 2942
ER_INDEX_CORRUPT, 2942
ER_INDEX_REBUILD, 2906
ER_INSERT_INFO, 2899
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_DIRECT, 2939
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_FORMAT, 2939
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_SQL_LOG_BIN, 2940
ER_INVALID_CHARACTER_STRING, 2913
ER_INVALID_DEFAULT, 2898
ER_INVALID_GROUP_FUNC_USE, 2901
ER_INVALID_ON_UPDATE, 2913
ER_INVALID_USE_OF_NULL, 2902
ER_IO_ERR_LOG_INDEX_READ, 2918
ER_IPSOCK_ERROR, 2899
ER_KEY_COLUMN_DOES_NOT_EXITS, 2898
ER_KEY_DOES_NOT_EXITS, 2905
ER_KEY_NOT_FOUND, 2895
ER_KEY_PART_0, 2919
ER_KEY_REF_DO_NOT_MATCH_TABLE_REF, 2909
ER_KILL_DENIED_ERROR, 2900
ER_LIMITED_PART_RANGE, 2928
ER_LIST_OF_FIELDS_ONLY_IN_HASH_ERROR, 2926
ER_LOAD_DATA_INVALID_COLUMN, 2934
ER_LOAD_FROM_FIXED_SIZE_ROWS_TO_VAR, 2920
ER_LOAD_INFO, 2899
ER_LOCAL_VARIABLE, 2909
ER_LOCK_ABORTED, 2940
ER_LOCK_DEADLOCK, 2908

ER_LOCK_OR_ACTIVE_TRANSACTION, 2906
ER_LOCK_TABLE_FULL, 2907
ER_LOCK_WAIT_TIMEOUT, 2907
ER_LOGGING_PROHIBIT_CHANGING_OF, 2919
ER_LOG_IN_USE, 2918
ER_LOG_PURGE_NO_FILE, 2934
ER_LOG_PURGE_UNKNOWN_ERR, 2918
ER_MALFORMED_DEFINER, 2923
ER_MASTER, 2906
ER_MASTER_FATAL_ERROR_READING_BINLOG, 2909
ER_MASTER_INFO, 2907
ER_MASTER_NET_READ, 2906
ER_MASTER_NET_WRITE, 2906
ER_MAXVALUE_IN_VALUES_IN, 2937
ER_MAX_PREPARED_STMT_COUNT_REACHED, 2924
ER_MESSAGE_AND_STATEMENT, 2939
ER_MISSING_SKIP_SLAVE, 2912
ER_MIXING_NOT_ALLOWED, 2909
ER_MIX_HANDLER_ERROR, 2926
ER_MIX_OF_GROUP_FUNC_AND_FIELDS, 2903
ER_MULTIPLE_DEF_CONST_IN_LIST_PART_ERROR, 2926
ER_MULTIPLE_PRI_KEY, 2898
ER_MULTI_UPDATE_KEY_CONFLICT, 2941
ER_M_BIGGER_THAN_D, 2921
ER_NAME_BECOMES_EMPTY, 2924
ER_NATIVE_FCT_NAME_COLLISION, 2932
ER_NDB_CANT_SWITCH_BINLOG_FORMAT, 2930
ER_NDB_REPLICATION_SCHEMA_ERROR, 2935
ER_NEED_REPREPARE, 2934
ER_NET_ERROR_ON_WRITE, 2904
ER_NET_FCNTL_ERROR, 2904
ER_NET_PACKETS_OUT_OF_ORDER, 2904
ER_NET_PACKET_TOO_LARGE, 2903
ER_NET_READ_ERROR, 2904
ER_NET_READ_ERROR_FROM_PIPE, 2904
ER_NET_READ_INTERRUPTED, 2904
ER_NET_UNCOMPRESS_ERROR, 2904
ER_NET_WRITE_INTERRUPTED, 2904
ER_NEVER_USED, 2933
ER_NEW_ABORTING_CONNECTION, 2906
ER_NISAMCHK, 2893
ER_NO, 2893
ER_NONEXISTING_GRANT, 2903
ER_NONEXISTING_PROC_GRANT, 2920
ER_NONEXISTING_TABLE_GRANT, 2903
ER_NONUNIQ_TABLE, 2898
ER_NONUPDATEABLE_COLUMN, 2916
ER_NON_GROUPING_FIELD_USED, 2924
ER_NON_INSERTABLE_TABLE, 2924
ER_NON_UNIQ_ERROR, 2896
ER_NON_UPDATABLE_TABLE, 2913
ER_NORMAL_SHUTDOWN, 2898
ER_NOT_ALLOWED_COMMAND, 2903
ER_NOT_FORM_FILE, 2895
ER_NOT_KEYFILE, 2895
ER_NOT_SUPPORTED_AUTH_MODE, 2910
ER_NOT_SUPPORTED_YET, 2909
ER_NO_BINARY_LOGGING, 2918

ER_NO_BINLOG_ERROR, 2927
ER_NO_CONST_EXPR_IN_RANGE_OR_LIST_ERROR, 2925
ER_NO_DB_ERROR, 2896
ER_NO_DEFAULT, 2909
ER_NO_DEFAULT_FOR_FIELD, 2917
ER_NO_DEFAULT_FOR_VIEW_FIELD, 2921
ER_NO_FILE_MAPPING, 2919
ER_NO_FORMAT_DESCRIPTION_EVENT_BEFORE_BINLOG_STATEMENT, 2934
ER_NO_GROUP_FOR_PROC, 2919
ER_NO_PARTITION_FOR_GIVEN_VALUE, 2928
ER_NO_PARTITION_FOR_GIVEN_VALUE_SILENT, 2932
ER_NO_PARTS_ERROR, 2926
ER_NO_PERMISSION_TO_CREATE_USER, 2907
ER_NO_RAID_COMPILED, 2905
ER_NO_REFERENCED_ROW, 2908
ER_NO_REFERENCED_ROW_2, 2923
ER_NO_SUCH_INDEX, 2899
ER_NO_SUCH_TABLE, 2903
ER_NO_SUCH_THREAD, 2900
ER_NO_SUCH_USER, 2923
ER_NO_TABLES_USED, 2900
ER_NO_TRIGGERS_ON_SYSTEM_SCHEMA, 2924
ER_NO_UNIQUE_LOGFILE, 2900
ER_NULL_COLUMN_IN_INDEX, 2901
ER_NULL_IN_VALUES_LESS_THAN, 2931
ER_OLD_FILE_FORMAT, 2923
ER_OLD_KEYFILE, 2895
ER_ONLY_INTEGERS_ALLOWED, 2931
ER_ONLY_ON_RANGE_LIST_PARTITION, 2927
ER_OPEN_AS_READONLY, 2896
ER_OPERAND_COLUMNS, 2910
ER_OPTION_PREVENTS_STATEMENT, 2913
ER_ORDER_WITH_PROC, 2919
ER_OUTOFMEMORY, 2896
ER_OUT_OF_RESOURCES, 2896
ER_OUT_OF_SORTMEMORY, 2896
ER_PARSE_ERROR, 2898
ER_PARTITIONS_MUST_BE_DEFINED_ERROR, 2926
ER_PARTITION_COLUMN_LIST_ERROR, 2936
ER_PARTITION_CONST_DOMAIN_ERROR, 2930
ER_PARTITION_ENTRY_ERROR, 2926
ER_PARTITION_FIELDS_TOO_LONG, 2937
ER_PARTITION_FUNCTION_FAILURE, 2928
ER_PARTITION_FUNCTION_IS_NOT_ALLOWED, 2930
ER_PARTITION_FUNC_NOT_ALLOWED_ERROR, 2926
ER_PARTITION_MAXVALUE_ERROR, 2925
ER_PARTITION_MERGE_ERROR, 2931
ER_PARTITION_MGMT_ON_NONPARTITIONED, 2927
ER_PARTITION_NAME, 2935
ER_PARTITION_NOT_DEFINED_ERROR, 2926
ER_PARTITION_NO_TEMPORARY, 2930
ER_PARTITION_REQUIRES_VALUES_ERROR, 2925
ER_PARTITION_SUBPARTITION_ERROR, 2925
ER_PARTITION_SUBPART_MIX_ERROR, 2925
ER_PARTITION_WRONG_NO_PART_ERROR, 2925
ER_PARTITION_WRONG_NO_SUBPART_ERROR, 2925
ER_PARTITION_WRONG_VALUES_ERROR, 2925
ER_PART_STATE_ERROR, 2928

ER_PASSWD_LENGTH, 2918
ER_PASSWORD_ANONYMOUS_USER, 2902
ER_PASSWORD_NOT_ALLOWED, 2902
ER_PASSWORD_NO_MATCH, 2902
ER_PATH_LENGTH, 2939
ER_PLUGIN_IS_NOT_LOADED, 2928
ER_PLUGIN_IS_PERMANENT, 2941
ER_PLUGIN_NO_INSTALL, 2943
ER_PLUGIN_NO_UNINSTALL, 2943
ER_PRIMARY_CANT_HAVE_NULL, 2905
ER_PROCACCESS_DENIED_ERROR, 2918
ER_PROC_AUTO_GRANT_FAIL, 2920
ER_PROC_AUTO_REVOKE_FAIL, 2920
ER_PS_MANY_PARAM, 2919
ER_PS_NO_RECURSION, 2922
ER_QUERY_CACHE_DISABLED, 2936
ER_QUERY_INTERRUPTED, 2914
ER_QUERY_ON_FOREIGN_DATA_SOURCE, 2922
ER_QUERY_ON_MASTER, 2908
ER_RANGE_NOT_INCREASING_ERROR, 2926
ER_RBR_NOT_AVAILABLE, 2931
ER_READY, 2898
ER_READ_ONLY_TRANSACTION, 2907
ER_RECORD_FILE_FULL, 2901
ER_REGEXP_ERROR, 2903
ER_RELAY_LOG_FAIL, 2918
ER_RELAY_LOG_INIT, 2918
ER_REMOVED_SPACES, 2924
ER_RENAMED_NAME, 2935
ER_REORG_HASH_ONLY_ON_SAME_NO, 2927
ER_REORG_NO_PARAM_ERROR, 2927
ER_REORG_OUTSIDE_RANGE, 2928
ER_REORG_PARTITION_NOT_EXIST, 2927
ER_REQUIRES_PRIMARY_KEY, 2905
ER_RESERVED_SYNTAX, 2918
ER_RESIGNAL_WITHOUT_ACTIVE_HANDLER, 2936
ER_REVOKE_GRANTS, 2911
ER_ROW_IS_REFERENCED, 2908
ER_ROW_IS_REFERENCED_2, 2923
ER_ROW_SINGLE_PARTITION_FIELD_ERROR, 2937
ER_SAME_NAME_PARTITION, 2927
ER_SAME_NAME_PARTITION_FIELD, 2936
ER_SELECT_REDUCED, 2910
ER_SERVER_IS_IN_SECURE_AUTH_MODE, 2912
ER_SERVER_SHUTDOWN, 2897
ER_SET_CONSTANTS_ONLY, 2907
ER_SET_PASSWORD_AUTH_PLUGIN, 2941
ER_SHUTDOWN_COMPLETE, 2899
ER_SIGNAL_BAD_CONDITION_TYPE, 2936
ER_SIGNAL_EXCEPTION, 2936
ER_SIGNAL_NOT_FOUND, 2936
ER_SIGNAL_WARN, 2936
ER_SIZE_OVERFLOW_ERROR, 2928
ER_SLAVE_AMBIGOUS_EXEC_MODE, 2933
ER_SLAVE_CANT_CREATE_CONVERSION, 2939
ER_SLAVE_CONVERSION_FAILED, 2939
ER_SLAVE_CORRUPT_EVENT, 2934
ER_SLAVE_CREATE_EVENT_FAILURE, 2933

ER_SLAVE_FATAL_ERROR, 2932
ER_SLAVE_HEARTBEAT_FAILURE, 2935
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE, 2935
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MAX, 2941
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MIN, 2941
ER_SLAVE_IGNORED_SSL_PARAMS, 2912
ER_SLAVE_IGNORED_TABLE, 2909
ER_SLAVE_IGNORE_SERVER_IDS, 2936
ER_SLAVE_INCIDENT, 2932
ER_SLAVE_MASTER_COM_FAILURE, 2933
ER_SLAVE_MUST_STOP, 2906
ER_SLAVE_NOT_RUNNING, 2907
ER_SLAVE_RELAY_LOG_READ_FAILURE, 2933
ER_SLAVE_RELAY_LOG_WRITE_FAILURE, 2933
ER_SLAVE_THREAD, 2907
ER_SLAVE_WAS_NOT_RUNNING, 2910
ER_SLAVE_WAS_RUNNING, 2910
ER_SPATIAL_CANT_HAVE_NULL, 2910
ER_SPATIAL_MUST_HAVE_GEOM_COL, 2940
ER_SPECIFIC_ACCESS_DENIED_ERROR, 2909
ER_SP_ALREADY_EXISTS, 2914
ER_SP_BADRETURN, 2914
ER_SP_BADSELECT, 2914
ER_SP_BADSTATEMENT, 2914
ER_SP_BAD_CURSOR_QUERY, 2915
ER_SP_BAD_CURSOR_SELECT, 2915
ER_SP_BAD_SQLSTATE, 2920
ER_SP_BAD_VAR_SHADOW, 2923
ER_SP_CANT_ALTER, 2915
ER_SP_CANT_SET_AUTOCOMMIT, 2923
ER_SP_CASE_NOT_FOUND, 2916
ER_SP_COND_MISMATCH, 2915
ER_SP_CURSOR_AFTER_HANDLER, 2916
ER_SP_CURSOR_ALREADY_OPEN, 2915
ER_SP_CURSOR_MISMATCH, 2915
ER_SP_CURSOR_NOT_OPEN, 2915
ER_SP_DOES_NOT_EXIST, 2914
ER_SP_DROP_FAILED, 2914
ER_SP_DUP_COND, 2915
ER_SP_DUP_CURS, 2915
ER_SP_DUP_HANDLER, 2920
ER_SP_DUP_PARAM, 2915
ER_SP_DUP_VAR, 2915
ER_SP_FETCH_NO_DATA, 2915
ER_SP_GOTO_IN_HNDLR, 2917
ER_SP_LABEL_MISMATCH, 2914
ER_SP_LABEL_REDEFINE, 2914
ER_SP_LILABEL_MISMATCH, 2914
ER_SP_NORETURN, 2915
ER_SP_NORETURNEND, 2915
ER_SP_NOT_VAR_ARG, 2920
ER_SP_NO_AGGREGATE, 2924
ER_SP_NO_DROP_SP, 2917
ER_SP_NO_RECURSION, 2921
ER_SP_NO_RECURSIVE_CREATE, 2914
ER_SP_NO_RETSET, 2921
ER_SP_PROC_TABLE_CORRUPT, 2923
ER_SP_RECURSION_LIMIT, 2923

ER_SP_STORE_FAILED, 2914
ER_SP_SUBSELECT_NYI, 2915
ER_SP_UNDECLARED_VAR, 2915
ER_SP_UNINIT_VAR, 2914
ER_SP_VARCOND_AFTER_CURSHNDLR, 2916
ER_SP_WRONG_NAME, 2923
ER_SP_WRONG_NO_OF_ARGS, 2914
ER_SP_WRONG_NO_OF_FETCH_ARGS, 2915
ER_SR_INVALID_CREATION_CTX, 2933
ER_STACK_OVERRUN, 2901
ER_STACK_OVERRUN_NEED_MORE, 2922
ER_STARTUP, 2920
ER_STMT_CACHE_FULL, 2941
ER_STMT_HAS_NO_OPEN_CURSOR, 2921
ER_STMT_NOT_ALLOWED_IN_SF_OR_TRG, 2916
ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_DIRECT, 2939
ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_FORMAT, 2930
ER_STORED_FUNCTION_PREVENTS_SWITCH_SQL_LOG_BIN, 2940
ER_SUBPARTITION_ERROR, 2926
ER_SUBPARTITION_NAME, 2935
ER_SUBQUERY_NO_1_ROW, 2910
ER_SYNTAX_ERROR, 2903
ER_TABLEACCESS_DENIED_ERROR, 2903
ER_TABLENAME_NOT_ALLOWED_HERE, 2910
ER_TABLESPACE_AUTO_EXTEND_ERROR, 2928
ER_TABLE_CANT_HANDLE_AUTO_INCREMENT, 2904
ER_TABLE_CANT_HANDLE_BLOB, 2904
ER_TABLE_CANT_HANDLE_FT, 2908
ER_TABLE_CANT_HANDLE_SPKEYS, 2924
ER_TABLE_DEF_CHANGED, 2920
ER_TABLE_EXISTS_ERROR, 2896
ER_TABLE_IN_FK_CHECK, 2944
ER_TABLE_MUST_HAVE_COLUMNS, 2901
ER_TABLE_NAME, 2935
ER_TABLE_NEEDS_REBUILD, 2942
ER_TABLE_NEEDS_UPGRADE, 2923
ER_TABLE_NOT_LOCKED, 2900
ER_TABLE_NOT_LOCKED_FOR_WRITE, 2900
ER_TEMPORARY_NAME, 2935
ER_TEMP_TABLE_PREVENTS_SWITCH_OUT_OF_RBR, 2930
ER_TEXTFILE_NOT_READABLE, 2899
ER_TOO_BIG_DISPLAYWIDTH, 2922
ER_TOO_BIG_FIELDLENGTH, 2898
ER_TOO_BIG_FOR_UNCOMPRESS, 2910
ER_TOO_BIG_PRECISION, 2921
ER_TOO_BIG_ROWSIZE, 2901
ER_TOO_BIG_SCALE, 2921
ER_TOO_BIG_SELECT, 2900
ER_TOO_BIG_SET, 2900
ER_TOO_HIGH_LEVEL_OF_NESTING_FOR_SELECT, 2924
ER_TOO_LONG_BODY, 2922
ER_TOO_LONG_FIELD_COMMENT, 2935
ER_TOO_LONG_IDENT, 2897
ER_TOO_LONG_INDEX_COMMENT, 2940
ER_TOO_LONG_KEY, 2898
ER_TOO_LONG_STRING, 2904
ER_TOO_LONG_TABLE_COMMENT, 2935
ER_TOO_MANY_CONCURRENT_TRXS, 2935

ER_TOO_MANY_DELAYED_THREADS, 2903
ER_TOO_MANY_FIELDS, 2901
ER_TOO_MANY_KEYS, 2898
ER_TOO_MANY_KEY_PARTS, 2898
ER_TOO_MANY_PARTITIONS_ERROR, 2926
ER_TOO_MANY_PARTITION_FUNC_FIELDS_ERROR, 2936
ER_TOO_MANY_ROWS, 2905
ER_TOO_MANY_TABLES, 2901
ER_TOO_MANY_USER_CONNECTIONS, 2907
ER_TOO_MANY_VALUES_ERROR, 2937
ER_TOO_MUCH_AUTO_TIMESTAMP_COLS, 2913
ER_TRANS_CACHE_FULL, 2906
ER_TRG_ALREADY_EXISTS, 2917
ER_TRG_CANT_CHANGE_ROW, 2917
ER_TRG_CANT_OPEN_TABLE, 2933
ER_TRG_CORRUPTED_FILE, 2933
ER_TRG_DOES_NOT_EXIST, 2917
ER_TRG_INVALID_CREATION_CTX, 2933
ER_TRG_IN_WRONG_SCHEMA, 2922
ER_TRG_NO_CREATION_CTX, 2933
ER_TRG_NO_DEFINER, 2923
ER_TRG_NO_SUCH_ROW_IN_TRG, 2917
ER_TRG_ON_VIEW_OR_TEMP_TABLE, 2917
ER_TRUNCATED_WRONG_VALUE, 2913
ER_TRUNCATED_WRONG_VALUE_FOR_FIELD, 2917
ER_TRUNCATE_ILLEGAL_FK, 2941
ER_UDF_EXISTS, 2902
ER_UDF_NO_PATHS, 2902
ER_UNDO_RECORD_TOO_BIG, 2942
ER_UNEXPECTED_EOF, 2896
ER_UNION_TABLES_IN_DIFFERENT_DIR, 2908
ER_UNIQUE_KEY_NEED_ALL_FIELDS_IN_PF, 2926
ER_UNKNOWN_CHARACTER_SET, 2901
ER_UNKNOWN_COLLATION, 2912
ER_UNKNOWN_COM_ERROR, 2896
ER_UNKNOWN_ERROR, 2900
ER_UNKNOWN_KEY_CACHE, 2912
ER_UNKNOWN_LOCALE, 2936
ER_UNKNOWN_PROCEDURE, 2900
ER_UNKNOWN_STMT_HANDLER, 2910
ER_UNKNOWN_STORAGE_ENGINE, 2912
ER_UNKNOWN_SYSTEM_VARIABLE, 2906
ER_UNKNOWN_TABLE, 2901
ER_UNKNOWN_TARGET_BINLOG, 2918
ER_UNKNOWN_TIME_ZONE, 2913
ER_UNSUPORTED_LOG_ENGINE, 2931
ER_UNSUPPORTED_ENGINE, 2944
ER_UNSUPPORTED_EXTENSION, 2901
ER_UNSUPPORTED_PS, 2913
ER_UNTIL_COND_IGNORED, 2912
ER_UPDATE_INFO, 2902
ER_UPDATE_LOG_DEPRECATED_IGNORED, 2914
ER_UPDATE_LOG_DEPRECATED_TRANSLATED, 2914
ER_UPDATE_TABLE_USED, 2899
ER_UPDATE_WITHOUT_KEY_IN_SAFE_MODE, 2905
ER_USERNAME, 2924
ER_USER_LIMIT_REACHED, 2909
ER_VALUES_IS_NOT_INT_TYPE_ERROR, 2941

ER_VARIABLE_IS_NOT_STRUCT, 2912
ER_VARIABLE_IS_READONLY, 2934
ER_VAR_CANT_BE_READ, 2909
ER_VIEW_CHECKSUM, 2919
ER_VIEW_CHECK_FAILED, 2918
ER_VIEW_DELETE_MERGE_VIEW, 2919
ER_VIEW_FRM_NO_USER, 2923
ER_VIEW_INVALID, 2917
ER_VIEW_INVALID_CREATION_CTX, 2933
ER_VIEW_MULTIUPDATE, 2919
ER_VIEW_NONUPD_CHECK, 2918
ER_VIEW_NO_CREATION_CTX, 2933
ER_VIEW_NO_EXPLAIN, 2916
ER_VIEW_NO_INSERT_FIELD_LIST, 2919
ER_VIEW_OTHER_USER, 2923
ER_VIEW_PREVENT_UPDATE, 2922
ER_VIEW_RECURSIVE, 2924
ER_VIEW_SELECT_CLAUSE, 2916
ER_VIEW_SELECT_DERIVED, 2916
ER_VIEW_SELECT_TMPTABLE, 2917
ER_VIEW_SELECT_VARIABLE, 2917
ER_VIEW_WRONG_LIST, 2917
ER_WARNING_NOT_COMPLETE_ROLLBACK, 2906
ER_WARN_ALLOWED_PACKET_OVERFLOWED, 2913
ER_WARN_CANT_DROP_DEFAULT_KEYCACHE, 2922
ER_WARN_DATA_OUT_OF_RANGE, 2911
ER_WARN_DEPRECATED_SYNTAX, 2913
ER_WARN_DEPRECATED_SYNTAX_NO_REPLACEMENT, 2939
ER_WARN_DEPRECATED_SYNTAX_WITH_VER, 2930
ER_WARN_ENGINE_TRANSACTION_ROLLBACK, 2934
ER_WARN_FIELD_RESOLVED, 2912
ER_WARN_HOSTNAME_WONT_WORK, 2912
ER_WARN_INVALID_TIMESTAMP, 2913
ER_WARN_I_S_SKIPPED_TABLE, 2939
ER_WARN_NULL_TO_NOTNULL, 2911
ER_WARN_QC_RESIZE, 2912
ER_WARN_TOO_FEW_RECORDS, 2911
ER_WARN_TOO_MANY_RECORDS, 2911
ER_WARN_USING_OTHER_HANDLER, 2911
ER_WARN_VIEW_MERGE, 2917
ER_WARN_VIEW_WITHOUT_KEY, 2917
ER_WRONG_ARGUMENTS, 2907
ER_WRONG_AUTO_KEY, 2898
ER_WRONG_COLUMN_NAME, 2904
ER_WRONG_DB_NAME, 2900
ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR, 2925
ER_WRONG_FIELD_SPEC, 2898
ER_WRONG_FIELD_TERMINATORS, 2899
ER_WRONG_FIELD_WITH_GROUP, 2897
ER_WRONG_FK_DEF, 2909
ER_WRONG_GROUP_FIELD, 2897
ER_WRONG_KEY_COLUMN, 2904
ER_WRONG_LOCK_OF_SYSTEM_TABLE, 2921
ER_WRONG_MAGIC, 2919
ER_WRONG_MRG_TABLE, 2904
ER_WRONG_NAME_FOR_CATALOG, 2912
ER_WRONG_NAME_FOR_INDEX, 2912
ER_WRONG_NATIVE_TABLE_STRUCTURE, 2939

ER_WRONG_NUMBER_OF_COLUMNS_IN_SELECT, 2908
ER_WRONG_OBJECT, 2916
ER_WRONG_OUTER_JOIN, 2901
ER_WRONG_PARAMCOUNT_TO_NATIVE_FCT, 2932
ER_WRONG_PARAMCOUNT_TO_PROCEDURE, 2900
ER_WRONG_PARAMETERS_TO_NATIVE_FCT, 2932
ER_WRONG_PARAMETERS_TO_PROCEDURE, 2900
ER_WRONG_PARAMETERS_TO_STORED_FCT, 2932
ER_WRONG_PARTITION_NAME, 2931
ER_WRONG_PERFSCHEMA_USAGE, 2939
ER_WRONG_SIZE_NUMBER, 2928
ER_WRONG_SPVAR_TYPE_IN_LIMIT, 2940
ER_WRONG_STRING_LENGTH, 2924
ER_WRONG_SUB_KEY, 2899
ER_WRONG_SUM_SELECT, 2897
ER_WRONG_TABLE_NAME, 2900
ER_WRONG_TYPE_COLUMN_VALUE_ERROR, 2936
ER_WRONG_TYPE_FOR_VAR, 2909
ER_WRONG_USAGE, 2908
ER_WRONG_VALUE, 2928
ER_WRONG_VALUE_COUNT, 2897
ER_WRONG_VALUE_COUNT_ON_ROW, 2902
ER_WRONG_VALUE_FOR_TYPE, 2920
ER_WRONG_VALUE_FOR_VAR, 2909
ER_WSAS_FAILED, 2918
ER_XAER_DUPID, 2922
ER_XAER_INVAL, 2919
ER_XAER_NOTA, 2919
ER_XAER_OUTSIDE, 2920
ER_XAER_RMERR, 2920
ER_XAER_RMFAIL, 2919
ER_XA_RBDEADLOCK, 2934
ER_XA_RBROLLBACK, 2920
ER_XA_RBTIMEOUT, 2934
ER_YES, 2893
ER_ZLIB_Z_BUF_ERROR, 2911
ER_ZLIB_Z_DATA_ERROR, 2911
ER_ZLIB_Z_MEM_ERROR, 2911
WARN_COND_ITEM_TRUNCATED, 2936
WARN_DATA_TRUNCATED, 2911
WARN_NON_ASCII_SEPARATOR_NOT_IMPLEMENTED, 2935
WARN_NO_MASTER_INFO, 2934
WARN_OPTION_BELOW_LIMIT, 2942
WARN_OPTION_IGNORED, 2934
WARN_PLUGIN_BUSY, 2934
WARN_PLUGIN_DELETE_BUILTIN, 2934
ERROR Events (NDB Cluster), 2333
error log, 3530
error logs (NDB Cluster), 2238
error messages
can't find file, 2962
Can't reopen table, 2978
displaying, 421
languages, 1061, 1062
The used command is not allowed with this MySQL version, 711
error-insert option
ndb_move_data, 2275
errors

access denied, 2949
and replication, 1998
checking tables for, 824
common, 2948
directory checksum, 157
handling for UDFs, 2824
in subqueries, 1452
known, 2978
linking, 2657
list of, 2949
lost connection, 2952
reporting, 20, 20
sources of information, 2891
error_count system variable, 514
ERROR_FOR_DIVISION_BY_ZERO SQL mode, 624
ER_ABORTING_CONNECTION error code, 2903
ER_ACCESS_DENIED_ERROR error code, 2896
ER_ACCESS_DENIED_NO_PASSWORD_ERROR error code, 2941
ER_ADD_PARTITION_NO_NEW_PARTITION error code, 2927
ER_ADD_PARTITION_SUBPART_ERROR error code, 2927
ER_ADMIN_WRONG_MRG_TABLE error code, 2924
ER_ALTER_FILEGROUP_FAILED error code, 2928
ER_ALTER_INFO error code, 2899
ER_AMBIGUOUS_FIELD_TERM error code, 2924
ER_AUTOINC_READ_FAILED error code, 2924
ER_AUTO_CONVERT error code, 2910
ER_BAD_DB_ERROR error code, 2896
ER_BAD_FIELD_ERROR error code, 2897
ER_BAD_FT_COLUMN error code, 2912
ER_BAD_HOST_ERROR error code, 2896
ER_BAD_LOG_STATEMENT error code, 2932
ER_BAD_NULL_ERROR error code, 2896
ER_BAD_SLAVE error code, 2907
ER_BAD_SLAVE_UNTIL_COND error code, 2912
ER_BAD_TABLE_ERROR error code, 2896
ER_BASE64_DECODE_ERROR error code, 2931
ER_BINLOG_CREATE_ROUTINE_NEED_SUPER error code, 2921
ER_BINLOG_LOGGING_IMPOSSIBLE error code, 2933
ER_BINLOG_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE error code, 2938
ER_BINLOG_PURGE_EMFILE error code, 2932
ER_BINLOG_PURGE_FATAL_ERR error code, 2918
ER_BINLOG_PURGE_PROHIBITED error code, 2918
ER_BINLOG_ROW_ENGINE_AND_STMT_ENGINE error code, 2937
ER_BINLOG_ROW_INJECTION_AND_STMT_ENGINE error code, 2937
ER_BINLOG_ROW_INJECTION_AND_STMT_MODE error code, 2937
ER_BINLOG_ROW_LOGGING_FAILED error code, 2928
ER_BINLOG_ROW_MODE_AND_STMT_ENGINE error code, 2937
ER_BINLOG_ROW_RBR_TO_SBR error code, 2929
ER_BINLOG_ROW_WRONG_TABLE_DEF error code, 2928
ER_BINLOG_STMT_MODE_AND_ROW_ENGINE error code, 2937
ER_BINLOG_UNSAFE_AND_STMT_ENGINE error code, 2937
ER_BINLOG_UNSAFE_AUTOINC_COLUMNS error code, 2938
ER_BINLOG_UNSAFE_AUTOINC_NOT_FIRST error code, 2944
ER_BINLOG_UNSAFE_CREATE_IGNORE_SELECT error code, 2943
ER_BINLOG_UNSAFE_CREATE_REPLACE_SELECT error code, 2943
ER_BINLOG_UNSAFE_CREATE_SELECT_AUTOINC error code, 2943
ER_BINLOG_UNSAFE_INSERT_DELAYED error code, 2938
ER_BINLOG_UNSAFE_INSERT_IGNORE_SELECT error code, 2942

ER_BINLOG_UNSAFE_INSERT_SELECT_UPDATE error code, 2942
ER_BINLOG_UNSAFE_INSERT_TWO_KEYS error code, 2943
ER_BINLOG_UNSAFE_LIMIT error code, 2938
ER_BINLOG_UNSAFE_MIXED_STATEMENT error code, 2940
ER_BINLOG_UNSAFE_MULTIPLE_ENGINES_AND_SELF_LOGGING_ENGINE error code, 2940
ER_BINLOG_UNSAFE_NONTRANS_AFTER_TRANS error code, 2938
ER_BINLOG_UNSAFE_REPLACE_SELECT error code, 2943
ER_BINLOG_UNSAFE_ROUTINE error code, 2921
ER_BINLOG_UNSAFE_STATEMENT error code, 2932
ER_BINLOG_UNSAFE_SYSTEM_FUNCTION error code, 2938
ER_BINLOG_UNSAFE_SYSTEM_TABLE error code, 2938
ER_BINLOG_UNSAFE_SYSTEM_VARIABLE error code, 2938
ER_BINLOG_UNSAFE_UDF error code, 2938
ER_BINLOG_UNSAFE_UPDATE_IGNORE error code, 2943
ER_BINLOG_UNSAFE_WRITE_AUTOINC_SELECT error code, 2943
ER_BLOBS_AND_NO_TERMINATED error code, 2899
ER_BLOB_CANT_HAVE_DEFAULT error code, 2900
ER_BLOB_FIELD_IN_PART_FUNC_ERROR error code, 2926
ER_BLOB_KEY_WITHOUT_LENGTH error code, 2905
ER_BLOB_USED_AS_KEY error code, 2898
ER_CANNOT_ADD_FOREIGN error code, 2908
ER_CANNOT_LOAD_FROM_TABLE error code, 2929
ER_CANNOT_USER error code, 2919
ER_CANT_ACTIVATE_LOG error code, 2931
ER_CANT_AGGREGATE_2COLLATIONS error code, 2911
ER_CANT_AGGREGATE_3COLLATIONS error code, 2911
ER_CANT_AGGREGATE_NCOLLATIONS error code, 2911
ER_CANT_CHANGE_TX_ISOLATION error code, 2931
ER_CANT_CREATE_DB error code, 2893
ER_CANT_CREATE_FEDERATED_TABLE error code, 2922
ER_CANT_CREATE_FILE error code, 2893
ER_CANT_CREATE_GEOMETRY_OBJECT error code, 2921
ER_CANT_CREATE_HANDLER_FILE error code, 2926
ER_CANT_CREATE_SROUTINE error code, 2933
ER_CANT_CREATE_TABLE error code, 2893
ER_CANT_CREATE_THREAD error code, 2902
ER_CANT_CREATE_USER_WITH_GRANT error code, 2920
ER_CANT_DELETE_FILE error code, 2894
ER_CANT_DO_THIS_DURING_AN_TRANSACTION error code, 2905
ER_CANT_DROP_FIELD_OR_KEY error code, 2899
ER_CANT_FIND_DL_ENTRY error code, 2902
ER_CANT_FIND_SYSTEM_REC error code, 2894
ER_CANT_FIND_UDF error code, 2901
ER_CANT_GET_STAT error code, 2894
ER_CANT_GET_WD error code, 2894
ER_CANT_INITIALIZE_UDF error code, 2902
ER_CANT_LOCK error code, 2894
ER_CANT_LOCK_LOG_TABLE error code, 2930
ER_CANT_OPEN_FILE error code, 2894
ER_CANT_OPEN_LIBRARY error code, 2902
ER_CANT_READ_DIR error code, 2894
ER_CANT_REMOVE_ALL_FIELDS error code, 2899
ER_CANT_RENAME_LOG_TABLE error code, 2932
ER_CANT_REOPEN_TABLE error code, 2902
ER_CANT_SET_WD error code, 2894
ER_CANT_UPDATE_USED_TABLE_IN_SF_OR_TRG error code, 2922
ER_CANT_UPDATE_WITH_READLOCK error code, 2908
ER_CANT_USE_OPTION_HERE error code, 2909

ER_CANT_WRITE_LOCK_LOG_TABLE error code, 2930
ER_CHECKREAD error code, 2894
ER_CHECK_NOT_IMPLEMENTED error code, 2905
ER_CHECK_NO_SUCH_TABLE error code, 2905
ER_COALESCE_ONLY_ON_HASH_PARTITION error code, 2927
ER_COALESCE_PARTITION_NO_PARTITION error code, 2927
ER_COLLATION_CHARSET_MISMATCH error code, 2910
ER_COLUMNACCESS_DENIED_ERROR error code, 2903
ER_COL_COUNT_DOESNT_MATCH_CORRUPTED error code, 2929
ER_COL_COUNT_DOESNT_MATCH_PLEASE_UPDATE error code, 2930
ER_COMMIT_NOT_ALLOWED_IN_SF_OR_TRG error code, 2921
ER_COND_ITEM_TOO_LONG error code, 2936
ER_CONFLICTING_DECLARATIONS error code, 2913
ER_CONFLICT_FN_PARSE_ERROR error code, 2935
ER_CONNECT_TO_FOREIGN_DATA_SOURCE error code, 2921
ER_CONNECT_TO_MASTER error code, 2908
ER_CONSECUTIVE_REORG_PARTITIONS error code, 2927
ER_CONST_EXPR_IN_PARTITION_FUNC_ERROR error code, 2925
ER_CON_COUNT_ERROR error code, 2896
ER_CORRUPT_HELP_DB error code, 2910
ER_CRASHED_ON_REPAIR error code, 2906
ER_CRASHED_ON_USAGE error code, 2906
ER_CREATE_DB_WITH_READ_LOCK error code, 2907
ER_CREATE_FILEGROUP_FAILED error code, 2928
ER_CUT_VALUE_GROUP_CONCAT error code, 2911
ER_CYCLIC_REFERENCE error code, 2910
ER_DATABASE_NAME error code, 2935
ER_DATA_OUT_OF_RANGE error code, 2940
ER_DATA_TOO_LONG error code, 2920
ER_DATETIME_FUNCTION_OVERFLOW error code, 2922
ER_DBACCESS_DENIED_ERROR error code, 2896
ER_DB_CREATE_EXISTS error code, 2893
ER_DB_DROP_DELETE error code, 2894
ER_DB_DROP_EXISTS error code, 2894
ER_DB_DROP_RMDIR error code, 2894
ER_DDL_LOG_ERROR error code, 2931
ER_DEBUG_SYNC_HIT_LIMIT error code, 2936
ER_DEBUG_SYNC_TIMEOUT error code, 2936
ER_DELAYED_CANT_CHANGE_LOCK error code, 2903
ER_DELAYED_INSERT_TABLE_LOCKED error code, 2904
ER_DELAYED_NOT_SUPPORTED error code, 2934
ER_DERIVED_MUST_HAVE_ALIAS error code, 2910
ER_DIFF_GROUPS_PROC error code, 2919
ER_DISK_FULL error code, 2895
ER_DIVISION_BY_ZERO error code, 2917
ER_DROP_DB_WITH_READ_LOCK error code, 2907
ER_DROP_FILEGROUP_FAILED error code, 2928
ER_DROP_INDEX_FK error code, 2930
ER_DROP_LAST_PARTITION error code, 2927
ER_DROP_PARTITION_NON_EXISTENT error code, 2927
ER_DROP_USER error code, 2911
ER_DUMP_NOT_IMPLEMENTED error code, 2906
ER_DUPLICATED_VALUE_IN_TYPE error code, 2913
ER_DUP_ARGUMENT error code, 2909
ER_DUP_ENTRY error code, 2898
ER_DUP_ENTRY_AUTOINCREMENT_CASE error code, 2931
ER_DUP_ENTRY_WITH_KEY_NAME error code, 2932
ER_DUP_FIELDNAME error code, 2897

ER_DUP_KEY error code, 2895
ER_DUP_KEYNAME error code, 2897
ER_DUP_SIGNAL_SET error code, 2936
ER_DUP_UNIQUE error code, 2904
ER_EMPTY_QUERY error code, 2898
ER_ERROR_DURING_CHECKPOINT error code, 2906
ER_ERROR_DURING_COMMIT error code, 2905
ER_ERROR_DURING_FLUSH_LOGS error code, 2905
ER_ERROR_DURING_ROLLBACK error code, 2905
ER_ERROR_IN_TRIGGER_BODY error code, 2942
ER_ERROR_IN_UNKNOWN_TRIGGER_BODY error code, 2942
ER_ERROR_ON_CLOSE error code, 2895
ER_ERROR_ON_READ error code, 2895
ER_ERROR_ON_RENAME error code, 2895
ER_ERROR_ON_WRITE error code, 2895
ER_ERROR_WHEN_EXECUTING_COMMAND error code, 2908
ER_EVENTS_DB_ERROR error code, 2931
ER_EVENT_ALREADY_EXISTS error code, 2929
ER_EVENT_CANNOT_ALTER_IN_THE_PAST error code, 2932
ER_EVENT_CANNOT_CREATE_IN_THE_PAST error code, 2932
ER_EVENT_CANNOT_DELETE error code, 2929
ER_EVENT_CANT_ALTER error code, 2929
ER_EVENT_COMPILE_ERROR error code, 2929
ER_EVENT_DATA_TOO_LONG error code, 2930
ER_EVENT_DOES_NOT_EXIST error code, 2929
ER_EVENT_DROP_FAILED error code, 2929
ER_EVENT_ENDS_BEFORE_STARTS error code, 2929
ER_EVENT_EXEC_TIME_IN_THE_PAST error code, 2929
ER_EVENT_INTERVAL_NOT_POSITIVE_OR_TOO_BIG error code, 2929
ER_EVENT_INVALID_CREATION_CTX error code, 2933
ER_EVENT_MODIFY_QUEUE_ERROR error code, 2931
ER_EVENT_NEITHER_M_EXPR_NOR_M_AT error code, 2929
ER_EVENT_OPEN_TABLE_FAILED error code, 2929
ER_EVENT_RECURSION_FORBIDDEN error code, 2931
ER_EVENT_SAME_NAME error code, 2929
ER_EVENT_SET_VAR_ERROR error code, 2931
ER_EVENT_STORE_FAILED error code, 2929
ER_EXCEPTIONS_WRITE_ERROR error code, 2935
ER_EXEC_STMT_WITH_OPEN_CURSOR error code, 2921
ER_FAILED_READ_FROM_PAR_FILE error code, 2940
ER_FAILED_ROUTINE_BREAK_BINLOG error code, 2921
ER_FEATURE_DISABLED error code, 2913
ER_FIELD_NOT_FOUND_PART_ERROR error code, 2925
ER_FIELD_SPECIFIED_TWICE error code, 2901
ER_FIELD_TYPE_NOT_ALLOWED_AS_PARTITION_FIELD error code, 2937
ER_FILEGROUP_OPTION_ONLY_ONCE error code, 2928
ER_FILE_EXISTS_ERROR error code, 2899
ER_FILE_NOT_FOUND error code, 2894
ER_FILE_USED error code, 2895
ER_FILSORT_ABORT error code, 2895
ER_FLUSH_MASTER_BINLOG_CLOSED error code, 2906
ER_FORBID_SCHEMA_CHANGE error code, 2923
ER_FORCING_CLOSE error code, 2899
ER_FOREIGN_DATA_SOURCE_DOESNT_EXIST error code, 2922
ER_FOREIGN_DATA_STRING_INVALID error code, 2922
ER_FOREIGN_DATA_STRING_INVALID_CANT_CREATE error code, 2922
ER_FOREIGN_DUPLICATE_KEY error code, 2930
ER_FOREIGN_KEY_ON_PARTITIONED error code, 2927

ER_FOREIGN_SERVER_DOESNT_EXIST error code, 2925
ER_FOREIGN_SERVER_EXISTS error code, 2925
ER_FORM_NOT_FOUND error code, 2895
ER_FPARSER_BAD_HEADER error code, 2916
ER_FPARSER_EOF_IN_COMMENT error code, 2916
ER_FPARSER_EOF_IN_UNKNOWN_PARAMETER error code, 2916
ER_FPARSER_ERROR_IN_PARAMETER error code, 2916
ER_FPARSER_TOO_BIG_FILE error code, 2916
ER_FRM_UNKNOWN_TYPE error code, 2916
ER_FSEEK_FAIL error code, 2918
ER_FT_MATCHING_KEY_NOT_FOUND error code, 2906
ER_FUNCTION_NOT_DEFINED error code, 2902
ER_FUNC_INEXISTENT_NAME_COLLISION error code, 2935
ER_GET_ERRMSG error code, 2913
ER_GET_ERRNO error code, 2895
ER_GET_TEMPORARY_ERRMSG error code, 2913
ER_GLOBAL_VARIABLE error code, 2909
ER_GOT_SIGNAL error code, 2899
ER_GRANT_PLUGIN_USER_EXISTS error code, 2941
ER_GRANT_WRONG_HOST_OR_USER error code, 2903
ER_HANDSHAKE_ERROR error code, 2896
ER_HASHCHK error code, 2893
ER_HOSTNAME error code, 2924
ER_HOST_IS_BLOCKED error code, 2902
ER_HOST_NOT_PRIVILEGED error code, 2902
ER_ILLEGAL_GRANT_FOR_TABLE error code, 2903
ER_ILLEGAL_HA error code, 2895
ER_ILLEGAL_HA_CREATE_OPTION error code, 2925
ER_ILLEGAL_REFERENCE error code, 2910
ER_ILLEGAL_VALUE_FOR_TYPE error code, 2918
ER_INCONSISTENT_PARTITION_INFO_ERROR error code, 2926
ER_INCONSISTENT_TYPE_OF_FUNCTIONS_ERROR error code, 2926
ER_INCORRECT_GLOBAL_LOCAL_VAR error code, 2909
ER_INDEX_COLUMN_TOO_LONG error code, 2942
ER_INDEX_CORRUPT error code, 2942
ER_INDEX_REBUILD error code, 2906
ER_INSERT_INFO error code, 2899
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_DIRECT error code, 2939
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_BINLOG_FORMAT error code, 2939
ER_INSIDE_TRANSACTION_PREVENTS_SWITCH_SQL_LOG_BIN error code, 2940
ER_INVALID_CHARACTER_STRING error code, 2913
ER_INVALID_DEFAULT error code, 2898
ER_INVALID_GROUP_FUNC_USE error code, 2901
ER_INVALID_ON_UPDATE error code, 2913
ER_INVALID_USE_OF_NULL error code, 2902
ER_IO_ERR_LOG_INDEX_READ error code, 2918
ER_IPSOCK_ERROR error code, 2899
ER_KEY_COLUMN_DOES_NOT_EXITS error code, 2898
ER_KEY_DOES_NOT_EXITS error code, 2905
ER_KEY_NOT_FOUND error code, 2895
ER_KEY_PART_0 error code, 2919
ER_KEY_REF_DO_NOT_MATCH_TABLE_REF error code, 2909
ER_KILL_DENIED_ERROR error code, 2900
ER_LIMITED_PART_RANGE error code, 2928
ER_LIST_OF_FIELDS_ONLY_IN_HASH_ERROR error code, 2926
ER_LOAD_DATA_INVALID_COLUMN error code, 2934
ER_LOAD_FROM_FIXED_SIZE_ROWS_TO_VAR error code, 2920
ER_LOAD_INFO error code, 2899

ER_LOCAL_VARIABLE error code, 2909
ER_LOCK_ABORTED error code, 2940
ER_LOCK_DEADLOCK error code, 2908
ER_LOCK_OR_ACTIVE_TRANSACTION error code, 2906
ER_LOCK_TABLE_FULL error code, 2907
ER_LOCK_WAIT_TIMEOUT error code, 2907
ER_LOGGING_PROHIBIT_CHANGING_OF error code, 2919
ER_LOG_IN_USE error code, 2918
ER_LOG_PURGE_NO_FILE error code, 2934
ER_LOG_PURGE_UNKNOWN_ERR error code, 2918
ER_MALFORMED_DEFINER error code, 2923
ER_MASTER error code, 2906
ER_MASTER_FATAL_ERROR_READING_BINLOG error code, 2909
ER_MASTER_INFO error code, 2907
ER_MASTER_NET_READ error code, 2906
ER_MASTER_NET_WRITE error code, 2906
ER_MAXVALUE_IN_VALUES_IN error code, 2937
ER_MAX_PREPARED_STMT_COUNT_REACHED error code, 2924
ER_MESSAGE_AND_STATEMENT error code, 2939
ER_MISSING_SKIP_SLAVE error code, 2912
ER_MIXING_NOT_ALLOWED error code, 2909
ER_MIX_HANDLER_ERROR error code, 2926
ER_MIX_OF_GROUP_FUNC_AND_FIELDS error code, 2903
ER_MULTIPLE_DEF_CONST_IN_LIST_PART_ERROR error code, 2926
ER_MULTIPLE_PRI_KEY error code, 2898
ER_MULTI_UPDATE_KEY_CONFLICT error code, 2941
ER_M_BIGGER_THAN_D error code, 2921
ER_NAME_BECOMES_EMPTY error code, 2924
ER_NATIVE_FCT_NAME_COLLISION error code, 2932
ER_NDB_CANT_SWITCH_BINLOG_FORMAT error code, 2930
ER_NDB_REPLICATION_SCHEMA_ERROR error code, 2935
ER_NEED_REPREPARE error code, 2934
ER_NET_ERROR_ON_WRITE error code, 2904
ER_NET_FCNTL_ERROR error code, 2904
ER_NET_PACKETS_OUT_OF_ORDER error code, 2904
ER_NET_PACKET_TOO_LARGE error code, 2903
ER_NET_READ_ERROR error code, 2904
ER_NET_READ_ERROR_FROM_PIPE error code, 2904
ER_NET_READ_INTERRUPTED error code, 2904
ER_NET_UNCOMPRESS_ERROR error code, 2904
ER_NET_WRITE_INTERRUPTED error code, 2904
ER_NEVER_USED error code, 2933
ER_NEW_ABORTING_CONNECTION error code, 2906
ER_NISAMCHK error code, 2893
ER_NO error code, 2893
ER_NONEXISTING_GRANT error code, 2903
ER_NONEXISTING_PROC_GRANT error code, 2920
ER_NONEXISTING_TABLE_GRANT error code, 2903
ER_NONUNIQ_TABLE error code, 2898
ER_NONUPDATEABLE_COLUMN error code, 2916
ER_NON_GROUPING_FIELD_USED error code, 2924
ER_NON_INSERTABLE_TABLE error code, 2924
ER_NON_UNIQ_ERROR error code, 2896
ER_NON_UPDATABLE_TABLE error code, 2913
ER_NORMAL_SHUTDOWN error code, 2898
ER_NOT_ALLOWED_COMMAND error code, 2903
ER_NOT_FORM_FILE error code, 2895
ER_NOT_KEYFILE error code, 2895

ER_NOT_SUPPORTED_AUTH_MODE error code, 2910
ER_NOT_SUPPORTED_YET error code, 2909
ER_NO_BINARY_LOGGING error code, 2918
ER_NO_BINLOG_ERROR error code, 2927
ER_NO_CONST_EXPR_IN_RANGE_OR_LIST_ERROR error code, 2925
ER_NO_DB_ERROR error code, 2896
ER_NO_DEFAULT error code, 2909
ER_NO_DEFAULT_FOR_FIELD error code, 2917
ER_NO_DEFAULT_FOR_VIEW_FIELD error code, 2921
ER_NO_FILE_MAPPING error code, 2919
ER_NO_FORMAT_DESCRIPTION_EVENT_BEFORE_BINLOG_STATEMENT error code, 2934
ER_NO_GROUP_FOR_PROC error code, 2919
ER_NO_PARTITION_FOR_GIVEN_VALUE error code, 2928
ER_NO_PARTITION_FOR_GIVEN_VALUE_SILENT error code, 2932
ER_NO_PARTS_ERROR error code, 2926
ER_NO_PERMISSION_TO_CREATE_USER error code, 2907
ER_NO_RAID_COMPILED error code, 2905
ER_NO_REFERENCED_ROW error code, 2908
ER_NO_REFERENCED_ROW_2 error code, 2923
ER_NO_SUCH_INDEX error code, 2899
ER_NO_SUCH_TABLE error code, 2903
ER_NO_SUCH_THREAD error code, 2900
ER_NO_SUCH_USER error code, 2923
ER_NO_TABLES_USED error code, 2900
ER_NO_TRIGGERS_ON_SYSTEM_SCHEMA error code, 2924
ER_NO_UNIQUE_LOGFILE error code, 2900
ER_NULL_COLUMN_IN_INDEX error code, 2901
ER_NULL_IN_VALUES_LESS_THAN error code, 2931
ER_OLD_FILE_FORMAT error code, 2923
ER_OLD_KEYFILE error code, 2895
ER_ONLY_INTEGERS_ALLOWED error code, 2931
ER_ONLY_ON_RANGE_LIST_PARTITION error code, 2927
ER_OPEN_AS_READONLY error code, 2896
ER_OPERAND_COLUMNS error code, 2910
ER_OPTION_PREVENTS_STATEMENT error code, 2913
ER_ORDER_WITH_PROC error code, 2919
ER_OUTOFMEMORY error code, 2896
ER_OUT_OF_RESOURCES error code, 2896
ER_OUT_OF_SORTMEMORY error code, 2896
ER_PARSE_ERROR error code, 2898
ER_PARTITIONS_MUST_BE_DEFINED_ERROR error code, 2926
ER_PARTITION_COLUMN_LIST_ERROR error code, 2936
ER_PARTITION_CONST_DOMAIN_ERROR error code, 2930
ER_PARTITION_ENTRY_ERROR error code, 2926
ER_PARTITION_FIELDS_TOO_LONG error code, 2937
ER_PARTITION_FUNCTION_FAILURE error code, 2928
ER_PARTITION_FUNCTION_IS_NOT_ALLOWED error code, 2930
ER_PARTITION_FUNC_NOT_ALLOWED_ERROR error code, 2926
ER_PARTITION_MAXVALUE_ERROR error code, 2925
ER_PARTITION_MERGE_ERROR error code, 2931
ER_PARTITION_MGMT_ON_NONPARTITIONED error code, 2927
ER_PARTITION_NAME error code, 2935
ER_PARTITION_NOT_DEFINED_ERROR error code, 2926
ER_PARTITION_NO_TEMPORARY error code, 2930
ER_PARTITION_REQUIRES_VALUES_ERROR error code, 2925
ER_PARTITION_SUBPARTITION_ERROR error code, 2925
ER_PARTITION_SUBPART_MIX_ERROR error code, 2925
ER_PARTITION_WRONG_NO_PART_ERROR error code, 2925

ER_PARTITION_WRONG_NO_SUBPART_ERROR error code, 2925
ER_PARTITION_WRONG_VALUES_ERROR error code, 2925
ER_PART_STATE_ERROR error code, 2928
ER_PASSWD_LENGTH error code, 2918
ER_PASSWORD_ANONYMOUS_USER error code, 2902
ER_PASSWORD_NOT_ALLOWED error code, 2902
ER_PASSWORD_NO_MATCH error code, 2902
ER_PATH_LENGTH error code, 2939
ER_PLUGIN_IS_NOT_LOADED error code, 2928
ER_PLUGIN_IS_PERMANENT error code, 2941
ER_PLUGIN_NO_INSTALL error code, 2943
ER_PLUGIN_NO_UNINSTALL error code, 2943
ER_PRIMARY_CANT_HAVE_NULL error code, 2905
ER_PROCACCESS_DENIED_ERROR error code, 2918
ER_PROC_AUTO_GRANT_FAIL error code, 2920
ER_PROC_AUTO_REVOKE_FAIL error code, 2920
ER_PS_MANY_PARAM error code, 2919
ER_PS_NO_RECURSION error code, 2922
ER_QUERY_CACHE_DISABLED error code, 2936
ER_QUERY_INTERRUPTED error code, 2914
ER_QUERY_ON_FOREIGN_DATA_SOURCE error code, 2922
ER_QUERY_ON_MASTER error code, 2908
ER_RANGE_NOT_INCREASING_ERROR error code, 2926
ER_RBR_NOT_AVAILABLE error code, 2931
ER_READY error code, 2898
ER_READ_ONLY_TRANSACTION error code, 2907
ER_RECORD_FILE_FULL error code, 2901
ER_REGEXP_ERROR error code, 2903
ER_RELAY_LOG_FAIL error code, 2918
ER_RELAY_LOG_INIT error code, 2918
ER_REMOVED_SPACES error code, 2924
ER_RENAMED_NAME error code, 2935
ER_REORG_HASH_ONLY_ON_SAME_NO error code, 2927
ER_REORG_NO_PARAM_ERROR error code, 2927
ER_REORG_OUTSIDE_RANGE error code, 2928
ER_REORG_PARTITION_NOT_EXIST error code, 2927
ER_REQUIRES_PRIMARY_KEY error code, 2905
ER_RESERVED_SYNTAX error code, 2918
ER_RESIGNAL_WITHOUT_ACTIVE_HANDLER error code, 2936
ER_REVOKE_GRANTS error code, 2911
ER_ROW_IS_REFERENCED error code, 2908
ER_ROW_IS_REFERENCED_2 error code, 2923
ER_ROW_SINGLE_PARTITION_FIELD_ERROR error code, 2937
ER_SAME_NAME_PARTITION error code, 2927
ER_SAME_NAME_PARTITION_FIELD error code, 2936
ER_SELECT_REDUCED error code, 2910
ER_SERVER_IS_IN_SECURE_AUTH_MODE error code, 2912
ER_SERVER_SHUTDOWN error code, 2897
ER_SET_CONSTANTS_ONLY error code, 2907
ER_SET_PASSWORD_AUTH_PLUGIN error code, 2941
ER_SHUTDOWN_COMPLETE error code, 2899
ER_SIGNAL_BAD_CONDITION_TYPE error code, 2936
ER_SIGNAL_EXCEPTION error code, 2936
ER_SIGNAL_NOT_FOUND error code, 2936
ER_SIGNAL_WARN error code, 2936
ER_SIZE_OVERFLOW_ERROR error code, 2928
ER_SLAVE_AMBIGOUS_EXEC_MODE error code, 2933
ER_SLAVE_CANT_CREATE_CONVERSION error code, 2939

ER_SLAVE_CONVERSION_FAILED error code, 2939
ER_SLAVE_CORRUPT_EVENT error code, 2934
ER_SLAVE_CREATE_EVENT_FAILURE error code, 2933
ER_SLAVE_FATAL_ERROR error code, 2932
ER_SLAVE_HEARTBEAT_FAILURE error code, 2935
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE error code, 2935
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MAX error code, 2941
ER_SLAVE_HEARTBEAT_VALUE_OUT_OF_RANGE_MIN error code, 2941
ER_SLAVE_IGNORED_SSL_PARAMS error code, 2912
ER_SLAVE_IGNORED_TABLE error code, 2909
ER_SLAVE_IGNORE_SERVER_IDS error code, 2936
ER_SLAVE_INCIDENT error code, 2932
ER_SLAVE_MASTER_COM_FAILURE error code, 2933
ER_SLAVE_MUST_STOP error code, 2906
ER_SLAVE_NOT_RUNNING error code, 2907
ER_SLAVE_RELAY_LOG_READ_FAILURE error code, 2933
ER_SLAVE_RELAY_LOG_WRITE_FAILURE error code, 2933
ER_SLAVE_THREAD error code, 2907
ER_SLAVE_WAS_NOT_RUNNING error code, 2910
ER_SLAVE_WAS_RUNNING error code, 2910
ER_SPATIAL_CANT_HAVE_NULL error code, 2910
ER_SPATIAL_MUST_HAVE_GEOM_COL error code, 2940
ER_SPECIFIC_ACCESS_DENIED_ERROR error code, 2909
ER_SP_ALREADY_EXISTS error code, 2914
ER_SP_BADRETURN error code, 2914
ER_SP_BADSELECT error code, 2914
ER_SP_BADSTATEMENT error code, 2914
ER_SP_BAD_CURSOR_QUERY error code, 2915
ER_SP_BAD_CURSOR_SELECT error code, 2915
ER_SP_BAD_SQLSTATE error code, 2920
ER_SP_BAD_VAR_SHADOW error code, 2923
ER_SP_CANT_ALTER error code, 2915
ER_SP_CANT_SET_AUTOCOMMIT error code, 2923
ER_SP_CASE_NOT_FOUND error code, 2916
ER_SP_COND_MISMATCH error code, 2915
ER_SP_CURSOR_AFTER_HANDLER error code, 2916
ER_SP_CURSOR_ALREADY_OPEN error code, 2915
ER_SP_CURSOR_MISMATCH error code, 2915
ER_SP_CURSOR_NOT_OPEN error code, 2915
ER_SP_DOES_NOT_EXIST error code, 2914
ER_SP_DROP_FAILED error code, 2914
ER_SP_DUP_COND error code, 2915
ER_SP_DUP_CURS error code, 2915
ER_SP_DUP_HANDLER error code, 2920
ER_SP_DUP_PARAM error code, 2915
ER_SP_DUP_VAR error code, 2915
ER_SP_FETCH_NO_DATA error code, 2915
ER_SP_GOTO_IN_HNDLR error code, 2917
ER_SP_LABEL_MISMATCH error code, 2914
ER_SP_LABEL_REDEFINE error code, 2914
ER_SP_LILABEL_MISMATCH error code, 2914
ER_SP_NORETURN error code, 2915
ER_SP_NORETURNEND error code, 2915
ER_SP_NOT_VAR_ARG error code, 2920
ER_SP_NO_AGGREGATE error code, 2924
ER_SP_NO_DROP_SP error code, 2917
ER_SP_NO_RECURSION error code, 2921
ER_SP_NO_RECURSIVE_CREATE error code, 2914

ER_SP_NO_RETSET error code, 2921
ER_SP_PROC_TABLE_CORRUPT error code, 2923
ER_SP_RECURSION_LIMIT error code, 2923
ER_SP_STORE_FAILED error code, 2914
ER_SP_SUBSELECT_NYI error code, 2915
ER_SP_UNDECLARED_VAR error code, 2915
ER_SP_UNINIT_VAR error code, 2914
ER_SP_VARCOND_AFTER_CURSHNDLR error code, 2916
ER_SP_WRONG_NAME error code, 2923
ER_SP_WRONG_NO_OF_ARGS error code, 2914
ER_SP_WRONG_NO_OF_FETCH_ARGS error code, 2915
ER_SR_INVALID_CREATION_CTX error code, 2933
ER_STACK_OVERRUN error code, 2901
ER_STACK_OVERRUN_NEED_MORE error code, 2922
ER_STARTUP error code, 2920
ER_STMT_CACHE_FULL error code, 2941
ER_STMT_HAS_NO_OPEN_CURSOR error code, 2921
ER_STMT_NOT_ALLOWED_IN_SF_OR_TRG error code, 2916
ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_DIRECT error code, 2939
ER_STORED_FUNCTION_PREVENTS_SWITCH_BINLOG_FORMAT error code, 2930
ER_STORED_FUNCTION_PREVENTS_SWITCH_SQL_LOG_BIN error code, 2940
ER_SUBPARTITION_ERROR error code, 2926
ER_SUBPARTITION_NAME error code, 2935
ER_SUBQUERY_NO_1_ROW error code, 2910
ER_SYNTAX_ERROR error code, 2903
ER_TABLEACCESS_DENIED_ERROR error code, 2903
ER_TABLENAME_NOT_ALLOWED_HERE error code, 2910
ER_TABLESPACE_AUTO_EXTEND_ERROR error code, 2928
ER_TABLE_CANT_HANDLE_AUTO_INCREMENT error code, 2904
ER_TABLE_CANT_HANDLE_BLOB error code, 2904
ER_TABLE_CANT_HANDLE_FT error code, 2908
ER_TABLE_CANT_HANDLE_SPKEYS error code, 2924
ER_TABLE_DEF_CHANGED error code, 2920
ER_TABLE_EXISTS_ERROR error code, 2896
ER_TABLE_IN_FK_CHECK error code, 2944
ER_TABLE_MUST_HAVE_COLUMNS error code, 2901
ER_TABLE_NAME error code, 2935
ER_TABLE_NEEDS_REBUILD error code, 2942
ER_TABLE_NEEDS_UPGRADE error code, 2923
ER_TABLE_NOT_LOCKED error code, 2900
ER_TABLE_NOT_LOCKED_FOR_WRITE error code, 2900
ER_TEMPORARY_NAME error code, 2935
ER_TEMP_TABLE_PREVENTS_SWITCH_OUT_OF_RBR error code, 2930
ER_TEXTFILE_NOT_READABLE error code, 2899
ER_TOO_BIG_DISPLAYWIDTH error code, 2922
ER_TOO_BIG_FIELDLENGTH error code, 2898
ER_TOO_BIG_FOR_UNCOMPRESS error code, 2910
ER_TOO_BIG_PRECISION error code, 2921
ER_TOO_BIG_ROWSIZE error code, 2901
ER_TOO_BIG_SCALE error code, 2921
ER_TOO_BIG_SELECT error code, 2900
ER_TOO_BIG_SET error code, 2900
ER_TOO_HIGH_LEVEL_OF_NESTING_FOR_SELECT error code, 2924
ER_TOO_LONG_BODY error code, 2922
ER_TOO_LONG_FIELD_COMMENT error code, 2935
ER_TOO_LONG_IDENT error code, 2897
ER_TOO_LONG_INDEX_COMMENT error code, 2940
ER_TOO_LONG_KEY error code, 2898

ER_TOO_LONG_STRING error code, 2904
ER_TOO_LONG_TABLE_COMMENT error code, 2935
ER_TOO_MANY_CONCURRENT_TRXS error code, 2935
ER_TOO_MANY_DELAYED_THREADS error code, 2903
ER_TOO_MANY_FIELDS error code, 2901
ER_TOO_MANY_KEYS error code, 2898
ER_TOO_MANY_KEY_PARTS error code, 2898
ER_TOO_MANY_PARTITIONS_ERROR error code, 2926
ER_TOO_MANY_PARTITION_FUNC_FIELDS_ERROR error code, 2936
ER_TOO_MANY_ROWS error code, 2905
ER_TOO_MANY_TABLES error code, 2901
ER_TOO_MANY_USER_CONNECTIONS error code, 2907
ER_TOO_MANY_VALUES_ERROR error code, 2937
ER_TOO_MUCH_AUTO_TIMESTAMP_COLS error code, 2913
ER_TRANS_CACHE_FULL error code, 2906
ER_TRG_ALREADY_EXISTS error code, 2917
ER_TRG_CANT_CHANGE_ROW error code, 2917
ER_TRG_CANT_OPEN_TABLE error code, 2933
ER_TRG_CORRUPTED_FILE error code, 2933
ER_TRG_DOES_NOT_EXIST error code, 2917
ER_TRG_INVALID_CREATION_CTX error code, 2933
ER_TRG_IN_WRONG_SCHEMA error code, 2922
ER_TRG_NO_CREATION_CTX error code, 2933
ER_TRG_NO_DEFINER error code, 2923
ER_TRG_NO_SUCH_ROW_IN_TRG error code, 2917
ER_TRG_ON_VIEW_OR_TEMP_TABLE error code, 2917
ER_TRUNCATED_WRONG_VALUE error code, 2913
ER_TRUNCATED_WRONG_VALUE_FOR_FIELD error code, 2917
ER_TRUNCATE_ILLEGAL_FK error code, 2941
ER_UDF_EXISTS error code, 2902
ER_UDF_NO_PATHS error code, 2902
ER_UNDO_RECORD_TOO_BIG error code, 2942
ER_UNEXPECTED_EOF error code, 2896
ER_UNION_TABLES_IN_DIFFERENT_DIR error code, 2908
ER_UNIQUE_KEY_NEED_ALL_FIELDS_IN_PF error code, 2926
ER_UNKNOWN_CHARACTER_SET error code, 2901
ER_UNKNOWN_COLLATION error code, 2912
ER_UNKNOWN_COM_ERROR error code, 2896
ER_UNKNOWN_ERROR error code, 2900
ER_UNKNOWN_KEY_CACHE error code, 2912
ER_UNKNOWN_LOCALE error code, 2936
ER_UNKNOWN_PROCEDURE error code, 2900
ER_UNKNOWN_STMT_HANDLER error code, 2910
ER_UNKNOWN_STORAGE_ENGINE error code, 2912
ER_UNKNOWN_SYSTEM_VARIABLE error code, 2906
ER_UNKNOWN_TABLE error code, 2901
ER_UNKNOWN_TARGET_BINLOG error code, 2918
ER_UNKNOWN_TIME_ZONE error code, 2913
ER_UNSUPORTED_LOG_ENGINE error code, 2931
ER_UNSUPPORTED_ENGINE error code, 2944
ER_UNSUPPORTED_EXTENSION error code, 2901
ER_UNSUPPORTED_PS error code, 2913
ER_UNTIL_COND_IGNORED error code, 2912
ER_UPDATE_INFO error code, 2902
ER_UPDATE_LOG_DEPRECATED_IGNORED error code, 2914
ER_UPDATE_LOG_DEPRECATED_TRANSLATED error code, 2914
ER_UPDATE_TABLE_USED error code, 2899
ER_UPDATE_WITHOUT_KEY_IN_SAFE_MODE error code, 2905

ER_USERNAME error code, 2924
ER_USER_LIMIT_REACHED error code, 2909
ER_VALUES_IS_NOT_INT_TYPE_ERROR error code, 2941
ER_VARIABLE_IS_NOT_STRUCT error code, 2912
ER_VARIABLE_IS_READONLY error code, 2934
ER_VAR_CANT_BE_READ error code, 2909
ER_VIEW_CHECKSUM error code, 2919
ER_VIEW_CHECK_FAILED error code, 2918
ER_VIEW_DELETE_MERGE_VIEW error code, 2919
ER_VIEW_FRM_NO_USER error code, 2923
ER_VIEW_INVALID error code, 2917
ER_VIEW_INVALID_CREATION_CTX error code, 2933
ER_VIEW_MULTIUPDATE error code, 2919
ER_VIEW_NONUPD_CHECK error code, 2918
ER_VIEW_NO_CREATION_CTX error code, 2933
ER_VIEW_NO_EXPLAIN error code, 2916
ER_VIEW_NO_INSERT_FIELD_LIST error code, 2919
ER_VIEW_OTHER_USER error code, 2923
ER_VIEW_PREVENT_UPDATE error code, 2922
ER_VIEW_RECURSIVE error code, 2924
ER_VIEW_SELECT_CLAUSE error code, 2916
ER_VIEW_SELECT_DERIVED error code, 2916
ER_VIEW_SELECT_TMPTABLE error code, 2917
ER_VIEW_SELECT_VARIABLE error code, 2917
ER_VIEW_WRONG_LIST error code, 2917
ER_WARNING_NOT_COMPLETE_ROLLBACK error code, 2906
ER_WARN_ALLOWED_PACKET_OVERFLOWED error code, 2913
ER_WARN_CANT_DROP_DEFAULT_KEYCACHE error code, 2922
ER_WARN_DATA_OUT_OF_RANGE error code, 2911
ER_WARN_DEPRECATED_SYNTAX error code, 2913
ER_WARN_DEPRECATED_SYNTAX_NO_REPLACEMENT error code, 2939
ER_WARN_DEPRECATED_SYNTAX_WITH_VER error code, 2930
ER_WARN_ENGINE_TRANSACTION_ROLLBACK error code, 2934
ER_WARN_FIELD_RESOLVED error code, 2912
ER_WARN_HOSTNAME_WONT_WORK error code, 2912
ER_WARN_INVALID_TIMESTAMP error code, 2913
ER_WARN_I_S_SKIPPED_TABLE error code, 2939
ER_WARN_NULL_TO_NOTNULL error code, 2911
ER_WARN_QC_RESIZE error code, 2912
ER_WARN_TOO_FEW_RECORDS error code, 2911
ER_WARN_TOO_MANY_RECORDS error code, 2911
ER_WARN_USING_OTHER_HANDLER error code, 2911
ER_WARN_VIEW_MERGE error code, 2917
ER_WARN_VIEW_WITHOUT_KEY error code, 2917
ER_WRONG_ARGUMENTS error code, 2907
ER_WRONG_AUTO_KEY error code, 2898
ER_WRONG_COLUMN_NAME error code, 2904
ER_WRONG_DB_NAME error code, 2900
ER_WRONG_EXPR_IN_PARTITION_FUNC_ERROR error code, 2925
ER_WRONG_FIELD_SPEC error code, 2898
ER_WRONG_FIELD_TERMINATORS error code, 2899
ER_WRONG_FIELD_WITH_GROUP error code, 2897
ER_WRONG_FK_DEF error code, 2909
ER_WRONG_GROUP_FIELD error code, 2897
ER_WRONG_KEY_COLUMN error code, 2904
ER_WRONG_LOCK_OF_SYSTEM_TABLE error code, 2921
ER_WRONG_MAGIC error code, 2919
ER_WRONG_MRG_TABLE error code, 2904

ER_WRONG_NAME_FOR_CATALOG error code, 2912
ER_WRONG_NAME_FOR_INDEX error code, 2912
ER_WRONG_NATIVE_TABLE_STRUCTURE error code, 2939
ER_WRONG_NUMBER_OF_COLUMNS_IN_SELECT error code, 2908
ER_WRONG_OBJECT error code, 2916
ER_WRONG_OUTER_JOIN error code, 2901
ER_WRONG_PARAMCOUNT_TO_NATIVE_FCT error code, 2932
ER_WRONG_PARAMCOUNT_TO_PROCEDURE error code, 2900
ER_WRONG_PARAMETERS_TO_NATIVE_FCT error code, 2932
ER_WRONG_PARAMETERS_TO_PROCEDURE error code, 2900
ER_WRONG_PARAMETERS_TO_STORED_FCT error code, 2932
ER_WRONG_PARTITION_NAME error code, 2931
ER_WRONG_PERFSCHEMA_USAGE error code, 2939
ER_WRONG_SIZE_NUMBER error code, 2928
ER_WRONG_SPVAR_TYPE_IN_LIMIT error code, 2940
ER_WRONG_STRING_LENGTH error code, 2924
ER_WRONG_SUB_KEY error code, 2899
ER_WRONG_SUM_SELECT error code, 2897
ER_WRONG_TABLE_NAME error code, 2900
ER_WRONG_TYPE_COLUMN_VALUE_ERROR error code, 2936
ER_WRONG_TYPE_FOR_VAR error code, 2909
ER_WRONG_USAGE error code, 2908
ER_WRONG_VALUE error code, 2928
ER_WRONG_VALUE_COUNT error code, 2897
ER_WRONG_VALUE_COUNT_ON_ROW error code, 2902
ER_WRONG_VALUE_FOR_TYPE error code, 2920
ER_WRONG_VALUE_FOR_VAR error code, 2909
ER_WSAS_FAILED error code, 2918
ER_XAER_DUPID error code, 2922
ER_XAER_INVAL error code, 2919
ER_XAER_NOTA error code, 2919
ER_XAER_OUTSIDE error code, 2920
ER_XAER_RMERR error code, 2920
ER_XAER_RMFAIL error code, 2919
ER_XA_RBDEADLOCK error code, 2934
ER_XA_RBROLLBACK error code, 2920
ER_XA_RBTIMEOUT error code, 2934
ER_YES error code, 2893
ER_ZLIB_Z_BUF_ERROR error code, 2911
ER_ZLIB_Z_DATA_ERROR error code, 2911
ER_ZLIB_Z_MEM_ERROR error code, 2911
escape (\\), 966
escape sequences
  option files, 264
  strings, 965
establishing encrypted connections, 752
estimating
  query performance, 916
event groups, 1479
event log format (NDB Cluster), 2330
event logs (NDB Cluster), 2327, 2329, 2329
event scheduler, 2515
  thread states, 964
Event Scheduler, 2523
  altering events, 1305
  and MySQL privileges, 2528
  and mysqladmin debug, 2528
  and replication, 1991, 1992

and SHOW PROCESSLIST, 2525
concepts, 2524
creating events, 1332
dropping events, 1388
enabling and disabling, 2525
event metadata, 2527
obtaining status information, 2528
SQL statements, 2527
starting and stopping, 2525
time representation, 2527
event severity levels (NDB Cluster), 2329
event table
system table, 638
event types (NDB Cluster), 2328, 2330
event-scheduler option
mysqld, 465
EventLogBufferSize, 2153
events, 2515, 2523
altering, 1305
creating, 1332
dropping, 1388
metadata, 2527
restrictions, 2983
status variables, 2531
EVENTS
INFORMATION_SCHEMA table, 2529, 2551
events option
mysqldump, 340
events_waits_current table
performance_schema, 2628
events_waits_history table
performance_schema, 2629
events_waits_history_long table
performance_schema, 2629
events_waits_summary_by_instance table
performance_schema, 2630
events_waits_summary_by_thread_by_event_name table
performance_schema, 2630
events_waits_summary_global_by_event_name table
performance_schema, 2630
event_scheduler system variable, 514
eviction, 3530
exact-value literals, 1294
exact-value numeric literals, 968, 1295
example option
mysqld_multi, 281
example programs
C API, 2655
EXAMPLE storage engine, 1781, 1815
examples
compressed tables, 388
myisamchk output, 378
queries, 241
exceptions table
NDB Cluster Replication, 2451
exclude-databases option
ndb_restore, 2285
exclude-intermediate-sql-tables option

ndb_restore, 2285
exclude-missing-columns option
ndb_move_data, 2275
ndb_restore, 2286
exclude-missing-tables option
ndb_restore, 2286
exclude-tables option
ndb_restore, 2286
exclusive lock, 1615, 3530
Execute
thread command, 952
EXECUTE, 1481, 1485
execute option
mysql, 301
execute option (ndb_mgm), 2250
ExecuteOnComputer, 2118, 2122, 2173
executing
thread state, 955
executing SQL statements from text files, 239, 314
Execution of init_command
thread state, 955
execution plan, 903
execution threads (NDB Cluster), 2160
EXISTS
with subqueries, 1448
exit command
mysql, 308
EXIT command (NDB Cluster), 2318
EXIT SINGLE USER MODE command (NDB Cluster), 2318
exit-info option
mysqld, 465
EXP(), 1191
expire_logs_days system variable, 515
EXPLAIN, 903, 1593
EXPLAIN PARTITIONS, 2496, 2497
EXPLAIN used with partitioned tables, 2496
explicit default values, 1131
EXPORT_SET(), 1167
expression aliases, 1289, 1429
expression syntax, 1009
expressions
extended, 232
extend-check option
myisamchk, 375, 376
extended option
mysqlcheck, 329
extended-insert option
mysqldump, 341
extensions
to standard SQL, 24
extent, 3530
ExteriorRing(), 1276
external locking, 465, 564, 823, 937, 957
external-locking option
mysqld, 465
external_user system variable, 515
extra-file option
my_print_defaults, 420

extra-node-info option
  ndb_desc, 2265
extra-partition-info option
  ndb_desc, 2265
EXTRACT(), 1206
extracting
  dates, 229
ExtractValue(), 1241
ExtraSendBufferMemory
  API nodes, 2174
  data nodes, 2169
  management nodes, 2120

F

failover
  in NDB Cluster replication, 2432
  Java clients, 2015
FALSE, 968, 973
  testing for, 1156, 1156
fanout, 3531
FAQs
  C API, 2765
  Virtualization Support, 2890
Fast Index Creation, 3531
  concurrency, 1702
  crash recovery, 1703
  examples, 1701
  implementation, 1702
  limitations, 1703
  overview, 1701
fast option
  myisamchk, 375
  mysqlcheck, 329
fast shutdown, 3531
features of MySQL, 5
FEDERATED storage engine, 1781, 1810
Fetch
  thread command, 952
FETCH, 1495
field
  changing, 1314
Field List
  thread command, 952
FIELD(), 1168
fields option
  ndb_config, 2255
fields-enclosed-by option
  mysqldump, 341, 353
  ndb_restore, 2287
fields-escaped-by option
  mysqldump, 341, 353
fields-optionally-enclosed-by option
  mysqldump, 341, 353
  ndb_restore, 2287
fields-terminated-by option
  mysqldump, 341, 353
  ndb_restore, 2287
FILE, 1170

file format, 1691, 3531
  Antelope, 1688
  Barracuda, 1681
  downgrading, 1695
  identifying, 1695
file format management
  downgrading, 1608
file-per-table, 3531
files
  binary log, 645
  created by CREATE TABLE, 1370
  DDL log, 659
  error messages, 1062
  general query log, 644
  log, 659
  metadata log, 659
  my.cnf, 1979
  not found message, 2962
  permissions, 2962
  repairing, 376
  script, 239
  size limits, 2994
  slow query log, 657
  text, 314, 350
  tmp, 184
FILES
  INFORMATION_SCHEMA table, 2586
filesort optimization, 856
FileSystemPath, 2124
FileSystemPathDataFiles, 2166
FileSystemPathDD, 2166
FileSystemPathUndoFiles, 2166
file_instances table
  performance_schema, 2624
file_summary_by_event_name table
  performance_schema, 2631
file_summary_by_instance table
  performance_schema, 2631
fill factor, 1680, 3532
FIND_IN_SET(), 1168
Finished reading one binlog; switching to next binlog
  thread state, 961
firewalls (software)
  and NDB Cluster, 2378, 2379
first-slave option
  mysqldump, 341
fix-db-names option
  mysqlcheck, 329
fix-table-names option
  mysqlcheck, 329
FIXED data type, 1086
fixed row format, 3532
fixed-point arithmetic, 1294
FLOAT data type, 1086, 1086, 1087
floating-point number, 1087
floating-point values
  and replication, 1989
floats, 968

FLOOR(), 1192
FLUSH
  and replication, 1989
flush, 3532
flush list, 3532
flush option
  mysqld, 466
FLUSH statement, 1587
flush system variable, 515
flush tables, 320
flush-logs option
  mysqldump, 341
flush-privileges option
  mysqldump, 341
flushlog option
  mysqlhotcopy, 412
flush_time system variable, 516
FOR UPDATE, 1433
FORCE
  plugin activation option, 663
FORCE INDEX, 918, 2977
FORCE KEY, 918
force option
  myisamchk, 375, 376
  myisampack, 387
  mysql, 301
  mysqladmin, 322
  mysqlcheck, 329
  mysqldump, 341
  mysqlimport, 353
  mysql_convert_table_format, 414
  mysql_install_db, 286
  mysql_upgrade, 294
force-if-open option
  mysqlbinlog, 400
force-read option
  mysqlbinlog, 400
FORCE_PLUS_PERMANENT
  plugin activation option, 663
foreign key, 3532
  constraint, 31, 31
  deleting, 1317, 1377
FOREIGN KEY constraint, 3532
foreign key constraints, 1374
  InnoDB, 1675
  restrictions, 1675
FOREIGN KEY constraints
  and fast index creation, 1703
foreign keys, 29, 243, 1316
foreign_key_checks system variable, 516
FORMAT(), 1168
forums, 19
FOUND_ROWS(), 1261
FragmentLogFileSize, 2135
FreeBSD troubleshooting, 180
freeing items
  thread state, 955
frequently-asked questions about NDB Cluster, 2858

.frm file, 3530
FROM, 1430
FROM_DAYS(), 1206
FROM_UNIXTIME(), 1206
fs option (ndb_error_reporter), 2268
FTS, 3533
ft_boolean_syntax system variable, 517
ft_max_word_len myisamchk variable, 373
ft_max_word_len system variable, 517
ft_min_word_len myisamchk variable, 373
ft_min_word_len system variable, 518
ft_query_expansion_limit system variable, 518
ft_stopword_file myisamchk variable, 373
ft_stopword_file system variable, 518
full backup, 3533
full disk, 2967
full table scan, 3533
full table scans
  avoiding, 865
full-text parser plugins, 2772
full-text queries
  optimization, 880, 894
full-text search, 1219, 3533
FULLTEXT, 1219
fulltext
  stopword list, 1230
FULLTEXT index, 3533
FULLTEXT initialization
  thread state, 955
fulltext join type
  optimizer, 908
func table
  system table, 638
function
  creating, 1536
  deleting, 1537
function names
  parsing, 982
  resolving ambiguity, 982
functions, 1139
  and replication, 1989
  arithmetic, 1250
  bit, 1250
  C API, 2664
  C prepared statement API, 2723, 2724
  cast, 1233
  control flow, 1162
  date and time, 1197
  encryption, 1252
  for SELECT and WHERE clauses, 1139
  GROUP BY, 1280
  grouping, 1153
  information, 1258
  mathematical, 1189
  miscellaneous, 1289
  native
    adding, 2827
  new, 2817

stored, 2517
string, 1164
string comparison, 1175
user-defined, 1536, 1537, 2817
adding, 2818
fuzzy checkpointing, 3533

G

GA, 3533
MySQL releases, 44
gap, 3533
gap event, 2419
gap lock, 1615, 3534
InnoDB, 1630, 1724
gb2312, gbk, 2871
gci option
ndb_select_all, 2301
gci64 option
ndb_select_all, 2301
GCP Stop errors (NDB Cluster), 2168
gdb
using, 2832
gdb option
mysqld, 466
general information, 1
General Public License, 5
general query log, 644, 3534
general tablespace, 3534
general-log option
mysqld, 466
general_log system variable, 519
general_log table
system table, 638
general_log_file system variable, 519
geographic feature, 1116
GeomCollFromText(), 1270
GeomCollFromWKB(), 1271
geometry, 1116
GEOMETRY data type, 1117
geometry values
internal storage format, 1125
WKB format, 1125
WKT format, 1124
GEOMETRYCOLLECTION data type, 1117
GeometryCollection(), 1271
GeometryCollectionFromText(), 1270
GeometryCollectionFromWKB(), 1271
GeometryFromText(), 1270
GeometryFromWKB(), 1271
GeometryN(), 1277
GeometryType(), 1273
GeomFromText(), 1270
GeomFromWKB(), 1271
geospatial feature, 1116
German dictionary collation, 1015, 1055, 1055
German phone book collation, 1015, 1055, 1055
getting MySQL, 45
GET_FORMAT(), 1206

GET_LOCK(), 1289
GIS, 1115
GIS data types
  storage requirements, 1136
Git tree, 166
GLength(), 1274
GLOBAL
  SET statement, 1552
global privileges, 1513, 1524
global transaction, 3534
globalization, 1013
GLOBAL_STATUS
  INFORMATION_SCHEMA table, 2555
GLOBAL_VARIABLES
  INFORMATION_SCHEMA table, 2555
go command
  mysql, 308
Google Test, 175
got handler lock
  thread state, 960
got old table
  thread state, 960
GRANT statement, 738, 1513
grant table distribution (NDB Cluster), 2401
grant tables
  columns_priv table, 638, 719
  db table, 190, 638, 719
  host table, 638, 719
  procs_priv table, 638, 719
  proxies_priv, 746
  proxies_priv table, 190, 638, 719
  re-creating, 185
  sorting, 727, 729
  structure, 718
  tables_priv table, 638, 719
  user table, 190, 638, 719
granting
  privileges, 1513
grants
  display, 1559
greater than (>), 1155
greater than or equal (>=), 1155
greatest timestamp wins (conflict resolution), 2448
greatest timestamp, delete wins (conflict resolution), 2448
GREATEST(), 1157
GROUP BY
  aliases in, 1289
  extensions to standard SQL, 1287, 1431
  implicit sorting, 856
  maximum sort length, 1431
  WITH ROLLUP, 1284
GROUP BY functions, 1280
GROUP BY optimizing, 858
group commit, 1615, 3534
grouping
  expressions, 1153
GROUP_CONCAT(), 1282
group_concat_max_len system variable, 519

H

HANDLER, 1399
Handlers, 1497
handling
  errors, 2824
hash index, 3534
hash indexes, 883
hash partitioning, 2475
hash partitions
  managing, 2494
  splitting and merging, 2494
have_compress system variable, 520
have_crypt system variable, 520
have_csv system variable, 520
have_dynamic_loading system variable, 520
have_geometry system variable, 520
have_innodb system variable, 520
have_openssl system variable, 520
have_partitioning system variable, 520
have_profiling system variable, 520
have_query_cache system variable, 520
have_rtree_keys system variable, 520
have_ssl system variable, 520
have_symlink system variable, 521
HAVING, 1431
HDD, 3535
header option
  ndb_select_all, 2300
header_file option
  comp_err, 284
HEAP storage engine, 1781, 1795
heartbeat, 3535
HeartbeatIntervalDbApi, 2144
HeartbeatIntervalDbDb, 2144
HeartbeatIntervalMgmdMgmd
  management nodes, 2121
HeartbeatOrder, 2145
HeartbeatThreadPriority, 2120, 2174
help command
  mysql, 307
HELP command (NDB Cluster), 2316
help option
  comp_err, 284
  myisamchk, 372
  myisampack, 387
  myisam_ftdump, 368
  mysql, 299
  mysqlaccess, 393
  mysqladmin, 321
  mysqlbinlog, 397
  mysqlcheck, 327
  mysqld, 457
  mysqldump, 337
  mysqldumpslow, 410
  mysqld_multi, 281
  mysqld_safe, 274
  mysqlhotcopy, 412

mysqlimport, 351
MySQLInstallerConsole, 82
mysqlshow, 357
mysqlslap, 362
mysql_convert_table_format, 414
mysql_find_rows, 415
mysql_install_db, 286
mysql_plugin, 288
mysql_setpermission, 416
mysql_upgrade, 293
mysql_waitpid, 417
my_print_defaults, 420
perror, 421
resolveip, 423
resolve_stack_dump, 420
HELP option
myisamchk, 372
help option (NDB Cluster programs), 2311
HELP statement, 1594
help tables
system tables, 638
help_category table
system table, 639
help_keyword table
system table, 639
help_relation table
system table, 639
help_topic table
system table, 639
hex option
ndb_restore, 2288
HEX(), 1168, 1192
hex-blob option
mysqldump, 341
hexadecimal literal introducer, 971
hexadecimal literals, 970
hexdump option
mysqlbinlog, 400
high-water mark, 3535
HIGH_NOT_PRECEDENCE SQL mode, 624
HIGH_PRIORITY
INSERT modifier, 1404
SELECT modifier, 1433
hints, 26
index, 918, 1430
history list, 3535
history of MySQL, 8
hole punching, 3535
HOME environment variable, 312, 423
host name
default, 255
host name caching, 948
host name resolution, 948
host names
in account names, 724
in default accounts, 190
host option, 257
mysql, 301

mysqlaccess, 393
mysqladmin, 323
mysqlbinlog, 400
mysqlcheck, 329
mysqldump, 341
mysqlhotcopy, 412
mysqlimport, 353
mysqlshow, 358
mysqlslap, 364
mysql_convert_table_format, 414
mysql_setpermission, 416
mysql_upgrade, 294
ndb_config, 2256
host table, 730
sorting, 729
system table, 638, 719
Host*SciId* parameters, 2229
HostName, 2118, 2122, 2173
HostName (NDB Cluster), 2377
hostname system variable, 521
HostName1, 2223, 2227, 2229
HostName2, 2223, 2227, 2229
hot, 3535
hot backup, 3535
HOUR(), 1207
howto option
mysqlaccess, 393
html option
mysql, 301

I

i-am-a-dummy option
mysql, 304
ib-file set, 1692, 3536
ibbackup_logfile, 3536
.ibd file, 3535
ibdata file, 3536
ibtmp file, 3537
.ibz file, 3536
ib_logfile, 3537
icc
and NDB Cluster support>, 2829
MySQL builds, 59
Id, 2117, 2122, 2172
ID
unique, 2765
identifiers, 974
case sensitivity, 978
quoting, 974
identity system variable, 521
IF, 1490
IF(), 1162
IFNULL(), 1163
IGNORE
DELETE modifier, 1396, 1411
INSERT modifier, 1404
UPDATE modifier, 1456
with partitioned tables, 1404

IGNORE INDEX, 918
IGNORE KEY, 918
ignore option
  mysqlimport, 353
ignore-builtin-innodb option
  mysqld, 1708
ignore-lines option
  mysqlimport, 353
ignore-spaces option
  mysql, 301
ignore-table option
  mysqldump, 342
IGNORE_AIO_CHECK option
  CMake, 175
ignore_builtin_innodb system variable, 1709
IGNORE_SPACE SQL mode, 624
ilist, 3537
implicit default values, 1131
implicit GROUP BY sorting, 856
implicit row lock, 3537
IMPORT TABLESPACE, 1318, 1658
importing
  data, 314, 350
IN, 1157, 1446
in-memory database, 3537
include option
  mysql_config, 418
include-databases option
  ndb_restore, 2288
include-master-host-port option
  mysqldump, 341
include-tables option
  ndb_restore, 2288
increasing with replication
  speed, 1881
incremental backup, 3537
incremental recovery, 820
  using NDB Cluster replication, 2439
index, 3537
  deleting, 1316, 1388
  rebuilding, 210
index cache, 3538
index condition pushdown, 3538
INDEX DIRECTORY
  and replication, 1988
index dives (for statistics estimation), 1652
index hint, 3538
index hints, 918, 1430
index join type
  optimizer, 909
index prefix, 3538
index statistics
  NDB, 2170
index-record lock
  InnoDB, 1630, 1724
indexes, 1337
  and BLOB columns, 879, 1353
  and IS NULL, 884

and LIKE, 883
and ndb_restore, 2292
and NULL values, 1353
and TEXT columns, 879, 1353
assigning to key cache, 1585
block size, 524
column prefixes, 879
columns, 879
creating and dropping, 1702
leftmost prefix of, 878, 881
multi-column, 880
multiple-part, 1337
names, 974
primary (clustered) and secondary, 1702
use of, 877
IndexMemory, 2126
IndexStatAutoCreate
data nodes, 2170
IndexStatAutoUpdate
data nodes, 2171
IndexStatSaveScale
data nodes, 2171
IndexStatSaveSize
data nodes, 2171
IndexStatTriggerPct
data nodes, 2171
IndexStatTriggerScale
data nodes, 2171
IndexStatUpdateDelay
data nodes, 2172
index_merge join type
optimizer, 908
index_subquery join type
optimizer, 908
INET_ATON(), 1290
INET_NTOA(), 1291
infimum record, 3538
INFO Events (NDB Cluster), 2334
information functions, 1258
information option
myisamchk, 375
INFORMATION SCHEMA
InnoDB tables, 1742
INFORMATION_SCHEMA, 2545, 3538
and security issues, 2381
collation and searching, 1041
InnoDB tables, 2573
INNODB_CMP table, 1742
INNODB_CMPMEM table, 1742
INNODB_CMPMEM_RESET table, 1742
INNODB_CMP_RESET table, 1742
INNODB_LOCKS table, 1744
INNODB_LOCK_WAITS table, 1744
INNODB_TRX table, 1744
NDB Cluster tables, 2585
Thread Pool tables, 2592
INFORMATION_SCHEMA plugins, 2773
INFORMATION_SCHEMA queries

optimization, 870
INFORMATION_SCHEMA.ENGINES table
and NDB Cluster, 2353
INFORMATION_SCHEMA.GLOBAL_STATUS table
and NDB Cluster, 2354
INFORMATION_SCHEMA.GLOBAL_VARIABLES table
and NDB Cluster, 2353
init
thread state, 955
Init DB
thread command, 952
init-command option
mysql, 301
init-file option
mysqld, 466
InitFragmentLogFiles, 2135
initial option (ndbd), 2234
initial option (ndbmtd), 2234
initial option (ndb_mgmd), 2245
initial-start option (ndbd), 2235
initial-start option (ndbmtd), 2235
Initialized
thread state, 964
InitialLogFileGroup, 2167
InitialNoOfOpenFiles, 2135
InitialTablespace, 2167
init_connect system variable, 521
init_file system variable, 521
init_slave system variable, 1930
INNER JOIN, 1436
innochecksum, 252, 367
InnoDB, 1600, 3539
.frm files, 1660
adaptive hash index, 1612
and application feature requirements, 2026
application performance, 1669
applications supported, 2025
asynchronous I/O, 1650
auto-inc lock, 1615
auto-increment columns, 1669
autocommit mode, 1622, 1623
availability, 2023
backups, 1770
change buffer, 1611
checkpoints, 1700
clustered index, 1680
COMPACT row format, 1663
compared to NDB Cluster, 2023, 2024, 2025, 2026
COMPRESSED row format, 1664
configuration parameters, 1704
consistent reads, 1623
corruption, 1771
crash recovery, 1771, 1772
creating tables, 1660
data files, 1653
deadlock detection, 1632
deadlock example, 1631
deadlocks, 1630, 1632, 1666

disk failure, 1771
disk I/O, 1698
disk I/O optimization, 895
DYNAMIC row format, 1664
exclusive lock, 1615
file space management, 1698
file-per-table setting, 1656
files, 1669
foreign key constraints, 1675
gap lock, 1615, 1630, 1724
index-record lock, 1630, 1724
indexes, 1659
insert-intention lock, 1615
intention lock, 1615
limits and restrictions, 1676
Linux, 1650
lock modes, 1615
locking, 1615, 1615, 1627
locking reads, 1625
log files, 1654
memory usage, 1665
migrating tables, 1664
Monitors, 1699, 1771, 1775
multi-versioning, 1609
next-key lock, 1615, 1630, 1724
NFS, 1635, 1676
page size, 1678, 1680
physical index structure, 1680
point-in-time recovery, 1771
primary keys, 1661, 1668
raw partitions, 1654
record-level locks, 1630, 1724
recovery, 1771
REDUNDANT row format, 1662
replication, 1773
row format, 1660, 1662
row structure, 1661
secondary index, 1680
semi-consistent read, 1724
shared lock, 1615
Solaris issues, 157
storage, 1668
storage layout, 1666
system variables, 1704
table properties, 1661
tables, 1659, 1660
  converting from other storage engines, 1664
transaction model, 1615, 1619
transactions, 1665
transferring data, 1667
troubleshooting, 1775
  CREATE TABLE failure, 1777
  data dictionary problems, 1777
  deadlocks, 1630, 1632
  defragmenting tables, 1700
  fast index creation, 1703
  I/O problems, 1775
  open file error, 1778

orphan temporary tables, 1778
performance problems, 891
recovery problems, 1776
SQL errors, 1779
tablespace does not exist, 1779
InnoDB buffer pool, 921, 1638, 1642, 1643, 1643, 1644
InnoDB Monitors, 1757
enabling, 1758
output, 1760
innodb option
mysqld, 1708
InnoDB parameters, deprecated
innodb_file_io_threads, 1649
InnoDB parameters, new
innodb_file_format_check, 1693
innodb_large_prefix, 1723
InnoDB parameters, with new defaults
innodb_max_dirty_pages_pct, 1644
InnoDB storage engine, 1600, 1781
compatibility, 1604
InnoDB tables
storage requirements, 1133
innodb-status-file option
mysqld, 1708
innodb_ system variable
innodb_rollback_segments, 1734
innodb_adaptive_flushing, 1644
innodb_adaptive_flushing system variable, 1709
innodb_adaptive_hash_index
and innodb_thread_concurrency, 1648
innodb_adaptive_hash_index system variable, 1709
innodb_additional_mem_pool_size system variable, 1710
and innodb_use_sys_malloc, 1646
innodb_autoextend_increment system variable, 1710
innodb_autoinc_lock_mode, 3539
innodb_autoinc_lock_mode system variable, 1710
INNODB_BUFFER_PAGE
INFORMATION_SCHEMA table, 2573
INNODB_BUFFER_PAGE_LRU
INFORMATION_SCHEMA table, 2575
innodb_buffer_pool_instances system variable, 1711
innodb_buffer_pool_size system variable, 1711
INNODB_BUFFER_POOL_STATS
INFORMATION_SCHEMA table, 2577
innodb_change_buffering, 1647
innodb_change_buffering system variable, 1712
innodb_change_buffering_debug, 1713
innodb_checksums system variable, 1713
INNODB_CMP
INFORMATION_SCHEMA table, 2579
INNODB_CMPMEM
INFORMATION_SCHEMA table, 2580
INNODB_CMPMEM_RESET
INFORMATION_SCHEMA table, 2580
INNODB_CMP_RESET
INFORMATION_SCHEMA table, 2579
innodb_commit_concurrency system variable, 1713
innodb_concurrency_tickets, 1648

innodb_concurrency_tickets system variable, 1714
innodb_data_file_path system variable, 1714
innodb_data_home_dir system variable, 1715
innodb_doublewrite system variable, 1715
innodb_fast_shutdown system variable, 1716
innodb_file_format, 1691, 3539
  Antelope, 1688
  Barracuda, 1681
  downgrading, 1608
  identifying, 1695
innodb_file_format system variable, 1716
innodb_file_format_check, 1693
innodb_file_format_check system variable, 1717
innodb_file_format_max system variable, 1718
innodb_file_io_threads, 1649
innodb_file_per_table, 1681, 3539
innodb_file_per_table system variable, 1718
innodb_flush_log_at_trx_commit system variable, 1719
innodb_flush_method system variable, 1720
innodb_force_load_corrupted system variable, 1721
innodb_force_recovery system variable, 1721
innodb_io_capacity, 1651
innodb_io_capacity system variable, 1722
innodb_large_prefix system variable, 1723
innodb_limit_optimistic_insert_debug, 1723
INNODB_LOCKS
  INFORMATION_SCHEMA table, 2581
innodb_locks_unsafe_for_binlog system variable, 1724
INNODB_LOCK_WAITS
  INFORMATION_SCHEMA table, 2582
innodb_lock_wait_timeout, 3539
innodb_lock_wait_timeout system variable, 1723
innodb_log_buffer_size system variable, 1726
innodb_log_files_in_group system variable, 1727
innodb_log_file_size system variable, 1727
innodb_log_group_home_dir system variable, 1728
innodb_max_dirty_pages_pct, 1644
innodb_max_dirty_pages_pct system variable, 1728
innodb_max_purge_lag system variable, 1728
innodb_mirrored_log_groups system variable, 1729
innodb_old_blocks_pct, 1642
innodb_old_blocks_pct system variable, 1729
innodb_old_blocks_time, 1642
innodb_old_blocks_time system variable, 1729
innodb_open_files system variable, 1730
innodb_print_all_deadlocks system variable, 1730
  innodb_print_all_deadlocks, 1730
innodb_purge_batch_size system variable, 1731
innodb_purge_threads system variable, 1731
innodb_random_read_ahead system variable, 1732
innodb_read_ahead_threshold, 1643
innodb_read_ahead_threshold system variable, 1732
innodb_read_io_threads, 1649
innodb_read_io_threads system variable, 1733
innodb_replication_delay system variable, 1733
innodb_rollback_on_timeout system variable, 1733
innodb_rollback_segments system variable, 1734
innodb_spin_wait_delay, 1651

innodb_spin_wait_delay system variable, 1734
innodb_stats_method system variable, 1735
innodb_stats_on_metadata system variable, 1735
innodb_stats_sample_pages, 1652
innodb_stats_sample_pages system variable, 1735
innodb_strict_mode, 2995, 3540
innodb_strict_mode system variable, 1736
innodb_support_xa system variable, 1737
innodb_sync_spin_loops system variable, 1737
innodb_table_locks system variable, 1737
innodb_thread_concurrency, 1648
innodb_thread_concurrency system variable, 1738
innodb_thread_sleep_delay, 1648
innodb_thread_sleep_delay system variable, 1739
INNODB_TRX
  INFORMATION_SCHEMA table, 2583
innodb_trx_purge_view_update_only_debug, 1740
innodb_trx_rseg_n_slots_debug, 1740
innodb_use_native_aio, 1650
innodb_use_native_aio system variable, 1739
innodb_use_sys_malloc
  and innodb_thread_concurrency, 1648
innodb_use_sys_malloc system variable, 1646, 1741
innodb_version system variable, 1741
innodb_write_io_threads, 1649
innodb_write_io_threads system variable, 1741
INSERT, 875, 1400
insert, 3540
  thread state, 960
INSERT ... SELECT, 1404
insert buffer, 3540
insert buffering, 3540
  disabling, 1647
INSERT DELAYED, 1407, 1407
insert intention lock, 3540
INSERT(), 1169
insert-ignore option
  mysqldump, 342
insert-intention lock, 1615
insertable views
  insertable, 2533
inserting
  speed of, 875
inserts
  concurrent, 933, 936
insert_id system variable, 522
install option
  mysqld, 467
  MySQLInstallerConsole, 82
install option (ndbd), 2236
install option (ndbmtd), 2236
install option (ndb_mgmd), 2248
INSTALL PLUGIN statement, 1537
install-manual option
  mysqld, 467
Installation, 81
installation layouts, 59
installation overview, 159

installing
binary distribution, 59
Linux RPM packages, 141
OS X DMG packages, 128
overview, 42
Perl, 212
Perl on Windows, 213
Solaris PKG packages, 157
source distribution, 159
user-defined functions, 2825
installing NDB Cluster, 2038
Debian Linux, 2045
Linux, 2040
Linux binary release, 2041
Linux RPM, 2043
Linux source release, 2045
Ubuntu Linux, 2045
Windows, 2046
Windows binary release, 2046
Windows source, 2050
installing plugins, 661, 1537
INSTALL_BINDIR option
CMake, 172
INSTALL_DOCDIR option
CMake, 172
INSTALL_DOCREADMEDIR option
CMake, 172
INSTALL_INCLUDEDIR option
CMake, 172
INSTALL_INFODIR option
CMake, 172
INSTALL_LAYOUT option
CMake, 172
INSTALL_LIBDIR option
CMake, 172
INSTALL_MANDIR option
CMake, 172
INSTALL_MYSQLSHAREDIR option
CMake, 172
INSTALL_MYSQLTESTDIR option
CMake, 172
INSTALL_PLUGINDIR option
CMake, 172
INSTALL_SBINDIR option
CMake, 172
INSTALL_SCRIPTDIR option
CMake, 173
INSTALL_SECURE_FILE_PRIVDIR option
CMake, 173
INSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR option
CMake, 173
INSTALL_SHAREDIR option
CMake, 173
INSTALL_SQLBENCHDIR option
CMake, 173
INSTALL_SUPPORTFILESDIR option
CMake, 173
instance, 3540

INSTR(), 1169
instrumentation, 3540
INT data type, 1085
integer arithmetic, 1294
INTEGER data type, 1085
integers, 968
intention lock, 1615, 3540
interactive option (ndb_mgmd), 2245
interactive_timeout system variable, 522
InteriorRingN(), 1277
internal locking, 932
internal memory allocator
  disabling, 1646
internal storage format
  geometry values, 1125
internals, 2769
internationalization, 1013
Internet Relay Chat, 20
Intersects(), 1280
INTERVAL(), 1158
INTO
  SELECT, 1434
introducer
  binary character set, 1061
  bit-value literal, 972
  character set, 1026
  hexadecimal literal, 971
  string literal, 966, 1024
invalid data
  constraint, 31
invalidating query cache entries
  thread state, 961
inverted index, 3541
invisible index, 1337
INVOKER privileges, 1560, 2536
in_file option
  comp_err, 284
IOPS, 3541
IP addresses
  in account names, 724
  in default accounts, 190
IPv6 addresses
  in account names, 724
  in default accounts, 190
IPv6 connections, 190, 481
IRC, 20
IS boolean_value, 1156
IS NOT boolean_value, 1156
IS NOT DISTINCT FROM operator, 1154
IS NOT NULL, 1156
IS NULL, 853, 1156
  and indexes, 884
IsClosed(), 1275
IsEmpty(), 1273
.isl file, 3536
ISNULL(), 1158
ISOLATION LEVEL, 1468
isolation level, 1620, 3541

IsSimple(), 1273
IS_FREE_LOCK(), 1291
IS_USED_LOCK(), 1291
ITERATE, 1492
iterations option
  mysqlslap, 364

J

Japanese character sets
  conversion, 2871
Japanese, Korean, Chinese character sets
  frequently asked questions, 2871
Java, 2646
JDBC, 2643
jdbc:mysql:loadbalance://, 2015
join, 3541
  nested-loop algorithm, 846
JOIN, 1436
join algorithm
  Block Nested-Loop, 842
  Nested-Loop, 842
join option
  myisampack, 387
join type
  ALL, 909
  const, 907
  eq_ref, 907
  fulltext, 908
  index, 909
  index_merge, 908
  index_subquery, 908
  range, 908
  ref, 907
  ref_or_null, 908
  system, 907
  unique_subquery, 908
joins
  USING versus ON, 1440
join_buffer_size system variable, 522

K

keepold option
  mysqlhotcopy, 413
keep_files_on_create system variable, 523
Key cache
  MyISAM, 921
key cache
  assigning indexes to, 1585
key partitioning, 2478
key partitions
  managing, 2494
  splitting and merging, 2494
key space
  MyISAM, 1791
key-value store, 884
keys, 879
  foreign, 29, 243

multi-column, 880
searching on two, 245
keys option
mysqlshow, 358
keys-used option
myisamchk, 376
keywords, 986
KEY_BLOCK_SIZE, 1681, 1685, 3541
key_buffer_size myisamchk variable, 373
key_buffer_size system variable, 524
key_cache_age_threshold system variable, 525
key_cache_block_size system variable, 525
key_cache_division_limit system variable, 526
KEY_COLUMN_USAGE
INFORMATION_SCHEMA table, 2555
Kill
thread command, 952
KILL statement, 1590
Killed
thread state, 955
Killing slave
thread state, 963
known errors, 2978
Korean, 2871
Korean, Chinese, Japanese character sets
frequently asked questions, 2871

L

labels
stored program block, 1487
language option
mysqld, 467
language support
error messages, 1062
language system variable, 526
lap option
ndb_redo_log_reader, 2279
large page support, 945
large tables
NDB Cluster, 1361
large-pages option
mysqld, 468
large_files_support system variable, 526
large_pages system variable, 526
large_page_size system variable, 527
last row
unique ID, 2765
LAST_DAY(), 1207
last_insert_id system variable, 527
LAST_INSERT_ID(), 1263, 1403, 2765
and replication, 1980
and stored routines, 2519
and triggers, 2519
latch, 3542
LateAlloc, 2139
layout of installation, 59
lc-messages option
mysqld, 468

lc-messages-dir option
  mysqld, 468
LCASE(), 1169
LcpScanProgressTimeout, 2136
lc_messages system variable, 527
lc_messages_dir system variable, 527
lc_time_names system variable, 527
ldata option
  mysql_install_db, 286
LDML syntax, 1072
LD_LIBRARY_PATH environment variable, 214, 2659
LD_RUN_PATH environment variable, 214, 423
LEAST(), 1158
LEAVE, 1492
ledir option
  mysqld_safe, 274
LEFT JOIN, 849, 1436
LEFT OUTER JOIN, 1436
LEFT(), 1169
leftmost prefix of indexes, 878, 881
legal names, 974
length option
  myisam_ftdump, 368
LENGTH(), 1169
less than (<), 1155
less than or equal (<=), 1155
libaio, 60, 146, 175, 200
libmysqlclient library, 2643
libmysqld, 2647
  options, 2649
libmysqld library, 2643
libmysqld-libs option
  mysql_config, 418
LIBMYSQL_ENABLE_CLEARTEXT_PLUGIN environment variable, 423
LIBMYSQL_PLUGINS environment variable, 2753
library
  libmysqlclient, 2643
  libmysqld, 2643
libs option
  mysql_config, 418
libs_r option
  mysql_config, 418
license system variable, 528
LIKE, 1176
  and indexes, 883
  and wildcards, 883
LIMIT, 1261, 1432
  and replication, 1993
  optimizations, 861
limitations
  MySQL Limitations, 2993
  replication, 1979
limitations of NDB Cluster, 2026
limits
  file-size, 2994
  InnoDB, 1676
  MySQL Limits, limits in MySQL, 2993
line-numbers option

mysql, 301
linear hash partitioning, 2477
linear key partitioning, 2480
linefeed (\n), 966, 1415
LineFromText(), 1270
LineFromWKB(), 1271
lines-terminated-by option
mysqldump, 342, 353
ndb_restore, 2289
LINESTRING data type, 1117
LineString(), 1271
LineStringFromText(), 1270
LineStringFromWKB(), 1271
linking, 2655
errors, 2657
problems, 2657
links
symbolic, 940
list, 3542
list option
MySQLInstallerConsole, 83
list partitioning, 2466, 2468
list partitions
adding and dropping, 2488
managing, 2488
literals, 965
bit value, 972
boolean, 973
date, 968
hexadecimal, 970
numeric, 968
string, 965
time, 968
LN(), 1192
LOAD DATA
and replication, 1993
LOAD DATA INFILE, 1409, 2973
load emulation, 359
LOAD INDEX INTO CACHE
and partitioning, 2505
LOAD XML, 1418
loading
tables, 224
LOAD_FILE(), 1170
local option
mysqlimport, 353
local-infile option
mysql, 301
local-load option
mysqlbinlog, 400
local-service option
mysqld, 469
localhost
special treatment of, 256
localization, 1013
LOCALTIME, 1207
LOCALTIMESTAMP, 1207
local_infile system variable, 528

LOCATE(), 1170
lock, 3542
lock escalation, 3542
LOCK IN SHARE MODE, 1433
lock mode, 3542
Lock Monitor, 1757, 1760
lock option
  ndb_select_all, 2300
LOCK TABLES, 1462
lock-all-tables option
  mysqldump, 342
lock-tables option
  mysqldump, 342
  mysqlimport, 353
locked_in_memory system variable, 529
LockExecuteThreadToCPU, 2157
locking, 938, 1615, 3542
  external, 465, 564, 823, 937, 957
  information schema, 1742, 1743
  InnoDB, 1615
  internal, 932
  metadata, 936
  row-level, 932
  table-level, 932
locking methods, 932
locking read, 3542
LockMaintThreadsToCPU, 2158
LockPagesInMainMemory, 2140
lock_wait_timeout system variable, 528
log, 3543
log buffer, 3543
log file, 3543
log files
  maintaining, 659
log files (NDB Cluster), 2237
  ndbmtd, 2241
log group, 3543
log option
  mysqld, 469
  mysqld_multi, 281
log system variable, 529
LOG(), 1192
log-bin option
  mysqld, 1937
log-bin-index option
  mysqld, 1937
log-bin-trust-function-creators option
  mysqld, 1937
log-bin-use-v1-row-events option
  mysqld, 1938
log-error option
  mysqld, 469
  mysqldump, 342
  mysqld_safe, 274
log-isam option
  mysqld, 469
log-long-format option
  mysqld, 470

log-name option (ndb_mgmd), 2245
log-output option
  mysqld, 470
log-queries-not-using-indexes option
  mysqld, 470
log-short-format option
  mysqld, 471
log-slave-updates option
  mysqld, 1916
log-slow-admin-statements option
  mysqld, 471
log-slow-queries option
  mysqld, 471
log-slow-slave-statements option
  mysqld, 1917
log-tc option
  mysqld, 471
log-tc-size option
  mysqld, 471
log-warnings option
  mysqld, 472, 1917
LOG10(), 1193
LOG2(), 1192
logbuffers
  ndbinfo table, 2364
LogDestination, 2118
logging
  passwords, 701
logging commands (NDB Cluster), 2329
logging slow query
  thread state, 955
logical, 3543
logical backup, 3543
logical operators, 1159
login
  thread state, 955
LogLevelCheckpoint, 2153
LogLevelCongestion, 2154
LogLevelConnection, 2154
LogLevelError, 2154
LogLevelInfo, 2154
LogLevelNodeRestart, 2154
LogLevelShutdown, 2153
LogLevelStartup, 2153
LogLevelStatistic, 2153
logs
  and TIMESTAMP, 202
  flushing, 639
  server, 639
logspaces
  ndbinfo table, 2365
log_bin system variable, 1945
log_bin_trust_function_creators system variable, 529
log_bin_trust_routine_creators system variable, 530
log_bin_use_v1_row_events system variable, 1945
log_error system variable, 530
log_output system variable, 530
log_queries_not_using_indexes system variable, 530

log_slave_updates system variable, 1946
log_slow_queries system variable, 531
log_warnings system variable, 531
Long Data
  thread command, 952
LONG data type, 1109
LONGBLOB data type, 1091
LongMessageBuffer, 2133
LONGTEXT data type, 1091
long_query_time system variable, 531
LOOP, 1492
  labels, 1487
loops option
  ndb_show_tables, 2303
loops option (ndbinfo_select_all), 2240
loops option (ndb_index_stat), 2273
Loose Index Scan
  GROUP BY optimizing, 859
--loose option prefix, 261
loose_, 3543
lossy-conversions option
  ndb_move_data, 2275
  ndb_restore, 2289
lost connection errors, 2952
low-priority option
  mysqlimport, 353
low-priority-updates option
  mysqld, 472
low-water mark, 3543
LOWER(), 1170
lower_case_file_system system variable, 532
lower_case_table_names system variable, 532
LOW_PRIORITY
  DELETE modifier, 1396
  INSERT modifier, 1403
  UPDATE modifier, 1456
low_priority_updates system variable, 532
LPAD(), 1170
LRU, 3544
LRU page replacement, 1642
LSN, 3544
LTRIM(), 1171

M

mailing lists, 17
  archive location, 17
  guidelines, 19
main features of MySQL, 5
maintaining
  log files, 659
  tables, 827
maintenance
  tables, 324
MAKEDATE(), 1208
MAKETIME(), 1208
MAKE_SET(), 1171
Making temp file
  thread state, 963

malicious SQL statements
  and NDB Cluster, 2381
manage keys
  thread state, 956
management client (NDB Cluster), 2249
  (see also mgm)
management node (NDB Cluster)
  defined, 2014
management nodes (NDB Cluster), 2241
  (see also mgmd)
managing NDB Cluster, 2313
managing NDB Cluster processes, 2232
manual
  available formats, 2
  online location, 2
  syntax conventions, 2
  typographical conventions, 2
Master has sent all binlog to slave; waiting for binlog to be updated
  thread state, 961
master server, 3544
master thread, 3544
master-data option
  mysqldump, 342
master-info-file option
  mysqld, 1918
master-retry-count option
  mysqld, 1918
MASTER_POS_WAIT(), 1291, 1479
MATCH ... AGAINST(), 1219
matching
  patterns, 232
math, 1294
mathematical functions, 1189
MAX(), 1283
MAX(DISTINCT), 1283
max-binlog-dump-events option
  mysqld, 1941
max-record-length option
  myisamchk, 376
max-relay-log-size option
  mysqld, 1919
MaxAllocate, 2133
MaxBufferedEpochBytes, 2148
MaxBufferedEpochs, 2148
MAXDB SQL mode, 629
MaxDMLOperationsPerTransaction, 2131
maximum memory used, 320
--maximum option prefix, 261
maximums
  maximum columns per table, 2995
  maximum number of databases, 2993
  maximum number of tables, 2993
  maximum row size, 2995
  maximum tables per join, 2993
  table size, 2994
MaxLCPStartDelay, 2136
MaxNoOfAttributes, 2136
MaxNoOfConcurrentIndexOperations, 2131

MaxNoOfConcurrentOperations, 2129
MaxNoOfConcurrentScans, 2132
MaxNoOfConcurrentSubOperations, 2139
MaxNoOfConcurrentTransactions, 2129
MaxNoOfExecutionThreads
  ndbmtd, 2160
MaxNoOfFiredTriggers, 2131
MaxNoOfIndexes, 2138
MaxNoOfLocalOperations, 2130
MaxNoOfLocalScans, 2132
MaxNoOfOpenFiles, 2135
MaxNoOfOrderedIndexes, 2138
MaxNoOfSavedMessages, 2136
MaxNoOfSubscribers, 2139
MaxNoOfSubscriptions, 2139
MaxNoOfTables, 2137
MaxNoOfTriggers, 2138
MaxNoOfUniqueHashIndexes, 2138
MaxParallelScansPerFragment, 2133
MaxScanBatchSize, 2175
MaxStartFailRetries, 2170
max_allowed_packet
  and replication, 1993
max_allowed_packet system variable, 533
max_allowed_packet variable, 306
max_binlog_cache_size system variable, 1946
max_binlog_size system variable, 1947
max_binlog_stmt_cache_size system variable, 1947
max_connections system variable, 534
MAX_CONNECTIONS_PER_HOUR, 739
max_connect_errors system variable, 533
max_delayed_threads system variable, 534
max_error_count system variable, 535
max_heap_table_size system variable, 535
max_insert_delayed_threads system variable, 536
max_join_size system variable, 536
max_join_size variable, 306
max_length_for_sort_data system variable, 536
max_long_data_size system variable, 537
max_prepared_stmt_count system variable, 537
MAX_QUERIES_PER_HOUR, 739
max_relay_log_size system variable, 537
MAX_ROWS
  and DataMemory (NDB Cluster), 2125
  and NDB Cluster, 2459
  NDB Cluster, 1361
max_seeks_for_key system variable, 538
max_sort_length system variable, 538
max_sp_recursion_depth system variable, 539
max_tmp_tables system variable, 539
MAX_UPDATES_PER_HOUR, 739
MAX_USER_CONNECTIONS, 739
max_user_connections system variable, 539
max_write_lock_count system variable, 539
MBR, 1279
MBRContains(), 1279
MBRDisjoint(), 1279
MBREqual(), 1279

MBRIntersects(), 1279
MBROverlaps(), 1279
MBRTouches(), 1279
MBRWithin(), 1279
MD5(), 1256
MDL, 3544
medium-check option
  myisamchk, 375
  mysqlcheck, 329
MEDIUMBLOB data type, 1091
MEDIUMINT data type, 1085
MEDIUMTEXT data type, 1091
membership
  ndbinfo table, 2365
memcached, 3545
MEMCACHED_HOME option
  CMake, 178
memlock option
  mysqld, 473
memory allocation library, 274
memory allocator
  innodb_use_sys_malloc, 1646
MEMORY storage engine, 1781, 1795
  and replication, 1994
  optimization, 880
memory usage
  myisamchk, 384
memory use, 320, 943
  in NDB Cluster, 2028
  Performance Schema, 2607
memoryusage
  ndbinfo table, 2367
MemReportFrequency, 2154
merge, 3545
MERGE storage engine, 1781, 1805
MERGE tables
  defined, 1805
metadata
  database, 2545
  database object, 1018
  InnoDB, 2573
  stored routines, 2518
  triggers, 2523
  views, 2535
metadata lock, 3545
metadata locking
  transactions, 936
metadata log, 659
metadata_locks_cache_size system variable, 540
method option
  mysqlhotcopy, 413
methods
  locking, 932
metrics counter, 3545
mgmd (NDB Cluster)
  defined, 2014
    (see also management node (NDB Cluster))
MICROSECOND(), 1208

MID(), 1171
midpoint insertion, 1642
midpoint insertion strategy, 3545
milestone
  MySQL releases, 44
MIN(), 1283
MIN(DISTINCT), 1283
min-examined-row-limit option
  mysqld, 473
MinFreePct, 2125, 2128
mini-transaction, 3545
minimum bounding rectangle, 1279
minus
  unary (-), 1187
MINUTE(), 1208
min_examined_row_limit system variable, 540
mirror sites, 45
miscellaneous functions, 1289
mixed statements (Replication), 2000
mixed-mode insert, 3545
MLineFromText(), 1270
MLineFromWKB(), 1271
MOD (modulo), 1193
MOD(), 1193
modes
  batch, 239
modify option
  MySQLInstallerConsole, 84
modulo (%), 1193
modulo (MOD), 1193
monitor
  terminal, 217
monitoring, 1611, 1644, 1685, 1755, 2841
  threads, 951
Monitors, 1757
  enabling, 1758
  InnoDB, 1699, 1771, 1775
  output, 1760
MONTH(), 1208
MONTHNAME(), 1208
MPointFromText(), 1270
MPointFromWKB(), 1271
MPolyFromText(), 1270
MPolyFromWKB(), 1271
.MRG file, 3544
mSQL compatibility, 1179
msql2mysql, 418
MSSQL SQL mode, 629
multi mysqld, 280
multi-column indexes, 880
multi-core, 3546
multi-master replication
  in NDB Cluster, 2440, 2444
multibyte character sets, 2960
multibyte characters, 1065
MULTILINESTRING data type, 1117
MultiLineString(), 1271
MultiLineStringFromText(), 1270

MultiLineStringFromWKB(), 1271
multiple buffer pools, 1641
multiple servers, 671
multiple-part index, 1337
multiplication (*), 1188
MULTIPOINT data type, 1117
MultiPoint(), 1271
MultiPointFromText(), 1270
MultiPointFromWKB(), 1271
MULTIPOLYGON data type, 1117
MultiPolygon(), 1272
MultiPolygonFromText(), 1270
MultiPolygonFromWKB(), 1271
mutex, 3546
mutex wait
  monitoring, 1755
mutex_instances table
  performance_schema, 2624
MVCC, 3546
MVCC (multi-version concurrency control), 1609
My
  derivation, 8
my-print-defaults option
  mysql_plugin, 288
my.cnf, 3546
  and NDB Cluster, 2055, 2108, 2109
  in NDB Cluster, 2324
my.cnf file, 1979
my.ini, 3546
mycnf option
  ndb_config, 2256
  ndb_mgmd, 2244
.MYD file, 3544
.MYI file, 3544
MyISAM
  compressed tables, 386, 1793
  converting tables to InnoDB, 1665
MyISAM key cache, 921
MyISAM storage engine, 1781, 1787
myisam-block-size option
  mysqld, 474
myisam-recover option
  mysqld, 474
myisam-recover-options option
  mysqld, 474, 1790
myisamchk, 252, 369
  analyze option, 377
  backup option, 376
  block-search option, 377
  character-sets-dir option, 376
  check option, 375
  check-only-changed option, 375
  correct-checksum option, 376
  data-file-length option, 376
  debug option, 372
  defaults-extra-file option, 372
  defaults-file option, 373
  defaults-group-suffix option, 373

description option, 377
example output, 378
extend-check option, 375, 376
fast option, 375
force option, 375, 376
help option, 372
HELP option, 372
information option, 375
keys-used option, 376
max-record-length option, 376
medium-check option, 375
no-defaults option, 373
no-symlinks option, 376
options, 372
parallel-recover option, 376
print-defaults option, 373
quick option, 376
read-only option, 375
recover option, 376
safe-recover option, 377
set-auto-increment[option, 377
set-collation option, 377
silent option, 373
sort-index option, 378
sort-records option, 378
sort-recover option, 377
tmpdir option, 377
unpack option, 377
update-state option, 375
verbose option, 373
version option, 373
wait option, 373
myisamlog, 252, 385
myisampack, 252, 386, 1379, 1793
backup option, 387
character-sets-dir option, 387
debug option, 387
force option, 387
help option, 387
join option, 387
silent option, 387
test option, 387
tmpdir option, 387
verbose option, 387
version option, 387
wait option, 387
myisam_block_size myisamchk variable, 373
myisam_data_pointer_size system variable, 541
myisam_ftdump, 252, 367
count option, 368
dump option, 368
help option, 368
length option, 368
stats option, 368
verbose option, 369
myisam_max_sort_file_size system variable, 541
myisam_mmap_size system variable, 542
myisam_recover_options system variable, 542

myisam_repair_threads system variable, 542
myisam_sort_buffer_size myisamchk variable, 373
myisam_sort_buffer_size system variable, 543
myisam_stats_method system variable, 544
myisam_use_mmap system variable, 544
MySQL
  defined, 4
  forums, 19
  introduction, 4
  pronunciation, 5
  upgrading, 290
  web sites, 17
mysql, 251, 295, 3546
  auto-rehash option, 299
  auto-vertical-output option, 299
  batch option, 299
  binary-as-hex option, 299
  bind-address option, 299
  character-sets-dir option, 299
  charset command, 307
  clear command, 307
  column-names option, 299
  column-type-info option, 299
  comments option, 299
  compress option, 300
  connect command, 307
  database option, 300
  debug option, 300
  debug-check option, 300
  debug-info option, 300
  default-auth option, 300
  default-character-set option, 300
  defaults-extra-file option, 300
  defaults-file option, 300
  defaults-group-suffix option, 300
  delimiter command, 307
  delimiter option, 301
  disable named commands, 301
  edit command, 308
  ego command, 308
  enable-cleartext-plugin option, 301
  execute option, 301
  exit command, 308
  force option, 301
  go command, 308
  help command, 307
  help option, 299
  host option, 301
  html option, 301
  i-am-a-dummy option, 304
  ignore-spaces option, 301
  init-command option, 301
  line-numbers option, 301
  local-infile option, 301
  named-commands option, 301
  no-auto-rehash option, 302
  no-beep option, 302
  no-defaults option, 302

no-named-commands option, 302
no-pager option, 302
no-tee option, 302
nopager command, 308
notee command, 308
nowarning command, 308
one-database option, 302
pager command, 308
pager option, 302
password option, 303
pipe option, 303
plugin-dir option, 303
port option, 303
print command, 309
print-defaults option, 303
prompt command, 309
prompt option, 303
protocol option, 303
quick option, 303
quit command, 309
raw option, 303
reconnect option, 304
rehash command, 309
safe-updates option, 304
secure-auth option, 304
shared-memory-base-name option, 304
show-warnings option, 304
sigint-ignore option, 304
silent option, 304
skip-column-names option, 305
skip-line-numbers option, 305
socket option, 305
source command, 309
SSL options, 305
ssl-mode option, 756
status command, 309
system command, 309
table option, 305
tee command, 309
tee option, 305
unbuffered option, 305
use command, 309
user option, 305
verbose option, 305
version option, 305
vertical option, 305
wait option, 305
warnings command, 309
xml option, 305
MySQL binary distribution, 43
MYSQL C type, 2659
MySQL Cluster Manager
and ndb_mgm, 2315
mysql command options, 296
mysql commands
list of, 306
MySQL Dolphin name, 8
MySQL Enterprise Audit, 784, 2843

MySQL Enterprise Backup, 2842, 3546
MySQL Enterprise Encryption, 2843
MySQL Enterprise Firewall, 2843
MySQL Enterprise Monitor, 2841
MySQL Enterprise Security, 768, 776, 2842
MySQL Enterprise Thread Pool, 665, 2844
  components, 666
  installing, 667
MySQL history, 8
mysql history file, 312
MySQL Installer, 66
MySQL mailing lists, 17
MySQL name, 8
MySQL Notifier, 84
MySQL privileges
  and NDB Cluster, 2380
mysql prompt command, 310
MySQL server
  mysqld, 272, 425
mysql source (command for reading from text files), 240, 314
MySQL source distribution, 43
MySQL storage engines, 1781
MySQL system tables
  and NDB Cluster, 2380
  and replication, 1994
MySQL version, 45
mysql \. (command for reading from text files), 240, 314
mysql.event table, 2530
mysql.ndb_binlog_index table, 2425
  (see also NDB Cluster replication)
mysql.server, 250, 278
  basedir option, 279
  datadir option, 279
  pid-file option, 279
  service-startup-timeout option, 280
mysql.sock
  protection, 2968
MYSQL323 SQL mode, 629
MYSQL40 SQL mode, 629
mysqlaccess, 252, 392
  brief option, 393
  commit option, 393
  copy option, 393
  db option, 393
  debug option, 393
  help option, 393
  host option, 393
  howto option, 393
  old_server option, 393
  password option, 393
  plan option, 393
  preview option, 393
  relnotes option, 394
  rhost option, 394
  rollback option, 394
  spassword option, 394
  superuser option, 394
  table option, 394

user option, 394
version option, 394
mysqladmin, 251, 317, 1332, 1388, 1576, 1581, 1587, 1590
bind-address option, 321
character-sets-dir option, 322
compress option, 322
count option, 322
debug option, 322
debug-check option, 322
debug-info option, 322
default-auth option, 322
default-character-set option, 322
defaults-extra-file option, 322
defaults-file option, 322
defaults-group-suffix option, 322
enable-cleartext-plugin option, 322
force option, 322
help option, 321
host option, 323
no-beep option, 323
no-defaults option, 323
password option, 323
pipe option, 323
plugin-dir option, 323
port option, 323
print-defaults option, 323
protocol option, 323
relative option, 323
shared-memory-base-name option, 323
silent option, 324
sleep option, 324
socket option, 324
SSL options, 324
user option, 324
verbose option, 324
version option, 324
vertical option, 324
wait option, 324
mysqladmin command options, 320
mysqladmin option
mysqld_multi, 281
mysqlbackup command, 3546
mysqlbinlog, 252, 394
base64-output option, 397
bind-address option, 398
character-sets-dir option, 398
database option, 398
debug option, 399
debug-check option, 399
debug-info option, 399
default-auth option, 399
defaults-extra-file option, 399
defaults-file option, 399
defaults-group-suffix option, 399
disable-log-bin option, 399
force-if-open option, 400
force-read option, 400
help option, 397

hexdump option, 400
host option, 400
local-load option, 400
no-defaults option, 400
offset option, 400
password option, 400
plugin-dir option, 400
port option, 400
position option, 401
print-defaults option, 401
protocol option, 401
read-from-remote-server option, 401
result-file option, 401
server-id option, 401
server-id-bits option, 401
set-charset option, 401
shared-memory-base-name option, 401
short-form option, 401
socket option, 401
SSL options, 401
start-datetime option, 402
start-position option, 402
stop-datetime option, 402
stop-position option, 402
to-last-log option, 402
user option, 402
verbose option, 402
version option, 402
mysqlbug, 284
mysqlcheck, 251, 324
all-databases option, 327
all-in-1 option, 327
analyze option, 327
auto-repair option, 327
bind-address option, 327
character-sets-dir option, 328
check option, 328
check-only-changed option, 328
check-upgrade option, 328
compress option, 328
databases option, 328
debug option, 328
debug-check option, 328
debug-info option, 328
default-auth option, 329
default-character-set option, 328
defaults-extra-file option, 328
defaults-file option, 328
defaults-group-suffix option, 329
enable-cleartext-plugin option, 329
extended option, 329
fast option, 329
fix-db-names option, 329
fix-table-names option, 329
force option, 329
help option, 327
host option, 329
medium-check option, 329

no-defaults option, 329
optimize option, 329
password option, 330
pipe option, 330
plugin-dir option, 330
port option, 330
print-defaults option, 330
protocol option, 330
quick option, 330
repair option, 330
shared-memory-base-name option, 330
silent option, 330
socket option, 330
SSL options, 331
tables option, 331
use-frm option, 331
user option, 331
verbose option, 331
version option, 331
write-binlog option, 331
mysqld, 250, 3546
abort-slave-event-count option, 1916
allow-suspicious-udfs option, 457
ansi option, 457
as NDB Cluster process, 2178, 2324
audit-log option, 800
basedir option, 458
big-tables option, 458
bind-address option, 458
binlog-do-db option, 1938
binlog-format option, 459
binlog-ignore-db option, 1940
binlog-row-event-max-size option, 1936
bootstrap option, 459
character-set-client-handshake option, 460
character-set-filesystem option, 460
character-set-server option, 460
character-sets-dir option, 460
chroot option, 460
collation-server option, 461
command options, 456
console option, 461
core-file option, 461
datadir option, 461
debug option, 461
debug-sync-timeout option, 462
default-character-set option, 462
default-collation option, 462
default-storage-engine option, 463
default-time-zone option, 463
defaults-extra-file option, 463
defaults-file option, 463
defaults-group-suffix option, 464
delay-key-write option, 464, 1790
des-key-file option, 464
disconnect-slave-event-count option, 1916
enable-named-pipe option, 464
enable-pstack option, 465

event-scheduler option, 465
exit-info option, 465
external-locking option, 465
flush option, 466
gdb option, 466
general-log option, 466
help option, 457
ignore-builtin-innodb option, 1708
init-file option, 466
innodb option, 1708
innodb-status-file option, 1708
install option, 467
install-manual option, 467
language option, 467
large-pages option, 468
lc-messages option, 468
lc-messages-dir option, 468
local-service option, 469
log option, 469
log-bin option, 1937
log-bin-index option, 1937
log-bin-trust-function-creators option, 1937
log-bin-use-v1-row-events option, 1938
log-error option, 469
log-isam option, 469
log-long-format option, 470
log-output option, 470
log-queries-not-using-indexes option, 470
log-short-format option, 471
log-slave-updates option, 1916
log-slow-admin-statements option, 471
log-slow-queries option, 471
log-slow-slave-statements option, 1917
log-tc option, 471
log-tc-size option, 471
log-warnings option, 472, 1917
low-priority-updates option, 472
master-info-file option, 1918
master-retry-count option, 1918
max-binlog-dump-events option, 1941
max-relay-log-size option, 1919
memlock option, 473
min-examined-row-limit option, 473
myisam-block-size option, 474
myisam-recover option, 474
myisam-recover-options option, 474, 1790
MySQL server, 272, 425
ndb-batch-size option, 2179
ndb-blob-read-batch-bytes option, 2180
ndb-blob-write-batch-bytes option, 2180
ndb-cluster-connection-pool option, 2179
ndb-connectstring option, 2181
ndb-log-apply-status, 2182
ndb-log-empty-epochs, 2183
ndb-log-empty-update, 2183
ndb-log-orig, 2184
ndb-log-transaction-id, 2184
ndb-nodeid, 2185

ndbcluster option, 2178
no-defaults option, 475
old-alter-table option, 475
old-style-user-limits option, 475
one-thread option, 476
open-files-limit option, 476
partition option, 476
pid-file option, 476
plugin option prefix, 477
plugin-load option, 477
port option, 477
port-open-timeout option, 478
print-defaults option, 478
relay-log option, 1919
relay-log-index option, 1920
relay-log-info-file option, 1920
relay-log-purge option, 1920
relay-log-recovery option, 1920
relay-log-space-limit option, 1921
remove option, 478
replicate-do-db option, 1921
replicate-do-table option, 1924
replicate-ignore-db option, 1923
replicate-ignore-table option, 1924
replicate-rewrite-db option, 1924
replicate-same-server-id option, 1925
replicate-wild-do-table option, 1925
replicate-wild-ignore-table option, 1925
report-host option, 1926
report-password option, 1926
report-port option, 1926
report-user option, 1927
role in NDB Cluster (see SQL Node (NDB Cluster))
safe-mode option, 478
safe-show-database option, 478
safe-user-create option, 479
secure-auth option, 479
secure-file-priv option, 479
server-id option, 1899
server-id-bits option, 2188
shared-memory option, 480
shared-memory-base-name option, 480
show-slave-auth-info option, 1912
skip-concurrent-insert option, 480
skip-event-scheduler option, 480
skip-grant-tables option, 481
skip-host-cache option, 481
skip-innodb option, 481, 1709
skip-name-resolve option, 481
skip-ndbcluster option, 2189
skip-networking option, 481
skip-partition option, 481
skip-safemalloc option, 482
skip-show-database option, 483
skip-slave-start option, 1927
skip-stack-trace option, 483
skip-symbolic-links option, 482
skip-thread-priority option, 483

slave-load-tmpdir option, 1927
slave-max-allowed-packet, 1918
slave-net-timeout option, 1928
slave-skip-errors option, 1928
slave_compressed_protocol option, 1927
slow-query-log option, 483
slow-start-timeout option, 483
socket option, 484
sporadic-binlog-dump-fail option, 1941
sql-mode option, 484
SSL options, 482
standalone option, 482
starting, 709
super-large-pages option, 482
symbolic-links option, 482
sysdate-is-now option, 485
tc-heuristic-recover option, 485
temp-pool option, 485
tmpdir option, 486
transaction-isolation option, 486
user option, 486
verbose option, 487
version option, 487
mysqld (NDB Cluster), 2232
mysqld option
malloc-lib, 274
mysqld_multi, 281
mysqld_safe, 275
mysql_plugin, 288
mysqld options, 426
mysqld options and variables
NDB Cluster, 2178
mysqld system variables, 426
mysqld-version option
mysqld_safe, 275
mysqldump, 212, 251, 331, 3547
add-drop-database option, 337
add-drop-table option, 337
add-drop-trigger option, 337
add-locks option, 337
all-databases option, 338
all-tablespaces option, 338
allow-keywords option, 338
apply-slave-statements option, 338
bind-address option, 338
character-sets-dir option, 338
comments option, 338
compact option, 338
compatible option, 338
complete-insert option, 338
compress option, 339
create-options option, 339
databases option, 339
debug option, 339
debug-check option, 339
debug-info option, 339
default-auth option, 339
default-character-set option, 339

defaults-extra-file option, 339
defaults-file option, 339
defaults-group-suffix option, 339
delayed-insert option, 340
delete-master-logs option, 340
disable-keys option, 340
dump-date option, 340
dump-slave option, 340
enable-cleartext-plugin option, 341
events option, 340
extended-insert option, 341
fields-enclosed-by option, 341, 353
fields-escaped-by option, 341, 353
fields-optionally-enclosed-by option, 341, 353
fields-terminated-by option, 341, 353
first-slave option, 341
flush-logs option, 341
flush-privileges option, 341
force option, 341
help option, 337
hex-blob option, 341
host option, 341
ignore-table option, 342
include-master-host-port option, 341
insert-ignore option, 342
lines-terminated-by option, 342, 353
lock-all-tables option, 342
lock-tables option, 342
log-error option, 342
master-data option, 342
no-autocommit option, 343
no-create-db option, 343
no-create-info option, 343
no-data option, 343
no-defaults option, 344
no-set-names option, 344
no-tablespaces option, 344
opt option, 344
order-by-primary option, 344
password option, 344
pipe option, 344
plugin-dir option, 344
port option, 344
print-defaults option, 345
problems, 350, 2990
protocol option, 345
quick option, 345
quote-names option, 345
replace option, 345
result-file option, 345
routines option, 345
set-charset option, 345
shared-memory-base-name option, 345
single-transaction option, 346
skip-comments option, 346
skip-opt option, 346
socket option, 346
SSL options, 346

tab option, 346
tables option, 347
triggers option, 347
tz-utc option, 347
user option, 347
using for backups, 814
verbose option, 347
version option, 347
views, 350, 2990
where option, 347
workarounds, 350, 2990
xml option, 347
mysqldumpslow, 252, 409
debug option, 410
help option, 410
verbose option, 411
mysqld_multi, 250, 280
config-file option, 281
defaults-extra-file option, 281
defaults-file option, 281
example option, 281
help option, 281
log option, 281
mysqladmin option, 281
mysqld option, 281
no-defaults option, 281
no-log option, 281
password option, 281
silent option, 282
tcp-ip option, 282
user option, 282
verbose option, 282
version option, 282
mysqld_safe, 250, 273
basedir option, 274
core-file-size option, 274
datadir option, 274
defaults-extra-file option, 274
defaults-file option, 274
help option, 274
ledir option, 274
log-error option, 274
malloc-lib option, 274
mysqld option, 275
mysqld-version option, 275
nice option, 275
no-defaults option, 276
open-files-limit option, 276
pid-file option, 276
plugin-dir option, 276
port option, 276
skip-kill-mysqld option, 276
skip-syslog option, 276
socket option, 276
syslog option, 276
syslog-tag option, 276
timezone option, 276
user option, 276

mysqlhotcopy, 252, 411
addtodest option, 412
allowold option, 412
checkpoint option, 412
chroot option, 412
debug option, 412
dryrun option, 412
flushlog option, 412
help option, 412
host option, 412
keepold option, 413
method option, 413
noindices option, 413
old_server option, 413
password option, 413
port option, 413
quiet option, 413
record_log_pos option, 413
regexp option, 413
resetmaster option, 413
resetslave option, 413
socket option, 413
suffix option, 413
tmpdir option, 414
user option, 414
mysqlimport, 212, 251, 350, 1410
bind-address option, 352
character-sets-dir option, 352
columns option, 352
compress option, 352
debug option, 352
debug-check option, 352
debug-info option, 352
default-auth option, 352
default-character-set option, 352
defaults-extra-file option, 352
defaults-file option, 352
defaults-group-suffix option, 352
delete option, 353
enable-cleartext-plugin option, 353
force option, 353
help option, 351
host option, 353
ignore option, 353
ignore-lines option, 353
local option, 353
lock-tables option, 353
low-priority option, 353
no-defaults option, 354
password option, 354
pipe option, 354
plugin-dir option, 354
port option, 354
print-defaults option, 354
protocol option, 354
replace option, 354
shared-memory-base-name option, 354
silent option, 354

socket option, 354
SSL options, 355
use-threads option, 355
user option, 355
verbose option, 355
version option, 355
MySQLInstallerConsole, 81
configure option, 82
help option, 82
install option, 82
list option, 83
modify option, 84
remove option, 84
status option, 84
update option, 84
upgrade option, 84
mysqlshow, 252, 355
bind-address option, 357
character-sets-dir option, 357
compress option, 357
count option, 357
debug option, 357
debug-check option, 357
debug-info option, 357
default-auth option, 358
default-character-set option, 357
defaults-extra-file option, 358
defaults-file option, 358
defaults-group-suffix option, 358
enable-cleartext-plugin option, 358
help option, 357
host option, 358
keys option, 358
no-defaults option, 358
password option, 358
pipe option, 358
plugin-dir option, 358
port option, 359
print-defaults option, 359
protocol option, 359
shared-memory-base-name option, 359
show-table-type option, 359
socket option, 359
SSL options, 359
status option, 359
user option, 359
verbose option, 359
version option, 359
mysqlslap, 252, 359
auto-generate-sql option, 362
auto-generate-sql-add-autoincrement option, 362
auto-generate-sql-execute-number option, 363
auto-generate-sql-guid-primary option, 363
auto-generate-sql-load-type option, 363
auto-generate-sql-secondary-indexes option, 363
auto-generate-sql-unique-query-number option, 363
auto-generate-sql-unique-write-number option, 363
auto-generate-sql-write-number option, 363

commit option, 363
compress option, 363
concurrency option, 363
create option, 363
create-schema option, 363
csv option, 363
debug option, 364
debug-check option, 364
debug-info option, 364
default-auth option, 364
defaults-extra-file option, 364
defaults-file option, 364
defaults-group-suffix option, 364
delimiter option, 364
detach option, 364
enable-cleartext-plugin option, 364
engine option, 364
help option, 362
host option, 364
iterations option, 364
no-defaults option, 365
no-drop option, 365
number-char-cols option, 365
number-int-cols option, 365
number-of-queries option, 365
only-print option, 365
password option, 365
pipe option, 365
plugin-dir option, 365
port option, 365
post-query option, 365
post-system option, 366
pre-query option, 366
pre-system option, 366
print-defaults option, 366
protocol option, 366
query option, 366
shared-memory-base-name option, 366
silent option, 366
socket option, 366
SSL options, 366
user option, 366
verbose option, 366
version option, 366
mysqltest
MySQL Test Suite, 2770
mysql_affected_rows(), 2669, 2765
mysql_autocommit(), 2670
MYSQL_BIND C type, 2719
mysql_change_user(), 2670
mysql_character_set_name(), 2671
mysql_clear_password authentication plugin, 767
mysql_client_find_plugin(), 2752
mysql_client_register_plugin(), 2753
mysql_close(), 2672
mysql_cluster_backup_privileges, 2402
mysql_cluster_move_grant_tables, 2402
mysql_cluster_move_privileges, 2402

mysql_cluster_privileges_are_distributed, 2402
mysql_cluster_restore_local_privileges, 2404
mysql_cluster_restore_privileges, 2404
mysql_cluster_restore_privileges_from_local, 2404
mysql_commit(), 2672
mysql_config, 418
  cflags option, 418
  embedded option, 418
  embedded-libs option, 418
  include option, 418
  libmysqld-libs option, 418
  libs option, 418
  libs_r option, 418
  plugindir option, 419
  port option, 419
  socket option, 419
  variable option, 419
  version option, 419
mysql_connect(), 2672
mysql_convert_table_format, 252, 414
  force option, 414
  help option, 414
  host option, 414
  password option, 414
  port option, 414
  socket option, 414
  type option, 414
  user option, 415
  verbose option, 415
  version option, 415
mysql_create_db(), 2673
MYSQL_DATADIR option
  CMake, 173
mysql_data_seek(), 2673
MYSQL_DEBUG environment variable, 254, 423, 2837
mysql_debug(), 2674
mysql_drop_db(), 2674
mysql_dump_debug_info(), 2675
mysql_eof(), 2675
mysql_errno(), 2676
mysql_error(), 2677
mysql_escape_string(), 2677
mysql_fetch_field(), 2677
mysql_fetch_fields(), 2679
mysql_fetch_field_direct(), 2678
mysql_fetch_lengths(), 2679
mysql_fetch_row(), 2680
MYSQL_FIELD C type, 2660
mysql_field_count(), 2681, 2694
MYSQL_FIELD_OFFSET C type, 2660
mysql_field_seek(), 2681
mysql_field_tell(), 2682
mysql_find_rows, 253, 415
  help option, 415
  regexp option, 415
  rows option, 415
  skip-use-db option, 415
  start_row option, 415

mysql_fix_extensions, 253, 415
mysql_free_result(), 2682
mysql_get_character_set_info(), 2682
mysql_get_client_info(), 2683
mysql_get_client_version(), 2683
mysql_get_host_info(), 2684
mysql_get_proto_info(), 2684
mysql_get_server_info(), 2684
mysql_get_server_version(), 2684
mysql_get_ssl_cipher(), 2685
MYSQL_GROUP_SUFFIX environment variable, 423
mysql_hex_string(), 2685
MYSQL_HISTFILE environment variable, 312, 423
MYSQL_HOME environment variable, 423
MYSQL_HOST environment variable, 258, 423
mysql_info(), 1311, 1403, 1418, 1457, 2686, 2765
mysql_init(), 2686
mysql_insert_id(), 1403, 2687, 2765, 2765
mysql_install_db, 184, 251, 285
  basedir option, 286
  builddir option, 286
  cross-bootstrap option, 286
  datadir option, 286
  force option, 286
  help option, 286
  ldata option, 286
  rpm option, 286
  skip-name-resolve option, 286
  srcdir option, 287
  user option, 287
  verbose option, 287
  windows option, 287
mysql_kill(), 2688
mysql_library_end(), 2689
mysql_library_init(), 2689
mysql_list_dbs(), 2690
mysql_list_fields(), 2691
mysql_list_processes(), 2692
mysql_list_tables(), 2692
mysql_load_plugin(), 2753
mysql_load_plugin_v(), 2754
MYSQL_MAINTAINER_MODE option
  CMake, 175
mysql_more_results(), 2693
mysql_native_password authentication plugin, 765
mysql_next_result(), 2693
mysql_num_fields(), 2694
mysql_num_rows(), 2695, 2765
mysql_old_password authentication plugin, 766
mysql_options(), 2696
mysql_ping(), 2700
mysql_plugin, 251, 287
  basedir option, 288
  datadir option, 288
  help option, 288
  my-print-defaults option, 288
  mysqld option, 288
  no-defaults option, 288

plugin-dir option, 289
plugin-ini option, 289
print-defaults option, 289
verbose option, 289
version option, 289
mysql_plugin_options(), 2754
MYSQL_PROJECT_NAME option
CMake, 176
MYSQL_PS1 environment variable, 423
MYSQL_PWD environment variable, 254, 258, 423
mysql_query(), 2701, 2765
mysql_real_connect(), 2702
mysql_real_escape_string(), 967, 1172, 2705
mysql_real_query(), 2706
mysql_refresh(), 2707
mysql_reload(), 2708
MYSQL_RES C type, 2660
mysql_rollback(), 2708
MYSQL_ROW C type, 2660
mysql_row_seek(), 2709
mysql_row_tell(), 2709
mysql_secure_installation, 251, 289
mysql_select_db(), 2709
MYSQL_SERVER_AUTH_INFO plugin structure, 2810
mysql_server_end(), 2751
mysql_server_init(), 2751
mysql_setpermission, 253, 416
help option, 416
host option, 416
password option, 416
port option, 416
socket option, 416
user option, 416
mysql_set_character_set(), 2710
mysql_set_local_infile_default(), 2710, 2710
mysql_set_server_option(), 2712
mysql_shutdown(), 2713
mysql_sqlstate(), 2713
mysql_ssl_set(), 2714
mysql_stat(), 2714
MYSQL_STMT C type, 2719
mysql_stmt_affected_rows(), 2727
mysql_stmt_attr_get(), 2727
mysql_stmt_attr_set(), 2728
mysql_stmt_bind_param(), 2729
mysql_stmt_bind_result(), 2730
mysql_stmt_close(), 2730
mysql_stmt_data_seek(), 2731
mysql_stmt_errno(), 2731
mysql_stmt_error(), 2732
mysql_stmt_execute(), 2732
mysql_stmt_fetch(), 2735
mysql_stmt_fetch_column(), 2740
mysql_stmt_field_count(), 2740
mysql_stmt_free_result(), 2741
mysql_stmt_init(), 2741
mysql_stmt_insert_id(), 2741
mysql_stmt_next_result(), 2742

mysql_stmt_num_rows(), 2743
mysql_stmt_param_count(), 2743
mysql_stmt_param_metadata(), 2743
mysql_stmt_prepare(), 2743
mysql_stmt_reset(), 2744
mysql_stmt_result_metadata, 2745
mysql_stmt_row_seek(), 2746
mysql_stmt_row_tell(), 2746
mysql_stmt_send_long_data(), 2747
mysql_stmt_sqlstate(), 2748
mysql_stmt_store_result(), 2749
mysql_store_result(), 2715, 2765
MYSQL_TCP_PORT environment variable, 254, 423, 677, 678
MYSQL_TCP_PORT option
  CMake, 176
mysql_thread_end(), 2750
mysql_thread_id(), 2716
mysql_thread_init(), 2751
mysql_thread_safe(), 2751
MYSQL_TIME C type, 2721
mysql_tzinfo_to_sql, 251, 289
MYSQL_UNIX_ADDR option
  CMake, 176
MYSQL_UNIX_PORT environment variable, 185, 254, 423, 677, 678
mysql_upgrade, 251, 290, 732
  basedir option, 293
  character-sets-dir option, 293
  compress option, 293
  datadir option, 293
  debug option, 293
  debug-check option, 293
  debug-info option, 293
  default-auth option, 293
  default-character-set option, 293
  defaults-extra-file option, 293
  defaults-file option, 293
  defaults-group-suffix option, 294
  force option, 294
  help option, 293
  host option, 294
  mysql_upgrade_info file, 291
  no-defaults option, 294
  password option, 294
  pipe option, 294
  plugin-dir option, 294
  port option, 294
  print-defaults option, 294
  protocol option, 294
  shared-memory-base-name option, 295
  socket option, 295
  SSL options, 295
  tmpdir option, 295
  upgrade-system-tables option, 295
  user option, 295
  verbose option, 295
  version-check option, 295
  write-binlog option, 295
mysql_upgrade_info file

mysql_upgrade, 291
mysql_use_result(), 2717
mysql_waitpid, 253, 416
help option, 417
verbose option, 417
version option, 417
mysql_warning_count(), 2718
mysql_zap, 253, 417
my_bool C type, 2660
my_bool values
printing, 2660
my_init(), 2750
my_print_defaults, 253, 419
config-file option, 420
debug option, 420
defaults-extra-file option, 420
defaults-file option, 420
defaults-group-suffix option, 420
extra-file option, 420
help option, 420
no-defaults option, 420
verbose option, 420
version option, 420
my_snprintf service, 2816
my_thd_scheduler service, 2816
my_ulonglong C type, 2660
my_ulonglong values
printing, 2660

N

named pipes, 117, 123
named-commands option
mysql, 301
named_pipe system variable, 544
names, 974
case sensitivity, 978
variables, 1006
NAME_CONST(), 1291, 2541
name_file option
comp_err, 284
naming
releases of MySQL, 44
NATIONAL CHAR data type, 1089
NATIONAL VARCHAR data type, 1090
native backup and restore
backup identifiers, 2321
native functions
adding, 2827
NATURAL JOIN, 1436
natural key, 3547
NATURAL LEFT JOIN, 1436
NATURAL LEFT OUTER JOIN, 1436
NATURAL RIGHT JOIN, 1436
NATURAL RIGHT OUTER JOIN, 1436
NCHAR data type, 1089
NDB API
and distributed grant tables, 2404
and distributed privileges, 2404

NDB API counters (NDB Cluster), 2404
  scope, 2407
  status variables associated with, 2410
  types, 2408
NDB API database objects
  and NDB Cluster replication, 2418
NDB API _slave status variables
  and NDB Cluster Replication, 2417
NDB client programs
  defaults-extra-file option, 2311
  defaults-file option, 2311
  no-defaults option, 2312
  print-defaults option, 2312
NDB Cluster, 2010
  "quick" configuration, 2064
  administration, 2178, 2233, 2242, 2249, 2249, 2309, 2315, 2334
  and application feature requirements, 2026
  and DNS, 2039
  and INFORMATION_SCHEMA, 2381
  and IP addressing, 2039
  and MySQL privileges, 2380
  and MySQL root user, 2380, 2382
  and networking, 2019
  and transactions, 2126
  API node, 2014, 2172
  applications supported, 2025
  availability, 2023
  available platforms, 2010
  BACKUP Events, 2334
  backups, 2280, 2319, 2319, 2320, 2323, 2323
  binlog_format system variable, 1943, 1944
  CHECKPOINT Events, 2331
  cluster logs, 2327, 2329
  CLUSTERLOG commands, 2329
  CLUSTERLOG STATISTICS command, 2334
  commands, 2178, 2233, 2242, 2249, 2315
  compared to InnoDB, 2023, 2024, 2025, 2026
  compared to standalone MySQL Server, 2023, 2024, 2025, 2026
  compiling with icc, 2829
  concepts, 2014
  configuration, 2038, 2064, 2064, 2116, 2117, 2121, 2172, 2248, 2324
  configuration (example), 2109
  configuration changes, 2325
  configuration files, 2055, 2108
  configuration parameters, 2066, 2067, 2082, 2084, 2087
  configuring, 2323
  CONNECT command, 2316
  CONNECTION Events, 2330
  connection string, 2115
  CREATE NODEGROUP command, 2318
  data node, 2014, 2121
  data nodes, 2233, 2240
  defining node hosts, 2116
  direct connections between nodes, 2225
  Disk Data tables (see NDB Cluster Disk Data)
  DROP NODEGROUP command, 2318
  ENTER SINGLE USER MODE command, 2317
  ERROR Events, 2333

error logs, 2238
event log format, 2330
event logging thresholds, 2329
event logs, 2327, 2329
event severity levels, 2329
event types, 2328, 2330
execution threads, 2160
EXIT command, 2318
EXIT SINGLE USER MODE command, 2318
FAQ, 2858
GCP Stop errors, 2168
general description, 2012
HELP command, 2316
HostName parameter
  and security, 2377
INFO Events, 2334
information sources, 2012
insecurity of communication protocols, 2376
installation, 2038
installation (Linux), 2040
installation (Windows), 2046
installing .deb file (Linux), 2045
installing binary (Windows), 2046
installing binary release (Linux), 2041
installing from source (Linux), 2045
installing from source (Windows), 2050
installing RPM (Linux), 2043
interconnects, 2232
Java clients, 2015
large tables, 1361
log files, 2237, 2241
logging commands, 2329
management client (ndb_mgm), 2249
management commands, 2334
management node, 2014, 2117
management nodes, 2241
managing, 2313
MAX_ROWS, 1361
memory usage and recovery, 2028, 2326
mgm, 2309
mgm client, 2315
mgm management client, 2334
mgm process, 2249
mgmd, 2309
mgmd process, 2242
monitoring, 2404
multiple management servers, 2327
mysqld options and variables for, 2178
mysqld process, 2178, 2324
ndbd, 2233, 2309
ndbd process, 2233, 2336
ndbinfo_select_all, 2239
ndbmtd, 2240
ndb_mgm, 2057, 2249
ndb_mgmd process, 2241
network configuration
  and security, 2377
network transporters, 2232

networking, 2225, 2226, 2228
node failure (single user mode), 2352
node identifiers, 2226, 2226, 2228, 2228
node logs, 2327
NODERESTART Events, 2332
nodes and node groups, 2016
nodes and types, 2014
partitioning support, 2027
partitions, 2016
performing queries, 2058
preparing for replication, 2428
process management, 2232
QUIT command, 2318
replicas, 2016
replication, 2416
  (see also NDB Cluster replication)
REPORT command, 2317
requirements, 2019
resetting, 2325
RESTART command, 2316
restarting, 2061
restoring backups, 2280
rolling restarts (multiple management servers), 2327
runtime statistics, 2334
SCHEMA Events, 2333
SCI (Scalable Coherent Interface), 2228
security, 2376
  and firewalls, 2378, 2379
  and HostName parameter, 2377
  and network configuration, 2377
  and network ports, 2380
  and remote administration, 2380
  networking, 2376
security procedures, 2382
shared memory transport, 2226
SHOW command, 2316
SHUTDOWN command, 2318
shutting down, 2061
single user mode, 2317, 2351
SINGLEUSER Events, 2334
SQL node, 2014, 2172
SQL nodes, 2324
SQL statements for monitoring, 2352
START BACKUP command, 2435
START command, 2316
start phases (summary), 2313
starting, 2064
starting nodes, 2050, 2057
starting or restarting, 2313
STARTUP Events, 2331
STATISTICS Events, 2333
STATUS command, 2317
status variables, 2210
STOP command, 2316
storage requirements, 1133
thread states, 963
trace files, 2238
transaction handling, 2031

transaction isolation level, 2029
transporters
Scalable Coherent Interface (SCI), 2228
shared memory (SHM), 2226
TCP/IP, 2225
troubleshooting backups, 2323
upgrades and downgrades, 2062, 2325
USING HASH, 1339
using tables and data, 2058
NDB Cluster 7.2, 2020
NDB Cluster Disk Data, 2383
creating log file groups, 2384
creating tables, 2384, 2385
creating tablespaces, 2385
dropping Disk Data objects, 2387
storage requirements, 2390
NDB Cluster How-To, 2038
NDB Cluster limitations, 2026
and differences from standard MySQL limits, 2028
binary logging, 2033
CREATE TABLE statements, 2036
database objects, 2032
Disk Data storage, 2034
error handling and reporting, 2031
geometry data types, 2027
implementation, 2033
imposed by configuration, 2028
INSERT IGNORE, UPDATE IGNORE, and REPLACE statements, 2036
memory usage and transaction handling, 2031
multiple data nodes, 2036
multiple management servers, 2035
multiple MySQL servers, 2034
partitioning, 2027
performance, 2033
replication, 2028, 2035
resolved in current version from previous versions, 2035
syntax, 2026
transactions, 2029
unsupported features, 2032
NDB Cluster processes, 2232
NDB Cluster programs, 2232
NDB Cluster replication, 2416
and --initial option, 2422
and circular replication, 2419
and NDB API database objects, 2418
and primary key, 2421
and single point of failure, 2431
and unique keys, 2421
backups, 2434
circular replication, 2440
concepts, 2417, 2417
conflict resolution, 2444
failover, 2431, 2432
gap event, 2419
known issues, 2419
loss of connection, 2419
multi-master replication, 2440
point-in-time recovery, 2439

preparing, 2428
requirements, 2418
reset-slave.pl backup automation script, 2437
restoring from backup, 2434
starting, 2429
storage engines other than NDB on slave, 2423
synchronization of master and slave, 2437
system tables used, 2425
NDB Cluster Replication
and NDB API _slave status variables, 2417
NDB Cluster replication conflict resolution
exceptions table, 2451
ndb option
perror, 421
NDB statistics variables
and NDB API counters, 2410
NDB statistics variables (NDB Cluster), 2404
scope, 2407
types, 2408
NDB storage engine (see NDB Cluster)
FAQ, 2858
NDB tables
and MySQL root user, 2380
NDB utilities
security issues, 2383
NDB$EPOCH(), 2448
limitations, 2450
NDB$EPOCH_TRANS(), 2448, 2450
NDB$MAX(), 2448
NDB$MAX_DELETE_WIN(), 2448
NDB$OLD, 2447
ndb-batch-size option
mysqld, 2179
ndb-blob-read-batch-bytes option
mysqld, 2180
ndb-blob-write-batch-bytes option
mysqld, 2180
ndb-cluster-connection-pool option
mysqld, 2179
ndb-connectstring option
mysqld, 2181
ndb_config, 2256
ndb-connectstring option (NDB Cluster programs), 2311
ndb-deferred-constraints option (NDB Cluster), 2181
ndb-distribution option (NDB Cluster), 2182
ndb-log-apply-status option
mysqld, 2182
ndb-log-empty-epochs option
mysqld, 2183
ndb-log-empty-update option
mysqld, 2183
ndb-log-orig option
mysqld, 2184
ndb-log-transaction-id option
mysqld, 2184
ndb-log-update-as-write (mysqld option), 2445
ndb-mgmd-host option (NDB Cluster programs), 2312
ndb-mgmd-host option (NDB Cluster), 2185

ndb-nodegroup-map option
  ndb_restore, 2290
ndb-nodeid option
  mysqld, 2185
ndb-nodeid option (NDB Cluster programs), 2312
ndb-optimized-node-selection option (NDB Cluster), 2312
ndbcluster option
  mysqld, 2178
NDBCLUSTER storage engine (see NDB Cluster)
ndbd, 2232, 2232
ndbd (NDB Cluster)
  defined, 2014
    (see also data node (NDB Cluster))
ndbinfo database, 2355
  and query cache, 2357
  basic usage, 2357
  determining support for, 2355
ndbinfo_select_all, 2232, 2239
ndbmtd, 2232, 2240
  configuration, 2162, 2162
  MaxNoOfExecutionThreads, 2160
  trace files, 2241, 2241
ndb_apply_status table (NDB Cluster replication), 2426, 2426, 2432
  (see also NDB Cluster replication)
ndb_binlog_index table
  system table, 639, 2425
ndb_binlog_index table (NDB Cluster replication), 2425, 2433
  (see also NDB Cluster replication)
ndb_blob_tool, 2232, 2250
  check-orphans option, 2251
  database option, 2251
  delete-orphans option, 2251
  dump-file option, 2251
  verbose option, 2252
ndb_config, 2232, 2253
  config-file option, 2255
  configinfo option, 2254
  config_from_node option, 2255
  connections option, 2255
  fields option, 2255
  host option, 2256
  mycnf option, 2256
  ndb-connectstring option, 2256
  nodeid option, 2256
  nodes option, 2257
  query option, 2257, 2257
  rows option, 2257
  system option, 2257
  type option, 2258
  usage option, 2258
  version option, 2258
  xml option, 2258
ndb_cpcd, 2232, 2260
ndb_delete_all, 2232, 2260
  transactional option, 2261
ndb_desc, 2232, 2261
  blob-info option, 2265
  database option, 2265

extra-node-info option, 2265
extra-partition-info option, 2265
retries option, 2265
table option, 2265
unqualified option, 2265
ndb_dist_priv.sql, 2401
ndb_drop_index, 2232, 2265
ndb_drop_table, 2232, 2266
ndb_error_reporter, 2232, 2267
options, 2268
ndb_index_stat, 2232, 2268
example, 2269
interpreting output, 2269
ndb_log_apply_status variable (NDB Cluster replication), 2432
ndb_log_empty_epochs system variable, 2199
ndb_log_empty_update system variable, 2199
ndb_log_orig system variable, 2200
ndb_log_transaction_id system variable, 2200
ndb_mgm, 2232, 2249 (see mgm)
using with MySQL Cluster Manager, 2315
ndb_mgm (NDB Cluster management node client), 2057
ndb_mgmd, 2232 (see mgmd)
mycnf option, 2244
ndb_mgmd (NDB Cluster process), 2241
ndb_mgmd (NDB Cluster)
defined, 2014
(see also management node (NDB Cluster))
ndb_move_data, 2232, 2273
abort-on-error option, 2274
character-sets-dir option, 2274
database option, 2274
drop-source option, 2274
error-insert option, 2275
exclude-missing-columns option, 2275
lossy-conversions option, 2275
promote-attributes option, 2275
staging-tries option, 2275
verbose option, 2275
ndb_print_backup_file, 2232, 2276
ndb_print_file, 2232, 2276
ndb_print_frag_file, 2232
ndb_print_schema_file, 2232, 2277
ndb_print_sys_file, 2232, 2277
ndb_redo_log_reader, 2277
dump option, 2278
lap option, 2279
twiddle option, 2280
ndb_replication system table, 2446
ndb_restore, 2280
and circular replication, 2442
and distributed privileges, 2404
append option, 2284
backupid option, 2284
backup_path option, 2284
connect option, 2285
disable-indexes option, 2285
dont_ignore_systab_0 option, 2285
errors, 2295

exclude-databases option, 2285
exclude-intermediate-sql-tables option, 2285
exclude-missing-columns option, 2286
exclude-missing-tables option, 2286
exclude-tables option, 2286
fields-enclosed-by option, 2287
fields-optionally-enclosed-by option, 2287
fields-terminated-by option, 2287
hex option, 2288
include-databases option, 2288
include-tables option, 2288
lines-terminated-by option, 2289
lossy-conversions option, 2289
ndb-nodegroup-map option, 2290
no-binlog option, 2289
no-restore-disk-objects option, 2289
no-upgrade option, 2289
nodeid option, 2290
parallelism option, 2290
preserve-trailing-spaces option, 2290
print option, 2291
print_data option, 2291
print_log option, 2291
print_meta option, 2291
progress-frequency option, 2291
promote-attributes option, 2292
rebuild-indexes option, 2292
restore-privilege-tables option, 2293
restore_data option, 2293
restore_epoch option, 2293
restore_meta option, 2293
rewrite-database option, 2294
skip-broken-objects option, 2294
skip-table-check option, 2294
skip-unknown-objects option, 2295
tab option, 2295
typical and required options, 2283
verbose option, 2295
ndb_schema table (NDB Cluster replication), 2427
(see also NDB Cluster replication)
ndb_select_all, 2232, 2299
database option, 2300
delimiter option, 2300
descending option, 2300
disk option, 2301
gci option, 2301
gci64 option, 2301
header option, 2300
lock option, 2300
nodata option, 2301
order option, 2300
parallelism option, 2300
rowid option, 2301
tupscan option, 2301
useHexFormat option, 2300
ndb_select_count, 2232, 2302
ndb_show_tables, 2232, 2303
database option, 2303

loops option, 2303
parsable option, 2303
show-temp-status option, 2303
type option, 2304
unqualified option, 2304
ndb_size.pl, 2232, 2304
ndb_transid_mysql_connection_map
INFORMATION_SCHEMA table, 2591
ndb_waiter, 2232, 2307
no-contact option, 2307
not-started option, 2308
nowait-nodes option, 2308
single-user option, 2308
timeout option, 2308
wait-nodes option, 2308
negative values, 968
neighbor page, 3547
nested queries, 1443
Nested-Loop join algorithm, 842
nested-loop join algorithm, 846
net etiquette, 19
netmask notation
in account names, 725
network ports
and NDB Cluster, 2380
net_buffer_length system variable, 545
net_buffer_length variable, 306
net_read_timeout system variable, 545
net_retry_count system variable, 545
net_write_timeout system variable, 546
new features in MySQL 5.5, 9
new features in NDB Cluster, 2020
new system variable, 546
new users
adding, 186
newline (\n), 966, 1415
next-key lock, 1615, 3547
InnoDB, 1630, 1724
NFS
InnoDB, 1635, 1676
nice option
mysqld_safe, 275
no matching rows, 2975
no-auto-rehash option
mysql, 302
no-autocommit option
mysqldump, 343
no-beep option
mysql, 302
mysqladmin, 323
no-binlog option
ndb_restore, 2289
no-contact option
ndb_waiter, 2307
no-create-db option
mysqldump, 343
no-create-info option
mysqldump, 343

no-data option
  mysqldump, 343
no-defaults option, 267, 286
  myisamchk, 373
  mysql, 302
  mysqladmin, 323
  mysqlbinlog, 400
  mysqlcheck, 329
  mysqld, 475
  mysqldump, 344
  mysqld_multi, 281
  mysqld_safe, 276
  mysqlimport, 354
  mysqlshow, 358
  mysqlslap, 365
  mysql_plugin, 288
  mysql_upgrade, 294
  my_print_defaults, 420
  NDB client programs, 2312
no-drop option
  mysqlslap, 365
no-log option
  mysqld_multi, 281
no-named-commands option
  mysql, 302
no-nodeid-checks option (ndb_mgmd), 2243
no-pager option
  mysql, 302
no-restore-disk-objects option
  ndb_restore, 2289
no-set-names option
  mysqldump, 344
no-symlinks option
  myisamchk, 376
no-tablespaces option
  mysqldump, 344
no-tee option
  mysql, 302
no-upgrade option
  ndb_restore, 2289
nodaemon option (ndb_mgmd), 2246
nodata option
  ndb_select_all, 2301
node groups (NDB Cluster), 2016
node logs (NDB Cluster), 2327
NodeGroup, 2123
NodeId, 2117, 2122, 2173
nodeid option
  ndb_config, 2256
  ndb_restore, 2290
NodeId1, 2223, 2226, 2228
NodeId2, 2223, 2226, 2228
NODERESTART Events (NDB Cluster), 2332
nodes
  ndbinfo table, 2368
nodes option
  ndb_config, 2257
noindices option

mysqlhotcopy, 413
non-blocking I/O, 3547
non-locking read, 3547
non-repeatable read, 3547
nondelimited strings, 970
nondeterministic functions
optimization, 863
replication, 863
Nontransactional tables, 2974
NoOfDiskPagesToDiskAfterRestartACC (DEPRECATED), 2150
NoOfDiskPagesToDiskAfterRestartTUP (DEPRECATED), 2150
NoOfDiskPagesToDiskDuringRestartACC, 2150
NoOfDiskPagesToDiskDuringRestartTUP, 2150
NoOfFragmentLogFiles, 2134
NoOfFragmentLogParts, 2162
NoOfReplicas, 2123
nopager command
mysql, 308
normalized, 3548
NoSQL, 3548
nostart option (ndbd), 2236
nostart option (ndbmtd), 2236
NOT
logical, 1159
NOT BETWEEN, 1157
not equal (!=), 1155
not equal (<>), 1155
NOT EXISTS
with subqueries, 1448
NOT IN, 1158
NOT LIKE, 1178
NOT NULL
constraint, 31
NOT NULL constraint, 3548
NOT REGEXP, 1179
not-started option
ndb_waiter, 2308
notee command
mysql, 308
Notifier, 84
NOW(), 1208
NOWAIT (START BACKUP command), 2320
nowait-nodes option
ndb_waiter, 2308
nowait-nodes option (ndbd), 2236
nowait-nodes option (ndbmtd), 2236
nowait-nodes option (ndb_mgmd), 2246
nowarning command
mysql, 308
NO_AUTO_CREATE_USER SQL mode, 625
NO_AUTO_VALUE_ON_ZERO SQL mode, 625
NO_BACKSLASH_ESCAPES SQL mode, 625
NO_DIR_IN_CREATE SQL mode, 625
NO_ENGINE_SUBSTITUTION SQL mode, 625
NO_FIELD_OPTIONS SQL mode, 626
NO_KEY_OPTIONS SQL mode, 626
NO_TABLE_OPTIONS SQL mode, 626
NO_UNSIGNED_SUBTRACTION SQL mode, 626

NO_ZERO_DATE SQL mode, 627
NO_ZERO_IN_DATE SQL mode, 627
NUL, 966, 1415
NULL, 231, 2972, 3548
  ORDER BY, 855, 1431
  testing for null, 1154, 1156, 1156, 1157, 1163
  thread state, 956
NULL value, 231, 974
NULL values
  and AUTO_INCREMENT columns, 2973
  and indexes, 1353
  and TIMESTAMP columns, 2973
  vs. empty values, 2972
NULL-complemented row, 847, 851
null-rejected condition, 851
NULLIF(), 1163
Numa, 2159
number-char-cols option
  mysqlslap, 365
number-int-cols option
  mysqlslap, 365
number-of-queries option
  mysqlslap, 365
numbers, 968
NUMERIC data type, 1086
numeric data types
  storage requirements, 1133
numeric literals
  approximate-value, 968, 1295
  exact-value, 968, 1295
numeric precision, 1084
numeric scale, 1084
numeric-dump-file option
  resolve_stack_dump, 421
NumGeometries(), 1277
NumInteriorRings(), 1277
NumPoints(), 1275
NVARCHAR data type, 1090

O

obtaining information about partitions, 2496
OCT(), 1171
OCTET_LENGTH(), 1171
ODBC compatibility, 567, 977, 1087, 1149, 1156, 1354, 1438
ODBC_INCLUDES= option
  CMake, 173
ODBC_LIB_DIR option
  CMake, 173
ODirect, 2141
OFF
  plugin activation option, 663
off-page column, 3549
offset option
  mysqlbinlog, 400
OGC (see Open Geospatial Consortium)
OLAP, 1284
old system variable, 546
old-alter-table option

mysqld, 475
old-style-user-limits option
mysqld, 475
old_alter_table system variable, 547
OLD_PASSWORD(), 1256
old_passwords system variable, 547
old_server option
mysqlaccess, 393
mysqlhotcopy, 413
OLTP, 3549
ON
plugin activation option, 663
ON DUPLICATE KEY
INSERT modifier, 1404
ON DUPLICATE KEY UPDATE, 1400
ON versus USING
joins, 1440
one-database option
mysql, 302
one-thread option
mysqld, 476
one_shot system variable, 548
online, 3549
online DDL, 3549
online location of manual, 2
online upgrades and downgrades (NDB Cluster), 2325
order of node updates, 2326
only-print option
mysqlslap, 365
ONLY_FULL_GROUP_BY
SQL mode, 1287
ONLY_FULL_GROUP_BY SQL mode, 627
OPEN, 1495
Open Geospatial Consortium, 1115
Open Source
defined, 5
open tables, 320, 888
open-files-limit option
mysqld, 476
mysqld_safe, 276
OpenGIS, 1115
opening
tables, 888
Opening master dump table
thread state, 963
Opening mysql.ndb_apply_status
thread state, 963
Opening table
thread state, 956
Opening tables
thread state, 956
opens, 320
OpenSSL, 751, 762
compared to yaSSL, 762
open_files_limit system variable, 548
open_files_limit variable, 403
operating systems
file-size limits, 2994

supported, 43
operations
arithmetic, 1187
operators, 1139
arithmetic, 1250
assignment, 1006, 1160
bit, 1250
cast, 1186, 1233
logical, 1159
precedence, 1152
.OPT file, 3549
opt option
mysqldump, 344
optimistic, 3549
optimization, 830, 895
benchmarking, 949
BLOB types, 887
buffering and caching, 921
character and string types, 887
data change statements, 875
data size, 885
DELETE statements, 876
disk I/O, 939
foreign keys, 879
full table scans, 865
full-text queries, 880, 894
indexes, 877
INFORMATION_SCHEMA queries, 870
InnoDB tables, 891
INSERT statements, 875
locking, 932
many tables, 888
MEMORY storage engine, 880
MEMORY tables, 902
memory usage, 943
MyISAM tables, 898
network usage, 947
nondeterministic functions, 863
numeric types, 886
Performance Schema queries, 888
PERFORMANCE_SCHEMA, 951
primary keys, 878
privileges, 876
REPAIR TABLE statements, 901
SELECT statements, 832
spatial queries, 880
SQL statements, 832
subqueries, 866
tips, 876
UPDATE statements, 876
WHERE clauses, 833
optimizations, 838
LIMIT clause, 861
row constructors, 864
optimize option
mysqlcheck, 329
OPTIMIZE TABLE
and partitioning, 2495

OPTIMIZE TABLE statement, 1532
optimizer, 3550
  and replication, 1994
  controlling, 916
  query plan evaluation, 916
  switchable optimizations, 917
Optimizer Statistics, 1652
optimizer_prune_level system variable, 548
optimizer_search_depth system variable, 548
optimizer_switch system variable, 549, 917
optimizing
  DISTINCT, 860
  filesort, 856
  GROUP BY, 858
  LEFT JOIN, 849
  ORDER BY, 854
  RIGHT JOIN, 849
  server configuration, 938
  tables, 827
  thread state, 956
option, 3550
option file, 3550
option files, 261, 732
  escape sequences, 264
option prefix
  --disable, 261
  --enable, 261
  --loose, 261
  --maximum, 261
  --skip, 261
options
  boolean, 261
  CMake, 167
  command-line
    mysql, 296
    mysqladmin, 320
  embedded server, 2649
  libmysqld, 2649
  myisamchk, 372
  mysqld, 426
  provided by MySQL, 217
  replication, 1979
OR, 245, 838
  bitwise, 1250
  logical, 1160
OR Index Merge optimization, 838
Oracle compatibility, 27, 1284, 1314, 1594
ORACLE SQL mode, 629
ORD(), 1171
ORDER BY, 228, 1318, 1430
  maximum sort length, 1431
  NULL, 855, 1431
ORDER BY optimization, 854
order option
  ndb_select_all, 2300
order-by-primary option
  mysqldump, 344
OS X

installation, 128
Out of resources error
and partitioned tables, 2505
out-of-range handling, 1095
OUTFILE, 1435
out_dir option
comp_err, 284
out_file option
comp_err, 284
overflow handling, 1095
overflow page, 3550
Overlaps(), 1280
OverloadLimit, 2223, 2227, 2230
overview, 1

P

packages
list of, 39
PAD SPACE collations, 1039, 1107
PAD_CHAR_TO_FULL_LENGTH SQL mode, 627
page, 3550
page cleaner, 3551
page size, 3551
InnoDB, 1678, 1680
pager command
mysql, 308
pager option
mysql, 302
PAM
pluggable authentication, 768
.par file, 3550
parallel-recover option
myisamchk, 376
parallelism option
ndb_restore, 2290
parameters
server, 426
PARAMETERS
INFORMATION_SCHEMA table, 2556
parent table, 3551
parentheses (and), 1153
parsable option
ndb_show_tables, 2303
partial backup, 3551
partial index, 3551
partial updates
and replication, 1998
PARTITION, 2455
PARTITION BY LIST COLUMNS, 2468
PARTITION BY RANGE COLUMNS, 2468
partition management, 2487
partition option
mysqld, 476
partition pruning, 2498
partitioning, 2455
advantages, 2459
and dates, 2460
and foreign keys, 2505

and FULLTEXT indexes, 2505
and key cache, 2505
and query cache, 2505
and replication, 1995, 1999
and SQL mode, 1999, 2502
and subqueries, 2506
and temporary tables, 2506, 2508
by hash, 2475
by key, 2478
by linear hash, 2477
by linear key, 2480
by list, 2466
by range, 2462
COLUMNS, 2468
concepts, 2457
data type of partitioning key, 2506
enabling, 2455
functions allowed in partitioning expressions, 2512
keys, 2459
limitations, 2502
operators not permitted in partitioning expressions, 2502
operators supported in partitioning expressions, 2502
optimization, 2497, 2498
partitioning expression, 2459
resources, 2457
storage engines (limitations), 2511
subpartitioning, 2506
support, 2455
support in NDB Cluster, 2027
tables, 2455
types, 2460
Partitioning
maximum number of partitions, 2505
partitioning information statements, 2496
partitioning keys and primary keys, 2508
partitioning keys and unique keys, 2508
partitions
adding and dropping, 2487
analyzing, 2495
checking, 2495
managing, 2487
modifying, 2487
optimizing, 2495
repairing, 2495
splitting and merging, 2487
truncating, 2487
PARTITIONS
INFORMATION_SCHEMA table, 2557
partitions (NDB Cluster), 2016
password
root user, 190
password encryption
reversibility of, 1257
password option, 257
mysql, 303
mysqlaccess, 393
mysqladmin, 323
mysqlbinlog, 400

mysqlcheck, 330
mysqldump, 344
mysqld_multi, 281
mysqlhotcopy, 413
mysqlimport, 354
mysqlshow, 358
mysqlslap, 365
mysql_convert_table_format, 414
mysql_setpermission, 416
mysql_upgrade, 294
PASSWORD(), 726, 741, 1256, 2960
passwords
administrator guidelines, 701
for users, 736
forgotten, 2962
hashing, 701
logging, 701
lost, 2962
resetting, 2962
security, 699, 713
setting, 741, 1520, 1525
user guidelines, 699
PATH environment variable, 119, 125, 188, 255, 423
path name separators
Windows, 264
pattern matching, 232, 1179
performance, 830
benchmarks, 950
disk I/O, 939
estimating, 916
Performance Schema, 1753, 2599, 3551
event filtering, 2611
memory use, 2607
Performance Schema queries
optimization, 888
performance_schema
cond_instances table, 2624
events_waits_current table, 2628
events_waits_history table, 2629
events_waits_history_long table, 2629
events_waits_summary_by_instance table, 2630
events_waits_summary_by_thread_by_event_name table, 2630
events_waits_summary_global_by_event_name table, 2630
file_instances table, 2624
file_summary_by_event_name table, 2631
file_summary_by_instance table, 2631
mutex_instances table, 2624
performance_timers table, 2632
rwlock_instances table, 2625
setup_consumers table, 2621
setup_instruments table, 2622
setup_timers table, 2623
threads table, 2633
performance_schema database, 2599
restrictions, 2991
TRUNCATE TABLE, 2619, 2991
PERFORMANCE_SCHEMA storage engine, 2599
performance_schema system variable, 2635

Performance_schema_cond_classes_lost status variable, 2640
Performance_schema_cond_instances_lost status variable, 2640
performance_schema_events_waits_history_long_size system variable, 2636
performance_schema_events_waits_history_size system variable, 2636
Performance_schema_file_classes_lost status variable, 2640
Performance_schema_file_handles_lost status variable, 2640
Performance_schema_file_instances_lost status variable, 2640
Performance_schema_locker_lost status variable, 2640
performance_schema_max_cond_classes system variable, 2636
performance_schema_max_cond_instances system variable, 2636
performance_schema_max_file_classes system variable, 2637
performance_schema_max_file_handles system variable, 2637
performance_schema_max_file_instances system variable, 2637
performance_schema_max_mutex_classes system variable, 2637
performance_schema_max_mutex_instances system variable, 2638
performance_schema_max_rwlock_classes system variable, 2638
performance_schema_max_rwlock_instances system variable, 2638
performance_schema_max_table_handles system variable, 2638
performance_schema_max_table_instances system variable, 2639
performance_schema_max_thread_classes system variable, 2639
performance_schema_max_thread_instances system variable, 2639
Performance_schema_mutex_classes_lost status variable, 2640
Performance_schema_mutex_instances_lost status variable, 2640
Performance_schema_rwlock_classes_lost status variable, 2641
Performance_schema_rwlock_instances_lost status variable, 2641
Performance_schema_table_handles_lost status variable, 2641
Performance_schema_table_instances_lost status variable, 2641
Performance_schema_thread_classes_lost status variable, 2641
Performance_schema_thread_instances_lost status variable, 2641
performance_timers table
  performance_schema, 2632
PERIOD_ADD(), 1209
PERIOD_DIFF(), 1209
Perl
  installing, 212
  installing on Windows, 213
Perl API, 2766
Perl DBI/DBD
  installation problems, 214
permission checks
  effect on speed, 876
perror, 253, 421
  help option, 421
  ndb option, 421
  silent option, 421
  verbose option, 422
  version option, 422
persistent statistics, 3551
pessimistic, 3551
phantom, 3552
phantom rows, 1630
phone book collation, German, 1015, 1055, 1055
physical, 3552
physical backup, 3552
PI(), 1193
pid-file option
  mysql.server, 279
  mysqld, 476

mysqld_safe, 276
pid_file system variable, 549
Ping
thread command, 952
pipe option, 257
mysql, 303, 330
mysqladmin, 323
mysqldump, 344
mysqlimport, 354
mysqlshow, 358
mysqlslap, 365
mysql_upgrade, 294
PIPES_AS_CONCAT SQL mode, 628
PITR, 3552
plan option
mysqlaccess, 393
plan stability, 3552
pluggable authentication
PAM, 768
restrictions, 2992
Windows, 776
plugin
audit_log, 784
plugin activation options
FORCE, 663
FORCE_PLUS_PERMANENT, 663
OFF, 663
ON, 663
plugin API, 661, 2771
plugin installing
audit_log, 786
MySQL Enterprise Thread Pool, 667
plugin option prefix
mysqld, 477
plugin service
my_snprintf, 2816
my_thd_scheduler, 2816
thd_alloc, 2816
thd_wait, 2816
plugin services, 2816
plugin table
system table, 638
plugin-dir option
mysql, 303
mysqladmin, 323
mysqlbinlog, 400
mysqlcheck, 330
mysqldump, 344
mysqld_safe, 276
mysqlimport, 354
mysqlshow, 358
mysqlslap, 365
mysql_plugin, 289
mysql_upgrade, 294
plugin-ini option
mysql_plugin, 289
plugin-load option
mysqld, 477

plugindir option
  mysql_config, 419
plugins
  activating, 661
  adding, 2771
  audit, 2773
  authentication, 2774
  daemon, 2773
  full-text parser, 2772
  INFORMATION_SCHEMA, 2773
  installing, 661, 1537
  security, 765
  semisynchronous replication, 2773
  server, 661
  storage engine, 2772
  uninstalling, 661, 1538
PLUGINS
  INFORMATION_SCHEMA table, 2560
plugin_dir system variable, 550
POINT data type, 1117
Point(), 1272
point-in-time recovery, 820, 3552
  InnoDB, 1771
  using NDB Cluster replication, 2439
PointFromText(), 1270
PointFromWKB(), 1271
PointN(), 1275
PolyFromText(), 1270
PolyFromWKB(), 1271
POLYGON data type, 1117
Polygon(), 1272
PolygonFromText(), 1270
PolygonFromWKB(), 1271
port option, 257
  mysql, 303
  mysqladmin, 323
  mysqlbinlog, 400
  mysqlcheck, 330
  mysqld, 477
  mysqldump, 344
  mysqld_safe, 276
  mysqlhotcopy, 413
  mysqlimport, 354
  mysqlshow, 359
  mysqlslap, 365
  mysql_config, 419
  mysql_convert_table_format, 414
  mysql_setpermission, 416
  mysql_upgrade, 294
port system variable, 550
port-open-timeout option
  mysqld, 478
portability, 831
  types, 1136
porting
  to other systems, 2829
PortNumber, 2118
PortNumber (OBSOLETE), 2224

PortNumberStats, 2120
ports, 698
position option
  mysqlbinlog, 401
POSITION(), 1172
post-filtering
  Performance Schema, 2611
post-query option
  mysqlslap, 365
post-system option
  mysqlslap, 366
PostgreSQL compatibility, 28
POSTGRESQL SQL mode, 629
postinstall
  multiple servers, 671
postinstallation
  setup and testing, 181
POW(), 1193
POWER(), 1194
pre-filtering
  Performance Schema, 2611
pre-query option
  mysqlslap, 366
pre-system option
  mysqlslap, 366
precedence
  command options, 259
  operator, 1152
precision
  arithmetic, 1294
  numeric, 1084
precision math, 1294
preload_buffer_size system variable, 550
Prepare
  thread command, 953
PREPARE, 1481, 1484
  XA transactions, 1470
prepared backup, 3552
prepared statements, 1481, 1484, 1485, 1485, 2718
  repreparation, 1486
preparing
  thread state, 956
preserve-trailing-spaces option
  ndb_restore, 2290
preview option
  mysqlaccess, 393
primary key, 3553
  constraint, 30
  deleting, 1315
PRIMARY KEY, 1315, 1355
primary keys
  and partitioning keys, 2508
print command
  mysql, 309
print option
  ndb_restore, 2291
print-defaults option, 267
  myisamchk, 373

mysql, 303
mysqladmin, 323
mysqlbinlog, 401
mysqlcheck, 330
mysqld, 478
mysqldump, 345
mysqlimport, 354
mysqlshow, 359
mysqlslap, 366
mysql_plugin, 289
mysql_upgrade, 294
NDB client programs, 2312
print-full-config option (ndb_mgmd), 2246
print_data option
ndb_restore, 2291
print_log option
ndb_restore, 2291
print_meta option
ndb_restore, 2291
privilege
changes, 730
privilege checks
effect on speed, 876
privilege information
location, 718
privilege system, 713
privileges
access, 713
adding, 738
and replication, 1994
default, 190
DEFINER, 1560, 2536
deleting, 739, 1513
display, 1559
dropping, 739, 1513
granting, 1513
INVOKER, 1560, 2536
revoking, 1524
SQL SECURITY, 2536
TEMPORARY tables, 715, 1370
problems
access denied errors, 2949
common errors, 2948
compiling, 179
DATE columns, 2971
date values, 1098
installing on Solaris, 157
installing Perl, 214
linking, 2657
lost connection errors, 2952
reporting, 2, 20
starting the server, 186
table locking, 934
time zone, 2969
proc table
system table, 638
PROCEDURE, 1433
PROCEDURE ANALYSE(), 888

procedures
  stored, 2517
process, 3553
process management (NDB Cluster), 2232
processes
  display, 1566
processing
  arguments, 2822
Processing events
  thread state, 963
Processing events from schema table
  thread state, 963
Processlist
  thread command, 953
PROCESSLIST, 1566
  INFORMATION_SCHEMA table, 2561
  possible inconsistency with INFORMATION_SCHEMA tables, 1749
procs_priv table
  system table, 638, 719
PROFILING
  INFORMATION_SCHEMA table, 2562
profiling system variable, 551
profiling_history_size system variable, 551
program options (NDB Cluster), 2309
program variables
  setting, 267
program-development utilities, 253
programs
  administrative, 252
  client, 251, 2655
  stored, 1486, 2515
  utility, 252
progress-frequency option
  ndb_restore, 2291
promote-attributes option
  ndb_move_data, 2275
  ndb_restore, 2292
prompt command
  mysql, 309
prompt option
  mysql, 303
prompts
  meanings, 220
pronunciation
  MySQL, 5
protocol option, 257
  mysql, 303
  mysqladmin, 323
  mysqlbinlog, 401
  mysqlcheck, 330
  mysqldump, 345
  mysqlimport, 354
  mysqlshow, 359
  mysqlslap, 366
  mysql_upgrade, 294
protocol_version system variable, 551
proxies_priv
  grant table, 746

proxies_priv table
  system table, 190, 638, 719
proxy users, 745
  conflict with anonymous users, 748
  default proxy user, 747
  PAM authentication, 774
  PROXY privilege, 746
  system variables, 749
  Windows authentication, 780
proxy_user system variable, 551
pseudo-record, 3553
pseudo_slave_mode system variable, 551
pseudo_thread_id system variable, 551
Pthreads, 3553
purge, 3553
PURGE BINARY LOGS, 1473
purge buffering, 3553
purge lag, 3553
PURGE MASTER LOGS, 1473
purge scheduling, 1651
purge thread, 3553
Purging old relay logs
  thread state, 956
Python, 2647
  third-party driver, 2767

Q

QUARTER(), 1209
queries
  entering, 218
  estimating performance, 916
  examples, 241
  speed of, 832
Query
  thread command, 953
query, 3553
Query Cache, 925
query cache
  and ndbinfo database tables, 2357
  and partitioned tables, 2505
  thread states, 960
query end
  thread state, 956
query execution plan, 903, 3554
query option
  mysqlslap, 366
  ndb_config, 2257, 2257
query option (ndb_index_stat), 2271
query_alloc_block_size system variable, 552
query_cache_limit system variable, 552
query_cache_min_res_unit system variable, 553
query_cache_size system variable, 553
query_cache_type system variable, 554
query_cache_wlock_invalidate system variable, 554
query_prealloc_size system variable, 555
questions, 319
  answering, 19
Queueing master event to the relay log

thread state, 961
QUICK
DELETE modifier, 1396
quick option
myisamchk, 376
mysql, 303
mysqlcheck, 330
mysqldump, 345
quiesce, 3554
quiet option
mysqlhotcopy, 413
Quit
thread command, 953
quit command
mysql, 309
QUIT command (NDB Cluster), 2318
quotation marks
in strings, 967
QUOTE(), 967, 1172, 2705
quote-names option
mysqldump, 345
quoting, 967
column alias, 975, 2973
quoting binary data, 967
quoting of identifiers, 974

R

R-tree, 3554
RADIANS(), 1194
RAID, 3554
RAND(), 1194
random dive, 3554
rand_seed1 system variable, 555
rand_seed2 system variable, 555
range join type
optimizer, 908
range partitioning, 2462, 2468
range partitions
adding and dropping, 2488
managing, 2488
range_alloc_block_size system variable, 555
raw backup, 3554
raw option
mysql, 303
raw partitions, 1654
RC
MySQL releases, 44
re-creating
grant tables, 185
READ COMMITTED, 3554
implementation in NDB Cluster, 2029
transaction isolation level, 1620
read phenomena, 3555
READ UNCOMMITTED, 3555
transaction isolation level, 1622
read view, 3555
read-ahead, 3555
linear, 1643

random, 1643
read-from-remote-server option
mysqlbinlog, 401
read-only option
myisamchk, 375
read-only transaction, 3555
Reading event from the relay log
thread state, 963
Reading from net
thread state, 956
Reading master dump table data
thread state, 963
read_buffer_size myisamchk variable, 373
read_buffer_size system variable, 556
read_only system variable, 557
read_rnd_buffer_size system variable, 557
REAL data type, 1087
RealtimeScheduler, 2158
REAL_AS_FLOAT SQL mode, 628
rebuild-indexes option
ndb_restore, 2292
Rebuilding the index on master dump table
thread state, 963
ReceiveBufferMemory, 2224
reconfiguring, 179
reconnect option
mysql, 304
Reconnecting after a failed binlog dump request
thread state, 962
Reconnecting after a failed master event read
thread state, 962
reconnection
automatic, 2764
record lock, 3555
record-level locks
InnoDB, 1630, 1724
record_log_pos option
mysqlhotcopy, 413
RECOVER
XA transactions, 1470
recover option
myisamchk, 376
recovery
from crash, 823
incremental, 820
InnoDB, 1771
point in time, 820
redo, 3555
redo log, 1654, 3555
RedoBuffer, 2152
RedoOverCommitCounter
data nodes, 2169
RedoOverCommitLimit
data nodes, 2170
reducing
data size, 885
redundant row format, 1697, 3556
ref join type

optimizer, 907
references, 1316
referential integrity, 1600, 3556
REFERENTIAL_CONSTRAINTS
INFORMATION_SCHEMA table, 2563
Refresh
thread command, 953
ref_or_null, 853
ref_or_null join type
optimizer, 908
REGEXP, 1179
REGEXP operator, 1179
regexp option
mysqlhotcopy, 413
mysql_find_rows, 415
Register Slave
thread command, 953
Registering slave on master
thread state, 962
regular expression syntax, 1179
rehash command
mysql, 309
relational, 3556
relational databases
defined, 5
relative option
mysqladmin, 323
relay-log option
mysqld, 1919
relay-log-index option
mysqld, 1920
relay-log-info-file option
mysqld, 1920
relay-log-purge option
mysqld, 1920
relay-log-recovery option
mysqld, 1920
relay-log-space-limit option
mysqld, 1921
relay_log system variable, 1930
relay_log_index system variable, 1930
relay_log_info_file system variable, 1930
relay_log_purge system variable, 558
relay_log_recovery system variable, 1931
relay_log_space_limit system variable, 558
release numbers, 43
RELEASE SAVEPOINT, 1461
releases
GA, 44
milestone, 44
naming scheme, 44
RC, 44
RELEASE_LOCK(), 1292
relevance, 3556
relnotes option
mysqlaccess, 394
reload option (ndb_mgmd), 2246
remote administration (NDB Cluster)

and security issues, 2380
remove option
mysqld, 478
MySQLInstallerConsole, 84
remove option (ndbd), 2237
remove option (ndbmtd), 2237
remove option (ndb_mgmd), 2249
removed features in MySQL 5.5, 9
Removing duplicates
thread state, 956
removing tmp table
thread state, 956
rename
thread state, 956
rename database, 1392
rename result table
thread state, 956
RENAME TABLE, 1392
RENAME USER statement, 1524
renaming user accounts, 1524
Reopen tables
thread state, 956
repair
tables, 324
Repair by sorting
thread state, 956
Repair done
thread state, 957
repair option
mysqlcheck, 330
repair options
myisamchk, 376
REPAIR TABLE
and partitioning, 2495
and replication, 1995
REPAIR TABLE statement, 1534
and replication, 1534
options, 1535
output, 1536
partitioning support, 1534, 1535
storage engine support, 1534
Repair with keycache
thread state, 957
repairing
tables, 824
REPEAT, 1492
labels, 1487
REPEAT(), 1172
REPEATABLE READ, 3556
transaction isolation level, 1620
repertoire
character set, 1016, 1045
string, 1016
replace, 253
REPLACE, 1426
replace option
mysqldump, 345
mysqlimport, 354

replace utility, 422
REPLACE(), 1172
replicas (NDB Cluster), 2016
replicate-do-db option
  mysqld, 1921
replicate-do-table option
  mysqld, 1924
replicate-ignore-db option
  mysqld, 1923
replicate-ignore-table option
  mysqld, 1924
replicate-rewrite-db option
  mysqld, 1924
replicate-same-server-id option
  mysqld, 1925
replicate-wild-do-table option
  mysqld, 1925
replicate-wild-ignore-table option
  mysqld, 1925
replication, 1881, 3557
  and AUTO_INCREMENT, 1980
  and character sets, 1981
  and CHECKSUM TABLE statement, 1981
  and CREATE ... IF NOT EXISTS, 1981
  and CREATE TABLE ... SELECT, 1981
  and DATA DIRECTORY, 1988
  and DROP ... IF EXISTS, 1989
  and errors on slave, 1998
  and floating-point values, 1989
  and FLUSH, 1989
  and functions, 1989
  and INDEX DIRECTORY, 1988
  and invoked features, 1991
  and LAST_INSERT_ID(), 1980
  and LIMIT, 1993
  and LOAD DATA, 1993
  and max_allowed_packet, 1993
  and MEMORY tables, 1994
  and mysql (system) database, 1994
  and partial updates, 1998
  and partitioned tables, 1995
  and partitioning, 1999
  and privileges, 1994
  and query optimizer, 1994
  and REPAIR TABLE statement, 1534, 1995
  and reserved words, 1995
  and scheduled events, 1991, 1992
  and slow query log, 1993
  and SQL mode, 1999
  and stored routines, 1991
  and temporary tables, 1999
  and time zones, 2000
  and TIMESTAMP, 202, 1980, 2000
  and transactions, 1999, 2000
  and triggers, 1991, 2001
  and TRUNCATE TABLE, 2002
  and variables, 2002
  and views, 2004

attribute demotion, 1985
attribute promotion, 1985
between MySQL server versions, 202, 2000
BLACKHOLE, 1981
circular, 2419
crashes, 1997
in NDB Cluster, 2416
(see also NDB Cluster replication)
nondeterministic functions, 863
row-based vs statement-based, 1892
safe and unsafe statements, 1897
semisynchronous, 1974
shutdown and restart, 1997, 1999
statements incompatible with STATEMENT format, 1893
timeouts, 1999
with differing tables on master and slave, 1983
with ZFS, 1819
replication filtering options
and case sensitivity, 1956
replication formats
compared, 1892
replication implementation, 1951
replication limitations, 1979
replication master
thread states, 961
replication masters
statements, 1472
replication options, 1979
replication slave
thread states, 961, 962, 963
replication slaves
statements, 1475
replication, asynchronous (see NDB Cluster replication)
REPORT command (NDB Cluster), 2317
report-host option
mysqld, 1926
report-password option
mysqld, 1926
report-port option
mysqld, 1926
report-user option
mysqld, 1927
reporting
bugs, 2, 20
errors, 20
problems, 2
report_host system variable, 559
report_password system variable, 559
report_port system variable, 559
report_user system variable, 559
Requesting binlog dump
thread state, 962
REQUIRE option
GRANT statement, 1520
reschedule
thread state, 960
reserved words, 986
and replication, 1995

ReservedSendBufferMemory, 2169
RESET MASTER, 1474
RESET SLAVE, 1479
RESET SLAVE ALL, 1479
Reset stmt
  thread command, 953
reset-slave.pl (see NDB Cluster replication)
resetmaster option
  mysqlhotcopy, 413
resetslave option
  mysqlhotcopy, 413
RESIGNAL, 1501
resolveip, 254, 422
  help option, 423
  silent option, 423
  version option, 423
resolve_stack_dump, 253, 420
  help option, 420
  numeric-dump-file option, 421
  symbols-file option, 421
  version option, 421
resource limits
  user accounts, 539, 739, 1523
resources
  ndbinfo table, 2369
RESTART command (NDB Cluster), 2316
restarting
  the server, 189
RestartOnErrorInsert, 2142
RestartSubscriberConnectTimeout, 2151
restore, 3557
restore-privilege-tables option
  ndb_restore, 2293
restore_data option
  ndb_restore, 2293
restore_epoch option
  ndb_restore, 2293
restore_meta option
  ndb_restore, 2293
restoring backups
  in NDB Cluster, 2280
restoring from backup
  in NDB Cluster replication, 2434
restrictions
  character sets, 2991
  events, 2983
  InnoDB, 1676
  performance_schema database, 2991
  pluggable authentication, 2992
  server-side cursors, 2987
  signals, 2987
  stored routines, 2983
  subqueries, 2987
  triggers, 2983
  views, 2989
  XA transactions, 2990
result-file option
  mysqlbinlog, 401

mysqldump, 345
retries option
ndb_desc, 2265
retrieving
data from tables, 225
RETURN, 1493
return (\r), 966, 1415
return values
UDFs, 2824
REVERSE(), 1172
REVOKE statement, 1524
revoking
privileges, 1524
rewrite-database option
ndb_restore, 2294
rhost option
mysqlaccess, 394
RIGHT JOIN, 849, 1436
RIGHT OUTER JOIN, 1436
RIGHT(), 1172
RLIKE, 1179
ROLLBACK, 1458
XA transactions, 1470
rollback, 3557
rollback option
mysqlaccess, 394
rollback segment, 3557
ROLLBACK TO SAVEPOINT, 1461
Rolling back
thread state, 957
rolling restart (NDB Cluster), 2325
ROLLUP, 1284
root password, 190
root user, 698
password resetting, 2962
ROUND(), 1195
rounding, 1294
rounding errors, 1086
ROUTINES
INFORMATION_SCHEMA table, 2563
routines option
mysqldump, 345
ROW, 1447
row, 3557
row constructors, 1447
optimizations, 864
row format, 3557
row lock, 3557
row size
maximum, 2995
row subqueries, 1447
row-based replication, 3558
advantages, 1894
disadvantages, 1895
row-level locking, 932, 3558
rowid option
ndb_select_all, 2301
rows

counting, 235
deleting, 2974
matching problems, 2975
selecting, 226
sorting, 228
rows option
mysql_find_rows, 415
ndb_config, 2257
ROW_COUNT(), 1266
ROW_FORMAT
COMPACT, 1697, 2995
COMPRESSED, 1681, 1696, 2995
DYNAMIC, 1696, 2995
REDUNDANT, 1697, 2995
RPAD(), 1172
Rpl_semi_sync_master_clients status variable, 617
rpl_semi_sync_master_enabled system variable, 560
Rpl_semi_sync_master_net_avg_wait_time status variable, 617
Rpl_semi_sync_master_net_waits status variable, 617
Rpl_semi_sync_master_net_wait_time status variable, 617
Rpl_semi_sync_master_no_times status variable, 617
Rpl_semi_sync_master_no_tx status variable, 617
Rpl_semi_sync_master_status status variable, 617
Rpl_semi_sync_master_timefunc_failures status variable, 617
rpl_semi_sync_master_timeout system variable, 560
rpl_semi_sync_master_trace_level system variable, 560
Rpl_semi_sync_master_tx_avg_wait_time status variable, 617
Rpl_semi_sync_master_tx_waits status variable, 617
Rpl_semi_sync_master_tx_wait_time status variable, 617
rpl_semi_sync_master_wait_no_slave system variable, 560
Rpl_semi_sync_master_wait_pos_backtraverse status variable, 618
Rpl_semi_sync_master_wait_sessions status variable, 618
Rpl_semi_sync_master_yes_tx status variable, 618
rpl_semi_sync_slave_enabled system variable, 561
Rpl_semi_sync_slave_status status variable, 618
rpl_semi_sync_slave_trace_level system variable, 561
Rpl_status status variable, 618
RPM file, 141
rpm option
mysql_install_db, 286
RPM Package Manager, 141
RTRIM(), 1173
Ruby API, 2767
running
ANSI mode, 25
batch mode, 239
multiple servers, 671
queries, 218
running CMake after prior invocation, 164, 179
rw-lock, 3558
rwlock_instances table
performance_schema, 2625

S

safe statement (replication)
defined, 1897
safe-mode option
mysqld, 478

safe-recover option
  myisamchk, 377
safe-show-database option
  mysqld, 478
safe-updates option, 316
  mysql, 304
safe-user-create option
  mysqld, 479
Sakila, 8
same value wins (conflict resolution), 2447
SAVEPOINT, 1461
savepoint, 3558
Saving state
  thread state, 957
scalability, 3558
scale
  arithmetic, 1294
  numeric, 1084
scale out, 3559
scale up, 3559
SchedulerExecutionTimer, 2158
SchedulerSpinTimer, 2158
schema, 3559
  altering, 1304
  creating, 1331
  deleting, 1387
SCHEMA Events (NDB Cluster), 2333
SCHEMA(), 1267
SCHEMATA
  INFORMATION_SCHEMA table, 2565
SCHEMA_PRIVILEGES
  INFORMATION_SCHEMA table, 2565
SCI (Scalable Coherent Interface) (see NDB Cluster)
script files, 239
scripts, 273, 280
  mysql_install_db, 184
  SQL, 295
search index, 3559
searching
  and case sensitivity, 2969
  full-text, 1219
  MySQL Web pages, 20
  two keys, 245
Searching rows for update
  thread state, 957
SECOND(), 1209
secondary index, 3559
  InnoDB, 1680
secure connections, 751
  command options, 754
secure-auth option
  mysql, 304
  mysqld, 479
secure-file-priv option
  mysqld, 479
secure_auth system variable, 561
secure_file_priv system variable, 562
securing an NDB Cluster, 2382

security
  against attackers, 707
  and malicious SQL statements, 2381
  and NDB utilities, 2383
  plugins, 765
security system, 713
SEC_TO_TIME(), 1210
segment, 3559
SELECT
  INTO, 1434
  LIMIT, 1428
  optimizing, 903, 1593
  Query Cache, 925
SELECT INTO TABLE, 29
selecting
  databases, 222
selectivity, 3560
select_limit variable, 306
semi-consistent read, 3560
  InnoDB, 1724
semisynchronous replication, 1974
  administrative interface, 1976
  configuration, 1977
  installation, 1977
  monitoring, 1979
semisynchronous replication plugins, 2773
SendBufferMemory, 2224
Sending binlog event to slave
  thread state, 961
sending cached result to client
  thread state, 961
SendLimit, 2230
SendSignalId, 2224, 2228, 2230
SEQUENCE, 246
sequence emulation, 1265
sequences, 246
SERIAL, 1084, 1085
SERIAL DEFAULT VALUE, 1132
SERIALIZABLE, 3560
  transaction isolation level, 1622
server, 3560
  connecting, 217, 255
  debugging, 2829
  disconnecting, 217
  logs, 639
  restart, 189
  shutdown, 189
  signal handling, 635
  starting, 182
  starting and stopping, 194
  starting problems, 186
server administration, 317
server configuration, 426
server plugins, 661
server variable (see system variable)
server variables (see system variables)
server-id option
  mysqlbinlog, 401

mysqld, 1899
server-id-bits option
mysqlbinlog, 401
mysqld, 2188
server-side cursors
restrictions, 2987
ServerPort, 2123
servers
multiple, 671
servers table
system table, 639
server_id system variable, 563
server_id_bits system variable, 2206
server_operations
ndbinfo table, 2370
server_transactions
ndbinfo table, 2372
service-startup-timeout option
mysql.server, 280
services
for plugins, 2816
SESSION
SET statement, 1552
session variables
and replication, 2002
SESSION_STATUS
INFORMATION_SCHEMA table, 2555
SESSION_USER(), 1267
SESSION_VARIABLES
INFORMATION_SCHEMA table, 2555
SET
CHARACTER SET, 1029
NAMES, 1029
ONE_SHOT, 1542
size, 1136
SET CHARACTER SET statement, 1542
SET CHARSET statement, 1542
SET data type, 1091, 1113
SET GLOBAL sql_slave_skip_counter, 1479
SET NAMES, 1031
SET NAMES statement, 1543
Set option
thread command, 953
SET OPTION, 1539
SET PASSWORD statement, 741, 1525
SET sql_log_bin, 1474
SET statement
assignment operator, 1161
CHARACTER SET, 1542
CHARSET, 1542
NAMES, 1543
variable assignment, 1539
SET TRANSACTION, 1468
set-auto-increment[option
myisamchk, 377
set-charset option
mysqlbinlog, 401
mysqldump, 345

set-collation option
  myisamchk, 377
setting
  passwords, 741
setting passwords, 1525
setting program variables, 267
setup
  postinstallation, 181
  thread state, 957
setup_consumers table
  performance_schema, 2621
setup_instruments table
  performance_schema, 2622
setup_timers table
  performance_schema, 2623
SHA(), 1257
SHA1(), 1257
SHA2(), 1258
shared lock, 1615, 3560
shared memory transporter (see NDB Cluster)
shared tablespace, 3560
shared-memory option
  mysqld, 480
shared-memory-base-name option, 257
  mysql, 304
  mysqladmin, 323
  mysqlbinlog, 401
  mysqlcheck, 330
  mysqld, 480
  mysqldump, 345
  mysqlimport, 354
  mysqlshow, 359
  mysqlslap, 366
  mysql_upgrade, 295
SharedBufferSize, 2230
SharedGlobalMemory, 2165
shared_memory system variable, 563
shared_memory_base_name system variable, 563
sharp checkpoint, 3560
shell syntax, 4
ShmKey, 2227
ShmSize, 2227
short-form option
  mysqlbinlog, 401
SHOW
  in NDB Cluster management client, 2066
SHOW AUTHORS, 1544
SHOW AUTHORS statement, 1543
SHOW BINARY LOGS statement, 1543, 1544
SHOW BINLOG EVENTS statement, 1543, 1544
SHOW CHARACTER SET statement, 1543, 1545
SHOW COLLATION statement, 1543, 1545
SHOW COLUMNS statement, 1543, 1546
SHOW command (NDB Cluster), 2316
SHOW CONTRIBUTORS, 1548
SHOW CONTRIBUTORS statement, 1543
SHOW CREATE DATABASE statement, 1543, 1548
SHOW CREATE EVENT statement, 1543

SHOW CREATE FUNCTION statement, 1543, 1549
SHOW CREATE PROCEDURE statement, 1543, 1549
SHOW CREATE SCHEMA statement, 1543, 1548
SHOW CREATE TABLE statement, 1543, 1550
SHOW CREATE TRIGGER statement, 1543, 1550
SHOW CREATE VIEW statement, 1543, 1551
SHOW DATABASES statement, 1543, 1552
SHOW ENGINE
  and NDB Cluster, 2352
SHOW ENGINE INNODB STATUS
  and innodb_use_sys_malloc, 1646
SHOW ENGINE INNODB STATUS statement, 1552
SHOW ENGINE NDB STATUS, 1552, 2352
SHOW ENGINE NDBCLUSTER STATUS, 1552, 2352
SHOW ENGINE statement, 1543, 1552
SHOW ENGINES
  and NDB Cluster, 2352
SHOW ENGINES statement, 1543, 1556
SHOW ERRORS statement, 1543, 1557
SHOW EVENTS statement, 1543, 1557
SHOW extensions, 2596
SHOW FIELDS statement, 1543, 1546
SHOW FUNCTION CODE statement, 1543, 1559
SHOW FUNCTION STATUS statement, 1543, 1559
SHOW GRANTS statement, 1543, 1559
SHOW INDEX statement, 1543, 1560
SHOW KEYS statement, 1543, 1560
SHOW MASTER LOGS statement, 1543, 1544
SHOW MASTER STATUS statement, 1543, 1562
SHOW OPEN TABLES statement, 1543, 1562
SHOW PLUGINS statement, 1543, 1563
SHOW PRIVILEGES statement, 1543, 1564
SHOW PROCEDURE CODE statement, 1543, 1564
SHOW PROCEDURE STATUS statement, 1543, 1565
SHOW PROCESSLIST statement, 1543, 1566
SHOW PROFILE statement, 1543, 1568
SHOW PROFILES statement, 1543, 1568, 1570
SHOW RELAYLOG EVENTS statement, 1543, 1570
SHOW SCHEDULER STATUS, 2528
SHOW SCHEMAS statement, 1552
SHOW SLAVE HOSTS statement, 1543, 1570
SHOW SLAVE STATUS statement, 1543, 1571
SHOW STATUS
  and NDB Cluster, 2354
SHOW STATUS statement, 1543, 1576
SHOW STORAGE ENGINES statement, 1556
SHOW TABLE STATUS statement, 1543, 1577
SHOW TABLES statement, 1543, 1579
SHOW TRIGGERS statement, 1543, 1580
SHOW VARIABLES
  and NDB Cluster, 2353
SHOW VARIABLES statement, 1543, 1581
SHOW WARNINGS statement, 1543, 1582
SHOW with WHERE, 2545, 2596
show-slave-auth-info option
  mysqld, 1912
show-table-type option
  mysqlshow, 359

show-temp-status option
  ndb_show_tables, 2303
show-warnings option
  mysql, 304
showing
  database information, 355
shutdown, 3561
  server, 635
Shutdown
  thread command, 953
SHUTDOWN command (NDB Cluster), 2318
shutdown_timeout variable, 324
shutting down
  the server, 189
Shutting down
  thread state, 963
sigint-ignore option
  mysql, 304
SIGN(), 1196
SIGNAL, 1505
signals
  restrictions, 2987
  server response, 635
SigNum, 2228
silent column changes, 1379
silent option
  myisamchk, 373
  myisampack, 387
  mysql, 304
  mysqladmin, 324
  mysqlcheck, 330
  mysqld_multi, 282
  mysqlimport, 354
  mysqlslap, 366
  perror, 421
  resolveip, 423
SIN(), 1196
single quote (\'), 966
single user mode (NDB Cluster), 2317, 2351
  and ndb_restore, 2280
single-transaction option
  mysqldump, 346
single-user option
  ndb_waiter, 2308
SINGLEUSER Events (NDB Cluster), 2334
size of tables, 2994
sizes
  display, 1084
--skip option prefix, 261
skip-broken-objects option
  ndb_restore, 2294
skip-column-names option
  mysql, 305
skip-comments option
  mysqldump, 346
skip-concurrent-insert option
  mysqld, 480
skip-event-scheduler option

mysqld, 480
skip-grant-tables option
mysqld, 481
skip-host-cache option
mysqld, 481
skip-innodb option
mysqld, 481, 1709
skip-kill-mysqld option
mysqld_safe, 276
skip-line-numbers option
mysql, 305
skip-name-resolve option
mysqld, 481
mysql_install_db, 286
skip-ndbcluster option
mysqld, 2189
skip-networking option
mysqld, 481
skip-nodegroup option (ndb_error_reporter), 2268
skip-opt option
mysqldump, 346
skip-partition option
mysqld, 481
skip-safemalloc option
mysqld, 482
skip-show-database option
mysqld, 483
skip-slave-start option
mysqld, 1927
skip-ssl option, 755
skip-stack-trace option
mysqld, 483
skip-symbolic-links option
mysqld, 482
skip-syslog option
mysqld_safe, 276
skip-table-check option
ndb_restore, 2294
skip-thread-priority option
mysqld, 483
skip-unknown-objects option
ndb_restore, 2295
skip-use-db option
mysql_find_rows, 415
skip_external_locking system variable, 564
skip_name_resolve system variable, 564
skip_networking system variable, 564
skip_show_database system variable, 564
Slave has read all relay log; waiting for the slave I/O thread to update it
thread state, 963
slave server, 3561
slave-load-tmpdir option
mysqld, 1927
slave-max-allowed-packet (mysqld), 1918
slave-net-timeout option
mysqld, 1928
slave-skip-errors option
mysqld, 1928

slave_allow_batching, 2431
slave_compressed_protocol option
  mysqld, 1927
slave_compressed_protocol system variable, 1931
slave_exec_mode system variable, 1931
slave_load_tmpdir system variable, 1932
slave_max_allowed_packet system variable, 1932
slave_net_timeout system variable, 1932
slave_skip_errors system variable, 1933
slave_transaction_retries system variable, 1933
slave_type_conversions system variable, 1934
Sleep
  thread command, 953
sleep option
  mysqladmin, 324
SLEEP(), 1292
slow queries, 319
slow query log, 657, 3561
  and replication, 1993
slow shutdown, 3561
slow-query-log option
  mysqld, 483
slow-start-timeout option
  mysqld, 483
slow_launch_time system variable, 565
slow_log table
  system table, 638
slow_query_log system variable, 565
slow_query_log_file system variable, 565
SMALLINT data type, 1085
snapshot, 3561
SNAPSHOTEND (START BACKUP command), 2321
SNAPSHOTSTART (START BACKUP command), 2321
socket option, 257
  mysql, 305
  mysqladmin, 324
  mysqlbinlog, 401
  mysqlcheck, 330
  mysqld, 484
  mysqldump, 346
  mysqld_safe, 276
  mysqlhotcopy, 413
  mysqlimport, 354
  mysqlshow, 359
  mysqlslap, 366
  mysql_config, 419
  mysql_convert_table_format, 414
  mysql_setpermission, 416
  mysql_upgrade, 295
socket system variable, 565
Solaris
  installation, 157
Solaris installation problems, 157
Solaris troubleshooting, 180
Solaris x86_64 issues, 895
SOME, 1446
sort buffer, 3561
sort-index option

myisamchk, 378
sort-records option
myisamchk, 378
sort-recover option
myisamchk, 377
sorting
data, 228
grant tables, 727, 729
table rows, 228
Sorting for group
thread state, 957
Sorting for order
thread state, 957
Sorting index
thread state, 957
Sorting result
thread state, 957
sort_buffer_size myisamchk variable, 373
sort_buffer_size system variable, 566
sort_key_blocks myisamchk variable, 373
SOUNDEX(), 1173
SOUNDS LIKE, 1173
source (mysql client command), 240, 314
source command
mysql, 309
source distribution
installing, 159
space ID, 3561
SPACE(), 1173
sparse file, 3562
spassword option
mysqlaccess, 394
spatial data types, 1115
storage requirements, 1136
spatial extensions in MySQL, 1115
spatial functions, 1268
spatial queries
optimization, 880
speed
increasing with replication, 1881
inserting, 875
of queries, 832
spin, 3562
sporadic-binlog-dump-fail option
mysqld, 1941
SQL, 3562
defined, 5
SQL mode, 622
ALLOW_INVALID_DATES, 624
and partitioning, 1999, 2502
and replication, 1999
ANSI, 623, 628
ANSI_QUOTES, 624
DB2, 629
ERROR_FOR_DIVISION_BY_ZERO, 624
HIGH_NOT_PRECEDENCE, 624
IGNORE_SPACE, 624
MAXDB, 629

MSSQL, 629
MYSQL323, 629
MYSQL40, 629
NO_AUTO_CREATE_USER, 625
NO_AUTO_VALUE_ON_ZERO, 625
NO_BACKSLASH_ESCAPES, 625
NO_DIR_IN_CREATE, 625
NO_ENGINE_SUBSTITUTION, 625
NO_FIELD_OPTIONS, 626
NO_KEY_OPTIONS, 626
NO_TABLE_OPTIONS, 626
NO_UNSIGNED_SUBTRACTION, 626
NO_ZERO_DATE, 627
NO_ZERO_IN_DATE, 627
ONLY_FULL_GROUP_BY, 627, 1287
ORACLE, 629
PAD_CHAR_TO_FULL_LENGTH, 627
PIPES_AS_CONCAT, 628
POSTGRESQL, 629
REAL_AS_FLOAT, 628
strict, 623
STRICT_ALL_TABLES, 628
STRICT_TRANS_TABLES, 623, 628
TRADITIONAL, 623, 629
SQL node (NDB Cluster)
defined, 2014
SQL nodes (NDB Cluster), 2324
SQL scripts, 295
SQL SECURITY
effect on privileges, 2536
SQL statements
replication masters, 1472
replication slaves, 1475
SQL statements relating to NDB Cluster, 2352
SQL-92
extensions to, 24
sql-mode option
mysqld, 484
sql_auto_is_null system variable, 567
SQL_BIG_RESULT
SELECT modifier, 1434
sql_big_selects system variable, 567
SQL_BUFFER_RESULT
SELECT modifier, 1434
sql_buffer_result system variable, 568
SQL_CACHE, 928
SELECT modifier, 1434
SQL_CALC_FOUND_ROWS, 861
SELECT modifier, 1434
sql_log_bin system variable, 568
sql_log_off system variable, 568
sql_log_update system variable, 569
sql_mode system variable, 569
sql_notes system variable, 570
SQL_NO_CACHE, 928
SELECT modifier, 1434
sql_quote_show_create system variable, 570
sql_safe_updates system variable, 570

sql_select_limit system variable, 570
sql_slave_skip_counter, 1479
sql_slave_skip_counter system variable, 1934
SQL_SMALL_RESULT
  SELECT modifier, 1434
sql_warnings system variable, 570
SQRT(), 1196
square brackets, 1084
srcdir option
  mysql_install_db, 287
SRID values
  handling by spatial functions, 1270
SRID(), 1273
SSD, 1681, 3562
SSH, 765
SSL, 751
  command options, 754
  configuring, 762
  establishing connections, 752
  OpenSSL compared to yaSSL, 762
  X509 Basics, 751
ssl option, 755
SSL options, 258
  mysql, 305
  mysqladmin, 324
  mysqlbinlog, 401
  mysqlcheck, 331
  mysqld, 482
  mysqldump, 346
  mysqlimport, 355
  mysqlshow, 359
  mysqlslap, 366
  mysql_upgrade, 295
SSL related options
  GRANT statement, 1520
ssl-ca option, 755
ssl-capath option, 755
ssl-cert option, 756
ssl-cipher option, 756
ssl-key option, 756
ssl-mode option
  mysql, 756
ssl-verify-server-cert option, 757
ssl_ca system variable, 571
ssl_capath system variable, 571
ssl_cert system variable, 571
ssl_cipher system variable, 571
ssl_key system variable, 571
staging-tries option
  ndb_move_data, 2275
standalone option
  mysqld, 482
Standard Monitor, 1757, 1760, 1763
Standard SQL
  differences from, 28, 1523
  extensions to, 24, 26
standards compatibility, 24
START

XA transactions, 1470
START BACKUP
NOWAIT, 2320
SNAPSHOTEND, 2321
SNAPSHOTSTART, 2321
syntax, 2320
WAIT COMPLETED, 2320
WAIT STARTED, 2320
START command (NDB Cluster), 2316
START SLAVE, 1480
START TRANSACTION, 1458
start-datetime option
mysqlbinlog, 402
start-position option
mysqlbinlog, 402
StartConnectBackoffMaxTime, 2177
StartFailRetryDelay, 2170
StartFailureTimeout, 2143
starting
comments, 30
mysqld, 709
the server, 182
the server automatically, 194
Starting many servers, 671
StartNoNodeGroupTimeout, 2144
StartPartialTimeout, 2143
StartPartitionedTimeout, 2143
StartPoint(), 1276
startup, 3562
STARTUP Events (NDB Cluster), 2331
startup options
default, 261
startup parameters, 426
mysql, 296
mysqladmin, 320
tuning, 938
StartupStatusReportFrequency, 2155
start_row option
mysql_find_rows, 415
statefile option
comp_err, 284
statement termination
Control+C, 296, 304
statement-based replication, 3562
advantages, 1893
disadvantages, 1893
unsafe statements, 1893
statements
compound, 1486
GRANT, 738
replication masters, 1472
replication slaves, 1475
Statistics
thread command, 953
statistics, 3562
thread state, 957
STATISTICS
INFORMATION_SCHEMA table, 2566

STATISTICS Events (NDB Cluster), 2333
stats option
  myisam_ftdump, 368
stats_method myisamchk variable, 373
status
  tables, 1577
status command
  mysql, 309
  results, 319
STATUS command (NDB Cluster), 2317
status option
  MySQLInstallerConsole, 84
  mysqlshow, 359
status variable
  Performance_schema_cond_classes_lost, 2640
  Performance_schema_cond_instances_lost, 2640
  Performance_schema_file_classes_lost, 2640
  Performance_schema_file_handles_lost, 2640
  Performance_schema_file_instances_lost, 2640
  Performance_schema_locker_lost, 2640
  Performance_schema_mutex_classes_lost, 2640
  Performance_schema_mutex_instances_lost, 2640
  Performance_schema_rwlock_classes_lost, 2641
  Performance_schema_rwlock_instances_lost, 2641
  Performance_schema_table_handles_lost, 2641
  Performance_schema_table_instances_lost, 2641
  Performance_schema_thread_classes_lost, 2641
  Performance_schema_thread_instances_lost, 2641
  Rpl_semi_sync_master_clients, 617
  Rpl_semi_sync_master_net_avg_wait_time, 617
  Rpl_semi_sync_master_net_waits, 617
  Rpl_semi_sync_master_net_wait_time, 617
  Rpl_semi_sync_master_no_times, 617
  Rpl_semi_sync_master_no_tx, 617
  Rpl_semi_sync_master_status, 617
  Rpl_semi_sync_master_timefunc_failures, 617
  Rpl_semi_sync_master_tx_avg_wait_time, 617
  Rpl_semi_sync_master_tx_waits, 617
  Rpl_semi_sync_master_tx_wait_time, 617
  Rpl_semi_sync_master_wait_pos_backtraverse, 618
  Rpl_semi_sync_master_wait_sessions, 618
  Rpl_semi_sync_master_yes_tx, 618
  Rpl_semi_sync_slave_status, 618
  Rpl_status, 618
status variables, 597, 1576
  NDB Cluster, 2210
  NDB Cluster replication conflict detection, 2449
STD(), 1284
STDDEV(), 1284
STDDEV_POP(), 1284
STDDEV_SAMP(), 1284
stemming, 3563
STOP command (NDB Cluster), 2316
STOP SLAVE, 1481
stop-datetime option
  mysqlbinlog, 402
stop-position option
  mysqlbinlog, 402

StopOnError, 2140
stopping
  the server, 194
stopword, 3563
stopword list
  user-defined, 1230
storage engine, 3563
  ARCHIVE, 1801
  InnoDB, 1600
  PERFORMANCE_SCHEMA, 2599
storage engine plugins, 2771
storage engines
  and application feature requirements, 2026
  applications supported, 2025
  availability, 2023
  choosing, 1781
  differences between NDB and InnoDB, 2024
  usage scenarios, 2026
storage nodes - see data nodes, ndbd (see data nodes, ndbd)
storage nodes - see data nodes, ndbd, ndbmtd (see data nodes, ndbd, ndbmtd)
storage requirements
  data types, 1132
  date data types, 1134
  InnoDB tables, 1133
  NDB Cluster, 1133
  numeric data types, 1133
  spatial data types, 1136
  string data types, 1134
  time data types, 1134
storage space
  minimizing, 885
storage_engine system variable, 571
stored functions, 2517
  and INSERT DELAYED, 1403
stored procedures, 2517
stored programs, 1486, 2515
stored routines
  and replication, 1991
  LAST_INSERT_ID(), 2519
  metadata, 2518
  restrictions, 2983
storing result in query cache
  thread state, 961
storing row into queue
  thread state, 960
STRAIGHT_JOIN, 850, 850, 903, 914, 1436, 1594
  SELECT modifier, 1433
STRCMP(), 1178
strict mode, 3563
strict SQL mode, 623
STRICT_ALL_TABLES SQL mode, 628
STRICT_TRANS_TABLES SQL mode, 623, 628
string collating, 1065
string comparison functions, 1175
string comparisons
  case sensitivity, 1176
string concatenation, 965, 1167
string data types

storage requirements, 1134
string functions, 1164
string literal introducer, 966, 1024
string literals, 965
string replacement
replace utility, 422
string types, 1106
StringMemory, 2127
strings
defined, 965
escape sequences, 965
nondelimited, 970
repertoire, 1016
striping
defined, 939
STR_TO_DATE(), 1210
SUBDATE(), 1211
sublist, 3563
SUBPARTITION BY KEY
known issues, 2506
subpartitioning, 2480
subpartitions, 2480
known issues, 2506
subqueries, 1443
correlated, 1449
errors, 1452
in FROM clause (see derived tables)
optimization, 866
restrictions, 2987
rewriting as joins, 1455
with ALL, 1446
with ANY, IN, SOME, 1445
with EXISTS, 1448
with NOT EXISTS, 1448
with row constructors, 1447
subquery (see subqueries)
subselects, 1443
SUBSTR(), 1174
SUBSTRING(), 1174
SUBSTRING_INDEX(), 1174
SUBTIME(), 1211
subtraction (-), 1187
suffix option
mysqlhotcopy, 413
SUM(), 1284
SUM(DISTINCT), 1284
super-large-pages option
mysqld, 482
superuser, 190
superuser option
mysqlaccess, 394
support
for operating systems, 43
suppression
default values, 31
supremum record, 3563
surrogate key, 3563
symbolic links, 940, 942

databases, 940
tables, 940
Windows, 942
symbolic-links option
mysqld, 482
symbols-file option
resolve_stack_dump, 421
synchronization of master and slave
in NDB Cluster Replication, 2437
Syncing ndb table schema operation and binlog
thread state, 964
sync_binlog system variable, 1948
sync_frm system variable, 572
sync_master_info system variable, 1934
sync_relay_log system variable, 1935
sync_relay_log_info system variable, 1935
syntax
regular expression, 1179
syntax conventions, 2
synthetic key, 3563
sys-check option (ndb_index_stat), 2272
sys-create option (ndb_index_stat), 2272
sys-create-if-not-exist option (ndb_index_stat), 2272
sys-create-if-not-valid option (ndb_index_stat), 2272
sys-drop option (ndb_index_stat), 2271
sys-skip-events option (ndb_index_stat), 2273
sys-skip-tables option (ndb_index_stat), 2272
SYSCONFDIR option
CMake, 173
SYSDATE(), 1211
sysdate-is-now option
mysqld, 485
syslog option
mysqld_safe, 276
syslog-tag option
mysqld_safe, 276
system
privilege, 713
security, 698
system command
mysql, 309
System lock
thread state, 957
system optimization, 938
system option
ndb_config, 2257
system table
optimizer, 907, 1433
system tables
columns_priv table, 638, 719
db table, 190, 638, 719
event table, 638
func table, 638
general_log table, 638
help tables, 638
help_category table, 639
help_keyword table, 639
help_relation table, 639

help_topic table, 639
host table, 638, 719
ndb_binlog_index table, 639, 2425
plugin table, 638
proc table, 638
procs_priv table, 638, 719
proxies_priv table, 190, 638, 719
servers table, 639
slow_log table, 638
tables_priv table, 638, 719
time zone tables, 639
time_zone table, 639
time_zone_leap_second table, 639
time_zone_name table, 639
time_zone_transition table, 639
time_zone_transition_type table, 639
user table, 190, 638, 719
system tablespace, 3564
system variable, 1581
and replication, 2002
audit_log_buffer_size, 801
audit_log_file, 801
audit_log_flush, 802
audit_log_format, 802
audit_log_policy, 803
audit_log_rotate_on_size, 803
audit_log_strategy, 804
authentication_windows_log_level, 501
authentication_windows_use_principal_name, 501
autocommit, 502
automatic_sp_privileges, 503
auto_increment_increment, 1913
auto_increment_offset, 1915
back_log, 503
basedir, 503
big_tables, 504
binlog_cache_size, 1941
binlog_direct_non_transactional_updates, 1942
binlog_format, 1943
binlog_stmt_cache_size, 1944
bulk_insert_buffer_size, 504
character_sets_dir, 506
character_set_client, 504
character_set_connection, 505
character_set_database, 505
character_set_filesystem, 505
character_set_results, 506
character_set_server, 506
character_set_system, 506
collation_connection, 507
collation_database, 507
collation_server, 507
completion_type, 507
concurrent_insert, 508
connect_timeout, 509
datadir, 509
datetime_format, 509
date_format, 509

debug, 509
debug_sync, 510
default_storage_engine, 511
default_week_format, 511
delayed_insert_limit, 512
delayed_insert_timeout, 513
delayed_queue_size, 513
delay_key_write, 512
div_precision_increment, 513
engine_condition_pushdown, 514
error_count, 514
event_scheduler, 514
expire_logs_days, 515
external_user, 515
flush, 515
flush_time, 516
foreign_key_checks, 516
ft_boolean_syntax, 517
ft_max_word_len, 517
ft_min_word_len, 518
ft_query_expansion_limit, 518
ft_stopword_file, 518
general_log, 519
general_log_file, 519
group_concat_max_len, 519
have_compress, 520
have_crypt, 520
have_csv, 520
have_dynamic_loading, 520
have_geometry, 520
have_innodb, 520
have_openssl, 520
have_partitioning, 520
have_profiling, 520
have_query_cache, 520
have_rtree_keys, 520
have_ssl, 520
have_symlink, 521
hostname, 521
identity, 521
ignore_builtin_innodb, 1709
init_connect, 521
init_file, 521
init_slave, 1930
innodb_adaptive_flushing, 1709
innodb_adaptive_hash_index, 1709
innodb_additional_mem_pool_size, 1710
innodb_autoextend_increment, 1710
innodb_autoinc_lock_mode, 1710
innodb_buffer_pool_instances, 1711
innodb_buffer_pool_size, 1711
innodb_change_buffering, 1712
innodb_change_buffering_debug, 1713
innodb_checksums, 1713
innodb_commit_concurrency, 1713
innodb_concurrency_tickets, 1714
innodb_data_file_path, 1714
innodb_data_home_dir, 1715

innodb_doublewrite, 1715
innodb_fast_shutdown, 1716
innodb_file_format, 1716
innodb_file_format_check, 1717
innodb_file_format_max, 1718
innodb_file_per_table, 1718
innodb_flush_log_at_trx_commit, 1719
innodb_flush_method, 1720
innodb_force_recovery, 1721
innodb_io_capacity, 1722
innodb_limit_optimistic_insert_debug, 1723
innodb_locks_unsafe_for_binlog, 1724
innodb_lock_wait_timeout, 1723
innodb_log_buffer_size, 1726
innodb_log_files_in_group, 1727
innodb_log_file_size, 1727
innodb_log_group_home_dir, 1728
innodb_max_dirty_pages_pct, 1728
innodb_max_purge_lag, 1728
innodb_mirrored_log_groups, 1729
innodb_old_blocks_pct, 1729
innodb_old_blocks_time, 1729
innodb_open_files, 1730
innodb_purge_batch_size, 1731
innodb_purge_threads, 1731
innodb_read_ahead_threshold, 1732
innodb_read_io_threads, 1733
innodb_replication_delay, 1733
innodb_rollback_on_timeout, 1733
innodb_spin_wait_delay, 1734
innodb_stats_method, 1735
innodb_stats_on_metadata, 1735
innodb_stats_sample_pages, 1735
innodb_strict_mode, 1736
innodb_support_xa, 1737
innodb_sync_spin_loops, 1737
innodb_table_locks, 1737
innodb_thread_concurrency, 1738
innodb_thread_sleep_delay, 1739
innodb_trx_purge_view_update_only_debug, 1740
innodb_trx_rseg_n_slots_debug, 1740
innodb_use_native_aio, 1739
innodb_use_sys_malloc, 1741
innodb_version, 1741
innodb_write_io_threads, 1741
insert_id, 522
interactive_timeout, 522
join_buffer_size, 522
keep_files_on_create, 523
key_buffer_size, 524
key_cache_age_threshold, 525
key_cache_block_size, 525
key_cache_division_limit, 526
language, 526
large_files_support, 526
large_pages, 526
large_page_size, 527
last_insert_id, 527

lc_messages, 527
lc_messages_dir, 527
lc_time_names, 527
license, 528
local_infile, 528
locked_in_memory, 529
lock_wait_timeout, 528
log, 529
log_bin, 1945
log_bin_trust_function_creators, 529
log_bin_trust_routine_creators, 530
log_bin_use_v1_row_events, 1945
log_error, 530
log_output, 530
log_queries_not_using_indexes, 530
log_slave_updates, 1946
log_slow_queries, 531
log_warnings, 531
long_query_time, 531
lower_case_file_system, 532
lower_case_table_names, 532
low_priority_updates, 532
max_allowed_packet, 533
max_binlog_cache_size, 1946
max_binlog_size, 1947
max_binlog_stmt_cache_size, 1947
max_connections, 534
max_connect_errors, 533
max_delayed_threads, 534
max_error_count, 535
max_heap_table_size, 535
max_insert_delayed_threads, 536
max_join_size, 536
max_length_for_sort_data, 536
max_long_data_size, 537
max_prepared_stmt_count, 537
max_relay_log_size, 537
max_seeks_for_key, 538
max_sort_length, 538
max_sp_recursion_depth, 539
max_tmp_tables, 539
max_user_connections, 539
max_write_lock_count, 539
metadata_locks_cache_size, 540
min_examined_row_limit, 540
myisam_data_pointer_size, 541
myisam_max_sort_file_size, 541
myisam_mmap_size, 542
myisam_recover_options, 542
myisam_repair_threads, 542
myisam_sort_buffer_size, 543
myisam_stats_method, 544
myisam_use_mmap, 544
named_pipe, 544
ndb_log_empty_epochs, 2199
ndb_log_empty_update, 2199
ndb_log_orig, 2200
ndb_log_transaction_id, 2200

net_buffer_length, 545
net_read_timeout, 545
net_retry_count, 545
net_write_timeout, 546
new, 546
old, 546
old_alter_table, 547
old_passwords, 547
one_shot, 548
open_files_limit, 548
optimizer_prune_level, 548
optimizer_search_depth, 548
optimizer_switch, 549
performance_schema, 2635
performance_schema_events_waits_history_long_size, 2636
performance_schema_events_waits_history_size, 2636
performance_schema_max_cond_classes, 2636
performance_schema_max_cond_instances, 2636
performance_schema_max_file_classes, 2637
performance_schema_max_file_handles, 2637
performance_schema_max_file_instances, 2637
performance_schema_max_mutex_classes, 2637
performance_schema_max_mutex_instances, 2638
performance_schema_max_rwlock_classes, 2638
performance_schema_max_rwlock_instances, 2638
performance_schema_max_table_handles, 2638
performance_schema_max_table_instances, 2639
performance_schema_max_thread_classes, 2639
performance_schema_max_thread_instances, 2639
pid_file, 549
plugin_dir, 550
port, 550
preload_buffer_size, 550
profiling, 551
profiling_history_size, 551
protocol_version, 551
proxy_user, 551
pseudo_slave_mode, 551
pseudo_thread_id, 551
query_alloc_block_size, 552
query_cache_limit, 552
query_cache_min_res_unit, 553
query_cache_size, 553
query_cache_type, 554
query_cache_wlock_invalidate, 554
query_prealloc_size, 555
rand_seed1, 555
rand_seed2, 555
range_alloc_block_size, 555
read_buffer_size, 556
read_only, 557
read_rnd_buffer_size, 557
relay_log, 1930
relay_log_index, 1930
relay_log_info_file, 1930
relay_log_purge, 558
relay_log_recovery, 1931
relay_log_space_limit, 558

report_host, 559
report_password, 559
report_port, 559
report_user, 559
rpl_semi_sync_master_enabled, 560
rpl_semi_sync_master_timeout, 560
rpl_semi_sync_master_trace_level, 560
rpl_semi_sync_master_wait_no_slave, 560
rpl_semi_sync_slave_enabled, 561
rpl_semi_sync_slave_trace_level, 561
secure_auth, 561
secure_file_priv, 562
server_id, 563
server_id_bits, 2206
shared_memory, 563
shared_memory_base_name, 563
skip_external_locking, 564
skip_name_resolve, 564
skip_networking, 564
skip_show_database, 564
slave_compressed_protocol, 1931
slave_exec_mode, 1931
slave_load_tmpdir, 1932
slave_max_allowed_packet, 1932
slave_net_timeout, 1932
slave_skip_errors, 1933
slave_transaction_retries, 1933
slave_type_conversions, 1934
slow_launch_time, 565
slow_query_log, 565
slow_query_log_file, 565
socket, 565
sort_buffer_size, 566
sql_auto_is_null, 567
sql_big_selects, 567
sql_buffer_result, 568
sql_log_bin, 568
sql_log_off, 568
sql_log_update, 569
sql_mode, 569
sql_notes, 570
sql_quote_show_create, 570
sql_safe_updates, 570
sql_select_limit, 570
sql_slave_skip_counter, 1934
sql_warnings, 570
ssl_ca, 571
ssl_capath, 571
ssl_cert, 571
ssl_cipher, 571
ssl_key, 571
storage_engine, 571
sync_binlog, 1948
sync_frm, 572
sync_master_info, 1934
sync_relay_log, 1935
sync_relay_log_info, 1935
system_time_zone, 572

sysvar_stored_program_cache, 572
table_definition_cache, 573
table_lock_wait_timeout, 573
table_open_cache, 573
table_type, 574
thread_cache_size, 574
thread_concurrency, 574
thread_handling, 575
thread_pool_algorithm, 575
thread_pool_high_priority_connection, 575
thread_pool_max_unused_threads, 576
thread_pool_prio_kickup_timer, 576
thread_pool_size, 577
thread_pool_stall_limit, 577
thread_stack, 578
timed_mutexes, 579
timestamp, 579
time_format, 578
time_zone, 578
tmpdir, 580
tmp_table_size, 579
transaction_alloc_block_size, 580
transaction_allow_batching, 2207
transaction_prealloc_size, 581
tx_isolation, 582
unique_checks, 582
updatable_views_with_limit, 583
version, 583
version_comment, 583
version_compile_machine, 583
version_compile_os, 583
wait_timeout, 584
warning_count, 584
system variables, 487, 584
mysqld, 426
system_time_zone system variable, 572
SYSTEM_USER(), 1267
sysvar_stored_program_cache system variable, 572

T

tab (\t), 966, 1415
tab option
mysqldump, 346
ndb_restore, 2295
table, 3564
changing, 1309, 1316, 2977
deleting, 1390
rebuilding, 210
repair, 210
row size, 1132
Table 'mysql.proxies_priv' doesn't exist, 200
table aliases, 1430
table cache, 888
table definition
retention, 1369
table description
myisamchk, 378
Table Dump

thread command, 953
table is full, 504, 2959
Table is full errors (NDB Cluster), 2125
table lock, 3565
Table Monitor, 1757, 1767
table names
case sensitivity, 26, 978
table option
mysql, 305
mysqlaccess, 394
ndb_desc, 2265
table scan, 1642
table type, 3565
choosing, 1781
table-level locking, 932
tables
BLACKHOLE, 1802
checking, 375
cloning, 1371
closing, 888
compressed, 386
compressed format, 1793
const, 907
constant, 834
copying, 1371
counting rows, 235
creating, 223
CSV, 1799
defragment, 1793
defragmenting, 828, 1532
deleting rows, 2974
displaying, 355
displaying status, 1577
dumping, 331, 411
dynamic, 1792
error checking, 824
EXAMPLE, 1815
FEDERATED, 1810
flush, 320
fragmentation, 1532
HEAP, 1795
host, 730
improving performance, 885
information, 378
information about, 238
InnoDB, 1600
loading data, 224
maintenance, 324
maintenance schedule, 827
maximum size, 2994
MEMORY, 1795
MERGE, 1805
merging, 1805
multiple, 237
MyISAM, 1787
names, 974
open, 888
opening, 888

optimizing, 827
partitioning, 1805
repair, 324
repairing, 824
retrieving data, 225
selecting columns, 227
selecting rows, 226
sorting rows, 228
symbolic links, 940
system, 907
TEMPORARY, 1370
too many, 890
unique ID for last row, 2765
TABLES
INFORMATION_SCHEMA table, 2566
tables option
mysqlcheck, 331
mysqldump, 347
tablespace, 3565
Tablespace Monitor, 1757, 1765
InnoDB, 1699, 1771
TABLESPACES
INFORMATION_SCHEMA table, 2568
tables_priv table
system table, 638, 719
TABLE_CONSTRAINTS
INFORMATION_SCHEMA table, 2568
table_definition_cache system variable, 573
table_lock_wait_timeout system variable, 573
table_open_cache, 888
table_open_cache system variable, 573
TABLE_PRIVILEGES
INFORMATION_SCHEMA table, 2569
table_type system variable, 574
TAN(), 1196
tar
problems on Solaris, 157, 157
tc-heuristic-recover option
mysqld, 485
Tcl API, 2768
tcmalloc
memory allocation library, 274
tcp-ip option
mysqld_multi, 282
TCP/IP, 117, 123, 303
TCP_MAXSEG_SIZE, 2225
TCP_RCV_BUF_SIZE, 2225
TCP_SND_BUF_SIZE, 2225
tee command
mysql, 309
tee option
mysql, 305
temp-pool option
mysqld, 485
temporary file
write access, 184
temporary files, 2968
temporary table, 3565

TEMPORARY table privileges, 715, 1370
temporary tables
  and replication, 1999
  internal, 890
  problems, 2978
TEMPORARY tables, 1370
temporary tablespace, 3565
terminal monitor
  defined, 217
test option
  myisampack, 387
testing
  connection to the server, 726
  installation, 182
  postinstallation, 181
testing mysqld
  mysqltest, 2770
test_plugin_server authentication plugin, 782
TEXT
  size, 1135
text collection, 3566
TEXT columns
  default values, 1109
  indexing, 879, 1353
TEXT data type, 1091, 1109
text files
  importing, 314, 350, 1409
thd_alloc service, 2816
thd_wait service, 2816
The used command is not allowed with this MySQL version
  error message, 711
thread, 3566
thread cache, 947
thread command
  Binlog Dump, 951
  Change user, 951
  Close stmt, 952
  Connect, 952
  Connect Out, 952
  Create DB, 952
  Daemon, 952
  Debug, 952
  Delayed insert, 952
  Drop DB, 952
  Error, 952
  Execute, 952
  Fetch, 952
  Field List, 952
  Init DB, 952
  Kill, 952
  Long Data, 952
  Ping, 952
  Prepare, 953
  Processlist, 953
  Query, 953
  Quit, 953
  Refresh, 953
  Register Slave, 953

Reset stmt, 953
Set option, 953
Shutdown, 953
Sleep, 953
Statistics, 953
Table Dump, 953
Time, 953
thread commands, 951
thread state
After create, 953
allocating local table, 959
Analyzing, 954
Changing master, 963
Checking master version, 961
checking permissions, 954
checking privileges on cached query, 960
checking query cache for query, 961
Checking table, 954
cleaning up, 954
Clearing, 964
closing tables, 954
Committing events to binlog, 963
Connecting to master, 961
converting HEAP to MyISAM, 954
copy to tmp table, 954
Copying to group table, 954
Copying to tmp table, 954
Copying to tmp table on disk, 954
Creating delayed handler, 959
Creating index, 954
Creating sort index, 954
creating table, 954
Creating tmp table, 954
deleting from main table, 955
deleting from reference tables, 955
discard_or_import_tablespace, 955
end, 955
executing, 955
Execution of init_command, 955
Finished reading one binlog; switching to next binlog, 961
freeing items, 955
FULLTEXT initialization, 955
got handler lock, 960
got old table, 960
init, 955
Initialized, 964
insert, 960
invalidating query cache entries, 961
Killed, 955
Killing slave, 963
logging slow query, 955
login, 955
Making temp file, 963
manage keys, 956
Master has sent all binlog to slave; waiting for binlog to be updated, 961
NULL, 956
Opening master dump table, 963
Opening mysql.ndb_apply_status, 963

Opening table, 956
Opening tables, 956
optimizing, 956
preparing, 956
Processing events, 963
Processing events from schema table, 963
Purging old relay logs, 956
query end, 956
Queueing master event to the relay log, 961
Reading event from the relay log, 963
Reading from net, 956
Reading master dump table data, 963
Rebuilding the index on master dump table, 963
Reconnecting after a failed binlog dump request, 962
Reconnecting after a failed master event read, 962
Registering slave on master, 962
Removing duplicates, 956
removing tmp table, 956
rename, 956
rename result table, 956
Reopen tables, 956
Repair by sorting, 956
Repair done, 957
Repair with keycache, 957
Requesting binlog dump, 962
reschedule, 960
Rolling back, 957
Saving state, 957
Searching rows for update, 957
Sending binlog event to slave, 961
sending cached result to client, 961
setup, 957
Shutting down, 963
Slave has read all relay log; waiting for the slave I/O thread to update it, 963
Sorting for group, 957
Sorting for order, 957
Sorting index, 957
Sorting result, 957
statistics, 957
storing result in query cache, 961
storing row into queue, 960
Syncing ndb table schema operation and binlog, 964
System lock, 957
update, 958
Updating, 958
updating main table, 958
updating reference tables, 958
upgrading lock, 960
User lock, 958
User sleep, 958
Waiting for allowed to take ndbcluster global schema lock, 964
Waiting for commit lock, 958
waiting for delay_list, 960
Waiting for event from ndbcluster, 964
Waiting for first event from ndbcluster, 964
Waiting for global metadata lock, 959
Waiting for global read lock, 958, 959
waiting for handler insert, 960

waiting for handler lock, 960
waiting for handler open, 960
Waiting for INSERT, 960
Waiting for master to send event, 962
Waiting for master update, 962
Waiting for ndbcluster binlog update to reach current position, 964
Waiting for ndbcluster global schema lock, 964
Waiting for ndbcluster to start, 964
Waiting for next activation, 964
Waiting for query cache lock, 961
Waiting for scheduler to stop, 964
Waiting for schema epoch, 964
Waiting for schema metadata lock, 959
Waiting for slave mutex on exit, 962, 963
Waiting for stored function metadata lock, 959
Waiting for stored procedure metadata lock, 959
Waiting for table, 958
Waiting for table flush, 958
Waiting for table level lock, 959
Waiting for table metadata lock, 959
Waiting for tables, 958
Waiting for the next event in relay log, 962
Waiting for the slave SQL thread to free enough relay log space, 962
Waiting for trigger metadata lock, 959
Waiting on cond, 959
Waiting on empty queue, 964
Waiting to finalize termination, 961
Waiting to reconnect after a failed binlog dump request, 962
Waiting to reconnect after a failed master event read, 962
Writing to net, 959
thread states, 951
delayed inserts, 959
event scheduler, 964
general, 953
NDB Cluster, 963
query cache, 960
replication master, 961
replication slave, 961, 962, 963
threadblocks
ndbinfo table, 2372
ThreadConfig, 2162
threaded clients, 2658
ThreadPool (see DiskIOThreadPool)
threads, 319, 1566, 2769
display, 1566
monitoring, 951, 1566, 1566, 2561
threads table
performance_schema, 2633
threadstat
ndbinfo table, 2373
thread_cache_size system variable, 574
thread_concurrency system variable, 574
thread_handling system variable, 575
thread_pool_algorithm system variable, 575
thread_pool_high_priority_connection system variable, 575
thread_pool_max_unused_threads system variable, 576
thread_pool_prio_kickup_timer system variable, 576
thread_pool_size system variable, 577

thread_pool_stall_limit system variable, 577
thread_stack system variable, 578
Time
  thread command, 953
TIME data type, 1088, 1099
time data types
  storage requirements, 1134
time literals, 968
time representation
  Event Scheduler, 2527
time zone problems, 2969
time zone tables, 289
  system tables, 639
time zones
  and replication, 2000
  leap seconds, 1078
  support, 1074
  upgrading, 1077
TIME(), 1212
TimeBetweenEpochs, 2147
TimeBetweenEpochsTimeout, 2147
TimeBetweenGlobalCheckpoints, 2146, 2168
TimeBetweenGlobalCheckpointsTimeout, 2147
TimeBetweenInactiveTransactionAbortCheck, 2148
TimeBetweenLocalCheckpoints, 2146
TimeBetweenWatchDogCheck, 2142
TimeBetweenWatchDogCheckInitial, 2143
TIMEDIFF(), 1212
timed_mutexes system variable, 579
timeout, 509, 1289, 1409
  connect_timeout variable, 306, 324
  shutdown_timeout variable, 324
timeout option
  ndb_waiter, 2308
timeouts (replication), 1999
TIMESTAMP
  and logs, 202
  and NULL values, 2973
  and replication, 202, 1980, 2000
  initialization and updating, 1101
TIMESTAMP data type, 1087, 1097
timestamp system variable, 579
TIMESTAMP(), 1212
TIMESTAMPADD(), 1213
TIMESTAMPDIFF(), 1213
timezone option
  mysqld_safe, 276
time_format system variable, 578
TIME_FORMAT(), 1213
TIME_TO_SEC(), 1213
time_zone system variable, 578
time_zone table
  system table, 639
time_zone_leap_second table
  system table, 639
time_zone_name table
  system table, 639
time_zone_transition table

system table, 639
time_zone_transition_type table
system table, 639
TINYBLOB data type, 1090
TINYINT data type, 1084
TINYTEXT data type, 1090
tips
optimization, 876
TLS, 751
command options, 754
establishing connections, 752
TMPDIR environment variable, 185, 254, 423, 2968
TMPDIR option
CMake, 173
tmpdir option
myisamchk, 377
myisampack, 387
mysqld, 486
mysqlhotcopy, 414
mysql_upgrade, 295
tmpdir system variable, 580
tmp_table_size system variable, 579
to-last-log option
mysqlbinlog, 402
tools
command-line, 81, 295
list of, 40
mysqld_multi, 280
mysqld_safe, 273
torn page, 1698, 3566
TotalSendBufferMemory
API and SQL nodes, 2175
data nodes, 2169
management nodes, 2121
Touches(), 1278
TO_DAYS(), 1214
TO_SECONDS(), 1214
TPS, 3566
TP_THREAD_GROUP_STATE
INFORMATION_SCHEMA table, 2592
TP_THREAD_GROUP_STATS
INFORMATION_SCHEMA table, 2594
TP_THREAD_STATE
INFORMATION_SCHEMA table, 2596
trace DBI method, 2833
trace files
ndbmtd, 2241
trace files (NDB Cluster), 2238
TRADITIONAL SQL mode, 623, 629
trailing spaces
CHAR, 1089, 1106
ENUM, 1112
in comparisons, 1106
SET, 1114
VARCHAR, 1090, 1106
transaction, 3566
transaction ID, 3566
transaction isolation level, 1468

NDB Cluster, 2029
READ COMMITTED, 1620
READ UNCOMMITTED, 1622
REPEATABLE READ, 1620
SERIALIZABLE, 1622
transaction-isolation option
mysqld, 486
transaction-safe tables, 1600
transactional option
ndb_delete_all, 2261
TransactionBufferMemory, 2132
TransactionDeadlockDetectionTimeout, 2149
TransactionInactiveTimeout, 2148
transactions, 1615
and replication, 1999, 2000
isolation levels, 1620
metadata locking, 936
support, 1600
transaction_alloc_block_size system variable, 580
transaction_allow_batching session variable (NDB Cluster), 2207
transaction_prealloc_size system variable, 581
Translators
list of, 38
transparent page compression, 3566
transportable tablespace, 3566
transporters
ndbinfo table, 2374
.TRG file, 3564
triggers, 1381, 1391, 1580, 2515, 2519
and INSERT DELAYED, 1403
and replication, 1991, 2001
LAST_INSERT_ID(), 2519
metadata, 2523
restrictions, 2983
TRIGGERS
INFORMATION_SCHEMA table, 2569
triggers option
mysqldump, 347
TRIM(), 1174
.TRN file, 3564
troubleshooting, 3567
C API, 2765
FreeBSD, 180
InnoDB deadlocks, 1630, 1632
InnoDB errors, 1779
InnoDB recovery problems, 1776
InnoDB table fragmentation, 1700
Solaris, 180
with MySQL Enterprise Monitor, 2841
TRUE, 968, 973
testing for, 1156, 1156
truncate, 3567
TRUNCATE TABLE, 1393
and NDB Cluster, 2028
and replication, 2002
performance_schema database, 2619, 2991
TRUNCATE(), 1197
tuning, 830

InnoDB compressed tables, 1682
tuple, 3567
tupscan option
ndb_select_all, 2301
tutorial, 217
twiddle option
ndb_redo_log_reader, 2280
two-phase commit, 1737, 3567
TwoPassInitialNodeRestartCopy, 2159
tx_isolation system variable, 582
type codes
C prepared statement API, 2722
type conversions, 1149, 1154
type option
mysql_convert_table_format, 414
ndb_config, 2258
ndb_show_tables, 2304
types
columns, 1083, 1136
data, 1083
Date and Time, 1096
of tables, 1781
portability, 1136
strings, 1106
typographical conventions, 2
TZ environment variable, 423, 2969
tz-utc option
mysqldump, 347

U

UCASE(), 1175
UCS-2, 1013
ucs2 character set, 1046
UDFs, 1536, 1537
compiling, 2825
defined, 2817
return values, 2824
ulimit, 2961
UMASK environment variable, 423, 2962
UMASK_DIR environment variable, 423, 2962
unary minus (-), 1187
unbuffered option
mysql, 305
UNCOMPRESS(), 1258
UNCOMPRESSED_LENGTH(), 1258
undo, 3567
undo log, 1656, 3567
undo log segment, 3568
undo tablespace, 3568
UndoDataBuffer, 2152
UndoIndexBuffer, 2151
UNHEX(), 1175
Unicode, 1013
Unicode Collation Algorithm, 1052
UNINSTALL PLUGIN statement, 1538
uninstalling plugins, 661, 1538
UNION, 245, 1441
UNIQUE, 1315

unique constraint, 3568
unique ID, 2765
unique index, 3568
unique key, 3568
  constraint, 31
unique keys
  and partitioning keys, 2508
unique_checks system variable, 582
unique_subquery join type
  optimizer, 908
Unix
  compiling clients on, 2655
UNIX_TIMESTAMP(), 1215
UNKNOWN
  testing for, 1156, 1156
Unknown column ... in 'on clause', 1441, 1441
unloading
  tables, 225
UNLOCK TABLES, 1462
unnamed views, 1449
unpack option
  myisamchk, 377
unqualified option
  ndb_desc, 2265
  ndb_show_tables, 2304
unsafe statement (replication)
  defined, 1897
unsafe statements (replication), 1898
UNSIGNED, 1084, 1092
UNTIL, 1492
updatable views, 2533
updatable_views_with_limit system variable, 583
UPDATE, 29, 1455
update
  thread state, 958
update option
  MySQLInstallerConsole, 84
update option (ndb_index_stat), 2271
update-state option
  myisamchk, 375
UpdateXML(), 1243
Updating
  thread state, 958
updating main table
  thread state, 958
updating reference tables
  thread state, 958
upgrade option
  MySQLInstallerConsole, 84
upgrade-system-tables option
  mysql_upgrade, 295
upgrades
  NDB Cluster, 2062, 2325
upgrades and downgrades (NDB Cluster)
  compatibility between versions, 2062
upgrading, 195, 195
  different architecture, 211
  to &current-series;, 199

upgrading lock
  thread state, 960
upgrading MySQL, 290
UPPER(), 1175
uptime, 319
URLs for downloading MySQL, 45
usage option
  ndb_config, 2258
usage option (NDB Cluster programs), 2311
USE, 1596
use command
  mysql, 309
USE INDEX, 918
USE KEY, 918
use-frm option
  mysqlcheck, 331
use-threads option
  mysqlimport, 355
useHexFormat option
  ndb_select_all, 2300
user accounts
  creating, 1510
  renaming, 1524
  resource limits, 539, 739, 1523
USER environment variable, 258, 423
User lock
  thread state, 958
user names
  and passwords, 736
  in account names, 724
  in default accounts, 190
user option, 258
  mysql, 305
  mysqlaccess, 394
  mysqladmin, 324
  mysqlbinlog, 402
  mysqlcheck, 331
  mysqld, 486
  mysqldump, 347
  mysqld_multi, 282
  mysqld_safe, 276
  mysqlhotcopy, 414
  mysqlimport, 355
  mysqlshow, 359
  mysqlslap, 366
  mysql_convert_table_format, 415
  mysql_install_db, 287
  mysql_setpermission, 416
  mysql_upgrade, 295
user privileges
  adding, 738
  deleting, 739, 1513
  dropping, 739, 1513
User sleep
  thread state, 958
user table
  sorting, 727
  system table, 190, 638, 719

user variables
  and replication, 2002
USER(), 1267
User-defined functions, 1536, 1537
user-defined functions
  adding, 2817, 2818
user-defined variables, 1006
users
  adding, 186
  deleting, 739, 1513
  root, 190
USER_PRIVILEGES
  INFORMATION_SCHEMA table, 2571
USING HASH
  with NDB tables, 1339
using multiple disks to start data, 942
using NDB Cluster programs, 2232
USING versus ON
  joins, 1440
UTC_DATE(), 1216
UTC_TIME(), 1216
UTC_TIMESTAMP(), 1216
UTF-8, 1013
  database object metadata, 1018
utf16 character set, 1046
utf16_bin collation, 1053
utf32 character set, 1047
utf8 character set, 1044
utf8mb3 character set, 1045
utf8mb4 character set, 1045
utilities
  program-development, 253
utility programs, 252
UUID(), 1293
UUID_SHORT(), 1293

V

valid numbers
  examples, 968
VALUES(), 1294
VARBINARY data type, 1090, 1108
VARCHAR
  size, 1135
VARCHAR data type, 1090, 1106
VARCHARACTER data type, 1090
variable option
  mysql_config, 419
variable-length type, 3568
variables
  and replication, 2002
  environment, 254
  server, 1581
  status, 597, 1576
  system, 487, 584, 1581
  user defined, 1006
VARIANCE(), 1284
VAR_POP(), 1284
VAR_SAMP(), 1284

verbose option
  myisamchk, 373
  myisampack, 387
  myisam_ftdump, 369
  mysql, 305
  mysqladmin, 324
  mysqlbinlog, 402
  mysqlcheck, 331
  mysqld, 487
  mysqldump, 347
  mysqldumpslow, 411
  mysqld_multi, 282
  mysqlimport, 355
  mysqlshow, 359
  mysqlslap, 366
  mysql_convert_table_format, 415
  mysql_install_db, 287
  mysql_plugin, 289
  mysql_upgrade, 295
  mysql_waitpid, 417
  my_print_defaults, 420
  ndb_blob_tool, 2252
  ndb_move_data, 2275
  ndb_restore, 2295
  perror, 422
verbose option (ndb_index_stat), 2273
version
  choosing, 43
  latest, 45
VERSION file
  CMake, 181
version option
  comp_err, 284
  myisamchk, 373
  myisampack, 387
  mysql, 305
  mysqlaccess, 394
  mysqladmin, 324
  mysqlbinlog, 402
  mysqlcheck, 331
  mysqld, 487
  mysqldump, 347
  mysqld_multi, 282
  mysqlimport, 355
  mysqlshow, 359
  mysqlslap, 366
  mysql_config, 419
  mysql_convert_table_format, 415
  mysql_plugin, 289
  mysql_waitpid, 417
  my_print_defaults, 420
  ndb_config, 2258
  perror, 422
  resolveip, 423
  resolve_stack_dump, 421
version option (NDB Cluster programs), 2312
version system variable, 583
VERSION(), 1267

version-check option
  mysql_upgrade, 295
version_comment system variable, 583
version_compile_machine system variable, 583
version_compile_os system variable, 583
vertical option
  mysql, 305
  mysqladmin, 324
victim, 3568
Vietnamese, 2871
views, 1383, 2515, 2531
  algorithms, 2532
  and replication, 2004
  limitations, 2990
  metadata, 2535
  privileges, 2990
  problems, 2990
  restrictions, 2989
  updatable, 1383, 2533
VIEWS
  INFORMATION_SCHEMA table, 2571

W

wait, 3569
WAIT COMPLETED (START BACKUP command), 2320
wait option
  myisamchk, 373
  myisampack, 387
  mysql, 305
  mysqladmin, 324
WAIT STARTED (START BACKUP command), 2320
wait-nodes option
  ndb_waiter, 2308
Waiting for allowed to take ndbcluster global schema lock
  thread state, 964
Waiting for commit lock
  thread state, 958
waiting for delay_list
  thread state, 960
Waiting for event from ndbcluster
  thread state, 964
Waiting for event metadata lock
  thread state, 959
Waiting for event read lock
  thread state, 959
Waiting for first event from ndbcluster
  thread state, 964
Waiting for global metadata lock
  thread state, 959
Waiting for global read lock
  thread state, 958, 959
waiting for handler insert
  thread state, 960
waiting for handler lock
  thread state, 960
waiting for handler open
  thread state, 960
Waiting for INSERT

thread state, 960
Waiting for master to send event
thread state, 962
Waiting for master update
thread state, 962
Waiting for ndbcluster binlog update to reach current position
thread state, 964
Waiting for ndbcluster global schema lock
thread state, 964
Waiting for ndbcluster to start
thread state, 964
Waiting for next activation
thread state, 964
Waiting for query cache lock
thread state, 961
Waiting for scheduler to stop
thread state, 964
Waiting for schema epoch
thread state, 964
Waiting for schema metadata lock
thread state, 959
Waiting for slave mutex on exit
thread state, 962, 963
Waiting for stored function metadata lock
thread state, 959
Waiting for stored procedure metadata lock
thread state, 959
Waiting for table
thread state, 958
Waiting for table flush
thread state, 958
Waiting for table level lock
thread state, 959
Waiting for table metadata lock
thread state, 959
Waiting for tables
thread state, 958
Waiting for the next event in relay log
thread state, 962
Waiting for the slave SQL thread to free enough relay log space
thread state, 962
Waiting for trigger metadata lock
thread state, 959
Waiting on cond
thread state, 959
Waiting on empty queue
thread state, 964
Waiting to finalize termination
thread state, 961
Waiting to reconnect after a failed binlog dump request
thread state, 962
Waiting to reconnect after a failed master event read
thread state, 962
wait_timeout system variable, 584
Wan, 2120, 2176
warm backup, 3569
warm up, 3569
warnings command

mysql, 309
warning_count system variable, 584
WARN_COND_ITEM_TRUNCATED error code, 2936
WARN_DATA_TRUNCATED error code, 2911
WARN_NON_ASCII_SEPARATOR_NOT_IMPLEMENTED error code, 2935
WARN_NO_MASTER_INFO error code, 2934
WARN_OPTION_BELOW_LIMIT error code, 2942
WARN_OPTION_IGNORED error code, 2934
WARN_PLUGIN_BUSY error code, 2934
WARN_PLUGIN_DELETE_BUILTIN error code, 2934
web sites, 17
WEEK(), 1216
WEEKDAY(), 1217
WEEKOFYEAR(), 1218
Well-Known Binary format
geometry values, 1125
Well-Known Text format
geometry values, 1124
WHERE, 833
with SHOW, 2545, 2596
where option
mysqldump, 347
WHILE, 1493
labels, 1487
widths
display, 1084
Wildcard character (%), 966
Wildcard character (_), 967
wildcards
and LIKE, 883
in account names, 725
in mysql.columns_priv table, 729
in mysql.db table, 728
in mysql.host table, 728
in mysql.procs_priv table, 729
in mysql.tables_priv table, 729
Windows
compiling clients on, 2656
MySQL limitations, 2998, 2998
path name separators, 264
pluggable authentication, 776
upgrading, 126
windows option
mysql_install_db, 287
WITH ROLLUP, 1284
Within(), 1280
WITHOUT_SERVER option
CMake, 177
WITH_ASAN option
CMake, 176
WITH_BUNDLED_LIBEVENT option
CMake, 178
WITH_BUNDLED_MEMCACHED option
CMake, 178
WITH_CLASSPATH option
CMake, 179
WITH_DEBUG option
CMake, 176

WITH_EMBEDDED_SERVER option
  CMake, 176
WITH_EMBEDDED_SHARED_LIBRARY option
  CMake, 176
WITH_ERROR_INSERT option
  CMake, 179
WITH_EXTRA_CHARSETS option
  CMake, 176
WITH_LIBEDIT option
  CMake, 176
WITH_LIBWRAP option
  CMake, 176
WITH_NDBCLUSTER option
  CMake, 179
WITH_NDBCLUSTER_STORAGE_ENGINE option
  CMake, 179
WITH_NDBMTD option
  CMake, 179
WITH_NDB_BINLOG option
  CMake, 179
WITH_NDB_DEBUG option
  CMake, 179
WITH_NDB_JAVA option
  CMake, 179
WITH_NDB_PORT option
  CMake, 179
WITH_NDB_TEST option
  CMake, 179
WITH_READLINE option
  CMake, 177
WITH_SSL option
  CMake, 177
WITH_UNIT_TESTS option
  CMake, 177
WITH_UNIXODBC option
  CMake, 177
WITH_VALGRIND option
  CMake, 177
WITH_ZLIB option
  CMake, 177
WKB format
  geometry values, 1125
WKT format
  geometry values, 1124
workload, 3569
wrappers
  Eiffel, 2768
write access
  tmp, 184
write combining, 3569
write-binlog option
  mysqlcheck, 331
  mysql_upgrade, 295
write_buffer_size myisamchk variable, 373
Writing to net
  thread state, 959

X

X(), 1274
X509/Certificate, 751
XA, 3569
XA BEGIN, 1470
XA COMMIT, 1470
XA PREPARE, 1470
XA RECOVER, 1470
XA ROLLBACK, 1470
XA START, 1470
XA transactions, 1469
  restrictions, 2990
  transaction identifiers, 1470
xid
  XA transaction identifier, 1470
xml option
  mysql, 305
  mysqldump, 347
  ndb_config, 2258
XOR
  bitwise, 1251
  logical, 1160

Y

Y(), 1274
yaSSL, 751, 762
  compared to OpenSSL, 762
YEAR data type, 1088, 1099
YEAR(), 1218
YEARWEEK(), 1218
Yen sign (Japanese), 2871
young, 3570

Z

ZEROFILL, 1084, 1092, 2764
ZFS, 1819

C Function Index

my_init()

Section 23.8.6, “C API Function Overview”
Section 23.8.12.1, “my_init()”
Section 23.8.12.3, “mysql_thread_init()”

mysql_affected_rows()

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 13.2.1, “CALL Syntax”
Section 12.14, “Information Functions”
Section 13.2.5, “INSERT Syntax”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.46, “mysql_next_result()”
Section 23.8.7.48, “mysql_num_rows()”
Section 23.8.11.1, “mysql_stmt_affected_rows()”
Section 23.8.7.71, “mysql_use_result()”
Section 13.2.8, “REPLACE Syntax”

Section 23.8.21.2, “What Results You Can Get from a Query”

mysql_autocommit()

Section 23.8.6, “C API Function Overview”

mysql_change_user()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.3, “mysql_change_user()”

mysql_character_set_name()

Section 23.8.6, “C API Function Overview”

mysql_client_find_plugin()

Section 23.8.6, “C API Function Overview”

mysql_client_register_plugin()

Section 23.8.6, “C API Function Overview”

mysql_close()

Section 23.8.6, “C API Function Overview”
Section B.5.2.11, “Communication Errors and Aborted Connections”
Section 23.8.7.5, “mysql_close()”
Section 23.8.7.6, “mysql_commit()”
Section 23.8.7.7, “mysql_connect()”
Section 23.8.7.36, “mysql_init()”
Section 23.8.7.57, “mysql_rollback()”

mysql_commit()

Section 23.8.6, “C API Function Overview”

mysql_connect()

Section 23.8.6, “C API Function Overview”
Section 23.8.12.1, “my_init()”
Section 23.8.7.5, “mysql_close()”
Section 23.8.7.7, “mysql_connect()”
Section 23.8.7.49, “mysql_options()”
Section 23.8.12.3, “mysql_thread_init()”
Section 23.8.4.2, “Writing C API Threaded Client Programs”

mysql_create_db()

Section 23.8.6, “C API Function Overview”

mysql_data_seek()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.9, “mysql_data_seek()”
Section 23.8.7.58, “mysql_row_seek()”
Section 23.8.7.71, “mysql_use_result()”

mysql_debug()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.10, “mysql_debug()”

mysql_drop_db()

Section 23.8.6, “C API Function Overview”

mysql_dump_debug_info()

Section 23.8.6, “C API Function Overview”

mysql_eof()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.13, “mysql_eof()”

mysql_errno()

Section 6.5.2.3, “Audit Log File Formats”
Section 23.8.7, “C API Function Descriptions”
Section 23.8.6, “C API Function Overview”
Section 23.8.14.1, “mysql_client_find_plugin()”
Section 23.8.14.2, “mysql_client_register_plugin()”
Section 23.8.7.7, “mysql_connect()”
Section 23.8.7.13, “mysql_eof()”
Section 23.8.7.14, “mysql_errno()”
Section 23.8.7.22, “mysql_field_count()”
Section 23.8.14.3, “mysql_load_plugin()”
Section 23.8.7.47, “mysql_num_fields()”
Section 23.8.7.66, “mysql_sqlstate()”
Section 23.8.11.6, “mysql_stmt_close()”
Section 23.8.11.8, “mysql_stmt_errno()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Signal Condition Information Items
Section B.2, “Types of Error Values”
Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 24.2.4.8, “Writing Audit Plugins”

mysql_error()

Section 23.8.7, “C API Function Descriptions”
Section 23.8.6, “C API Function Overview”
Section 23.8.14.1, “mysql_client_find_plugin()”
Section 23.8.14.2, “mysql_client_register_plugin()”
Section 23.8.7.7, “mysql_connect()”
Section 23.8.7.13, “mysql_eof()”
Section 23.8.7.15, “mysql_error()”
Section 23.8.14.3, “mysql_load_plugin()”
Section 23.8.11.6, “mysql_stmt_close()”
Section 23.8.11.9, “mysql_stmt_error()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Signal Condition Information Items
Section B.2, “Types of Error Values”
Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 24.2.4.8, “Writing Audit Plugins”

mysql_escape_string()

Section 23.8.6, “C API Function Overview”
Section 6.1.7, “Client Programming Security Guidelines”
Section 23.8.7.16, “mysql_escape_string()”

mysql_fetch_field()

Section 23.8.5, “C API Data Structures”

Section 23.8.6, “C API Function Overview”
Section 23.8.7.17, “mysql_fetch_field()”
Section 23.8.7.23, “mysql_field_seek()”
Section 23.8.7.24, “mysql_field_tell()”
Section 23.8.11.23, “mysql_stmt_result_metadata()”

mysql_fetch_field_direct()

Section 23.8.6, “C API Function Overview”
Section 23.8.11.23, “mysql_stmt_result_metadata()”

mysql_fetch_fields()

Section 23.8.6, “C API Function Overview”
Section 23.8.11.23, “mysql_stmt_result_metadata()”

mysql_fetch_lengths()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.20, “mysql_fetch_lengths()”
Section 23.8.7.21, “mysql_fetch_row()”

mysql_fetch_row()

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 15.9.1, “FEDERATED Storage Engine Overview”
Section 23.8.7.13, “mysql_eof()”
Section 23.8.7.14, “mysql_errno()”
Section 23.8.7.20, “mysql_fetch_lengths()”
Section 23.8.7.21, “mysql_fetch_row()”
Section 23.8.7.59, “mysql_row_tell()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Section 23.8.21.2, “What Results You Can Get from a Query”

mysql_field_count()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.22, “mysql_field_count()”
Section 23.8.7.47, “mysql_num_fields()”
Section 23.8.7.51, “mysql_query()”
Section 23.8.7.54, “mysql_real_query()”
Section 23.8.11.23, “mysql_stmt_result_metadata()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”

mysql_field_seek()

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 23.8.7.17, “mysql_fetch_field()”
Section 23.8.7.24, “mysql_field_tell()”
Section 23.8.11.23, “mysql_stmt_result_metadata()”

mysql_field_tell()

Section 23.8.6, “C API Function Overview”
Section 23.8.11.23, “mysql_stmt_result_metadata()”

mysql_free_result()

Section 23.8.6, “C API Function Overview”

Section 23.8.10, “C API Prepared Statement Function Overview”
Section B.5.2.14, “Commands out of sync”
Section 23.8.7.25, “mysql_free_result()”
Section 23.8.7.41, “mysql_list_dbs()”
Section 23.8.7.42, “mysql_list_fields()”
Section 23.8.7.43, “mysql_list_processes()”
Section 23.8.7.44, “mysql_list_tables()”
Section 23.8.7.46, “mysql_next_result()”
Section 23.8.11.23, “mysql_stmt_result_metadata()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”

mysql_get_character_set_info()

Section 23.8.6, “C API Function Overview”
Section 10.4.2, “Choosing a Collation ID”

mysql_get_client_info()

Section 23.8.6, “C API Function Overview”
Section 23.8.4.4, “C API Server and Client Library Versions”
Section 23.8.7.7, “mysql_connect()”

mysql_get_client_version()

Section 23.8.6, “C API Function Overview”
Section 23.8.4.4, “C API Server and Client Library Versions”

mysql_get_host_info()

Section 23.8.6, “C API Function Overview”

mysql_get_proto_info()

Section 23.8.6, “C API Function Overview”

mysql_get_server_info()

Section 23.8.6, “C API Function Overview”
Section 23.8.4.4, “C API Server and Client Library Versions”

mysql_get_server_version()

Section 23.8.6, “C API Function Overview”
Section 23.8.4.4, “C API Server and Client Library Versions”

mysql_get_ssl_cipher()

Section 23.8.15, “C API Encrypted Connection Support”
Section 23.8.6, “C API Function Overview”
Section 23.8.7.33, “mysql_get_ssl_cipher()”

mysql_hex_string()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.34, “mysql_hex_string()”

mysql_info()

Section 13.1.7, “ALTER TABLE Syntax”
Section 23.8.6, “C API Function Overview”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 23.8.7.35, “mysql_info()”
Section 23.8.7.49, “mysql_options()”

Section 1.7.3.1, “PRIMARY KEY and UNIQUE Index Constraints”
Section 13.2.11, “UPDATE Syntax”
Section 23.8.21.2, “What Results You Can Get from a Query”

mysql_init()

Section 23.8.6, “C API Function Overview”
Section 23.8.12.1, “my_init()”
Section 23.8.7.5, “mysql_close()”
Section 23.8.7.33, “mysql_get_ssl_cipher()”
Section 23.8.7.36, “mysql_init()”
Section 23.8.7.40, “mysql_library_init()”
Section 23.8.7.49, “mysql_options()”
Section 23.8.7.52, “mysql_real_connect()”
Section 23.8.7.67, “mysql_ssl_set()”
Section 23.8.12.3, “mysql_thread_init()”
Section 23.8.4.2, “Writing C API Threaded Client Programs”

mysql_insert_id()

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 13.1.17, “CREATE TABLE Syntax”
Section 23.8.21.3, “How to Get the Unique ID for the Last Inserted Row”
Section 12.14, “Information Functions”
Section 13.2.5, “INSERT Syntax”
Section 23.8.7.37, “mysql_insert_id()”
Section 5.1.5, “Server System Variables”
Section 3.6.9, “Using AUTO_INCREMENT”
Section 23.8.21.2, “What Results You Can Get from a Query”

mysql_kill()

Section 23.8.20, “C API Automatic Reconnection Control”
Section 23.8.6, “C API Function Overview”
Section 23.8.7.70, “mysql_thread_id()”

mysql_library_end()

Section 23.8.13, “C API Embedded Server Function Descriptions”
Section 23.8.6, “C API Function Overview”
Section 23.7, “libmysqld, the Embedded MySQL Server Library”
Section 23.8.7.39, “mysql_library_end()”
Section 23.8.7.40, “mysql_library_init()”
Section 23.8.13.2, “mysql_server_end()”

mysql_library_init()

Section 23.8.13, “C API Embedded Server Function Descriptions”
Section 23.8.6, “C API Function Overview”
Section 23.7, “libmysqld, the Embedded MySQL Server Library”
Section 23.8.12.1, “my_init()”
Section 23.8.7.36, “mysql_init()”
Section 23.8.7.40, “mysql_library_init()”
Section 23.8.14.3, “mysql_load_plugin()”
Section 23.8.13.1, “mysql_server_init()”
Section 23.8.12.3, “mysql_thread_init()”
Section 23.7.3, “Options with the Embedded Server”
Section 23.8.4.2, “Writing C API Threaded Client Programs”

mysql_list_dbs()

Section 23.8.6, “C API Function Overview”

Section 23.8.7.25, “mysql_free_result()”
Section 23.8.7.41, “mysql_list_dbs()”

mysql_list_fields()

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 23.8.7.42, “mysql_list_fields()”

mysql_list_processes()

Section 23.8.6, “C API Function Overview”

mysql_list_tables()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.44, “mysql_list_tables()”

mysql_load_plugin()

Section 23.8.6, “C API Function Overview”
Client Plugin Descriptors
Section 23.8.14.4, “mysql_load_plugin_v()”

mysql_load_plugin_v()

Section 23.8.6, “C API Function Overview”

mysql_more_results()

Section 23.8.6, “C API Function Overview”
Section 23.8.16, “C API Multiple Statement Execution Support”
Section 23.8.7.45, “mysql_more_results()”
Section 23.8.7.46, “mysql_next_result()”
Section 23.8.11.17, “mysql_stmt_next_result()”

mysql_next_result()

Section 23.8.6, “C API Function Overview”
Section 23.8.16, “C API Multiple Statement Execution Support”
Section 13.2.1, “CALL Syntax”
Section 23.8.7.45, “mysql_more_results()”
Section 23.8.7.46, “mysql_next_result()”
Section 23.8.7.52, “mysql_real_connect()”
Section 23.8.7.64, “mysql_set_server_option()”
Section 23.8.7.69, “mysql_store_result()”

mysql_num_fields()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.18, “mysql_fetch_field_direct()”
Section 23.8.7.21, “mysql_fetch_row()”
Section 23.8.11.23, “mysql_stmt_result_metadata()”

mysql_num_rows()

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.9, “mysql_data_seek()”
Section 23.8.7.48, “mysql_num_rows()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Section 23.8.21.2, “What Results You Can Get from a Query”

mysql_options()

Section 23.8.20, “C API Automatic Reconnection Control”
Section 23.8.14, “C API Client Plugin Functions”
Section 23.8.15, “C API Encrypted Connection Support”
Section 23.8.6, “C API Function Overview”
Section 23.8.9, “C API Prepared Statement Data Structures”
Client Plugin Descriptors
Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 10.1.4, “Connection Character Sets and Collations”
Section B.5.2.9, “MySQL server has gone away”
Section 23.8.7.49, “mysql_options()”
Section 23.8.7.50, “mysql_ping()”
Section 23.8.7.52, “mysql_real_connect()”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section 24.2.3, “Plugin API Components”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 6.3.1, “User Names and Passwords”
Section 5.6.4, “Using Client Programs in a Multiple-Server Environment”
Using the Authentication Plugins

mysql_ping()

Section 23.8.20, “C API Automatic Reconnection Control”
Section 23.8.6, “C API Function Overview”
Section B.5.2.9, “MySQL server has gone away”
Section 23.8.7.50, “mysql_ping()”
Section 23.8.7.70, “mysql_thread_id()”

mysql_plugin_options()

Section 23.8.6, “C API Function Overview”

mysql_query()

Section 23.8.6, “C API Function Overview”
Section 23.8.16, “C API Multiple Statement Execution Support”
Section 13.2.1, “CALL Syntax”
Section 23.8.21.3, “How to Get the Unique ID for the Last Inserted Row”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.8, “mysql_create_db()”
Section 23.8.7.11, “mysql_drop_db()”
Section 23.8.7.17, “mysql_fetch_field()”
Section 23.8.7.38, “mysql_kill()”
Section 23.8.7.46, “mysql_next_result()”
Section 23.8.7.51, “mysql_query()”
Section 23.8.7.52, “mysql_real_connect()”
Section 23.8.7.54, “mysql_real_query()”
Section 23.8.7.56, “mysql_reload()”
Section 23.8.7.63, “mysql_set_local_infile_handler()”
Section 23.8.7.64, “mysql_set_server_option()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 23.8.4.2, “Writing C API Threaded Client Programs”

mysql_real_connect()

Section 23.8.15, “C API Encrypted Connection Support”
Section 23.8.6, “C API Function Overview”
Section 23.8.16, “C API Multiple Statement Execution Support”

Section 13.2.1, “CALL Syntax”
Chapter 12, *Functions and Operators*
Section 12.14, “Information Functions”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 13.2.5, “INSERT Syntax”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.3, “mysql_change_user()”
Section 23.8.7.7, “mysql_connect()”
Section 23.8.7.36, “mysql_init()”
Section 23.8.7.46, “mysql_next_result()”
Section 23.8.7.49, “mysql_options()”
Section 23.8.7.52, “mysql_real_connect()”
Section 23.8.7.64, “mysql_set_server_option()”
Section 23.8.7.66, “mysql_sqlstate()”
Section 23.8.7.67, “mysql_ssl_set()”
Section 13.5, “Prepared SQL Statement Syntax”
Section 5.1.5, “Server System Variables”
Section 20.2.1, “Stored Routine Syntax”
Section 5.6.4, “Using Client Programs in a Multiple-Server Environment”

mysql_real_escape_string()

Section 23.8.6, “C API Function Overview”
Section 6.1.7, “Client Programming Security Guidelines”
Section 23.8.7.16, “mysql_escape_string()”
Section 23.8.7.53, “mysql_real_escape_string()”
Section 23.8.7.61, “mysql_set_character_set()”
Section 11.5.5, “Populating Spatial Columns”
Section 9.1.1, “String Literals”

mysql_real_query()

Section 23.8.6, “C API Function Overview”
Section 23.8.16, “C API Multiple Statement Execution Support”
Section 13.2.1, “CALL Syntax”
Section 15.9.1, “FEDERATED Storage Engine Overview”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.46, “mysql_next_result()”
Section 23.8.7.51, “mysql_query()”
Section 23.8.7.52, “mysql_real_connect()”
Section 23.8.7.54, “mysql_real_query()”
Section 23.8.7.64, “mysql_set_server_option()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”

mysql_refresh()

Section 23.8.6, “C API Function Overview”

mysql_reload()

Section 23.8.6, “C API Function Overview”

mysql_rollback()

Section 23.8.6, “C API Function Overview”

mysql_row_seek()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.58, “mysql_row_seek()”
Section 23.8.7.59, “mysql_row_tell()”

Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”

mysql_row_tell()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.58, “mysql_row_seek()”
Section 23.8.7.59, “mysql_row_tell()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”

mysql_select_db()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.60, “mysql_select_db()”

mysql_server_end()

Section 23.8.6, “C API Function Overview”
Section 23.8.13.2, “mysql_server_end()”

mysql_server_init()

Section 23.8.6, “C API Function Overview”
Section 23.8.12.1, “my_init()”
Section 23.8.13.1, “mysql_server_init()”
Section 23.8.12.3, “mysql_thread_init()”

mysql_set_character_set()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.26, “mysql_get_character_set_info()”
Section 23.8.7.53, “mysql_real_escape_string()”

mysql_set_local_infile_default()

Section 23.8.6, “C API Function Overview”

mysql_set_local_infile_handler()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.62, “mysql_set_local_infile_default()”
Section 23.8.7.63, “mysql_set_local_infile_handler()”

mysql_set_server_option()

Section 23.8.6, “C API Function Overview”
Section 23.8.16, “C API Multiple Statement Execution Support”
Section 23.8.7.64, “mysql_set_server_option()”

mysql_shutdown()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.65, “mysql_shutdown()”
Section 6.2.1, “Privileges Provided by MySQL”

mysql_sqlstate()

Section 23.8.6, “C API Function Overview”
Section 23.8.7.14, “mysql_errno()”
Section 23.8.7.66, “mysql_sqlstate()”
Section 23.8.11.6, “mysql_stmt_close()”
Section 23.8.11.27, “mysql_stmt_sqlstate()”
Signal Condition Information Items

Section B.2, “Types of Error Values”

mysql_ssl_set()

Section 23.8.15, “C API Encrypted Connection Support”
Section 23.8.6, “C API Function Overview”
Section 23.8.7.52, “mysql_real_connect()”
Section 23.8.7.67, “mysql_ssl_set()”

mysql_stat()

Section 23.8.6, “C API Function Overview”

mysql_stmt_affected_rows()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.1, “mysql_stmt_affected_rows()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.17, “mysql_stmt_next_result()”
Section 23.8.11.18, “mysql_stmt_num_rows()”

mysql_stmt_attr_get()

Section 23.8.10, “C API Prepared Statement Function Overview”

mysql_stmt_attr_set()

Section 23.8.5, “C API Data Structures”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.9.2, “C API Prepared Statement Type Conversions”
Section 23.8.11.3, “mysql_stmt_attr_set()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section 23.8.11.28, “mysql_stmt_store_result()”
Section C.3, “Restrictions on Server-Side Cursors”

mysql_stmt_bind_param()

Section 23.8.9, “C API Prepared Statement Data Structures”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.17, “C API Prepared Statement Handling of Date and Time Values”
Section 23.8.11.4, “mysql_stmt_bind_param()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.21, “mysql_stmt_prepare()”
Section 23.8.11.26, “mysql_stmt_send_long_data()”

mysql_stmt_bind_result()

Section 23.8.9, “C API Prepared Statement Data Structures”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.17, “C API Prepared Statement Handling of Date and Time Values”
Section 23.8.11.5, “mysql_stmt_bind_result()”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section 23.8.11.12, “mysql_stmt_fetch_column()”
Section 23.8.11.17, “mysql_stmt_next_result()”
Section 23.8.11.28, “mysql_stmt_store_result()”

mysql_stmt_close()

Section 23.8.9, “C API Prepared Statement Data Structures”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.6, “mysql_stmt_close()”
Section 23.8.11.8, “mysql_stmt_errno()”
Section 23.8.11.9, “mysql_stmt_error()”

Section 23.8.11.15, “mysql_stmt_init()”
Section 23.8.11.27, “mysql_stmt_sqlstate()”

mysql_stmt_data_seek()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.7, “mysql_stmt_data_seek()”
Section 23.8.11.24, “mysql_stmt_row_seek()”
Section 23.8.11.28, “mysql_stmt_store_result()”

mysql_stmt_errno()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.6, “mysql_stmt_close()”
Section 23.8.11.8, “mysql_stmt_errno()”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section B.2, “Types of Error Values”

mysql_stmt_error()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.6, “mysql_stmt_close()”
Section 23.8.11.9, “mysql_stmt_error()”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section 23.8.11.21, “mysql_stmt_prepare()”
Section B.2, “Types of Error Values”

mysql_stmt_execute()

Section 23.8.9, “C API Prepared Statement Data Structures”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.17, “C API Prepared Statement Handling of Date and Time Values”
Section 23.8.9.2, “C API Prepared Statement Type Conversions”
Section 8.10.3.1, “How the Query Cache Operates”
Section 23.8.11.1, “mysql_stmt_affected_rows()”
Section 23.8.11.3, “mysql_stmt_attr_set()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section 23.8.11.17, “mysql_stmt_next_result()”
Section 23.8.11.26, “mysql_stmt_send_long_data()”
Section 23.8.11.28, “mysql_stmt_store_result()”

mysql_stmt_fetch()

Section 23.8.9, “C API Prepared Statement Data Structures”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.9.2, “C API Prepared Statement Type Conversions”
Section 23.8.11.5, “mysql_stmt_bind_result()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section 23.8.11.23, “mysql_stmt_result_metadata()”
Section 23.8.11.25, “mysql_stmt_row_tell()”
Section 23.8.11.28, “mysql_stmt_store_result()”

mysql_stmt_fetch_column()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section B.4, “Client Error Codes and Messages”
Section 23.8.11.11, “mysql_stmt_fetch()”

mysql_stmt_field_count()

Section 23.8.10, “C API Prepared Statement Function Overview”

Section 23.8.11.13, “mysql_stmt_field_count()”

mysql_stmt_free_result()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.3, “mysql_stmt_attr_set()”
Section 23.8.11.14, “mysql_stmt_free_result()”
Section 23.8.11.17, “mysql_stmt_next_result()”

mysql_stmt_init()

Section 23.8.9, “C API Prepared Statement Data Structures”
Section 23.8.11, “C API Prepared Statement Function Descriptions”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.8, “C API Prepared Statements”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.21, “mysql_stmt_prepare()”

mysql_stmt_insert_id()

Section 23.8.10, “C API Prepared Statement Function Overview”

mysql_stmt_next_result()

Section 23.8.18, “C API Prepared CALL Statement Support”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 13.2.1, “CALL Syntax”
Section 23.8.11.17, “mysql_stmt_next_result()”

mysql_stmt_num_rows()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.7, “mysql_stmt_data_seek()”
Section 23.8.11.18, “mysql_stmt_num_rows()”

mysql_stmt_param_count()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.10, “mysql_stmt_execute()”

mysql_stmt_param_metadata()

Section 23.8.10, “C API Prepared Statement Function Overview”

mysql_stmt_prepare()

Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 23.8.9, “C API Prepared Statement Data Structures”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.17, “C API Prepared Statement Handling of Date and Time Values”
Section 8.10.3.1, “How the Query Cache Operates”
Section 23.8.11.4, “mysql_stmt_bind_param()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.13, “mysql_stmt_field_count()”
Section 23.8.11.21, “mysql_stmt_prepare()”
Section 23.8.11.22, “mysql_stmt_reset()”
Section 23.8.11.23, “mysql_stmt_result_metadata()”
Section 13.5, “Prepared SQL Statement Syntax”

mysql_stmt_reset()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.3, “mysql_stmt_attr_set()”
Section 23.8.11.26, “mysql_stmt_send_long_data()”

mysql_stmt_result_metadata()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.9.2, “C API Prepared Statement Type Conversions”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section 23.8.11.23, “mysql_stmt_result_metadata()”
Section 23.8.11.28, “mysql_stmt_store_result()”

mysql_stmt_row_seek()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.24, “mysql_stmt_row_seek()”
Section 23.8.11.25, “mysql_stmt_row_tell()”
Section 23.8.11.28, “mysql_stmt_store_result()”

mysql_stmt_row_tell()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.24, “mysql_stmt_row_seek()”
Section 23.8.11.25, “mysql_stmt_row_tell()”
Section 23.8.11.28, “mysql_stmt_store_result()”

mysql_stmt_send_long_data()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section B.4, “Client Error Codes and Messages”
Section 23.8.11.22, “mysql_stmt_reset()”
Section 23.8.11.26, “mysql_stmt_send_long_data()”
Section 5.1.5, “Server System Variables”

mysql_stmt_sqlstate()

Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.6, “mysql_stmt_close()”
Section 23.8.11.27, “mysql_stmt_sqlstate()”
Section B.2, “Types of Error Values”

mysql_stmt_store_result()

Section 23.8.5, “C API Data Structures”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 23.8.11.3, “mysql_stmt_attr_set()”
Section 23.8.11.7, “mysql_stmt_data_seek()”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section 23.8.11.18, “mysql_stmt_num_rows()”
Section 23.8.11.24, “mysql_stmt_row_seek()”
Section 23.8.11.25, “mysql_stmt_row_tell()”
Section 23.8.11.28, “mysql_stmt_store_result()”

mysql_store_result()

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section B.5.2.14, “Commands out of sync”
Section 15.9.1, “FEDERATED Storage Engine Overview”
Section 4.5.1, “`mysql` — The MySQL Command-Line Tool”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.9, “mysql_data_seek()”
Section 23.8.7.13, “mysql_eof()”
Section 23.8.7.17, “mysql_fetch_field()”
Section 23.8.7.21, “mysql_fetch_row()”
Section 23.8.7.22, “mysql_field_count()”
Section 23.8.7.25, “mysql_free_result()”

Section 23.8.7.46, “mysql_next_result()”
Section 23.8.7.47, “mysql_num_fields()”
Section 23.8.7.48, “mysql_num_rows()”
Section 23.8.7.58, “mysql_row_seek()”
Section 23.8.7.59, “mysql_row_tell()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.23, “mysql_stmt_result_metadata()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Section 23.8.21.2, “What Results You Can Get from a Query”
Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 23.8.4.2, “Writing C API Threaded Client Programs”

mysql_thread_end()

Section 23.8.6, “C API Function Overview”
Section 23.7, “libmysqld, the Embedded MySQL Server Library”
Section 23.8.12.2, “mysql_thread_end()”
Section 23.8.4.2, “Writing C API Threaded Client Programs”

mysql_thread_id()

Section 23.8.20, “C API Automatic Reconnection Control”
Section 23.8.6, “C API Function Overview”
Section 23.8.7.50, “mysql_ping()”
Section 23.8.7.70, “mysql_thread_id()”

mysql_thread_init()

Section 23.8.6, “C API Function Overview”
Section 23.7, “libmysqld, the Embedded MySQL Server Library”
Section 23.8.12.1, “my_init()”
Section 23.8.12.2, “mysql_thread_end()”
Section 23.8.12.3, “mysql_thread_init()”
Section 23.8.4.2, “Writing C API Threaded Client Programs”

mysql_thread_safe()

Section 23.8.6, “C API Function Overview”

mysql_use_result()

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section B.5.2.14, “Commands out of sync”
Section 4.5.1, “`mysql` — The MySQL Command-Line Tool”
Section 23.8.7.9, “mysql_data_seek()”
Section 23.8.7.13, “mysql_eof()”
Section 23.8.7.21, “mysql_fetch_row()”
Section 23.8.7.25, “mysql_free_result()”
Section 23.8.7.46, “mysql_next_result()”
Section 23.8.7.47, “mysql_num_fields()”
Section 23.8.7.48, “mysql_num_rows()”
Section 23.8.7.58, “mysql_row_seek()”
Section 23.8.7.59, “mysql_row_tell()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Section B.5.2.8, “Out of memory”
Section 23.8.21.2, “What Results You Can Get from a Query”
Section 23.8.4.2, “Writing C API Threaded Client Programs”

mysql_warning_count()
Section 23.8.6, “C API Function Overview”
Section 23.8.7.46, “mysql_next_result()”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section B.2, “Types of Error Values”

Command Index

A | B | C | D | E | G | H | I | K | L | M | N | O | P | R | S | T | U | V | W | Y | Z

A

[index top]

Access
Section 13.2.2, “DELETE Syntax”

addgroup
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

addr2line
Section 24.5.1.5, “Using a Stack Trace”

adduser
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

ALL STATUS
Section 18.5.8, “NDB Cluster Single User Mode”

APF
Section 18.5.11.1, “NDB Cluster Security and Networking Issues”

apt-get
Section 16.2.1, “Installing `memcached`”
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”
Section 16.2.3.3, “Using `libmemcached` with C and C++”

B

[index top]

bash
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 2.4.1, “General Notes on Installing MySQL on OS X”
Section 4.2.1, “Invoking MySQL Programs”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 4.2.10, “Setting Environment Variables”
Section 1.2, “Typographical and Syntax Conventions”

bison
Section 1.8.1, “Contributors to MySQL”

Section 2.9.5, “Dealing with Problems Compiling MySQL”
Section 2.9, “Installing MySQL from Source”

C

[index top]

c++filt

Section 24.5.1.5, “Using a Stack Trace”

cat

Section 4.5.1.1, “mysql Options”

cd

Resetting the Root Password: Windows Systems

chkconfig

Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”
Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”

chroot

Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”

clang

Section 23.8.4.1, “Building C API Client Programs”

CMake

Section 10.3, “Adding a Character Set”
Section 6.4.5, “Building MySQL with Support for Encrypted Connections”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section B.5.2.17, “Can't initialize character set”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 10.1.5, “Configuring Application Character Set and Collation”
Section 2.9.5, “Dealing with Problems Compiling MySQL”
Section B.5.3.6, “How to Protect or Change the MySQL Unix Socket File”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 2.9, “Installing MySQL from Source”
Section 2.9.3, “Installing MySQL Using a Development Source Tree”
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”
Chapter 18, *MySQL NDB Cluster 7.2*
Section 4.9, “MySQL Program Environment Variables”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 24.3, “MySQL Services for Plugins”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”
Section 22.2, “Performance Schema Build Configuration”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 10.1.3.2, “Server Character Set and Collation”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 15.6, “The ARCHIVE Storage Engine”

Section 15.7, “The BLACKHOLE Storage Engine”
Section 15.10, “The EXAMPLE Storage Engine”
Section 15.9, “The FEDERATED Storage Engine”
Section 1.3.2, “The Main Features of MySQL”
Section 5.7, “Tracing mysqld Using DTrace”
Section 24.4.2.5, “UDF Compiling and Installing”
Section 4.2.6, “Using Option Files”
Section 1.4, “What Is New in MySQL 5.5”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”

cmake

Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”
Section 24.4.2.5, “UDF Compiling and Installing”

cmd

Resetting the Root Password: Windows Systems

cmd.exe

Section 4.2.1, “Invoking MySQL Programs”
Section 1.2, “Typographical and Syntax Conventions”

command.com

Section 4.2.1, “Invoking MySQL Programs”
Section 1.2, “Typographical and Syntax Conventions”

comp_err

Section 4.4.1, “`comp_err` — Compile MySQL Error Message File”
Section 4.1, “Overview of MySQL Programs”

configure

Section 1.6, “How to Report Bugs or Problems”
Section 16.2.1, “Installing `memcached`”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 1.2, “Typographical and Syntax Conventions”
Section 16.2.3.3, “Using `libmemcached` with C and C++”
Section 16.2.3.6, “Using MySQL and `memcached` with PHP”
Section 1.4, “What Is New in MySQL 5.5”

copy

Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”

coreadm

Section 2.7, “Installing MySQL on Solaris”
Section 5.1.4, “Server Command Options”

cp

Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”

crash-me

Section 8.13.2, “The MySQL Benchmark Suite”

cron
Section B.5.2.2, “Can't connect to [local] MySQL server”
Section 13.7.2.2, “CHECK TABLE Syntax”
Section 15.3.1, “MyISAM Startup Options”
Section 5.4.7, “Server Log Maintenance”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section 3.5, “Using mysql in Batch Mode”

csh
Section 4.2.1, “Invoking MySQL Programs”
Section 4.2.10, “Setting Environment Variables”
Section 1.2, “Typographical and Syntax Conventions”

D

[index top]

date
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”

df
Section B.5.1, “How to Determine What Is Causing a Problem”

Directory Utility
Section 2.4.1, “General Notes on Installing MySQL on OS X”

docker exec
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

docker inspect
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

docker logs mysqld-container
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

docker ps
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

docker pull
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

docker rm
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

docker run
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

docker stop
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

drwtsn32.exe
Section 24.5.1.3, “Using WER with PDB to create a Windows crashdump”

dump
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”

E

[index top]

emerge
Section 16.2.1, “Installing `memcached`”
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”

EXIT SINGLE USER MODE
Section 18.5.8, “NDB Cluster Single User Mode”

G

[index top]

gcc
Section 23.8.4.1, “Building C API Client Programs”
Section 23.7.1, “Compiling Programs with libmysqld”
Section 2.12.3, “Problems Using the Perl DBI/DBD Interface”
Section 1.8.4, “Tools that were used to create MySQL”
Section 24.4.2.5, “UDF Compiling and Installing”
Section 1.4, “What Is New in MySQL 5.5”

gdb
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 24.5.1.4, “Debugging mysqld under gdb”
Section 1.8.4, “Tools that were used to create MySQL”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”

git branch
Section 2.9.3, “Installing MySQL Using a Development Source Tree”

git checkout
Section 2.9.3, “Installing MySQL Using a Development Source Tree”

git checkout 5.7
Section 2.9.3, “Installing MySQL Using a Development Source Tree”

gmake
Section 2.9, “Installing MySQL from Source”
Section 2.8, “Installing MySQL on FreeBSD”
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”

GnuPG
Section 2.1.3.2, “Signature Checking Using GnuPG”

gnutar
Section 2.9, “Installing MySQL from Source”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

gogoc
Section 5.1.9.5, “Obtaining an IPv6 Address from a Broker”

gpg
Section 2.1.3.2, “Signature Checking Using GnuPG”

grep
Section 4.6.8, “`mysqldumpslow` — Summarize Slow Query Log Files”
Section 3.3.4.7, “Pattern Matching”

groupadd
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.7, “Installing MySQL on Solaris”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

gtar
Section 2.9, “Installing MySQL from Source”
Section 2.7, “Installing MySQL on Solaris”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

gunzip
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”

gzip
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 1.6, “How to Report Bugs or Problems”
Section 2.4, “Installing MySQL on OS X”

H

[index top]

help contents
Section 4.5.1.4, “mysql Server-Side Help”

hostname
Section B.5.2.2, “Can't connect to [local] MySQL server”

I

[index top]

icc
Section 2.1.5, “Compiler-Specific Build Characteristics”
Section 24.5, “Debugging and Porting MySQL”

ifconfig
Section 5.1.9.1, “Verifying System Support for IPv6”

innochecksum
Section 13.7.2.2, “CHECK TABLE Syntax”
Section 4.6.1, “`innochecksum` — Offline InnoDB File Checksum Utility”
MySQL Glossary
Section 4.1, “Overview of MySQL Programs”

install.rb
Section 16.2.3.7, “Using MySQL and memcached with Ruby”

iptables
Section 18.5.11.1, “NDB Cluster Security and Networking Issues”

K

[index top]

kill
Section B.5.2.2, “Can't connect to [local] MySQL server”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section C.6, “Restrictions on XA Transactions”

ksh
Section 4.2.1, “Invoking MySQL Programs”
Section 4.2.10, “Setting Environment Variables”

kswapd
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”

L

[index top]

ldconfig
Section 24.4.2.5, “UDF Compiling and Installing”

ldd libmysqlclient.so
Section 23.8.4.1, “Building C API Client Programs”

less
Section 4.5.1.2, “mysql Commands”
Section 4.5.1.1, “mysql Options”

libmemcached
libmemcached Command-Line Utilities

ln
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

logger
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

lsof +L1
Section B.5.3.5, “Where MySQL Stores Temporary Files”

M

[index top]

m4
Section 2.9, “Installing MySQL from Source”

make
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 2.9.5, “Dealing with Problems Compiling MySQL”
Section 16.2.1, “Installing `memcached`”
Section 2.9, “Installing MySQL from Source”
Section 2.8, “Installing MySQL on FreeBSD”
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”
Section 2.12.3, “Problems Using the Perl DBI/DBD Interface”

make && make install
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”

make install
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 16.2.1, “Installing `memcached`”
Section 2.9.4, “MySQL Source-Configuration Options”

make package
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”
Section 2.9.4, “MySQL Source-Configuration Options”

make test
Section 2.9.3, “Installing MySQL Using a Development Source Tree”
Section 2.12.1, “Installing Perl on Unix”
Section 24.1.2, “The MySQL Test Suite”

make VERBOSE=1
Section 2.9.5, “Dealing with Problems Compiling MySQL”

md5
Section 2.1.3.1, “Verifying the MD5 Checksum”

md5.exe
Section 2.1.3.1, “Verifying the MD5 Checksum”

md5sum
Section 2.1.3.1, “Verifying the MD5 Checksum”

memcache
Section 16.2.2.5, “`memcached` Hashing/Distribution Types”
Section 16.2.3.5, “Using MySQL and `memcached` with Python”

memcached
Section 16.2.3.1, “Basic `memcached` Operations”
Section 16.2.2.4, “Data Expiry”
Section 16.2.3, “Developing a `memcached` Application”
Section 16.2.4, “Getting `memcached` Statistics”
Section 16.2.1, “Installing `memcached`”
`libmemcached` Command-Line Utilities
`libmemcached` Set Functions
Section 16.2.2.1, “`memcached` Command-Line Options”

Section 16.2.2.2, “memcached Deployment”
Section 16.2.4.5, “memcached Detail Statistics”
Section 16.2.5, “memcached FAQ”
Section 16.2.4.1, “memcached General Statistics”
Section 16.2.2.5, “memcached Hashing/Distribution Types”
Section 16.2.4.3, “memcached Item Statistics”
Section 16.2.2.9, “memcached Logs”
Section 16.2.4.4, “memcached Size Statistics”
Section 16.2.4.2, “memcached Slabs Statistics”
Section 16.2.2.8, “memcached Thread Support”
Section 16.2.2.7, “Memory Allocation within memcached”
MySQL Glossary
Section 2.9.4, “MySQL Source-Configuration Options”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 16.2.3.3, “Using libmemcached with C and C++”
Section 16.2.2, “Using memcached”
Section 16.2.2.6, “Using memcached and DTrace”
Section 16.2.3.2, “Using memcached as a MySQL Caching Layer”
Section 16.2.4.6, “Using memcached-tool”
Section 16.2.3.8, “Using MySQL and memcached with Java”
Section 16.2.3.4, “Using MySQL and memcached with Perl”
Section 16.2.3.6, “Using MySQL and memcached with PHP”
Section 16.2.3.5, “Using MySQL and memcached with Python”
Section 16.2.3.7, “Using MySQL and memcached with Ruby”
Section 16.2, “Using MySQL with memcached”
Section 16.2.2.3, “Using Namespaces”
Section 16.2.3.9, “Using the memcached TCP Text Protocol”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

memcached-1.2.5 directory:

Section 16.2.1, “Installing memcached”

memcached-tool

Section 16.2.4, “Getting memcached Statistics”
Section 16.2.4.6, “Using memcached-tool”

memcat

libmemcached Command-Line Utilities

memcp

libmemcached Command-Line Utilities

memflush

libmemcached Command-Line Utilities

memrm

libmemcached Command-Line Utilities

memslap

libmemcached Command-Line Utilities

mgmd

Section 18.2, “NDB Cluster Installation”

mkdir

Section 13.1.10, “CREATE DATABASE Syntax”

mklink

Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”

more

Section 4.5.1.2, “mysql Commands”
Section 4.5.1.1, “mysql Options”

msiexec.exe

Section 2.3.5.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

msql2mysql

Section 4.7.1, “`msql2mysql` — Convert mSQL Programs for Use with MySQL”
Section 4.1, “Overview of MySQL Programs”
Section 4.8.2, “`replace` — A String-Replacement Utility”

mv

Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 5.4.7, “Server Log Maintenance”
Section 5.4.3, “The General Query Log”

my_print_defaults

Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 4.7, “MySQL Program Development Utilities”
Section 4.4.4, “`mysql_plugin` — Configure MySQL Server Plugins”
Section 4.1, “Overview of MySQL Programs”

myisam_ftdump

Section 12.9, “Full-Text Search Functions”
Section 4.6.2, “`myisam_ftdump` — Display Full-Text Index information”
Section 4.1, “Overview of MySQL Programs”

myisamchk

Section 13.7.2.1, “ANALYZE TABLE Syntax”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 10.5, “Character Set Configuration”
Section 13.7.2.2, “CHECK TABLE Syntax”
Choosing an Install Type
Section 15.3.3.3, “Compressed Table Characteristics”
Section 15.3.4.1, “Corrupted MyISAM Tables”
Section 7.2, “Database Backup Methods”
Section 24.5.1, “Debugging a MySQL Server”
Section 13.2.2, “DELETE Syntax”
Section 15.3.3.2, “Dynamic Table Characteristics”
Section 8.8.2, “EXPLAIN Output Format”
Section 8.11.5, “External Locking”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 7.6.2, “How to Check MyISAM Tables for Errors”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 1.6, “How to Report Bugs or Problems”
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section C.10.3, “Limits on Table Size”
Section 13.7.6.5, “LOAD INDEX INTO CACHE Syntax”
Section 19.3.3, “Maintenance of Partitions”
Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”
Section 15.3.1, “MyISAM Startup Options”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”

Section 7.6.4, “MyISAM Table Optimization”
Section 15.3.3, “MyISAM Table Storage Formats”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.3, “`myisamchk` — MyISAM Table-Maintenance Utility”
Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 4.6.3.5, “Obtaining Table Information with myisamchk”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 4.6.3.4, “Other myisamchk Options”
Section 4.1, “Overview of MySQL Programs”
Section 15.3.4.2, “Problems from Tables Not Being Closed Properly”
Section 13.7.2.5, “REPAIR TABLE Syntax”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.4, “Server Command Options”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section 13.7.5.23, “SHOW INDEX Syntax”
Section 13.7.5.37, “SHOW TABLE STATUS Syntax”
Section 15.3.3.1, “Static (Fixed-Length) Table Characteristics”
Section 8.12.1, “System Factors”
Section 1.3.2, “The Main Features of MySQL”
Section 15.3, “The MyISAM Storage Engine”
Section 7.6.1, “Using myisamchk for Crash Recovery”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”

myisamchk *.MYI

Section 7.6.3, “How to Repair MyISAM Tables”

myisamchk tbl_name

Section 7.6.2, “How to Check MyISAM Tables for Errors”

myisamlog

Section 4.6.4, “`myisamlog` — Display MyISAM Log File Contents”
Section 4.1, “Overview of MySQL Programs”

myisampack

Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 15.3.3.3, “Compressed Table Characteristics”
Section 13.1.17, “CREATE TABLE Syntax”
Section 8.11.5, “External Locking”
Section C.10.3, “Limits on Table Size”
Section 15.8.1, “MERGE Table Advantages and Disadvantages”
Section 15.3.3, “MyISAM Table Storage Formats”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”
Section 4.6.3.5, “Obtaining Table Information with myisamchk”
Section 8.4.1, “Optimizing Data Size”
Section 4.1, “Overview of MySQL Programs”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 13.1.17.7, “Silent Column Specification Changes”
Section 15.8, “The MERGE Storage Engine”

Section 15.3, “The MyISAM Storage Engine”

mysql

Section 1.7.2.4, “'--' as the Start of a Comment”
Section 18.5.13.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.5.13.1, “Adding NDB Cluster Data Nodes Online: General Issues”
Section 6.3.2, “Adding User Accounts”
Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 7.1, “Backup and Recovery Types”
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”
Section 13.6.1, “BEGIN ... END Compound-Statement Syntax”
Section 23.8.20, “C API Automatic Reconnection Control”
Changes Made by MySQL Installation Wizard
Choosing an Install Type
Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 4.2.7, “Command-Line Options that Affect Option-File Handling”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 9.6, “Comment Syntax”
Section 18.3, “Configuration of NDB Cluster”
Section 10.1.5, “Configuring Application Character Set and Collation”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”
Section 3.1, “Connecting to and Disconnecting from the Server”
Section 4.2.2, “Connecting to the MySQL Server”
Section 5.1.9.4, “Connecting Using IPv6 Nonlocal Host Addresses”
Section 5.1.9.3, “Connecting Using the IPv6 Local Host Address”
Section 10.1.4, “Connection Character Sets and Collations”
Section 1.8.1, “Contributors to MySQL”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 2.11.4, “Copying MySQL Databases to Another Machine”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 3.3.1, “Creating and Selecting a Database”
Section 2.3.7.6, “Customizing the PATH for MySQL Tools”
Section 24.5.2, “Debugging a MySQL Client”
Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”
Section 20.1, “Defining Stored Programs”
Disabling mysql Auto-Reconnect
Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”
Section 2.11.2, “Downgrading MySQL”
Section 14.20.2, “Enabling InnoDB Monitors”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 3.2, “Entering Queries”
Section 20.4.2, “Event Scheduler Configuration”
Section 7.3, “Example Backup and Recovery Strategy”
Section 23.8.3, “Example C API Client Programs”
Section 3.6, “Examples of Common Queries”
Section 4.5.1.5, “Executing SQL Statements from a Text File”
Chapter 12, *Functions and Operators*
Section 2.4.1, “General Notes on Installing MySQL on OS X”
Section 13.7.1.3, “GRANT Syntax”
Section 13.8.3, “HELP Syntax”
Section B.5.1, “How to Determine What Is Causing a Problem”
Section 14.8.5.3, “How to Minimize and Handle Deadlocks”
Section 1.6, “How to Report Bugs or Problems”
Section 6.1.5, “How to Run MySQL as a Normal User”
Section B.5.2.15, “Ignoring user”
Section 12.14, “Information Functions”

Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 14.21.2, “InnoDB Recovery”
Input-Line Editing
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 4.2.1, “Invoking MySQL Programs”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 8.2.1.13, “LIMIT Query Optimization”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 13.2.7, “LOAD XML Syntax”
Section 7.4.5.1, “Making a Copy of a Database”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 18.5, “Management of NDB Cluster”
Section 8.13.1, “Measuring the Speed of Expressions and Functions”
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 4.5.1.2, “mysql Commands”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Glossary
Section 2.3.3.1, “MySQL Installer Initial Setup”
Section 4.5.1.3, “mysql Logging”
Chapter 18, *MySQL NDB Cluster 7.2*
Section 4.5.1.1, “mysql Options”
Section 4.9, “MySQL Program Environment Variables”
Section 10.6, “MySQL Server Time Zone Support”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 4.5.1.4, “mysql Server-Side Help”
Section 4.5.1.6, “mysql Tips”
Section 4.5.1, “`mysql` — The MySQL Command-Line Tool”
Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”
Section 23.8.7.14, “mysql_errno()”
Section 23.8.7.66, “mysql_sqlstate()”
Section 4.4.6, “`mysql_tzinfo_to_sql` — Load the Time Zone Tables”
Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 18.5.15, “NDB API Statistics Counters and Variables”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.2.5, “NDB Cluster Example with Tables and Data”
Section 18.6, “NDB Cluster Replication”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 18.4.5, “`ndb_mgm` — The NDB Cluster Management Client”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 18.4.2, “`ndbinfo_select_all` — Select From ndbinfo Tables”
Section 4.2.9, “Option Defaults, Options Expecting Values, and the = Sign”
Section B.5.2.8, “Out of memory”
Section 4.1, “Overview of MySQL Programs”
Section B.5.2.10, “Packet Too Large”
Section 6.5.1.4, “PAM Pluggable Authentication”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 6.3.6, “Pluggable Authentication”
Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”
Section 13.5, “Prepared SQL Statement Syntax”
Section 18.6.5, “Preparing the NDB Cluster for Replication”
Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”

Section 4.2.5, “Program Option Modifiers”
Section 19.2.3.1, “RANGE COLUMNS partitioning”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 7.4.4, “Reloading Delimited-Text Format Backups”
Section 7.4.2, “Reloading SQL-Format Backups”
Section 17.4.1.26, “Replication of Server-Side Help Tables”
Resetting the Root Password: Generic Instructions
Restoring to More Nodes Than the Original
Section C.9, “Restrictions on Pluggable Authentication”
Section 13.7.1.5, “REVOKE Syntax”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 13.2.9.1, “SELECT ... INTO Syntax”
Section 5.1.4, “Server Command Options”
Section B.3, “Server Error Codes and Messages”
Section 5.1.5, “Server System Variables”
Section 5.1.10, “Server-Side Help”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section 13.6.7.4, “SIGNAL Syntax”
Section 6.5.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 4.2.3, “Specifying Program Options”
Section 2.3.7.7, “Starting MySQL as a Windows Service”
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”
Section 2.3.6.1, “Starting the MySQL Server Instance Configuration Wizard”
Section 2.10.2, “Starting the Server”
Section 9.1.1, “String Literals”
Section 2.10.3, “Testing the Server”
Section 11.4.3, “The BLOB and TEXT Types”
Section 18.5.10.19, “The ndbinfo transporters Table”
Section 20.3.1, “Trigger Syntax and Examples”
Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Chapter 3, *Tutorial*
Section 1.2, “Typographical and Syntax Conventions”
Section 2.11.1, “Upgrading MySQL”
Section 7.3.2, “Using Backups for Recovery”
Section 3.5, “Using mysql in Batch Mode”
Section 7.4, “Using mysqldump for Backups”
Section 4.2.6, “Using Option Files”
Section 4.2.4, “Using Options on the Command Line”
Section 4.2.8, “Using Options to Set Program Variables”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”
Section 18.5.12.2, “Using Symbolic Links with Disk Data Objects”
Using the --safe-updates Option
Section 1.4, “What Is New in MySQL 5.5”
Section 2.3.9, “Windows Postinstallation Procedures”
Section 12.11, “XML Functions”

mysql ...

Section 24.5.1.1, “Compiling MySQL for Debugging”

mysql-server

Section 2.8, “Installing MySQL on FreeBSD”

mysql-test-run.pl

Section 24.1.2, “The MySQL Test Suite”

mysql-test-run.pl test_name

Section 24.1.2, “The MySQL Test Suite”

mysql.exe

Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”

mysql.server

Section 2.5, “Installing MySQL on Linux”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”
Section 4.6.8, “`mysqldumpslow` — Summarize Slow Query Log Files”
Section 4.1, “Overview of MySQL Programs”
Section 5.1.4, “Server Command Options”
Section 2.10.5, “Starting and Stopping MySQL Automatically”
Section B.5.3.7, “Time Zone Problems”

mysql.server stop

Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”

mysql_config

Section 23.8.4.1, “Building C API Client Programs”
Section 23.7.1, “Compiling Programs with libmysqld”
Section 2.9.5, “Dealing with Problems Compiling MySQL”
Section 23.8.1, “MySQL C API Implementations”
Section 4.7.2, “`mysql_config` — Display Options for Compiling Clients”
Section 4.1, “Overview of MySQL Programs”
Section 24.2.3, “Plugin API Components”

mysql_config_editor

Section 4.2.6, “Using Option Files”

mysql_convert_table_format

Section 4.6.10, “`mysql_convert_table_format` — Convert Tables to Use a Given Storage Engine”
Section 4.1, “Overview of MySQL Programs”

mysql_find_rows

Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”
Section 4.6.11, “`mysql_find_rows` — Extract SQL Statements from Files”
Section 4.1, “Overview of MySQL Programs”

mysql_fix_extensions

Section 4.6.12, “`mysql_fix_extensions` — Normalize Table File Name Extensions”
Section 4.1, “Overview of MySQL Programs”

mysql_install_db

Section 2.10.1, “Initializing the Data Directory”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.4.3, “`mysql_install_db` — Initialize MySQL Data Directory”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 4.1, “Overview of MySQL Programs”
Section 2.10.1.1, “Problems Running mysql_install_db”
Section 5.1.4, “Server Command Options”

mysql_plugin

Section 4.4.4, “`mysql_plugin` — Configure MySQL Server Plugins”
Section 4.1, “Overview of MySQL Programs”

mysql_secure_installation

Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”
Section 2.7.1, “Installing MySQL on Solaris Using a Solaris PKG”
Section 4.4.5, “`mysql_secure_installation` — Improve MySQL Installation Security”
Section 4.1, “Overview of MySQL Programs”
Section 2.10.4, “Securing the Initial MySQL Accounts”

mysql_setpermission

Section 1.8.1, “Contributors to MySQL”
Section 4.6.13, “`mysql_setpermission` — Interactively Set Permissions in Grant Tables”
Section 4.1, “Overview of MySQL Programs”
Section 2.10.2, “Starting the Server”

mysql_setpermissions

Section 4.6.13, “`mysql_setpermission` — Interactively Set Permissions in Grant Tables”

mysql_stmt_execute()

Section 5.1.7, “Server Status Variables”

mysql_stmt_prepare()

Section 5.1.7, “Server Status Variables”

mysql_tzinfo_to_sql

Section 10.6, “MySQL Server Time Zone Support”
Section 4.4.6, “`mysql_tzinfo_to_sql` — Load the Time Zone Tables”
Section 4.1, “Overview of MySQL Programs”

mysql_upgrade

Section 13.1.1, “ALTER DATABASE Syntax”
Section 2.11.2.1, “Changes Affecting Downgrades from MySQL 5.5”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 2.11.2, “Downgrading MySQL”
Section 6.2.2, “Grant Tables”
Section B.5.2.15, “Ignoring user”
Section 2.10.1, “Initializing the Data Directory”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.1, “Overview of MySQL Programs”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 22.2, “Performance Schema Build Configuration”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 17.4.1.26, “Replication of Server-Side Help Tables”
Section 5.1.4, “Server Command Options”
Section B.3, “Server Error Codes and Messages”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 2.11.1, “Upgrading MySQL”
Section 2.3.10, “Upgrading MySQL on Windows”

mysql_waitpid

Section 4.6.14, “`mysql_waitpid` — Kill Process and Wait for Its Termination”
Section 4.1, “Overview of MySQL Programs”

mysql_waitpid()

Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”

mysql_zap

Section B.5.2.2, “Can't connect to [local] MySQL server”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.1, “Overview of MySQL Programs”

mysqlaccess

Section 1.8.1, “Contributors to MySQL”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.1, “Overview of MySQL Programs”
Section 2.10.2, “Starting the Server”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”

mysqladmin

Section 6.3.5, “Assigning Account Passwords”
Section 17.3.1.1, “Backing Up a Slave Using mysqldump”
Section B.5.2.2, “Can't connect to [local] MySQL server”
Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 5.1.1, “Configuring the Server”
Section 4.2.2, “Connecting to the MySQL Server”
Section 10.1.4, “Connection Character Sets and Collations”
Section 1.8.1, “Contributors to MySQL”
Section 13.1.10, “CREATE DATABASE Syntax”
Section 2.3.7.6, “Customizing the PATH for MySQL Tools”
Section 24.5.1, “Debugging a MySQL Server”
Section 13.1.21, “DROP DATABASE Syntax”
Section 23.8.3, “Example C API Client Programs”
Section 13.7.6.3, “FLUSH Syntax”
Section 2.4.1, “General Notes on Installing MySQL on OS X”
Section B.5.1, “How to Determine What Is Causing a Problem”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 1.6, “How to Report Bugs or Problems”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 2.3.3.1, “MySQL Installer Initial Setup”
Section 5.4, “MySQL Server Logs”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.1, “Overview of MySQL Programs”
Section 6.2.1, “Privileges Provided by MySQL”
Section C.9, “Restrictions on Pluggable Authentication”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 2.3.7.7, “Starting MySQL as a Windows Service”
Section 2.3.7.5, “Starting MySQL from the Windows Command Line”
Section 2.10.3, “Testing the Server”
Section 1.3.2, “The Main Features of MySQL”
Section 5.1.12, “The Server Shutdown Process”
Section 2.3.10, “Upgrading MySQL on Windows”
Section 4.2.6, “Using Option Files”
Section 4.2.4, “Using Options on the Command Line”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”

mysqladmin debug

Section 24.5.1, “Debugging a MySQL Server”
Section 20.4.5, “Event Scheduler Status”

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”

mysqladmin extended-status

Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.7.5.36, “SHOW STATUS Syntax”

mysqladmin flush-hosts

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section B.5.2.6, “Host 'host_name' is blocked”
Section 5.1.5, “Server System Variables”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”

mysqladmin flush-logs

Section 7.3.3, “Backup Strategy Summary”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 7.3.1, “Establishing a Backup Policy”
Section 5.4.7, “Server Log Maintenance”
Section 5.4.4, “The Binary Log”
Section 17.2.2.1, “The Slave Relay Log”

mysqladmin flush-privileges

Section 2.11.4, “Copying MySQL Databases to Another Machine”
Section 6.2.2, “Grant Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 5.1.4, “Server Command Options”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 6.2.6, “When Privilege Changes Take Effect”

mysqladmin flush-tables

Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 8.11.5, “External Locking”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”
Section 7.6.1, “Using myisamchk for Crash Recovery”

mysqladmin flush-xxx

Section 6.3.2, “Adding User Accounts”

mysqladmin kill

Section B.5.3.4, “How MySQL Handles a Full Disk”
Section 13.7.6.4, “KILL Syntax”
Section 12.17, “Miscellaneous Functions”
Section B.5.2.9, “MySQL server has gone away”
Section 6.2.1, “Privileges Provided by MySQL”

mysqladmin password

Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”

mysqladmin processlist

Section 6.3.2, “Adding User Accounts”
Section 8.14, “Examining Thread Information”
Section 13.7.6.4, “KILL Syntax”

Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 24.1.1, “MySQL Threads”
Section 23.8.7.43, “mysql_list_processes()”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.5.30, “SHOW PROCESSLIST Syntax”

mysqladmin processlist status

Section 24.5.1, “Debugging a MySQL Server”

mysqladmin refresh

Section 6.3.2, “Adding User Accounts”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 5.4.7, “Server Log Maintenance”

mysqladmin reload

Section 6.3.2, “Adding User Accounts”
Section 6.2.2, “Grant Tables”
Section 1.6, “How to Report Bugs or Problems”
Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”
Section 5.1.4, “Server Command Options”
Section 6.3.4, “Setting Account Resource Limits”
Section 6.2.6, “When Privilege Changes Take Effect”

mysqladmin reload version

Section 1.6, “How to Report Bugs or Problems”

mysqladmin shutdown

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 24.5.1.2, “Creating Trace Files”
Section 13.7.1.3, “GRANT Syntax”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 6.1.5, “How to Run MySQL as a Normal User”
Section 2.4.2, “Installing MySQL on OS X Using Native Packages”
Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.31, “Replication and Temporary Tables”
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”
Section 2.3.7.7, “Starting MySQL as a Windows Service”
Section 5.1.12, “The Server Shutdown Process”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”

mysqladmin status

Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 23.8.7.68, “mysql_stat()”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”

mysqladmin variables

Section B.5.2.9, “MySQL server has gone away”
Section 13.7.5.40, “SHOW VARIABLES Syntax”

mysqladmin variables extended-status processlist

Section 1.6, “How to Report Bugs or Problems”

mysqladmin ver

Section 24.5.1.1, “Compiling MySQL for Debugging”

mysqladmin version

Section B.5.2.2, “Can't connect to [local] MySQL server”
Section 1.6, “How to Report Bugs or Problems”
Section B.5.2.9, “MySQL server has gone away”
Section 2.10.3, “Testing the Server”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”

mysqlanalyze

Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”

mysqlbackup

Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 14.21.1, “InnoDB Backup”
MySQL Glossary
Section 4.5.4, “`mysqldump` — A Database Backup Program”

mysqlbinlog

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.7.6.1, “BINLOG Syntax”
Section 5.7.1.2, “Command Probes”
Section 17.4.5, “How to Report Replication Bugs or Problems”
Section 14.21.2, “InnoDB Recovery”
Section B.5.7, “Known Issues in MySQL”
Section 12.17, “Miscellaneous Functions”
MySQL Glossary
MySQL Server Options for NDB Cluster
Section 4.6.7.1, “mysqlbinlog Hex Dump Format”
Section 4.6.7.2, “mysqlbinlog Row Event Display”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.1, “Overview of MySQL Programs”
Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”
Section 7.5.2, “Point-in-Time Recovery Using Event Positions”
Section 7.5.1, “Point-in-Time Recovery Using Event Times”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Section 17.4.1.38, “Replication and Variables”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 13.7.5.3, “SHOW BINLOG EVENTS Syntax”
Section 13.7.5.33, “SHOW RELAYLOG EVENTS Syntax”
Section 13.4.2.5, “START SLAVE Syntax”
Section 5.4.4, “The Binary Log”
Section 5.4.3, “The General Query Log”
Section 17.2.2.1, “The Slave Relay Log”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”
Section 7.3.2, “Using Backups for Recovery”
Section 1.4, “What Is New in MySQL 5.5”

mysqlbinlog binary-log-file | mysql

Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”

mysqlbinlog|mysql

Section B.5.7, “Known Issues in MySQL”

mysqlbug

Section 4.4.2, “`mysqlbug` — Generate Bug Report”

mysqlcheck

Section 13.1.1, “ALTER DATABASE Syntax”
Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 10.1.4, “Connection Character Sets and Collations”
Section 19.3.3, “Maintenance of Partitions”
Section 9.2.3, “Mapping of Identifiers to File Names”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.1, “Overview of MySQL Programs”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.5, “Server System Variables”
Section 1.3.2, “The Main Features of MySQL”
Section 15.3, “The MyISAM Storage Engine”

mysqld

Section 24.4.2, “Adding a New User-Defined Function”
Section 24.4, “Adding New Functions to MySQL”
Section 8.2.1.16, “Avoiding Full Table Scans”
Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.4.4.1, “Binary Logging Formats”
Section 6.4.5, “Building MySQL with Support for Encrypted Connections”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section B.5.2.2, “Can't connect to [local] MySQL server”
Section B.5.2.13, “Can't create/write to file”
Section B.5.2.17, “Can't initialize character set”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 14.10.2, “Changing the Number or Size of InnoDB Redo Log Files”
Section B.5.2.4, “Client does not support authentication protocol”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 9.6, “Comment Syntax”
Section B.5.2.11, “Communication Errors and Aborted Connections”
Section 4.4.1, “`comp_err` — Compile MySQL Error Message File”
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 18.3, “Configuration of NDB Cluster”
Section 5.1.1, “Configuring the Server”
Section 15.3.4.1, “Corrupted MyISAM Tables”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 13.1.17, “CREATE TABLE Syntax”
Section 24.5.1.2, “Creating Trace Files”
Section 14.8.5, “Deadlocks in InnoDB”
Section 24.5.1, “Debugging a MySQL Server”
Section 24.5, “Debugging and Porting MySQL”
Section 24.5.1.4, “Debugging mysqld under gdb”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”
Section 14.7.7, “Doublewrite Buffer”
Section 14.13.1, “Enabling File Formats”
Section 14.20.2, “Enabling InnoDB Monitors”
Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 5.4.2.2, “Error Logging on Unix and Unix-Like Systems”

Section 5.4.2.1, “Error Logging on Windows”
Section 5.4.2.3, “Error Logging to the System Log”
Section 8.11.5, “External Locking”
Section B.5.2.18, “File Not Found and Similar Errors”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 14.23.2, “Forcing InnoDB Recovery”
Section 18.6.2, “General Requirements for NDB Cluster Replication”
Section 8.14.2, “General Thread States”
Section 16.1.3, “Handling MySQL Recovery with ZFS”
Section B.5.2.6, “Host 'host_name' is blocked”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section B.5.1, “How to Determine What Is Causing a Problem”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 1.6, “How to Report Bugs or Problems”
Section 6.1.5, “How to Run MySQL as a Normal User”
Section 9.2.2, “Identifier Case Sensitivity”
Section B.5.2.15, “Ignoring user”
Section 18.6.8, “Implementing Failover with NDB Cluster Replication”
Section 12.14, “Information Functions”
Section 18.2.3, “Initial Configuration of NDB Cluster”
Section 18.2.4, “Initial Startup of NDB Cluster”
Section 14.21.1, “InnoDB Backup”
Section 14.15.1, “InnoDB Disk I/O”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 14.21.2, “InnoDB Recovery”
Section 14.9.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.23, “InnoDB Troubleshooting”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.4.2, “Installing MySQL on OS X Using Native Packages”
Section 2.7, “Installing MySQL on Solaris”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 18.2.1, “Installing NDB Cluster on Linux”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 13.7.6.4, “KILL Syntax”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 24.5.1.7, “Making a Test Case If You Experience Table Corruption”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 18.5, “Management of NDB Cluster”
Section 12.17, “Miscellaneous Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 15.3.1, “MyISAM Startup Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3, “`myisamchk` — MyISAM Table-Maintenance Utility”
Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”
Section A.1, “MySQL 5.5 FAQ: General”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”

Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Glossary
Section 2.3.1, “MySQL Installation Layout on Microsoft Windows”
Chapter 18, *MySQL NDB Cluster 7.2*
Section 4.9, “MySQL Program Environment Variables”
Chapter 5, *MySQL Server Administration*
Section 4.3, “MySQL Server and Server-Startup Programs”
Section B.5.2.9, “MySQL server has gone away”
Section 5.4, “MySQL Server Logs”
MySQL Server Options for NDB Cluster
Section 10.6, “MySQL Server Time Zone Support”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 18.1.5, “MySQL Server Using InnoDB Compared with NDB Cluster”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 1.7, “MySQL Standards Compliance”
Section 24.1.1, “MySQL Threads”
Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”
Section 23.8.7.1, “mysql_affected_rows()”
Section 4.4.3, “`mysql_install_db` — Initialize MySQL Data Directory”
Section 23.8.7.49, “mysql_options()”
Section 4.4.4, “`mysql_plugin` — Configure MySQL Server Plugins”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.3.1, “`mysqld` — The MySQL Server”
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 18.5.15, “NDB API Statistics Counters and Variables”
Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 18.3.3.1, “NDB Cluster Configuration: Basic Example”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.2, “NDB Cluster Installation”
Section 18.3.2.5, “NDB Cluster mysqld Option and Variable Reference”
Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”
Section 18.1, “NDB Cluster Overview”
Section 18.4, “NDB Cluster Programs”
Section 18.6, “NDB Cluster Replication”
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”
Section 18.4.24, “`ndb_show_tables` — Display List of NDB Tables”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 13.7.2.4, “OPTIMIZE TABLE Syntax”
Section B.5.5, “Optimizer-Related Issues”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 23.7.3, “Options with the Embedded Server”
Section 4.1, “Overview of MySQL Programs”
Section 18.3.2, “Overview of NDB Cluster Configuration Parameters, Options, and Variables”
Section B.5.2.10, “Packet Too Large”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.5, “Preparing the NDB Cluster for Replication”

Section 15.3.4.2, “Problems from Tables Not Being Closed Properly”
Section 2.10.1.1, “Problems Running mysql_install_db”
Section B.5.3.1, “Problems with File Permissions”
Section 4.2.5, “Program Option Modifiers”
Section 8.10.3.3, “Query Cache Configuration”
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”
Section 13.7.2.5, “REPAIR TABLE Syntax”
Section 17.1.3.1, “Replication and Binary Logging Option and Variable Reference”
Section 17.1.3, “Replication and Binary Logging Options and Variables”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.4.2.3, “RESET SLAVE Syntax”
Resetting the Root Password: Unix and Unix-Like Systems
Resetting the Root Password: Windows Systems
Section 4.7.4, “`resolve_stack_dump` — Resolve Numeric Stack Trace Dump to Symbols”
Section B.5.4.5, “Rollback Failure for Nontransactional Tables”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 6.1.4, “Security-Related mysqld Options and Variables”
Section 13.2.9.1, “SELECT ... INTO Syntax”
Section 2.3.7.3, “Selecting a MySQL Server Type”
Section 10.1.3.2, “Server Character Set and Collation”
Section 5.1.4, “Server Command Options”
Section 5.4.7, “Server Log Maintenance”
Server Plugin Status and System Variables
Section 5.1.11, “Server Response to Signals”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”
Section 13.3.6, “SET TRANSACTION Syntax”
Section 10.2, “Setting the Error Message Language”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section 13.7.5.16, “SHOW ENGINE Syntax”
Section 23.8.2, “Simultaneous MySQL Server and Connector/C Installations”
Section 2.10.5, “Starting and Stopping MySQL Automatically”
Section 5.6.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 5.6.2.1, “Starting Multiple MySQL Instances at the Windows Command Line”
Section 2.3.7.7, “Starting MySQL as a Windows Service”
Section 2.3.7.5, “Starting MySQL from the Windows Command Line”
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”
Section 10.6.1, “Staying Current with Time Zone Changes”
Section 1.8.5, “Supporters of MySQL”
Section 17.3.6, “Switching Masters During Failover”
Section 8.11.2, “Table Locking Issues”
Section B.5.2.19, “Table-Corruption Issues”
Section 2.3.7.8, “Testing The MySQL Installation”
Section 2.10.3, “Testing the Server”
Section 5.4.4, “The Binary Log”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 24.5.3, “The DBUG Package”
Section 5.4.6, “The DDL Log”
Section 5.4.2, “The Error Log”
Section 5.4.3, “The General Query Log”
Section 15.3, “The MyISAM Storage Engine”
Section 8.10.3, “The MySQL Query Cache”
Section 5.1, “The MySQL Server”
Section 24.1.2, “The MySQL Test Suite”
Section 5.4.5, “The Slow Query Log”
Section B.5.3.7, “Time Zone Problems”

Section B.5.2.7, “Too many connections”
Section 5.7, “Tracing mysqld Using DTrace”
Section 2.3.8, “Troubleshooting a Microsoft Windows MySQL Server Installation”
Section 14.23.1, “Troubleshooting InnoDB I/O Problems”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”
Section 1.2, “Typographical and Syntax Conventions”
Section 24.4.2.5, “UDF Compiling and Installing”
Section 24.4.2.6, “UDF Security Precautions”
Section 2.11.1, “Upgrading MySQL”
Section 2.3.10, “Upgrading MySQL on Windows”
Section 24.5.1.5, “Using a Stack Trace”
Section 7.6.1, “Using myisamchk for Crash Recovery”
Section 4.2.6, “Using Option Files”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”
Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”
Section 18.6.7, “Using Two Replication Channels for NDB Cluster Replication”
Section 24.5.1.3, “Using WER with PDB to create a Windows crashdump”
Section 1.4, “What Is New in MySQL 5.5”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”
Section 6.2.6, “When Privilege Changes Take Effect”
Section B.5.3.5, “Where MySQL Stores Temporary Files”
Section 2.1.1, “Which MySQL Version and Distribution to Install”
Section 24.2.4, “Writing Plugins”

mysqld mysqld.trace

Section 24.5.1.2, “Creating Trace Files”

mysqld-debug

Section 24.5.1.2, “Creating Trace Files”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”
Section 2.3.7.3, “Selecting a MySQL Server Type”

mysqld.exe

Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

mysqld_multi

Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 4.1, “Overview of MySQL Programs”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 1.4, “What Is New in MySQL 5.5”

mysqld_safe

Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 5.1.1, “Configuring the Server”
Section 8.12.4.2, “Enabling Large Page Support”
Section 5.4.2.2, “Error Logging on Unix and Unix-Like Systems”
Section 5.4.2.3, “Error Logging to the System Log”
Section B.5.2.18, “File Not Found and Similar Errors”
Section B.5.3.6, “How to Protect or Change the MySQL Unix Socket File”
Section 14.23, “InnoDB Troubleshooting”

Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 10.6, “MySQL Server Time Zone Support”
Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”
Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 4.2.9, “Option Defaults, Options Expecting Values, and the = Sign”
Section 4.1, “Overview of MySQL Programs”
Section B.5.2.10, “Packet Too Large”
Section B.5.3.1, “Problems with File Permissions”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 2.10.5, “Starting and Stopping MySQL Automatically”
Section 2.10.2, “Starting the Server”
Section 2.10.3, “Testing the Server”
Section 5.4.2, “The Error Log”
Section B.5.3.7, “Time Zone Problems”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”
Section 4.2.6, “Using Option Files”

mysqldump

Section 17.3.1.3, “Backing Up a Master or Slave by Making It Read Only”
Section 17.3.1.1, “Backing Up a Slave Using mysqldump”
Chapter 7, *Backup and Recovery*
Section 7.1, “Backup and Recovery Types”
Section 7.3.3, “Backup Strategy Summary”
Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Choosing an Install Type
Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 4.2.2, “Connecting to the MySQL Server”
Section 1.8.1, “Contributors to MySQL”
Section 10.1.9.7, “Converting Between 3-Byte and 4-Byte Unicode Character Sets”
Section 7.4.5.2, “Copy a Database from one Server to Another”
Section 2.11.4, “Copying MySQL Databases to Another Machine”
Section 13.1.17, “CREATE TABLE Syntax”
Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 14.11.1.1, “Creating InnoDB Tables”
Section 2.3.7.6, “Customizing the PATH for MySQL Tools”
Section 7.2, “Database Backup Methods”
Section 14.15.4, “Defragmenting a Table”
Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”
Section 2.11.2, “Downgrading MySQL”
Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 7.4.5.3, “Dumping Stored Programs”
Section 7.4.5.4, “Dumping Table Definitions and Content Separately”
Section 14.10.4.1, “Enabling and Disabling File-Per-Table Tablespaces”
Section 7.3.1, “Establishing a Backup Policy”
Section 7.3, “Example Backup and Recovery Strategy”
Section 1.6, “How to Report Bugs or Problems”
Section 17.1.1, “How to Set Up Replication”
Section 9.2.2, “Identifier Case Sensitivity”

Section 4.6.1, “`innochecksum` — Offline InnoDB File Checksum Utility”
Section 14.21.1, “InnoDB Backup”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 2.6, “Installing MySQL Using Unbreakable Linux Network (ULN)”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 13.2.7, “LOAD XML Syntax”
Section 7.4.5.1, “Making a Copy of a Database”
Section 9.2.3, “Mapping of Identifiers to File Names”
Section 14.11.1.3, “Moving or Copying InnoDB Tables”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.5.1.1, “mysql Options”
Section 5.4, “MySQL Server Logs”
Section 7.4.5, “mysqldump Tips”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.2.5, “NDB Cluster Example with Tables and Data”
Section 18.1, “NDB Cluster Overview”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”
Section 18.5.3, “Online Backup of NDB Cluster”
Section 4.1, “Overview of MySQL Programs”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Section 18.6.5, “Preparing the NDB Cluster for Replication”
Section B.5.4.8, “Problems with Floating-Point Values”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 7.4.4, “Reloading Delimited-Text Format Backups”
Section 7.4.2, “Reloading SQL-Format Backups”
Section 17.3.4, “Replicating Different Databases to Different Slaves”
Section 14.10.1, “Resizing the InnoDB System Tablespace”
Restoring to More Nodes Than the Original
Section C.8, “Restrictions on Performance Schema”
Section C.5, “Restrictions on Views”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.4.7, “Server Log Maintenance”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”
Section 17.1.1.8, “Setting Up Replication with Existing Data”
Section B.5.4.7, “Solving Problems with No Matching Rows”
Section 4.2.3, “Specifying Program Options”
Section 2.3.7.7, “Starting MySQL as a Windows Service”
Section 2.3.6.1, “Starting the MySQL Server Instance Configuration Wizard”
Section 11.4.3, “The BLOB and TEXT Types”
Section 14.9.2.1, “The InnoDB Buffer Pool”
Section 1.3.2, “The Main Features of MySQL”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 13.7.3.4, “UNINSTALL PLUGIN Syntax”
Section 2.11.1, “Upgrading MySQL”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”
Section 7.4, “Using mysqldump for Backups”
Section 4.2.6, “Using Option Files”
Section 17.3.1, “Using Replication for Backups”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”
Section 1.4, “What Is New in MySQL 5.5”
Section 12.11, “XML Functions”
Section 11.3.4, “YEAR(2) Limitations and Migrating to YEAR(4)”

mysqldump mysql

Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”

mysqldumpslow

Section 4.6.8, “`mysqldumpslow` — Summarize Slow Query Log Files”
Section 4.1, “Overview of MySQL Programs”
Section 5.4.5, “The Slow Query Log”

mysqlfailover

Section 17.3.6, “Switching Masters During Failover”

mysqlhotcopy

Chapter 7, *Backup and Recovery*
Section 7.1, “Backup and Recovery Types”
Section 1.8.1, “Contributors to MySQL”
Section 7.2, “Database Backup Methods”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 4.1, “Overview of MySQL Programs”
Section 1.4, “What Is New in MySQL 5.5”

mysqlimport

Section 7.1, “Backup and Recovery Types”
Section 10.1.4, “Connection Character Sets and Collations”
Section 2.11.4, “Copying MySQL Databases to Another Machine”
Section 7.2, “Database Backup Methods”
Section 2.11.2, “Downgrading MySQL”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.1, “Overview of MySQL Programs”
Section 7.4.4, “Reloading Delimited-Text Format Backups”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

MySQLInstallerConsole.exe

Section 2.3.3.4, “MySQLInstallerConsole Reference”

MySQLInstanceConfig.exe

Section 2.3.6.13, “MySQL Server Instance Config Wizard: Creating an Instance from the Command Line”

mysqloptimize

Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”

mysqlrepair

Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”

mysqlshow

Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 4.2.2, “Connecting to the MySQL Server”
Section 10.1.4, “Connection Character Sets and Collations”
Section 23.8.3, “Example C API Client Programs”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.1, “Overview of MySQL Programs”
Section 13.7.5.15, “SHOW DATABASES Syntax”
Section 13.7.5.23, “SHOW INDEX Syntax”
Section 13.7.5.37, “SHOW TABLE STATUS Syntax”
Section 2.3.7.8, “Testing The MySQL Installation”
Section 2.10.3, “Testing the Server”
Section 2.3.9, “Windows Postinstallation Procedures”

mysqlshow db_name
Section 13.7.5.38, “SHOW TABLES Syntax”

mysqlshow db_name tbl_name
Section 13.7.5.6, “SHOW COLUMNS Syntax”

mysqlslap
Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 14.19.1, “Monitoring InnoDB Mutex Waits Using Performance Schema”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 4.1, “Overview of MySQL Programs”
Section 8.13.3, “Using Your Own Benchmarks”

mysqltest
Section 24.1.2, “The MySQL Test Suite”

N

[index top]

nbdmtd
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”

NDB
Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”

ndb_blob_tool
Section 18.4.6, “`ndb_blob_tool` — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”

ndb_config
Section 18.4, “NDB Cluster Programs”
Section 18.4.7, “`ndb_config` — Extract NDB Cluster Configuration Information”
Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”

ndb_cpcd
Section 18.4.8, “`ndb_cpcd` — Automate Testing for NDB Development”

ndb_delete_all
Section 18.4.9, “`ndb_delete_all` — Delete All Rows from an NDB Table”

ndb_desc
Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 19.2.5, “KEY Partitioning”
MySQL Server Options for NDB Cluster
Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.4.10, “`ndb_desc` — Describe NDB Tables”
Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”
Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”
Section 18.5.10.4, “The ndbinfo cluster_operations Table”
Section 18.5.10.15, “The ndbinfo server_operations Table”

ndb_drop_index
Section 18.4.11, “`ndb_drop_index` — Drop Index from an NDB Table”

ndb_drop_table

Section 18.4.11, “`ndb_drop_index` — Drop Index from an NDB Table”
Section 18.4.12, “`ndb_drop_table` — Drop an NDB Table”

ndb_error_reporter

Section 18.4.13, “`ndb_error_reporter` — NDB Error-Reporting Utility”

ndb_index_stat

Section 18.4.14, “`ndb_index_stat` — NDB Index Statistics Utility”

ndb_mgm

Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.5.13.1, “Adding NDB Cluster Data Nodes Online: General Issues”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”
Section 18.2.4, “Initial Startup of NDB Cluster”
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 18.2.1, “Installing NDB Cluster on Linux”
Section 18.2.1.3, “Installing NDB Cluster Using .deb Files”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Chapter 18, *MySQL NDB Cluster 7.2*
MySQL Server Options for NDB Cluster
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.5.6.1, “NDB Cluster Logging Management Commands”
Section 18.4, “NDB Cluster Programs”
Section 18.5.11.1, “NDB Cluster Security and Networking Issues”
Section 18.5.8, “NDB Cluster Single User Mode”
Section 18.4.5, “`ndb_mgm` — The NDB Cluster Management Client”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”
Section 18.5.3, “Online Backup of NDB Cluster”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Restoring to More Nodes Than the Original
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”
Section 18.5.10.1, “The ndbinfo arbitrator_validity_detail Table”
Section 18.5.10.11, “The ndbinfo membership Table”
Section 18.5.10.12, “The ndbinfo memoryusage Table”
Section 18.5.10.13, “The ndbinfo nodes Table”
Section 18.5.10.19, “The ndbinfo transporters Table”
Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”

ndb_mgm.exe

Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”

ndb_mgmd

Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.3.3.5, “Defining an NDB Cluster Management Server”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.2.4, “Initial Startup of NDB Cluster”

Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 18.2.1, “Installing NDB Cluster on Linux”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.1.3, “Installing NDB Cluster Using .deb Files”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Server Options for NDB Cluster
Section 2.9.4, “MySQL Source-Configuration Options”
Section 18.3.3.1, “NDB Cluster Configuration: Basic Example”
Section 18.3.3.3, “NDB Cluster Connection Strings”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.5.6.1, “NDB Cluster Logging Management Commands”
Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”
Section 18.4, “NDB Cluster Programs”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.3.1, “Quick Test Setup of NDB Cluster”
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”
Section 18.5.1, “Summary of NDB Cluster Start Phases”

ndb_mgmd.exe

Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

ndb_move_data

Section 18.4.15, “`ndb_move_data` — NDB Data Copy Utility”

ndb_print_backup_file

Section 18.4.16, “`ndb_print_backup_file` — Print NDB Backup File Contents”
Section 18.4.18, “`ndb_print_schema_file` — Print NDB Schema File Contents”
Section 18.4.19, “`ndb_print_sys_file` — Print NDB System File Contents”
Section 18.4.20, “`ndb_redo_log_reader` — Check and Print Content of Cluster Redo Log”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

ndb_print_file

Section 18.4.17, “`ndb_print_file` — Print NDB Disk Data File Contents”

ndb_print_schema_file

Section 18.4.16, “`ndb_print_backup_file` — Print NDB Backup File Contents”
Section 18.4.17, “`ndb_print_file` — Print NDB Disk Data File Contents”
Section 18.4.18, “`ndb_print_schema_file` — Print NDB Schema File Contents”
Section 18.4.19, “`ndb_print_sys_file` — Print NDB System File Contents”
Section 18.4.20, “`ndb_redo_log_reader` — Check and Print Content of Cluster Redo Log”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

ndb_print_sys_file

Section 18.4.16, “`ndb_print_backup_file` — Print NDB Backup File Contents”
Section 18.4.17, “`ndb_print_file` — Print NDB Disk Data File Contents”
Section 18.4.18, “`ndb_print_schema_file` — Print NDB Schema File Contents”
Section 18.4.19, “`ndb_print_sys_file` — Print NDB System File Contents”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

ndb_redo_log_reader

Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”

ndb_restore

Section 7.1, “Backup and Recovery Types”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.1, “NDB Cluster Overview”
Section 18.4, “NDB Cluster Programs”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
Section 18.5.8, “NDB Cluster Single User Mode”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.5.3, “Online Backup of NDB Cluster”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Restoring to Fewer Nodes Than the Original
Restoring to More Nodes Than the Original

ndb_select_all

Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”

ndb_select_count

Section 18.4.23, “ndb_select_count — Print Row Counts for NDB Tables”

ndb_show_tables

MySQL Server Options for NDB Cluster
Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 18.4, “NDB Cluster Programs”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 18.5.10.4, “The ndbinfo cluster_operations Table”
Section 18.5.10.15, “The ndbinfo server_operations Table”

ndb_size.pl

Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Server Options for NDB Cluster
Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”
Section 2.12, “Perl Installation Notes”

ndb_waiter

Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

ndbd

Section 18.5.13.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.2.4, “Initial Startup of NDB Cluster”
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”

Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 18.2.1, “Installing NDB Cluster on Linux”
Section 18.2.1.3, “Installing NDB Cluster Using .deb Files”
Section 18.5, “Management of NDB Cluster”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Server Options for NDB Cluster
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.3.3.1, “NDB Cluster Configuration: Basic Example”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.3.2.1, “NDB Cluster Data Node Configuration Parameters”
Section 18.2, “NDB Cluster Installation”
Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”
Section 18.4, “NDB Cluster Programs”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.4.26, “`ndb_waiter` — Wait for NDB Cluster to Reach a Given Status”
Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”
Section 18.4.3, “`ndbmtd` — The NDB Cluster Data Node Daemon (Multi-Threaded)”
Section 18.3.2, “Overview of NDB Cluster Configuration Parameters, Options, and Variables”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Section 18.3.1, “Quick Test Setup of NDB Cluster”
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”
Section 18.3.3.12, “SCI Transport Connections in NDB Cluster”
Section 18.5.1, “Summary of NDB Cluster Start Phases”
Section 18.5.10.13, “The ndbinfo nodes Table”
Section 18.5.6.3, “Using CLUSTERLOG STATISTICS in the NDB Cluster Management Client”
Section 18.3.4, “Using High-Speed Interconnects with NDB Cluster”

ndbd.exe

Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

ndbd_redo_log_reader

Section 18.4.20, “`ndb_redo_log_reader` — Check and Print Content of Cluster Redo Log”

ndbinfo_select_all

Section 18.4.2, “`ndbinfo_select_all` — Select From ndbinfo Tables”

ndbmtd

Section 18.5.13.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 18.2.1.2, “Installing NDB Cluster from RPM”
Section 18.2.1, “Installing NDB Cluster on Linux”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.3.2.1, “NDB Cluster Data Node Configuration Parameters”
Section 18.1.2, “NDB Cluster Nodes, Node Groups, Replicas, and Partitions”
Section 18.4, “NDB Cluster Programs”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”
Section 18.4.3, “`ndbmtd` — The NDB Cluster Data Node Daemon (Multi-Threaded)”

Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”
Restoring to Fewer Nodes Than the Original
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”
Section 18.5.10.13, “The ndbinfo nodes Table”
Section 18.5.10.14, “The ndbinfo resources Table”

ndbmtd.exe

Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

NET

Section 2.3.7.7, “Starting MySQL as a Windows Service”

NET START

Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 5.6.2.2, “Starting Multiple MySQL Instances as Windows Services”

net start

Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

NET START MySQL

Section 2.3.7.7, “Starting MySQL as a Windows Service”
Section 2.3.8, “Troubleshooting a Microsoft Windows MySQL Server Installation”
Section 2.3.10, “Upgrading MySQL on Windows”

NET STOP

Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 5.6.2.2, “Starting Multiple MySQL Instances as Windows Services”

net stop

Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”

NET STOP MYSQL

Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”

NET STOP MySQL

Section 2.3.7.7, “Starting MySQL as a Windows Service”

nm

Section 4.7.4, “`resolve_stack_dump` — Resolve Numeric Stack Trace Dump to Symbols”
Section 24.5.1.5, “Using a Stack Trace”

numactl

Section 18.3.3.6, “Defining NDB Cluster Data Nodes”

O

[index top]

openssl

Section 6.4.3, “Creating SSL Certificates and Keys Using openssl”

openssl md5 package_name
Section 2.1.3.1, “Verifying the MD5 Checksum”

otool
Section 23.8.4.1, “Building C API Client Programs”

P

[index top]

perror
Section B.5.2.13, “Can't create/write to file”
Section B.5.2.18, “File Not Found and Similar Errors”
Section 7.6.3, “How to Repair MyISAM Tables”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.1, “Overview of MySQL Programs”
Section 4.8.1, “`perror` — Explain Error Codes”
Section B.1, “Sources of Error Information”

pfexec
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

PGP
Section 2.1.3.2, “Signature Checking Using GnuPG”

ping6
Section 5.1.9.5, “Obtaining an IPv6 Address from a Broker”

pkgadd
Section 2.7.1, “Installing MySQL on Solaris Using a Solaris PKG”

pkgrm
Section 2.7.1, “Installing MySQL on Solaris Using a Solaris PKG”

ppm
Section 2.12, “Perl Installation Notes”

ps
Section 6.3.5, “Assigning Account Passwords”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 8.12.4.1, “How MySQL Uses Memory”
Section B.5.1, “How to Determine What Is Causing a Problem”
Section 4.6.15, “`mysql_zap` — Kill Processes That Match a Pattern”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”

ps auxw
Section 4.2.2, “Connecting to the MySQL Server”

ps xa | grep mysqld
Section B.5.2.2, “Can't connect to [local] MySQL server”

R

[index top]

rename
Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 5.4.7, “Server Log Maintenance”
Section 5.4.3, “The General Query Log”

replace
Section 4.7.1, “`msql2mysql` — Convert mSQL Programs for Use with MySQL”
Section 4.1, “Overview of MySQL Programs”
Section 4.8.2, “`replace` — A String-Replacement Utility”
Section 17.3.3, “Using Replication for Scale-Out”

resolve_stack_dump
Section 4.1, “Overview of MySQL Programs”
Section 4.7.4, “`resolve_stack_dump` — Resolve Numeric Stack Trace Dump to Symbols”
Section 24.5.1.5, “Using a Stack Trace”

resolveip
Section 4.1, “Overview of MySQL Programs”
Section 4.8.3, “`resolveip` — Resolve Host name to IP Address or Vice Versa”

rm
Section 13.4.1.1, “PURGE BINARY LOGS Syntax”

rpm
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”
Section 2.1.3.4, “Signature Checking Using RPM”

rpmbuild
Section 2.9, “Installing MySQL from Source”
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”

rsync
Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”

S

[index top]

scp
Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”

sed
Section 3.3.4.7, “Pattern Matching”

SELECT
Section 18.2.5, “NDB Cluster Example with Tables and Data”

service
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”

Service Control Manager
Section 2.3, “Installing MySQL on Microsoft Windows”

Section 2.3.7.7, “Starting MySQL as a Windows Service”

Services

Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 2.3.7.7, “Starting MySQL as a Windows Service”

setenv

Section 4.2.10, “Setting Environment Variables”

setrlimit

Section 16.2.2.1, “`memcached` Command-Line Options”
Section 16.2.2, “Using `memcached`”

sh

Section B.5.2.18, “File Not Found and Similar Errors”
Section 4.2.1, “Invoking MySQL Programs”
Section 4.2.10, “Setting Environment Variables”
Section 1.2, “Typographical and Syntax Conventions”

SHOW

Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”
Section 18.3.1, “Quick Test Setup of NDB Cluster”

SHOW ERRORS

Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”

SHOW WARNINGS

Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”

sleep

Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”

ssh

Section 18.5.11.1, “NDB Cluster Security and Networking Issues”
Section 16.1.1, “Using ZFS for File System Replication”

Start>Run>cmd.exe

Section 6.4.3, “Creating SSL Certificates and Keys Using openssl”

strings

Section 6.1.1, “Security Guidelines”

su root

Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”

sudo

Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

System Preferences...

Section 2.4.4, “Installing and Using the MySQL Preference Pane”

T

[index top]

tar
Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 7.1, “Backup and Recovery Types”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 3.3, “Creating and Using a Database”
Section 1.6, “How to Report Bugs or Problems”
Section 2.9, “Installing MySQL from Source”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.4, “Installing MySQL on OS X”
Section 2.7, “Installing MySQL on Solaris”
Section 2.7.1, “Installing MySQL on Solaris Using a Solaris PKG”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”
Section 2.12.1, “Installing Perl on Unix”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
Section 23.8.2, “Simultaneous MySQL Server and Connector/C Installations”
Section 2.1.1, “Which MySQL Version and Distribution to Install”

tcpdump
Section 6.1.1, “Security Guidelines”

tcsh
Section B.5.2.18, “File Not Found and Similar Errors”
Section 2.4.1, “General Notes on Installing MySQL on OS X”
Section 4.2.1, “Invoking MySQL Programs”
Section 4.2.10, “Setting Environment Variables”
Section 1.2, “Typographical and Syntax Conventions”

tee
Section 4.5.1.2, “mysql Commands”

Telnet
Section 16.2.4, “Getting `memcached` Statistics”

telnet
Section 16.2.4, “Getting `memcached` Statistics”
Section 6.1.1, “Security Guidelines”

Terminal
Section 2.4, “Installing MySQL on OS X”

Text in this style
Section 1.2, “Typographical and Syntax Conventions”

top
Section B.5.1, “How to Determine What Is Causing a Problem”

U

[index top]

ulimit
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 8.12.4.2, “Enabling Large Page Support”
Section B.5.2.18, “File Not Found and Similar Errors”

Section 16.2.2.1, “memcached Command-Line Options”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section B.5.2.10, “Packet Too Large”
Section 5.1.4, “Server Command Options”

update-rc.d

Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”

useradd

Section 18.2.1.1, “Installing an NDB Cluster Binary Release on Linux”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 2.7, “Installing MySQL on Solaris”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”

usermod

Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”

V

[index top]

vi

Section 18.2.3, “Initial Configuration of NDB Cluster”
Section 4.5.1.2, “mysql Commands”
Section 3.3.4.7, “Pattern Matching”

vmstat

Section 16.2.2.1, “memcached Command-Line Options”

W

[index top]

WinDbg

Section 24.5.1.3, “Using WER with PDB to create a Windows crashdump”

windbg.exe

Section 24.5.1.3, “Using WER with PDB to create a Windows crashdump”

winMd5Sum

Section 2.1.3.1, “Verifying the MD5 Checksum”

WinZip

Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 2.9, “Installing MySQL from Source”
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”

WordPad

Section 13.2.6, “LOAD DATA INFILE Syntax”

Y

[index top]

yacc
Section 2.9.5, “Dealing with Problems Compiling MySQL”
Section 9.3, “Keywords and Reserved Words”

yum
Section 16.2.1, “Installing `memcached`”
Section 2.5.4, “Installing MySQL on Linux Using Native Package Managers”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 16.2.3.3, “Using `libmemcached` with C and C++”

yum install MySQL*rpm
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”

Z

[index top]

zfs recv
Section 16.1.1, “Using ZFS for File System Replication”

zip
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 1.6, “How to Report Bugs or Problems”

zsh
Section 4.2.10, “Setting Environment Variables”

Function Index

Symbols | A | B | C | D | E | F | G | H | I | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y

Symbols

[index top]

%
Section 1.7.1, “MySQL Extensions to Standard SQL”

A

[index top]

ABS()
Section 24.4, “Adding New Functions to MySQL”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 12.6.2, “Mathematical Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

ACOS()
Section 12.6.2, “Mathematical Functions”

add()
Section 16.2.3.1, “Basic `memcached` Operations”

ADDDATE()
Section 12.7, “Date and Time Functions”

addslashes()
Section 6.1.7, “Client Programming Security Guidelines”

ADDTIME()
Section 12.7, “Date and Time Functions”

AES_DECRYPT()
Section 12.13, “Encryption and Compression Functions”

AES_ENCRYPT()
Section 12.13, “Encryption and Compression Functions”

Area()
Section 12.15.7, “Geometry Property Functions”
Section 12.15.7.4, “Polygon and MultiPolygon Property Functions”

AsBinary()
Section 11.5.6, “Fetching Spatial Data”
Section 12.15.6, “Geometry Format Conversion Functions”

ASCII()
Section 13.8.3, “HELP Syntax”
Section 12.5, “String Functions”

ASIN()
Section 12.6.2, “Mathematical Functions”

AsText()
Section 11.5.6, “Fetching Spatial Data”
Section 12.15.6, “Geometry Format Conversion Functions”

AsWKB()
Section 12.15.6, “Geometry Format Conversion Functions”

AsWKT()
Section 12.15.6, “Geometry Format Conversion Functions”

ATAN()
Section 12.6.2, “Mathematical Functions”

ATAN2()
Section 12.6.2, “Mathematical Functions”

AVG()
Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 11.1.2, “Date and Time Type Overview”
Section 8.2.1.11, “GROUP BY Optimization”
Section 11.4.4, “The ENUM Type”
Section 1.3.2, “The Main Features of MySQL”
Section 11.4.5, “The SET Type”

B

[index top]

BENCHMARK()
Section 13.2.10.8, “Derived Tables (Subqueries in the FROM Clause)”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.14, “Information Functions”
Section 8.13.1, “Measuring the Speed of Expressions and Functions”
Section 13.2.10.10, “Optimizing Subqueries”

BIN()
Section 9.1.5, “Bit-Value Literals”
Section 12.5, “String Functions”

BIT_AND()
Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”

BIT_COUNT()
Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”

BIT_LENGTH()
Section 12.5, “String Functions”

BIT_OR()
Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”

BIT_XOR()
Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”

C

[index top]

CAST()
Section 9.1.5, “Bit-Value Literals”
Section 12.10, “Cast Functions and Operators”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.3.2, “Comparison Functions and Operators”
Section 11.3.7, “Conversion Between Date and Time Types”
Section 12.7, “Date and Time Functions”
Section 9.1.4, “Hexadecimal Literals”
Section 1.7.2, “MySQL Differences from Standard SQL”
Section 11.3.1, “The DATE, DATETIME, and TIMESTAMP Types”
Section 12.2, “Type Conversion in Expression Evaluation”
Section 9.4, “User-Defined Variables”

CEIL()
Section 12.6.2, “Mathematical Functions”

CEILING()
Section 19.2.4.1, “LINEAR HASH Partitioning”
Section 12.6.2, “Mathematical Functions”

Section 19.5.3, “Partitioning Limitations Relating to Functions”

Centroid()

Section 12.15.7.4, “Polygon and MultiPolygon Property Functions”

CHAR()

Section 12.13, “Encryption and Compression Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.5, “String Functions”

CHAR_LENGTH()

Section 12.5, “String Functions”
Section 10.1.10.1, “Unicode Character Sets”

CHARACTER_LENGTH()

Section 12.5, “String Functions”

CHARSET()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.14, “Information Functions”

COALESCE()

Section 12.3.2, “Comparison Functions and Operators”
Section 13.2.9.2, “JOIN Syntax”

COERCIBILITY()

Section 10.1.8.4, “Collation Coercibility in Expressions”
Section 12.14, “Information Functions”

COLLATION()

Section B.5.4.1, “Case Sensitivity in String Searches”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.14, “Information Functions”

COMPRESS()

Section 12.13, “Encryption and Compression Functions”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 5.1.5, “Server System Variables”

CONCAT()

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.10, “Cast Functions and Operators”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 10.1.2.1, “Character Set Repertoire”
Section 10.1.8.4, “Collation Coercibility in Expressions”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 5.1.8, “Server SQL Modes”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 12.5, “String Functions”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 12.2, “Type Conversion in Expression Evaluation”
Section 12.11, “XML Functions”

CONCAT_WS()

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”

Section 12.5, “String Functions”

CONNECTION_ID()

Section 6.5.2.3, “Audit Log File Formats”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.14, “Information Functions”
Section 13.7.6.4, “KILL Syntax”
Section 13.7.5.30, “SHOW PROCESSLIST Syntax”
Section 22.9.6.2, “The threads Table”

Contains()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

CONV()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.6.2, “Mathematical Functions”
Section 12.5, “String Functions”

CONVERT()

Section 12.10, “Cast Functions and Operators”
Section 10.1.3.8, “Character Set Introducers”
Section 10.1.3.6, “Character String Literal Character Set and Collation”
Section 12.3.2, “Comparison Functions and Operators”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”

CONVERT_TZ()

Section 12.7, “Date and Time Functions”
Section 8.10.3.1, “How the Query Cache Operates”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”

COS()

Section 12.6.2, “Mathematical Functions”

COT()

Section 12.6.2, “Mathematical Functions”

COUNT()

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 3.3.4.8, “Counting Rows”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 8.2.1.11, “GROUP BY Optimization”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.1, “Overview of Partitioning in MySQL”
Section B.5.4.3, “Problems with NULL Values”
Section 5.1.8, “Server SQL Modes”
Section 1.3.2, “The Main Features of MySQL”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”
Section 8.2.1.1, “WHERE Clause Optimization”

CRC32()

Section 12.6.2, “Mathematical Functions”

Crosses()
Section 12.15.9.1, “Spatial Relation Functions That Use Object Shapes”

crypt()
Section 12.13, “Encryption and Compression Functions”
Section 5.1.5, “Server System Variables”

CURDATE()
Section 12.7, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”

CURRENT_DATE
Section 13.1.17, “CREATE TABLE Syntax”
Section 11.6, “Data Type Default Values”
Section 12.7, “Date and Time Functions”

CURRENT_DATE()
Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”

CURRENT_TIME
Section 12.7, “Date and Time Functions”

CURRENT_TIME()
Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”

CURRENT_TIMESTAMP
Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 11.6, “Data Type Default Values”
Section 12.7, “Date and Time Functions”

CURRENT_TIMESTAMP()
Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”

CURRENT_USER
Section 20.6, “Access Control for Stored Programs and Views”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 6.2.2, “Grant Tables”
Section 12.14, “Information Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.8, “Replication of CURRENT_USER()”

Section 6.2.3, “Specifying Account Names”

CURRENT_USER()

Section 6.2.4, “Access Control, Stage 1: Connection Verification”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 8.10.3.1, “How the Query Cache Operates”
Implementing Proxy User Support in Authentication Plugins
Section 12.14, “Information Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 6.3.7, “Proxy Users”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 13.7.1.6, “SET PASSWORD Syntax”
Section 6.2.3, “Specifying Account Names”
Section 6.3.8, “SQL-Based MySQL Account Activity Auditing”
Section 10.1.2.2, “UTF-8 for Metadata”
Writing the Server-Side Authentication Plugin

CURTIME()

Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 10.6, “MySQL Server Time Zone Support”

D

[index top]

DATABASE()

Section 17.1.3.4, “Binary Log Options and Variables”
Section 3.3.1, “Creating and Selecting a Database”
Section 13.1.21, “DROP DATABASE Syntax”
Section 3.4, “Getting Information About Databases and Tables”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.14, “Information Functions”
Section B.5.7, “Known Issues in MySQL”
Section 10.1.2.2, “UTF-8 for Metadata”

DATE()

Section 12.7, “Date and Time Functions”

DATE_ADD()

Section 12.6.1, “Arithmetic Operators”
Section 13.1.11, “CREATE EVENT Syntax”
Section 12.7, “Date and Time Functions”
Section 11.3, “Date and Time Types”
Section 3.3.4.5, “Date Calculations”
Section 9.5, “Expression Syntax”

DATE_FORMAT()

Section 23.8.19, “C API Prepared Statement Problems”
Section 12.10, “Cast Functions and Operators”
Section 12.7, “Date and Time Functions”
Section 10.7, “MySQL Server Locale Support”

Section 5.1.5, “Server System Variables”

DATE_SUB()

Section 12.7, “Date and Time Functions”
Section 11.3, “Date and Time Types”

DATEDIFF()

Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

DAY()

Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

DAYNAME()

Section 12.7, “Date and Time Functions”
Section 10.7, “MySQL Server Locale Support”
Section 5.1.5, “Server System Variables”

DAYOFMONTH()

Section 12.7, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

DAYOFWEEK()

Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

DAYOFYEAR()

Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”

DECODE()

Section 12.13, “Encryption and Compression Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

decr()

Section 16.2.3.1, “Basic `memcached` Operations”

DEFAULT()

Section 11.6, “Data Type Default Values”
Section 13.2.5, “INSERT Syntax”
Section 12.17, “Miscellaneous Functions”
Section 13.2.8, “REPLACE Syntax”

DEGREES()

Section 12.6.2, “Mathematical Functions”

delete()

Section 16.2.3.1, “Basic `memcached` Operations”

DES_DECRYPT()

Section 12.13, “Encryption and Compression Functions”
Section 5.1.4, “Server Command Options”

DES_ENCRYPT()
Section 12.13, “Encryption and Compression Functions”
Section 6.2.1, “Privileges Provided by MySQL”
Section 5.1.4, “Server Command Options”

Dimension()
Section 12.15.7.1, “General Geometry Property Functions”

Disjoint()
Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

E

[index top]

ELT()
Section 12.5.3, “Character Set and Collation of Function Results”
Section B.5.7, “Known Issues in MySQL”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.5, “String Functions”

ENCODE()
Section 12.13, “Encryption and Compression Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

ENCRYPT()
Section 1.8.1, “Contributors to MySQL”
Section 12.13, “Encryption and Compression Functions”
Section 8.10.3.1, “How the Query Cache Operates”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section C.7, “Restrictions on Character Sets”
Section 5.1.5, “Server System Variables”

EndPoint()
Section 12.15.7.3, “LineString and MultiLineString Property Functions”
Section 12.15.8, “Spatial Operator Functions”

Envelope()
Section 12.15.7.1, “General Geometry Property Functions”
Section 12.15.8, “Spatial Operator Functions”

Equals()
Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

EXP()
Section 12.6.2, “Mathematical Functions”

EXPORT_SET()
Section 12.5, “String Functions”

expr IN ()
Section 12.3.2, “Comparison Functions and Operators”

expr NOT IN ()
Section 12.3.2, “Comparison Functions and Operators”

ExteriorRing()

Section 12.15.7.4, “Polygon and MultiPolygon Property Functions”
Section 12.15.8, “Spatial Operator Functions”

EXTRACT()

Section 12.10, “Cast Functions and Operators”
Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

ExtractValue()

Section 12.11, “XML Functions”

F

[index top]

FIELD()

Section 12.5, “String Functions”

FIND_IN_SET()

Section 12.5, “String Functions”
Section 11.4.5, “The SET Type”

FLOOR()

Section 12.6.2, “Mathematical Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

flush_all

Section 16.2.3.1, “Basic `memcached` Operations”

FORMAT()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.6.2, “Mathematical Functions”
Section 12.17, “Miscellaneous Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 10.7, “MySQL Server Locale Support”
Section 12.5, “String Functions”

FOUND_ROWS()

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.14, “Information Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.14, “Replication and System Functions”

FROM_DAYS()

Section 12.7, “Date and Time Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

FROM_UNIXTIME()

Section 6.5.2.4, “Audit Log Logging Control”
Section 1.8.1, “Contributors to MySQL”
Section 12.7, “Date and Time Functions”
Section 17.4.1.34, “Replication and Time Zones”

G

[index top]

GeomCollFromText()
Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

GeomCollFromWKB()
Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

GeometryCollection()
Section 12.15.5, “MySQL-Specific Functions That Create Geometry Values”

GeometryCollectionFromText()
Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

GeometryCollectionFromWKB()
Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

GeometryFromText()
Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

GeometryFromWKB()
Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

GeometryN()
Section 12.15.7.5, “GeometryCollection Property Functions”
Section 12.15.8, “Spatial Operator Functions”

GeometryType()
Section 12.15.7.1, “General Geometry Property Functions”

GeomFromText()
Section 12.15.3, “Functions That Create Geometry Values from WKT Values”
Section 11.5.5, “Populating Spatial Columns”
Section 11.5.3, “Supported Spatial Data Formats”

GeomFromWKB()
Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

get()
Section 16.2.3.1, “Basic `memcached` Operations”

GET_FORMAT()
Section 12.7, “Date and Time Functions”
Section 10.7, “MySQL Server Locale Support”

GET_LOCK()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 23.8.20, “C API Automatic Reconnection Control”
Section 13.1.11, “CREATE EVENT Syntax”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 20.4.1, “Event Scheduler Overview”

Section 8.14.2, “General Thread States”
Section 8.10.3.1, “How the Query Cache Operates”
Section 8.11.1, “Internal Locking Methods”
Section 13.7.6.4, “KILL Syntax”
Section 12.17, “Miscellaneous Functions”
Section 23.8.7.3, “mysql_change_user()”
Section 17.4.1.14, “Replication and System Functions”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”

gethostbyaddr()

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”

gethostbyaddr_r()

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”

gethostbyname()

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”

gethostbyname_r()

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”

getrusage()

Section 18.5.10.18, “The ndbinfo threadstat Table”

gettimeofday()

Section 18.5.10.18, “The ndbinfo threadstat Table”

GLength()

Section 12.15.7.3, “LineString and MultiLineString Property Functions”
Section 11.5, “Spatial Data Types”
Section 12.5, “String Functions”

GREATEST()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.3.2, “Comparison Functions and Operators”

GROUP_CONCAT()

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section B.5.7, “Known Issues in MySQL”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 5.1.5, “Server System Variables”
Section 1.3.2, “The Main Features of MySQL”

H

[index top]

HEX()

Section 9.1.5, “Bit-Value Literals”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 10.1.3.6, “Character String Literal Character Set and Collation”
Section 9.1.4, “Hexadecimal Literals”
Section 12.6.2, “Mathematical Functions”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”

Section 12.5, “String Functions”

HOUR()

Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

I

[index top]

IF()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.4, “Control Flow Functions”
Section 13.6.5.2, “IF Syntax”
Section B.5.7, “Known Issues in MySQL”
Section 1.7.1, “MySQL Extensions to Standard SQL”

IFNULL()

Section 12.4, “Control Flow Functions”
Section B.5.4.3, “Problems with NULL Values”

IN

Section 12.3.1, “Operator Precedence”

IN()

Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.2, “Range Optimization”
Section C.4, “Restrictions on Subqueries”
Section 12.2, “Type Conversion in Expression Evaluation”

incr()

Section 16.2.3.1, “Basic `memcached` Operations”

INET_ATON()

Section 12.17, “Miscellaneous Functions”

INET_NTOA()

Section 12.17, “Miscellaneous Functions”

INSERT()

Section 12.5, “String Functions”

INSTR()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

InteriorRingN()

Section 12.15.7.4, “Polygon and MultiPolygon Property Functions”
Section 12.15.8, “Spatial Operator Functions”

Intersects()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

INTERVAL()

Section 12.3.2, “Comparison Functions and Operators”

IS_FREE_LOCK()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.17, “Miscellaneous Functions”
Section 17.4.1.14, “Replication and System Functions”

IS_USED_LOCK()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.17, “Miscellaneous Functions”
Section 17.4.1.14, “Replication and System Functions”

IsClosed()
Section 12.15.7.3, “LineString and MultiLineString Property Functions”

IsEmpty()
Section 12.15.7.1, “General Geometry Property Functions”

ISNULL()
Section 12.3.2, “Comparison Functions and Operators”

IsSimple()
Section 12.15.7.1, “General Geometry Property Functions”

L

[index top]

LAST_DAY()
Section 12.7, “Date and Time Functions”

LAST_INSERT_ID()
Section 23.8.20, “C API Automatic Reconnection Control”
Section 12.3.2, “Comparison Functions and Operators”
Section 13.1.17, “CREATE TABLE Syntax”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 23.8.21.3, “How to Get the Unique ID for the Last Inserted Row”
Section 12.14, “Information Functions”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 23.8.7.37, “mysql_insert_id()”
Section 23.8.11.16, “mysql_stmt_insert_id()”
Section 4.6.7.1, “mysqlbinlog Hex Dump Format”
Section 17.4.1.1, “Replication and AUTO_INCREMENT”
Section 17.4.1.14, “Replication and System Functions”
Section 5.1.5, “Server System Variables”
Section 20.2.4, “Stored Procedures, Functions, Triggers, and LAST_INSERT_ID()”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”
Section 17.4.4, “Troubleshooting Replication”
Section 20.5.3, “Updatable and Insertable Views”

Section 3.6.9, “Using AUTO_INCREMENT”

LCASE()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

LEAST()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.3.2, “Comparison Functions and Operators”

LEFT()

Section 12.5, “String Functions”

LENGTH()

Section 11.7, “Data Type Storage Requirements”
Section 12.5, “String Functions”
Section 11.5.3, “Supported Spatial Data Formats”

Length()

Section 12.15.7.3, “LineString and MultiLineString Property Functions”
Section 11.5, “Spatial Data Types”

LineFromText()

Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

LineFromWKB()

Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

LineString()

Section 12.15.5, “MySQL-Specific Functions That Create Geometry Values”

LineStringFromText()

Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

LineStringFromWKB()

Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

LN()

Section 12.6.2, “Mathematical Functions”

LOAD_FILE()

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 13.2.7, “LOAD XML Syntax”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.14, “Replication and System Functions”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 12.5, “String Functions”

LOCALTIME

Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.7, “Date and Time Functions”

LOCALTIME()
Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”

LOCALTIMESTAMP
Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.7, “Date and Time Functions”

LOCALTIMESTAMP()
Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”

LOCATE()
Section 12.5, “String Functions”

LOG()
Section 19.2.4.1, “LINEAR HASH Partitioning”
Section 12.6.2, “Mathematical Functions”

LOG10()
Section 12.6.2, “Mathematical Functions”

LOG2()
Section 12.6.2, “Mathematical Functions”

LOWER()
Section 12.10, “Cast Functions and Operators”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”
Section 10.1.8.7, “Using Collation in INFORMATION_SCHEMA Searches”

LPAD()
Section 12.5, “String Functions”

LTRIM()
Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

M

[index top]

MAKE_SET()
Section 12.5, “String Functions”

MAKEDATE()
Section 12.7, “Date and Time Functions”

MAKETIME()
Section 12.7, “Date and Time Functions”

MASTER_POS_WAIT()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”

Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.17, “Miscellaneous Functions”
Section A.13, “MySQL 5.5 FAQ: Replication”

MATCH

Section 9.5, “Expression Syntax”

MATCH ()

Section 12.9, “Full-Text Search Functions”

MATCH()

Section 12.9.2, “Boolean Full-Text Searches”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 12.9.5, “Full-Text Restrictions”
Section 12.9, “Full-Text Search Functions”
MySQL Glossary
Section 12.9.1, “Natural Language Full-Text Searches”

MAX()

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 8.2.1.11, “GROUP BY Optimization”
Section 8.3.1, “How MySQL Uses Indexes”
Section B.5.7, “Known Issues in MySQL”
Section 11.1.1, “Numeric Type Overview”
Section 13.2.10.10, “Optimizing Subqueries”
Section 5.1.8, “Server SQL Modes”
Section 21.30.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 1.3.2, “The Main Features of MySQL”
Section 11.3.8, “Two-Digit Years in Dates”
Section 20.5.3, “Updatable and Insertable Views”
Section 3.6.9, “Using AUTO_INCREMENT”
Section 20.5.2, “View Processing Algorithms”

MBRContains()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”
Section 11.5.9, “Using Spatial Indexes”

MBRDisjoint()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBREqual()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBRIntersects()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBROverlaps()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBRTouches()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

MBRWithin()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”
Section 11.5.9, “Using Spatial Indexes”

MD5()

Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”
Section 19.2.5, “KEY Partitioning”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 9.2, “Schema Object Names”

MICROSECOND()

Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

MID()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

MIN()

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 23.8.19, “C API Prepared Statement Problems”
Section 8.2.1.11, “GROUP BY Optimization”
Section 8.3.1, “How MySQL Uses Indexes”
Section B.5.7, “Known Issues in MySQL”
Section 11.1.1, “Numeric Type Overview”
Section 13.2.10.10, “Optimizing Subqueries”
Section B.5.4.3, “Problems with NULL Values”
Section 1.3.2, “The Main Features of MySQL”
Section 11.3.8, “Two-Digit Years in Dates”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”
Section 8.2.1.1, “WHERE Clause Optimization”

MINUTE()

Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

MLineFromText()

Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

MLineFromWKB()

Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

MOD()

Section 12.6.1, “Arithmetic Operators”
Section 3.3.4.5, “Date Calculations”
Section 12.6.2, “Mathematical Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 5.1.8, “Server SQL Modes”

MONTH()

Section 12.7, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”

MONTHNAME()

Section 12.7, “Date and Time Functions”

Section 10.7, “MySQL Server Locale Support”
Section 5.1.5, “Server System Variables”

MPointFromText()
Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

MPointFromWKB()
Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

MPolyFromText()
Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

MPolyFromWKB()
Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

MultiLineString()
Section 12.15.5, “MySQL-Specific Functions That Create Geometry Values”

MultiLineStringFromText()
Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

MultiLineStringFromWKB()
Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

MultiPoint()
Section 12.15.5, “MySQL-Specific Functions That Create Geometry Values”

MultiPointFromText()
Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

MultiPointFromWKB()
Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

MultiPolygon()
Section 12.15.5, “MySQL-Specific Functions That Create Geometry Values”

MultiPolygonFromText()
Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

MultiPolygonFromWKB()
Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

my_open()
Section 5.1.7, “Server Status Variables”

N

[index top]

NAME_CONST()
Section 20.7, “Binary Logging of Stored Programs”
Section 12.17, “Miscellaneous Functions”

NOW()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”

Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 11.6, “Data Type Default Values”
Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section A.1, “MySQL 5.5 FAQ: General”
Section 10.6, “MySQL Server Time Zone Support”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.34, “Replication and Time Zones”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 11.3.3, “The YEAR Type”
Section 10.6.2, “Time Zone Leap Second Support”

NULLIF()

Section 12.4, “Control Flow Functions”

NumGeometries()

Section 12.15.7.5, “GeometryCollection Property Functions”

NumInteriorRings()

Section 12.15.7.4, “Polygon and MultiPolygon Property Functions”

NumPoints()

Section 12.15.7.3, “LineString and MultiLineString Property Functions”

O

[index top]

OCT()

Section 12.5, “String Functions”

OCTET_LENGTH()

Section 12.5, “String Functions”

OLD_PASSWORD()

Section B.5.2.4, “Client does not support authentication protocol”
Section 13.7.1.1, “CREATE USER Syntax”
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 5.1.5, “Server System Variables”
Section 13.7.1.6, “SET PASSWORD Syntax”

ORD()

Section 12.5, “String Functions”

Overlaps()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

P

[index top]

PASSWORD()

Section 6.2.4, “Access Control, Stage 1: Connection Verification”
Section 6.3.5, “Assigning Account Passwords”
Section 13.7.1.1, “CREATE USER Syntax”
Section 12.13, “Encryption and Compression Functions”
Section B.5.2.15, “Ignoring user”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”
Section 19.2.5, “KEY Partitioning”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 6.1.2.3, “Passwords and Logging”
Section 5.1.5, “Server System Variables”
Section 13.7.1.6, “SET PASSWORD Syntax”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”

PERIOD_ADD()

Section 12.7, “Date and Time Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

PERIOD_DIFF()

Section 12.7, “Date and Time Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”

PI()

Section 9.2.4, “Function Name Parsing and Resolution”
Section 12.6.2, “Mathematical Functions”

Point()

Section 12.15.5, “MySQL-Specific Functions That Create Geometry Values”
Section 11.5.3, “Supported Spatial Data Formats”

PointFromText()

Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

PointFromWKB()

Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

PointN()

Section 12.15.7.3, “LineString and MultiLineString Property Functions”
Section 12.15.8, “Spatial Operator Functions”

PolyFromText()

Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

PolyFromWKB()

Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

Polygon()

Section 12.15.5, “MySQL-Specific Functions That Create Geometry Values”

PolygonFromText()

Section 12.15.3, “Functions That Create Geometry Values from WKT Values”

PolygonFromWKB()

Section 12.15.4, “Functions That Create Geometry Values from WKB Values”

POSITION()
Section 12.5, “String Functions”

POW()
Section 8.2.1.14, “Function Call Optimization”
Section 19.2.4, “HASH Partitioning”
Section 12.6.2, “Mathematical Functions”

POWER()
Section 19.2.4.1, “LINEAR HASH Partitioning”
Section 12.6.2, “Mathematical Functions”

pthread_mutex()
Section 1.8.1, “Contributors to MySQL”

Q

[index top]

QUARTER()
Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

QUOTE()
Section 23.8.7.53, “mysql_real_escape_string()”
Section 12.5, “String Functions”
Section 9.1.1, “String Literals”

R

[index top]

RADIANS()
Section 12.6.2, “Mathematical Functions”

RAND()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.2.1.14, “Function Call Optimization”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.6.2, “Mathematical Functions”
Section 4.6.7.1, “mysqlbinlog Hex Dump Format”
Section 17.4.1.14, “Replication and System Functions”
Section 5.1.5, “Server System Variables”

RELEASE_ALL_LOCKS()
Section 8.10.3.1, “How the Query Cache Operates”

RELEASE_LOCK()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 13.2.3, “DO Syntax”
Section 8.10.3.1, “How the Query Cache Operates”
Section 8.11.1, “Internal Locking Methods”

Section 12.17, “Miscellaneous Functions”
Section 17.4.1.14, “Replication and System Functions”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”

REPEAT()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

REPLACE()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

replace()

Section 16.2.3.1, “Basic `memcached` Operations”

REVERSE()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

RIGHT()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

ROUND()

Section 12.6.2, “Mathematical Functions”
Section 12.18, “Precision Math”
Section 12.18.5, “Precision Math Examples”
Section 12.18.4, “Rounding Behavior”

ROW_COUNT()

Section 13.2.1, “CALL Syntax”
Section 13.2.2, “DELETE Syntax”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 12.14, “Information Functions”
Section 13.2.5, “INSERT Syntax”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 23.8.7.1, “mysql_affected_rows()”
Section 17.4.1.14, “Replication and System Functions”

RPAD()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

RTRIM()

Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

S

[index top]

SCHEMA()

Section 12.14, “Information Functions”

SEC_TO_TIME()

Section 12.7, “Date and Time Functions”

SECOND()
Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

SESSION_USER()
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 12.14, “Information Functions”
Section 10.1.2.2, “UTF-8 for Metadata”

set()
Section 16.2.3.1, “Basic `memcached` Operations”

setrlimit()
Section 5.1.4, “Server Command Options”

SHA()
Section 12.13, “Encryption and Compression Functions”

SHA1()
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”

SHA2()
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”
Section 6.1.1, “Security Guidelines”

SIGN()
Section 12.6.2, “Mathematical Functions”

SIN()
Section 12.6.2, “Mathematical Functions”
Section 24.4.2.3, “UDF Argument Processing”

SLEEP()
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.14.2, “General Thread States”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.17, “Miscellaneous Functions”
Section 17.4.1, “Replication Features and Issues”
Section 21.30.2, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table”

SOUNDEX()
Section 24.4, “Adding New Functions to MySQL”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

SPACE()
Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

SQRT()
Section 12.6.2, “Mathematical Functions”

SRID()
Section 12.15.7.1, “General Geometry Property Functions”

StartPoint()
Section 12.15.7.3, “LineString and MultiLineString Property Functions”
Section 12.15.8, “Spatial Operator Functions”

STD()
Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 1.3.2, “The Main Features of MySQL”

STDDEV()
Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”

STDDEV_POP()
Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”

STDDEV_SAMP()
Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”

STR_TO_DATE()
Section 12.7, “Date and Time Functions”
Section 10.7, “MySQL Server Locale Support”

STRCMP()
Section B.5.4.2, “Problems Using DATE Columns”
Section 12.5.1, “String Comparison Functions”

SUBDATE()
Section 12.7, “Date and Time Functions”

SUBSTR()
Section 12.5, “String Functions”

SUBSTRING()
Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

SUBSTRING_INDEX()
Section 6.3.8, “SQL-Based MySQL Account Activity Auditing”
Section 12.5, “String Functions”

SUBTIME()
Section 12.7, “Date and Time Functions”

SUM()
Section 24.4.2, “Adding a New User-Defined Function”
Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 11.1.2, “Date and Time Type Overview”
Section 8.2.1.11, “GROUP BY Optimization”
Section 19.1, “Overview of Partitioning in MySQL”
Section B.5.4.3, “Problems with NULL Values”

Section 11.4.4, “The ENUM Type”
Section 1.3.2, “The Main Features of MySQL”
Section 11.4.5, “The SET Type”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”

SYSDATE()

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 17.4.1.14, “Replication and System Functions”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

SYSTEM_USER()

Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 12.14, “Information Functions”
Section 10.1.2.2, “UTF-8 for Metadata”

T

[index top]

TAN()

Section 12.6.2, “Mathematical Functions”

thr_setconcurrency()

Section 5.1.5, “Server System Variables”

TIME()

Section 12.7, “Date and Time Functions”

TIME_FORMAT()

Section 12.10, “Cast Functions and Operators”
Section 12.7, “Date and Time Functions”

TIME_TO_SEC()

Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

TIMEDIFF()

Section 12.7, “Date and Time Functions”

TIMESTAMP()

Section 12.7, “Date and Time Functions”

TIMESTAMPADD()

Section 12.7, “Date and Time Functions”
Section 1.4, “What Is New in MySQL 5.5”

TIMESTAMPDIFF()

Section 12.7, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”

TO_DAYS()
Section 12.7, “Date and Time Functions”
Section 19.2.4, “HASH Partitioning”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.4, “Partition Pruning”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”

TO_SECONDS()
Section 12.7, “Date and Time Functions”
Section 19.4, “Partition Pruning”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”
Section 1.4, “What Is New in MySQL 5.5”

Touches()
Section 12.15.9.1, “Spatial Relation Functions That Use Object Shapes”

TRIM()
Section 12.5.3, “Character Set and Collation of Function Results”
Section 10.1.7, “Column Character Set Conversion”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.5, “String Functions”

TRUNCATE()
Section 12.6.2, “Mathematical Functions”

U

[index top]

UCASE()
Section 12.5.3, “Character Set and Collation of Function Results”
Section 12.5, “String Functions”

UNCOMPRESS()
Section 12.13, “Encryption and Compression Functions”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 5.1.5, “Server System Variables”

UNCOMPRESSED_LENGTH()
Section 12.13, “Encryption and Compression Functions”

UNHEX()
Section 12.13, “Encryption and Compression Functions”
Section 12.5, “String Functions”

UNIX_TIMESTAMP()
Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2.1, “RANGE Partitioning”
Section 5.1.5, “Server System Variables”
Section B.5.3.7, “Time Zone Problems”

UpdateXML()

Section 12.11, “XML Functions”

UPPER()

Section 12.10, “Cast Functions and Operators”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 10.1.2.1, “Character Set Repertoire”
Section 12.5, “String Functions”
Section 10.1.8.7, “Using Collation in INFORMATION_SCHEMA Searches”

USER()

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 10.1.8.4, “Collation Coercibility in Expressions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Implementing Proxy User Support in Authentication Plugins
Section 12.14, “Information Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 6.3.7, “Proxy Users”
Section 17.4.1.14, “Replication and System Functions”
Section 6.3.8, “SQL-Based MySQL Account Activity Auditing”
Section 10.1.2.2, “UTF-8 for Metadata”
Writing the Server-Side Authentication Plugin

UTC_DATE

Section 12.7, “Date and Time Functions”

UTC_DATE()

Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”

UTC_TIME

Section 12.7, “Date and Time Functions”

UTC_TIME()

Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”

UTC_TIMESTAMP

Section 12.7, “Date and Time Functions”

UTC_TIMESTAMP()

Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 10.6, “MySQL Server Time Zone Support”

UUID()

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 20.7, “Binary Logging of Stored Programs”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.2.1.14, “Function Call Optimization”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.17, “Miscellaneous Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.14, “Replication and System Functions”

Section 5.4.4.2, “Setting The Binary Log Format”

UUID_SHORT()

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.17, “Miscellaneous Functions”

V

[index top]

VALUES()

Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 12.17, “Miscellaneous Functions”

VAR_POP()

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”

VAR_SAMP()

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”

VARIANCE()

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”

VERSION()

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 6.5.2.3, “Audit Log File Formats”
Section B.5.4.1, “Case Sensitivity in String Searches”
Section 10.1.8.4, “Collation Coercibility in Expressions”
Section 12.14, “Information Functions”
Section 17.4.1.14, “Replication and System Functions”
Section 10.1.2.2, “UTF-8 for Metadata”

W

[index top]

WEEK()

Section 12.7, “Date and Time Functions”
Section 5.1.5, “Server System Variables”

WEEKDAY()

Section 12.7, “Date and Time Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”

WEEKOFYEAR()

Section 12.7, “Date and Time Functions”

Within()

Section 12.15.9.2, “Spatial Relation Functions That Use Minimum Bounding Rectangles”

X

[index top]

X()
Section 12.15.7.2, “Point Property Functions”
Section 11.5.3, “Supported Spatial Data Formats”

Y

[index top]

Y()
Section 12.15.7.2, “Point Property Functions”

YEAR()
Section 12.7, “Date and Time Functions”
Section 3.3.4.5, “Date Calculations”
Section 19.2.4, “HASH Partitioning”
Section 19.2.7, “How MySQL Partitioning Handles NULL”
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 19.4, “Partition Pruning”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.2, “Partitioning Types”
Section 19.2.1, “RANGE Partitioning”

YEARWEEK()
Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

INFORMATION_SCHEMA Index

C | E | F | G | I | K | N | P | R | S | T | U | V

C

[index top]

CHARACTER_SETS
Section 10.1.2, “Character Sets and Collations in MySQL”
Section 13.7.5.4, “SHOW CHARACTER SET Syntax”
Section 10.1.10, “Supported Character Sets and Collations”
Section 21.1, “The INFORMATION_SCHEMA CHARACTER_SETS Table”

COLLATION_CHARACTER_SET_APPLICABILITY
Section 21.3, “The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table”

COLLATIONS
Section 23.8.5, “C API Data Structures”
Section 10.1.2, “Character Sets and Collations in MySQL”
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 13.7.5.5, “SHOW COLLATION Syntax”
Section 21.2, “The INFORMATION_SCHEMA COLLATIONS Table”

COLUMN_PRIVILEGES
Section 21.5, “The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table”

COLUMNS
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”

Section 13.7.5.6, “SHOW COLUMNS Syntax”
Section 21.4, “The INFORMATION_SCHEMA COLUMNS Table”
Section 21.11, “The INFORMATION_SCHEMA PARAMETERS Table”
Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”

E

[index top]

ENGINES

Section 14.1.3, “Checking InnoDB Availability”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”
Section 5.1.5, “Server System Variables”
Section 13.7.5.17, “SHOW ENGINES Syntax”
Section 21.6, “The INFORMATION_SCHEMA ENGINES Table”

EVENTS

Section 20.4.4, “Event Metadata”
Section 20.4.2, “Event Scheduler Configuration”
Section 17.4.1.15, “Replication of Invoked Features”
Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”

F

[index top]

FILES

Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 21.29, “NDB Cluster INFORMATION_SCHEMA Tables”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”

G

[index top]

GLOBAL_STATUS

Section 18.5, “Management of NDB Cluster”
Section 18.5.15, “NDB API Statistics Counters and Variables”
Section 18.6, “NDB Cluster Replication”
Section 13.7.5.36, “SHOW STATUS Syntax”
Section 21.8, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”

GLOBAL_VARIABLES

Section 13.7.5.40, “SHOW VARIABLES Syntax”
Section 21.9, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”

I

[index top]

INFORMATION_SCHEMA

Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”
MySQL Glossary

Section 5.2, “The MySQL Data Directory”

INFORMATION_SCHEMA.CHARACTER_SETS

Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”

INFORMATION_SCHEMA.COLLATIONS

Section 10.4.2, “Choosing a Collation ID”

INFORMATION_SCHEMA.COLUMNS

Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 18.4.14, “`ndb_index_stat` — NDB Index Statistics Utility”
Section 22.1, “Performance Schema Quick Start”

INFORMATION_SCHEMA.ENGINES

Section 22.1, “Performance Schema Quick Start”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”

INFORMATION_SCHEMA.EVENTS

Section 20.4.4, “Event Metadata”
Section 17.4.1.15, “Replication of Invoked Features”
Section C.1, “Restrictions on Stored Programs”
Section 13.7.5.19, “SHOW EVENTS Syntax”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

INFORMATION_SCHEMA.FILES

Section 13.1.4, “ALTER LOGFILE GROUP Syntax”
Section 13.1.8, “ALTER TABLESPACE Syntax”
Section 13.1.14, “CREATE LOGFILE GROUP Syntax”
Section 13.1.18, “CREATE TABLESPACE Syntax”
Section 18.5.12.3, “NDB Cluster Disk Data Storage Requirements”
Section 18.4.10, “`ndb_desc` — Describe NDB Tables”

INFORMATION_SCHEMA.GLOBAL_STATUS

Section 18.5.15, “NDB API Statistics Counters and Variables”

INFORMATION_SCHEMA.INNODB_BUFFER_PAGE

Section 14.7.2, “Change Buffer”

INFORMATION_SCHEMA.INNODB_CMP

MySQL Glossary
Section 14.12.3, “Tuning Compression for InnoDB Tables”
Section 14.18.1.3, “Using the Compression Information Schema Tables”

INFORMATION_SCHEMA.INNODB_CMPMEM

Section 14.18.1.3, “Using the Compression Information Schema Tables”

INFORMATION_SCHEMA.INNODB_LOCK_WAITS

Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”

INFORMATION_SCHEMA.INNODB_LOCKS

Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”

INFORMATION_SCHEMA.INNODB_TRX

Section 14.17, “InnoDB Startup Options and System Variables”

Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”

INFORMATION_SCHEMA.KEY_COLUMN_USAGE

Section 1.7.3.2, “FOREIGN KEY Constraints”
Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”

INFORMATION_SCHEMA.PARTITIONS

Section 19.2.7, “How MySQL Partitioning Handles NULL”
Section 19.2.5, “KEY Partitioning”
Section 19.3.4, “Obtaining Information About Partitions”
Section 19.2.3.1, “RANGE COLUMNS partitioning”
Section 5.1.4, “Server Command Options”
Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”

INFORMATION_SCHEMA.PLUGINS

Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”
Section 13.7.3.3, “INSTALL PLUGIN Syntax”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 6.5.2.1, “Installing MySQL Enterprise Audit”
Section 5.5.2, “Obtaining Server Plugin Information”
Section 6.5.1.4, “PAM Pluggable Authentication”
Chapter 19, *Partitioning*
Section 24.2.2, “Plugin API Characteristics”
Section 24.2.3, “Plugin API Components”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Server Plugin Library and Plugin Descriptors
Section 6.5.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.5.1.7, “Test Pluggable Authentication”
Section 5.5.3.2, “Thread Pool Installation”
Section 6.5.1.5, “Windows Pluggable Authentication”
Section 24.2.4.8, “Writing Audit Plugins”
Section 24.2.4.5, “Writing Daemon Plugins”
Section 24.2.4.4, “Writing Full-Text Parser Plugins”
Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”
Writing the Server-Side Authentication Plugin

INFORMATION_SCHEMA.PROCESSLIST

Section 12.14, “Information Functions”
Section 13.7.6.4, “KILL Syntax”
Section 13.7.5.30, “SHOW PROCESSLIST Syntax”
Section 21.14, “The INFORMATION_SCHEMA PROCESSLIST Table”
Section 22.9.6.2, “The threads Table”
Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”

INFORMATION_SCHEMA.ROUTINES

Chapter 21, *INFORMATION_SCHEMA Tables*
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”

INFORMATION_SCHEMA.SESSION_STATUS

Section 18.5.15, “NDB API Statistics Counters and Variables”

INFORMATION_SCHEMA.STATISTICS

Section 13.7.2.1, “ANALYZE TABLE Syntax”
Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”

Section 8.9.3, “Index Hints”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 18.4.14, “`ndb_index_stat` — NDB Index Statistics Utility”

INFORMATION_SCHEMA.TABLE_CONSTRAINTS

Section 21.16, “The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table”

INFORMATION_SCHEMA.TABLES

Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 13.1.7, “ALTER TABLE Syntax”
Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.1.4, “Server Command Options”

INFORMATION_SCHEMA.TRIGGERS

Section A.5, “MySQL 5.5 FAQ: Triggers”

INFORMATION_SCHEMA.VIEWS

Section 20.5.3, “Updatable and Insertable Views”

INNODB_BUFFER_PAGE

Section 14.7.2, “Change Buffer”
Section 14.18.3, “InnoDB INFORMATION_SCHEMA Buffer Pool Tables”
Section 21.28.2, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table”

INNODB_BUFFER_PAGE_LRU

Section 14.18.3, “InnoDB INFORMATION_SCHEMA Buffer Pool Tables”
Section 21.28.2, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table”

INNODB_BUFFER_POOL_STATS

Section 14.18.3, “InnoDB INFORMATION_SCHEMA Buffer Pool Tables”
Section 14.9.2.6, “Monitoring the Buffer Pool Using the InnoDB Standard Monitor”

INNODB_CMP

Section 14.18.1, “InnoDB INFORMATION_SCHEMA Tables about Compression”
Section 14.18.1.1, “INNODB_CMP and INNODB_CMP_RESET”
Section 14.18.1.2, “INNODB_CMPMEM and INNODB_CMPMEM_RESET”
Section 14.12.4, “Monitoring InnoDB Table Compression at Runtime”
Section 21.28.4, “The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables”
Section 14.18.1.3, “Using the Compression Information Schema Tables”

INNODB_CMP_RESET

Section 14.18.1, “InnoDB INFORMATION_SCHEMA Tables about Compression”
Section 14.18.1.1, “INNODB_CMP and INNODB_CMP_RESET”
Section 14.18.1.2, “INNODB_CMPMEM and INNODB_CMPMEM_RESET”

INNODB_CMPMEM

Section 14.18.1, “InnoDB INFORMATION_SCHEMA Tables about Compression”
Section 14.18.1.2, “INNODB_CMPMEM and INNODB_CMPMEM_RESET”
Section 21.28.5, “The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables”
Section 14.18.1.3, “Using the Compression Information Schema Tables”

INNODB_CMPMEM_RESET

Section 14.18.1.2, “INNODB_CMPMEM and INNODB_CMPMEM_RESET”

INNODB_LOCK_WAITS

Section 14.18.2, “InnoDB INFORMATION_SCHEMA Transaction and Locking Information”
Section 14.18.2.2, “InnoDB Lock and Lock-Wait Information”
Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”
Section 21.28.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”

INNODB_LOCKS

Section 14.18.2, “InnoDB INFORMATION_SCHEMA Transaction and Locking Information”
Section 14.18.2.2, “InnoDB Lock and Lock-Wait Information”
Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”
Section 21.28.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”
Section 21.28.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”
Section 21.28.8, “The INFORMATION_SCHEMA INNODB_TRX Table”

INNODB_METRICS

MySQL Glossary

INNODB_TRX

Section 14.18.2, “InnoDB INFORMATION_SCHEMA Transaction and Locking Information”
Section 14.18.2.2, “InnoDB Lock and Lock-Wait Information”
Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”
Section 21.28.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”
Section 21.28.8, “The INFORMATION_SCHEMA INNODB_TRX Table”
Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”

K

[index top]

KEY_COLUMN_USAGE

Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 21.10, “The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table”

N

[index top]

NDB_TRANSID_MYSQL_CONNECTION_MAP

Section 18.5.10.15, “The ndbinfo server_operations Table”
Section 18.5.10.16, “The ndbinfo server_transactions Table”

ndb_transid_mysql_connection_map

MySQL Server Options for NDB Cluster
Section 21.29, “NDB Cluster INFORMATION_SCHEMA Tables”

P

[index top]

PARAMETERS

Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 21.11, “The INFORMATION_SCHEMA PARAMETERS Table”
Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”

PARTITIONS

Section 19.2.7, “How MySQL Partitioning Handles NULL”

Section 19.3.4, “Obtaining Information About Partitions”
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Chapter 19, *Partitioning*
Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”

PLUGINS

Section 5.5.2, “Obtaining Server Plugin Information”
Section 21.13, “The INFORMATION_SCHEMA PLUGINS Table”

PROCESSLIST

Section 8.14, “Examining Thread Information”
Section 14.18.2.3, “Persistence and Consistency of InnoDB Transaction and Locking Information”
Section 13.7.5.30, “SHOW PROCESSLIST Syntax”
Section 21.28.8, “The INFORMATION_SCHEMA INNODB_TRX Table”
Section 21.14, “The INFORMATION_SCHEMA PROCESSLIST Table”
Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”

PROFILING

Section 13.7.5.31, “SHOW PROFILE Syntax”
Section 21.15, “The INFORMATION_SCHEMA PROFILING Table”

R

[index top]

REFERENTIAL_CONSTRAINTS

Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 21.16, “The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table”

ROUTINES

Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 13.7.5.29, “SHOW PROCEDURE STATUS Syntax”
Section 20.2.3, “Stored Routine Metadata”
Section 21.11, “The INFORMATION_SCHEMA PARAMETERS Table”
Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”

S

[index top]

SCHEMA_PRIVILEGES

Section 21.19, “The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table”

SCHEMATA

Section 6.2.2, “Grant Tables”
Section 21.18, “The INFORMATION_SCHEMA SCHEMATA Table”

SESSION_STATUS

Section 18.5, “Management of NDB Cluster”
Section 18.5.15, “NDB API Statistics Counters and Variables”
Section 18.6, “NDB Cluster Replication”
Section 13.7.5.36, “SHOW STATUS Syntax”
Section 21.8, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”

SESSION_VARIABLES

Section 13.7.5.40, “SHOW VARIABLES Syntax”

Section 21.9, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”

STATISTICS

Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 13.7.5.23, “SHOW INDEX Syntax”
Section 21.20, “The INFORMATION_SCHEMA STATISTICS Table”

T

[index top]

TABLE_CONSTRAINTS

Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 21.23, “The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table”

TABLE_PRIVILEGES

Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”

TABLES

Chapter 21, *INFORMATION_SCHEMA Tables*
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 21.21, “The INFORMATION_SCHEMA TABLES Table”

TABLESPACES

Section 21.22, “The INFORMATION_SCHEMA TABLESPACES Table”

TP_THREAD_GROUP_STATE

Section 21.30.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 5.5.3.1, “Thread Pool Components”
Section 21.30, “Thread Pool INFORMATION_SCHEMA Tables”

TP_THREAD_GROUP_STATS

Section 21.30.3, “The INFORMATION_SCHEMA TP_THREAD_STATE Table”
Section 5.5.3.1, “Thread Pool Components”
Section 21.30, “Thread Pool INFORMATION_SCHEMA Tables”

TP_THREAD_STATE

Section 5.5.3.1, “Thread Pool Components”
Section 21.30, “Thread Pool INFORMATION_SCHEMA Tables”
Section 5.5.3.2, “Thread Pool Installation”

TRIGGERS

Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 13.7.5.13, “SHOW CREATE TRIGGER Syntax”
Section 13.7.5.39, “SHOW TRIGGERS Syntax”
Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”
Section 20.3.2, “Trigger Metadata”

U

[index top]

USER_PRIVILEGES

Section 21.26, “The INFORMATION_SCHEMA USER_PRIVILEGES Table”

V

[index top]

VIEWS

Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 20.5.5, “View Metadata”

Join Types Index

A | C | E | F | I | R | S | U

A

[index top]

ALL

Section 8.2.1.16, “Avoiding Full Table Scans”
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.5, “Nested-Loop Join Algorithms”

C

[index top]

const

Section 8.8.2, “EXPLAIN Output Format”
Section 8.8.3, “Extended EXPLAIN Output Format”
NDB Cluster System Variables
Section 8.2.1.10, “ORDER BY Optimization”
Section 8.2.1.2, “Range Optimization”
Section 13.2.9, “SELECT Syntax”

E

[index top]

eq_ref

Section 8.8.2, “EXPLAIN Output Format”
Section 15.8.1, “MERGE Table Advantages and Disadvantages”
NDB Cluster System Variables
Section 8.2.2, “Subquery Optimization”

F

[index top]

fulltext

Section 8.8.2, “EXPLAIN Output Format”

I

[index top]

index
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.5, “Nested-Loop Join Algorithms”

index_merge
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.3, “Index Merge Optimization”

index_subquery
Section 8.8.2, “EXPLAIN Output Format”
Section 13.2.10.10, “Optimizing Subqueries”
Section 8.2.2, “Subquery Optimization”

R

[index top]

range
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.11, “GROUP BY Optimization”
Section 8.2.1.3, “Index Merge Optimization”
Section 8.2.1.5, “Nested-Loop Join Algorithms”
Section 8.2.1.2, “Range Optimization”

ref
Section 8.8.2, “EXPLAIN Output Format”
Section 8.8.3, “Extended EXPLAIN Output Format”
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section 15.8.1, “MERGE Table Advantages and Disadvantages”
NDB Cluster System Variables
Section 8.2.2, “Subquery Optimization”

ref_or_null
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.9, “IS NULL Optimization”
Section 8.2.2, “Subquery Optimization”

S

[index top]

system
Section 8.8.2, “EXPLAIN Output Format”
Section 8.8.3, “Extended EXPLAIN Output Format”
Section 8.2.1.2, “Range Optimization”
Section 13.2.9, “SELECT Syntax”

U

[index top]

unique_subquery
Section 8.8.2, “EXPLAIN Output Format”
Section 13.2.10.10, “Optimizing Subqueries”
Section 8.2.2, “Subquery Optimization”

Operator Index

Symbols | A | B | C | D | E | I | L | N | O | R | X

Symbols

[index top]

-
Section 12.6.1, “Arithmetic Operators”
Section 12.10, “Cast Functions and Operators”
Section 12.7, “Date and Time Functions”
Section 11.1.1, “Numeric Type Overview”
Section 19.5, “Restrictions and Limitations on Partitioning”

!
Section 9.5, “Expression Syntax”
Section 12.3.3, “Logical Operators”
Section 12.3.1, “Operator Precedence”

!=
Section 12.3.2, “Comparison Functions and Operators”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”

%
Section 12.6.1, “Arithmetic Operators”

&
Section 12.12, “Bit Functions and Operators”
Section 13.1.17, “CREATE TABLE Syntax”
Section 19.5, “Restrictions and Limitations on Partitioning”

&&
Section 12.3.3, “Logical Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”

>
Section 12.3.2, “Comparison Functions and Operators”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 8.8.2, “EXPLAIN Output Format”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”

>>
Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.5, “Restrictions and Limitations on Partitioning”

>=
Section 12.3.2, “Comparison Functions and Operators”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 8.8.2, “EXPLAIN Output Format”
Section 1.7.1, “MySQL Extensions to Standard SQL”

Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”

<

Section 12.3.2, “Comparison Functions and Operators”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 8.8.2, “EXPLAIN Output Format”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”
Section 3.3.4.6, “Working with NULL Values”

<>

Section 12.3.2, “Comparison Functions and Operators”
Section 8.8.2, “EXPLAIN Output Format”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”
Section 3.3.4.6, “Working with NULL Values”

<<

Section 12.12, “Bit Functions and Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.5, “Restrictions and Limitations on Partitioning”

<=

Section 12.3.2, “Comparison Functions and Operators”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 8.8.2, “EXPLAIN Output Format”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”

<=>

Section 12.3.2, “Comparison Functions and Operators”
Section 8.8.2, “EXPLAIN Output Format”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”
Section 12.2, “Type Conversion in Expression Evaluation”

*****

Section 12.6.1, “Arithmetic Operators”
Section 11.1.1, “Numeric Type Overview”
Section 19.5, “Restrictions and Limitations on Partitioning”

+

Section 12.6.1, “Arithmetic Operators”
Section 12.10, “Cast Functions and Operators”
Section 12.7, “Date and Time Functions”
Section 11.1.1, “Numeric Type Overview”
Section 19.5, “Restrictions and Limitations on Partitioning”

/

Section 12.6.1, “Arithmetic Operators”
Section 19.5, “Restrictions and Limitations on Partitioning”

Section 5.1.5, “Server System Variables”

:=

Section 12.3.4, “Assignment Operators”
Section 12.3.1, “Operator Precedence”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 9.4, “User-Defined Variables”

=

Section 12.3.4, “Assignment Operators”
Section 12.3.2, “Comparison Functions and Operators”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 8.8.2, “EXPLAIN Output Format”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”
Section C.4, “Restrictions on Subqueries”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 12.5.1, “String Comparison Functions”
Section 9.4, “User-Defined Variables”
Section 3.3.4.6, “Working with NULL Values”

^

Section 12.12, “Bit Functions and Operators”
Section 9.5, “Expression Syntax”
Section 12.3.1, “Operator Precedence”
Section 19.5, “Restrictions and Limitations on Partitioning”

|

Section 12.12, “Bit Functions and Operators”
Section 19.5, “Restrictions and Limitations on Partitioning”

||

Section 12.5.3, “Character Set and Collation of Function Results”
Section 10.1.8.2, “COLLATE Clause Precedence”
Section 9.5, “Expression Syntax”
Section 12.3.3, “Logical Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 5.1.8, “Server SQL Modes”

~

Section 12.12, “Bit Functions and Operators”
Section 19.5, “Restrictions and Limitations on Partitioning”

A

[index top]

AND

Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 13.1.17, “CREATE TABLE Syntax”
Section 8.2.1.3, “Index Merge Optimization”
Section 12.3.3, “Logical Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 8.2.1.2, “Range Optimization”

Section C.4, “Restrictions on Subqueries”
Section 8.2.1.15, “Row Constructor Expression Optimization”
Section 3.6.7, “Searching on Two Keys”
Section 3.3.4.2, “Selecting Particular Rows”
Section 12.5.1, “String Comparison Functions”
Section 8.2.2, “Subquery Optimization”
Section 20.5.2, “View Processing Algorithms”

B

[index top]

BETWEEN
Section 12.3.2, “Comparison Functions and Operators”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.2, “Range Optimization”
Section 12.2, “Type Conversion in Expression Evaluation”

BINARY
Section 12.10, “Cast Functions and Operators”
Section 8.4.2.2, “Optimizing for Character and String Types”
Section 3.3.4.7, “Pattern Matching”
Section 3.3.4.4, “Sorting Rows”

C

[index top]

CASE
Section 13.6.5.1, “CASE Syntax”
Section 12.4, “Control Flow Functions”
Section 9.5, “Expression Syntax”
Section 1.7.1, “MySQL Extensions to Standard SQL”

CASE value WHEN END
Section 12.4, “Control Flow Functions”

CASE WHEN END
Section 12.4, “Control Flow Functions”

CASE WHEN expr1 = expr2 THEN NULL ELSE expr1 END
Section 12.4, “Control Flow Functions”

D

[index top]

DIV
Section 12.6.1, “Arithmetic Operators”
Section 19.5, “Restrictions and Limitations on Partitioning”

E

[index top]

expr BETWEEN min AND max
Section 12.3.2, “Comparison Functions and Operators”

expr LIKE pat
Section 12.5.1, “String Comparison Functions”

expr NOT BETWEEN min AND max
Section 12.3.2, “Comparison Functions and Operators”

expr NOT LIKE pat
Section 12.5.1, “String Comparison Functions”

expr NOT REGEXP pat
Section 12.5.2, “Regular Expressions”

expr NOT RLIKE pat
Section 12.5.2, “Regular Expressions”

expr REGEXP pat
Section 12.5.2, “Regular Expressions”

expr RLIKE pat
Section 12.5.2, “Regular Expressions”

expr1 SOUNDS LIKE expr2
Section 12.5, “String Functions”

I

[index top]

IS
Section 12.3.1, “Operator Precedence”

IS boolean_value
Section 12.3.2, “Comparison Functions and Operators”

IS NOT boolean_value
Section 12.3.2, “Comparison Functions and Operators”

IS NOT NULL
Section 12.3.2, “Comparison Functions and Operators”
Section B.5.4.3, “Problems with NULL Values”
Section 8.2.1.2, “Range Optimization”
Section 3.3.4.6, “Working with NULL Values”

IS NULL
Section 12.3.2, “Comparison Functions and Operators”
Section 8.8.2, “EXPLAIN Output Format”
Section 8.2.1.9, “IS NULL Optimization”
Section B.5.4.3, “Problems with NULL Values”
Section 8.2.1.2, “Range Optimization”
Section 5.1.5, “Server System Variables”
Section 8.2.2, “Subquery Optimization”
Section 3.3.4.6, “Working with NULL Values”

L

[index top]

LIKE

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 12.10, “Cast Functions and Operators”
Section 10.1.2, “Character Sets and Collations in MySQL”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 22.4.3, “Event Pre-Filtering”
Section 21.31, “Extensions to SHOW Statements”
Section 13.8.3, “HELP Syntax”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.5.1.4, “mysql Server-Side Help”
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
Section 12.3.1, “Operator Precedence”
Section 3.3.4.7, “Pattern Matching”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”
Section 8.2.1.2, “Range Optimization”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.4, “SHOW CHARACTER SET Syntax”
Section 13.7.5.5, “SHOW COLLATION Syntax”
Section 13.7.5.6, “SHOW COLUMNS Syntax”
Section 13.7.5.15, “SHOW DATABASES Syntax”
Section 13.7.5.19, “SHOW EVENTS Syntax”
Section 13.7.5.25, “SHOW OPEN TABLES Syntax”
Section 13.7.5.29, “SHOW PROCEDURE STATUS Syntax”
Section 13.7.5.36, “SHOW STATUS Syntax”
Section 13.7.5.37, “SHOW TABLE STATUS Syntax”
Section 13.7.5.38, “SHOW TABLES Syntax”
Section 13.7.5.39, “SHOW TRIGGERS Syntax”
Section 13.7.5.40, “SHOW VARIABLES Syntax”
Section 6.2.3, “Specifying Account Names”
Section 12.5.1, “String Comparison Functions”
Section 9.1.1, “String Literals”
Section 5.1.6.1, “Structured System Variables”
Section 11.4.1, “The CHAR and VARCHAR Types”
Section 11.4.5, “The SET Type”
Section 5.1.6, “Using System Variables”

LIKE '_A%'

Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”

LIKE 'pattern'

Section 8.2.1.2, “Range Optimization”
Section 13.7.5, “SHOW Syntax”

LIKE ... ESCAPE

Section B.5.7, “Known Issues in MySQL”

N

[index top]

N % M

Section 12.6.1, “Arithmetic Operators”

Section 12.6.2, “Mathematical Functions”

N MOD M

Section 12.6.1, “Arithmetic Operators”
Section 12.6.2, “Mathematical Functions”

NOT

Section 12.3.3, “Logical Operators”
Section 5.1.8, “Server SQL Modes”

NOT LIKE

Section 3.3.4.7, “Pattern Matching”
Section 12.5.1, “String Comparison Functions”

NOT REGEXP

Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 3.3.4.7, “Pattern Matching”
Section 12.5.1, “String Comparison Functions”

NOT RLIKE

Section 3.3.4.7, “Pattern Matching”
Section 12.5.1, “String Comparison Functions”

O

[index top]

OR

Section 9.5, “Expression Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 8.2.1.3, “Index Merge Optimization”
Section 12.3.3, “Logical Operators”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 8.2.1.2, “Range Optimization”
Section 8.2.1.15, “Row Constructor Expression Optimization”
Section 3.6.7, “Searching on Two Keys”
Section 3.3.4.2, “Selecting Particular Rows”
Section 5.1.8, “Server SQL Modes”
Section 12.5.1, “String Comparison Functions”
Section 8.2.2, “Subquery Optimization”

R

[index top]

REGEXP

Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 12.3.1, “Operator Precedence”
Section 3.3.4.7, “Pattern Matching”
Section 12.5.2, “Regular Expressions”
Section C.7, “Restrictions on Character Sets”

RLIKE

Section 3.3.4.7, “Pattern Matching”

Section 12.5.2, “Regular Expressions”
Section C.7, “Restrictions on Character Sets”

X

[index top]

XOR

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 12.3.3, “Logical Operators”

Option Index

Symbols | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z

Symbols

[index top]

--

Section 1.7.2.4, “'--' as the Start of a Comment”
Section 4.8.2, “`replace` — A String-Replacement Utility”

-#

Section 4.4.1, “`comp_err` — Compile MySQL Error Message File”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 4.8.2, “`replace` — A String-Replacement Utility”
Section 5.1.4, “Server Command Options”
Section 24.5.3, “The DBUG Package”

/i

Section 2.3.5.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

/opt/mysql/server-5.5

Section 2.5.2, “Installing MySQL on Linux Using Debian Packages”

/passive

Section 2.3.5.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

/quiet

Section 2.3.5.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

/uninstall

Section 2.3.5.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

/x

Section 2.3.5.2, “Automating MySQL Installation on Microsoft Windows Using the MSI Package”

-1

Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

-?

Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 4.8.1, “perror — Explain Error Codes”
Section 4.8.2, “replace — A String-Replacement Utility”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”
Section 5.1.4, “Server Command Options”
Section 1.3.2, “The Main Features of MySQL”
Section 4.2.4, “Using Options on the Command Line”

A

[index top]

-A

Section 4.5.1.1, “mysql Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 4.6.3.4, “Other myisamchk Options”

-a

Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 16.2.2.1, “memcached Command-Line Options”
Section 7.6.4, “MyISAM Table Optimization”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.7, “mysqlslap — Load Emulation Client”

Section 4.6.3.4, “Other myisamchk Options”

--abort-on-error

Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”

--abort-slave-event-count

Section 17.1.3.3, “Replication Slave Options and Variables”

--add-drop-database

Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 4.5.4, “mysqldump — A Database Backup Program”

--add-drop-table

Section 4.5.4, “mysqldump — A Database Backup Program”

--add-drop-trigger

Section 4.5.4, “mysqldump — A Database Backup Program”

--add-locks

Section 4.5.4, “mysqldump — A Database Backup Program”

--addtodest

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--all

Section 1.4, “What Is New in MySQL 5.5”

--all-databases

Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 9.2.3, “Mapping of Identifiers to File Names”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 7.4.2, “Reloading SQL-Format Backups”
Section 2.11.1, “Upgrading MySQL”

--all-in-1

Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--all-tablespaces

Section 4.5.4, “mysqldump — A Database Backup Program”

--allow-keywords

Section 4.5.4, “mysqldump — A Database Backup Program”

--allow-suspicious-udfs

Section 5.1.4, “Server Command Options”
Section 24.4.2.6, “UDF Security Precautions”

--allowold

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--analyze

Section 7.6.4, “MyISAM Table Optimization”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.6.3.4, “Other myisamchk Options”

--ansi

Section 1.7, “MySQL Standards Compliance”
Section 5.1.4, “Server Command Options”

antonio

Section 6.5.1.4, “PAM Pluggable Authentication”

--append

Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”

--apply-slave-statements

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--audit-log

Section 6.5.2.7, “Audit Log Options and System Variables”
Section 6.5.2.1, “Installing MySQL Enterprise Audit”

--auto-generate-sql

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--auto-generate-sql-add-autoincrement

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--auto-generate-sql-execute-number

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--auto-generate-sql-guid-primary

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--auto-generate-sql-load-type

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--auto-generate-sql-secondary-indexes

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--auto-generate-sql-unique-query-number

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--auto-generate-sql-unique-write-number

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--auto-generate-sql-write-number

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--auto-rehash

Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”
Section 4.5.1.2, “mysql Commands”
Section 4.5.1.1, “mysql Options”

--auto-repair
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--auto-vertical-output
Section 4.5.1.1, “mysql Options”

--autocommit
Section 5.1.5, “Server System Variables”

B

[index top]

-B
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.5.1.1, “mysql Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”

-b
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 4.6.3.4, “Other myisamchk Options”
Section 5.1.4, “Server Command Options”

--back_log
Section 2.7, “Installing MySQL on Solaris”

--backup
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”

--backup_path
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to Fewer Nodes Than the Original

backup_path
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--backupid
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to Fewer Nodes Than the Original

--base64-output
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 4.6.7.2, “mysqlbinlog Row Event Display”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”
Section 1.4, “What Is New in MySQL 5.5”

--basedir

Section 2.10.1, “Initializing the Data Directory”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.4.3, “`mysql_install_db` — Initialize MySQL Data Directory”
Section 4.4.4, “`mysql_plugin` — Configure MySQL Server Plugins”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”
Section 18.1.6.1, “Noncompliance with SQL Syntax in NDB Cluster”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.1.4, “Server Command Options”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”

basedir

Section 2.3.7.2, “Creating an Option File”
Section 2.3.6.13, “MySQL Server Instance Config Wizard: Creating an Instance from the Command Line”
Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”
Section 2.3.8, “Troubleshooting a Microsoft Windows MySQL Server Installation”

--batch

Section 4.5.1.3, “mysql Logging”
Section 4.5.1.1, “mysql Options”

--big-tables

Section 5.1.4, “Server Command Options”

--binary-as-hex

Section 4.5.1.1, “mysql Options”

--binary-mode

Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”

--bind-address

Section B.5.2.2, “Can't connect to [local] MySQL server”
Section 5.1.9.2, “Configuring the MySQL Server to Permit IPv6 Connections”
Section 5.1.9.4, “Connecting Using IPv6 Nonlocal Host Addresses”
Section 5.1.9.3, “Connecting Using the IPv6 Local Host Address”
Section 5.1.9, “IPv6 Support”
Section 4.5.1.1, “mysql Options”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”
Section 5.1.9.5, “Obtaining an IPv6 Address from a Broker”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.1.4, “Server Command Options”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”

--binlog-do-db

Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”

Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.4.4, “The Binary Log”

--binlog-format

Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.4.4.1, “Binary Logging Formats”
Section 18.6.2, “General Requirements for NDB Cluster Replication”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 5.1.4, “Server Command Options”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”
Section 18.1.6.6, “Unsupported or Missing Features in NDB Cluster”

--binlog-ignore-db

Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.4.4, “The Binary Log”

--binlog-row-event-max-size

Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.4.4.2, “Setting The Binary Log Format”

--binlog_format

Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--blob-info

Section 18.4.10, “ndb_desc — Describe NDB Tables”

--block-search

Section 4.6.3.4, “Other myisamchk Options”

--bootstrap

Section 5.1.4, “Server Command Options”

--brief

Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--builddir

Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

C

[index top]

-C

Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.1.1, “mysql Options”

Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.1.4, “Server Command Options”

-c

Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.5.1.1, “mysql Options”
Section 2.3.6.13, “MySQL Server Instance Config Wizard: Creating an Instance from the Command Line”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Restoring to Fewer Nodes Than the Original

--cflags

Section 2.9.5, “Dealing with Problems Compiling MySQL”
Section 4.7.2, “mysql_config — Display Options for Compiling Clients”

--character-set-client-handshake

Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 5.1.4, “Server Command Options”
The cp932 Character Set

--character-set-filesystem

Section 5.1.4, “Server Command Options”

--character-set-server

Section 10.5, “Character Set Configuration”
Section 10.1.5, “Configuring Application Character Set and Collation”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 10.1.3.2, “Server Character Set and Collation”
Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--character-sets-dir

Section B.5.2.17, “Can't initialize character set”
Section 10.5, “Character Set Configuration”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”

Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 5.1.4, “Server Command Options”

--character_set_server

Section 2.9.4, “MySQL Source-Configuration Options”

--charset

Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--check

Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--check-only-changed

Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--check-orphans

Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”

--check-upgrade

Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--checkpoint

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--chroot

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 5.1.4, “Server Command Options”

CMAKE_BUILD_TYPE

Section 2.9.4, “MySQL Source-Configuration Options”

CMAKE_C_FLAGS

Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 2.9.5, “Dealing with Problems Compiling MySQL”
Section 2.9.4, “MySQL Source-Configuration Options”

CMAKE_C_FLAGS_build_type

Section 2.9.4, “MySQL Source-Configuration Options”

CMAKE_C_FLAGS_RELWITHDEBINFO

Section 2.9.4, “MySQL Source-Configuration Options”

CMAKE_CXX_FLAGS
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 2.9.5, “Dealing with Problems Compiling MySQL”
Section 2.9.4, “MySQL Source-Configuration Options”

CMAKE_CXX_FLAGS_build_type
Section 2.9.4, “MySQL Source-Configuration Options”

CMAKE_CXX_FLAGS_RELWITHDEBINFO
Section 2.9.4, “MySQL Source-Configuration Options”

CMAKE_INSTALL_PREFIX
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 2.9.3, “Installing MySQL Using a Development Source Tree”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.5, “Server System Variables”

--collation-server
Section 10.5, “Character Set Configuration”
Section 10.1.5, “Configuring Application Character Set and Collation”
Section 10.1.3.2, “Server Character Set and Collation”
Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--collation_server
Section 2.9.4, “MySQL Source-Configuration Options”

--column-names
Section 4.5.1.1, “mysql Options”
Section 4.2.5, “Program Option Modifiers”

--column-type-info
Section 8.2.1.13, “LIMIT Query Optimization”
Section 4.5.1.1, “mysql Options”

--columns
Section 4.5.5, “`mysqlimport` — A Data Import Program”

--comments
Section 4.5.1.1, “mysql Options”
Section 4.5.4, “`mysqldump` — A Database Backup Program”

--commit
Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--comp
Section 4.2.3, “Specifying Program Options”

--compact
Section 4.5.4, “`mysqldump` — A Database Backup Program”

--compatible
Section 4.5.4, “`mysqldump` — A Database Backup Program”

COMPILATION_COMMENT

Section 5.1.5, “Server System Variables”

--complete-insert

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--compr

Section 4.2.3, “Specifying Program Options”

--compress

Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 4.2.3, “Specifying Program Options”

--concurrency

Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--config-cache

Section 18.3.3, “NDB Cluster Configuration Files”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”

--config-dir

Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”

--config-file

Section 18.2.4, “Initial Startup of NDB Cluster”
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 18.3.3.1, “NDB Cluster Configuration: Basic Example”
Section 18.4.7, “`ndb_config` — Extract NDB Cluster Configuration Information”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 1.4, “What Is New in MySQL 5.5”

--config_from_node

Section 18.4.7, “`ndb_config` — Extract NDB Cluster Configuration Information”

--configdir

Section 18.3.3, “NDB Cluster Configuration Files”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”

--configinfo

Section 18.4.7, “`ndb_config` — Extract NDB Cluster Configuration Information”

--connect

Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”

--connect-delay

Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--connect-retries

Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--connect-string

Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

--connection-timeout

Section 18.4.13, “ndb_error_reporter — NDB Error-Reporting Utility”

--connections

Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--console

Section 14.20.2, “Enabling InnoDB Monitors”
Section 5.4.2.1, “Error Logging on Windows”
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 14.23, “InnoDB Troubleshooting”
Resetting the Root Password: Windows Systems
Section 5.1.4, “Server Command Options”
Section 2.3.7.5, “Starting MySQL from the Windows Command Line”
Section 2.3.7.4, “Starting the Server for the First Time”

--copy

Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--core-file

Section 24.5.1.4, “Debugging mysqld under gdb”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 5.1.4, “Server Command Options”

core-file

Section 24.5.1.3, “Using WER with PDB to create a Windows crashdump”

--core-file-size

Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 5.1.4, “Server Command Options”

--correct-checksum

Section 4.6.3.3, “myisamchk Repair Options”

--count

Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

--create

Section 4.5.7, “mysqlslap — Load Emulation Client”

--create-options

Section 4.5.4, “mysqldump — A Database Backup Program”

Section 1.4, “What Is New in MySQL 5.5”

--create-schema

Section 4.5.7, “mysqlslap — Load Emulation Client”

--cross-bootstrap

Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

--csv

Section 4.5.7, “mysqlslap — Load Emulation Client”

D

[index top]

-D

Section 10.3, “Adding a Character Set”
Section 6.4.5, “Building MySQL with Support for Encrypted Connections”
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section B.5.2.17, “Can't initialize character set”
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 23.7.1, “Compiling Programs with libmysqld”
Section 24.5.2, “Debugging a MySQL Client”
Section 2.9.2, “Installing MySQL Using a Standard Source Distribution”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.5.1.1, “mysql Options”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 24.1.1, “MySQL Threads”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Chapter 19, *Partitioning*
Section 22.2, “Performance Schema Build Configuration”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 15.6, “The ARCHIVE Storage Engine”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 15.10, “The EXAMPLE Storage Engine”
Section 15.9, “The FEDERATED Storage Engine”
Section 5.7, “Tracing mysqld Using DTrace”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”
Section 2.1.1, “Which MySQL Version and Distribution to Install”

-d

Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.6.3.1, “myisamchk General Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”

Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 4.6.3.4, “Other myisamchk Options”
Section 5.1.5, “Server System Variables”

--daemon

Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--data-file-length

Section 4.6.3.3, “myisamchk Repair Options”

--database

Section 4.5.1.1, “mysql Options”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--databases

Section 7.4.5.2, “Copy a Database from one Server to Another”
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 7.4.5.1, “Making a Copy of a Database”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 7.4.2, “Reloading SQL-Format Backups”

--datadir

Section 2.3.7.2, “Creating an Option File”
Section 2.10.1, “Initializing the Data Directory”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.4, “Server Command Options”
Section 5.6.1, “Setting Up Multiple Data Directories”

Section 5.2, “The MySQL Data Directory”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”
Section 4.2.6, “Using Option Files”

datadir

Section 2.3.7.2, “Creating an Option File”
Section 2.4.1, “General Notes on Installing MySQL on OS X”
Section 4.3.3, “`mysql.server` — MySQL Server Startup Script”
Section 2.3.8, “Troubleshooting a Microsoft Windows MySQL Server Installation”
Section C.10.6, “Windows Platform Limitations”

--db

Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”

--debug

Section 4.4.1, “`comp_err` — Compile MySQL Error Message File”
Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.8, “`mysqldumpslow` — Summarize Slow Query Log Files”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 2.3.7.5, “Starting MySQL from the Windows Command Line”
Section 24.5.3, “The DBUG Package”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”

--debug-check

Section 4.5.1.1, “mysql Options”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--debug-info

Section 4.4.1, “`comp_err` — Compile MySQL Error Message File”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”

Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”

--debug-sync-timeout

Section 2.9.4, “MySQL Source-Configuration Options”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

--default-auth

Section 23.8.14, “C API Client Plugin Functions”
Client Plugin Descriptors
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 6.5.1.1, “Native Pluggable Authentication”
Section 6.5.1.2, “Old Native Pluggable Authentication”
Section 6.3.6, “Pluggable Authentication”
Using the Authentication Plugins

--default-character-set

Section 10.5, “Character Set Configuration”
Section 10.1.5, “Configuring Application Character Set and Collation”
Section 10.1.4, “Connection Character Sets and Collations”
Section 4.5.1.5, “Executing SQL Statements from a Text File”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 6.3.1, “User Names and Passwords”
Section 1.4, “What Is New in MySQL 5.5”

--default-collation

Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--default-storage-engine

Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

Section 15.1, “Setting the Storage Engine”
Section 14.1.6, “Turning Off InnoDB”
Section 1.4, “What Is New in MySQL 5.5”

default-storage-engine

Section 15.1, “Setting the Storage Engine”

--default-table-type

Section 1.4, “What Is New in MySQL 5.5”

--default-time-zone

Section 10.6, “MySQL Server Time Zone Support”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

--default.key_buffer_size

Section 5.1.6.1, “Structured System Variables”

DEFAULT_CHARSET

Section 10.1.5, “Configuring Application Character Set and Collation”
Section 10.1.3.2, “Server Character Set and Collation”

DEFAULT_COLLATION

Section 10.1.5, “Configuring Application Character Set and Collation”
Section 10.1.3.2, “Server Character Set and Collation”

--defaults-extra-file

Section 4.2.7, “Command-Line Options that Affect Option-File Handling”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Options”
Section 4.4.3, “`mysql_install_db` — Initialize MySQL Data Directory”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 5.1.4, “Server Command Options”
Section 4.2.6, “Using Option Files”
Section 1.4, “What Is New in MySQL 5.5”

--defaults-file

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 4.2.7, “Command-Line Options that Affect Option-File Handling”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 14.9.1, “InnoDB Startup Configuration”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Options”

Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.4.3, “`mysql_install_db` — Initialize MySQL Data Directory”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 23.7.3, “Options with the Embedded Server”
Resetting the Root Password: Unix and Unix-Like Systems
Resetting the Root Password: Windows Systems
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.4, “Server Command Options”
Section 5.6.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 5.6.2.1, “Starting Multiple MySQL Instances at the Windows Command Line”
Section 2.3.7.7, “Starting MySQL as a Windows Service”
Section 2.3.6.1, “Starting the MySQL Server Instance Configuration Wizard”

--defaults-group-suffix

Section 4.2.7, “Command-Line Options that Affect Option-File Handling”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Options”
Section 4.9, “MySQL Program Environment Variables”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 5.1.4, “Server Command Options”

--delay

Section 18.4.2, “`ndbinfo_select_all` — Select From ndbinfo Tables”

--delay-key-write

Section 8.11.5, “External Locking”
Section 15.3.1, “MyISAM Startup Options”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”

--delay-key-write-for-all-tables

Section 1.4, “What Is New in MySQL 5.5”

--delay_key_write

Section 5.1.5, “Server System Variables”

Section 5.1.6, “Using System Variables”

--delayed-insert

Section 4.5.4, “mysqldump — A Database Backup Program”

--delete

Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--delete-master-logs

Section 4.5.4, “mysqldump — A Database Backup Program”

--delete-orphans

Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”

--delimiter

Section 4.5.1.1, “mysql Options”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--demangle

Section 24.5.1.5, “Using a Stack Trace”

--des-key-file

Section 12.13, “Encryption and Compression Functions”
Section 13.7.6.3, “FLUSH Syntax”
Section 5.1.4, “Server Command Options”

--descending

Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--description

Section 4.6.3.4, “Other myisamchk Options”

--detach

Section 4.5.7, “mysqlslap — Load Emulation Client”

--disable

Section 4.2.5, “Program Option Modifiers”

--disable-auto-rehash

Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”
Section 4.5.1.1, “mysql Options”

--disable-indexes

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to More Nodes Than the Original

--disable-keys

Section 4.5.4, “mysqldump — A Database Backup Program”

--disable-log-bin

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--disable-named-commands
Section 4.5.1.1, “mysql Options”

--disable-plugin_name
Section 5.5.1, “Installing and Uninstalling Plugins”

--disable-ssl
Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”

--disconnect-slave-event-count
Section 17.1.3.3, “Replication Slave Options and Variables”

--disk
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--dont_ignore_systab_0
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--drop-source
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”

--dry-scp
Section 18.4.13, “ndb_error_reporter — NDB Error-Reporting Utility”

--dryrun
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--dump
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--dump-date
Section 4.5.4, “mysqldump — A Database Backup Program”

--dump-file
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”

--dump-slave
Section 4.5.4, “mysqldump — A Database Backup Program”

E

[index top]

-E
Section 4.5.1.1, “mysql Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.4, “mysqldump — A Database Backup Program”

-e
Section 7.6.2, “How to Check MyISAM Tables for Errors”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”

Section 13.2.7, “LOAD XML Syntax”
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.5.1.1, “mysql Options”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.4.5, “`ndb_mgm` — The NDB Cluster Management Client”
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”
Section 4.6.3.5, “Obtaining Table Information with myisamchk”
Section 18.2.6, “Safe Shutdown and Restart of NDB Cluster”
Section 4.2.4, “Using Options on the Command Line”
Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”

--embedded

Section 4.7.2, “`mysql_config` — Display Options for Compiling Clients”

--embedded-libs

Section 4.7.2, “`mysql_config` — Display Options for Compiling Clients”

--enable-64bit

Section 16.2.1, “Installing `memcached`”

--enable-cleartext-plugin

Section 6.5.1.3, “Client-Side Cleartext Pluggable Authentication”
Section 4.5.1.1, “mysql Options”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 6.5.1.4, “PAM Pluggable Authentication”

--enable-dtrace

Section 16.2.1, “Installing `memcached`”
Section 16.2.2.6, “Using `memcached` and DTrace”

--enable-locking

Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--enable-memcache

Section 16.2.3.6, “Using MySQL and `memcached` with PHP”

--enable-named-pipe

Section B.5.2.2, “Can't connect to [local] MySQL server”
Section 4.2.2, “Connecting to the MySQL Server”
Section 2.3.7.3, “Selecting a MySQL Server Type”
Section 5.1.4, “Server Command Options”
Section 1.3.2, “The Main Features of MySQL”

--enable-plugin_name
Section 5.5.1, “Installing and Uninstalling Plugins”

--enable-pstack
Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--enable-threads
Section 16.2.1, “Installing `memcached`”

ENABLE_DEBUG_SYNC
Section 2.9.4, “MySQL Source-Configuration Options”

ENABLED_LOCAL_INFILE
Section 2.9.4, “MySQL Source-Configuration Options”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

--engine
Section 4.5.7, “`mysqlslap` — Load Emulation Client”

--engine-condition-pushdown
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”

--env
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

--error-insert
Section 18.4.15, “`ndb_move_data` — NDB Data Copy Utility”

--event-scheduler
Section 20.4.2, “Event Scheduler Configuration”
Section 5.1.4, “Server Command Options”

event-scheduler
Section 20.4.2, “Event Scheduler Configuration”

--events
Section 7.4.5.3, “Dumping Stored Programs”
Section 7.4.5.4, “Dumping Table Definitions and Content Separately”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 2.11.1, “Upgrading MySQL”

--example
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”

--exclude-*
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”

--exclude-databases
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”

--exclude-intermediate-sql-tables
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”

--exclude-missing-columns

Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--exclude-missing-tables

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--exclude-tables

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--excludedbs

Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--excludetables

Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--execute

Section 4.5.1.3, “mysql Logging”
Section 4.5.1.1, “mysql Options”
Section 18.4.5, “ndb_mgm — The NDB Cluster Management Client”
Section 4.2.4, “Using Options on the Command Line”
Section 18.5.3.2, “Using The NDB Cluster Management Client to Create a Backup”

--exit-info

Section 5.1.4, “Server Command Options”

--extend-check

Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.3, “myisamchk Repair Options”

--extended

Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--extended-insert

Section 4.5.4, “mysqldump — A Database Backup Program”

--external-locking

Section 8.11.5, “External Locking”
Section 15.3.1, “MyISAM Startup Options”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 8.12.1, “System Factors”
Section 1.4, “What Is New in MySQL 5.5”

--extra-file

Section 4.7.3, “my_print_defaults — Display Options from Option Files”

--extra-node-info

Section 18.4.10, “ndb_desc — Describe NDB Tables”

--extra-partition-info

Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.5.10.4, “The ndbinfo cluster_operations Table”

Section 18.5.10.15, “The ndbinfo server_operations Table”

F

[index top]

-F

Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.1.2, “mysql Commands”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”

-f

Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.2.4, “Initial Startup of NDB Cluster”
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.5.1.1, “mysql Options”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 24.5.1.5, “Using a Stack Trace”

--fast

Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--federated

Section 15.9, “The FEDERATED Storage Engine”

--fields

Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--fields-enclosed-by

Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--fields-escaped-by

Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”

Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”

--fields-optionally-enclosed-by

Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--fields-terminated-by

Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--fields-xxx

Section 4.5.4, “mysqldump — A Database Backup Program”

--first-slave

Section 4.5.4, “mysqldump — A Database Backup Program”
Section 1.4, “What Is New in MySQL 5.5”

--fix-db-names

Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--fix-table-names

Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--flush

Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”

--flush-logs

Section 7.3.1, “Establishing a Backup Policy”
Section 5.4, “MySQL Server Logs”
Section 4.5.4, “mysqldump — A Database Backup Program”

--flush-privileges

Section 4.5.4, “mysqldump — A Database Backup Program”

--flush_time

Section 24.1.1, “MySQL Threads”

--flushlog

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--force

Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 24.1.2, “The MySQL Test Suite”
Section 3.5, “Using mysql in Batch Mode”

--force-if-open

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--force-read

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--foreground

Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--format

Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--fs

Section 18.4.13, “ndb_error_reporter — NDB Error-Reporting Utility”

G

[index top]

-G

Section 4.5.1.1, “mysql Options”

-g

Section 24.5.1.1, “Compiling MySQL for Debugging”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.5.1.1, “mysql Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”

--gci

Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--gci64

Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--gdb

Section 24.5.1.4, “Debugging mysqld under gdb”
Section 5.1.4, “Server Command Options”

--general-log

Section 5.1.4, “Server Command Options”

--general_log

Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

Section 5.4.3, “The General Query Log”

--general_log_file

Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 5.4.3, “The General Query Log”

H

[index top]

-H

Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Options”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

-h

Section 4.2.2, “Connecting to the MySQL Server”
Section 4.2.1, “Invoking MySQL Programs”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”
Section 5.1.4, “Server Command Options”
Section 1.2, “Typographical and Syntax Conventions”
Section 4.2.4, “Using Options on the Command Line”

--header

Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--header_file

Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--HELP

Section 4.6.3.1, “myisamchk General Options”

--help

Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”

Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.6.13, “mysql_setpermission — Interactively Set Permissions in Grant Tables”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.13, “ndb_error_reporter — NDB Error-Reporting Utility”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 4.1, “Overview of MySQL Programs”
Section 4.8.1, “perror — Explain Error Codes”
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”
Section 5.1.4, “Server Command Options”
Section 2.10.3, “Testing the Server”
Section 1.3.2, “The Main Features of MySQL”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”
Chapter 3, *Tutorial*
Section 4.2.6, “Using Option Files”
Section 4.2.4, “Using Options on the Command Line”

--hex

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--hex-blob

Section 4.5.4, “mysqldump — A Database Backup Program”

--hexdump

Section 4.6.7.1, “mysqlbinlog Hex Dump Format”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--host

Section 5.1.9.2, “Configuring the MySQL Server to Permit IPv6 Connections”
Section 4.2.2, “Connecting to the MySQL Server”
Section 4.2.1, “Invoking MySQL Programs”

Section 4.5.1.1, “mysql Options”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.6.13, “mysql_setpermission — Interactively Set Permissions in Grant Tables”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 4.2.9, “Option Defaults, Options Expecting Values, and the = Sign”
Section 5.1.4, “Server Command Options”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 1.2, “Typographical and Syntax Conventions”
Section 5.6.4, “Using Client Programs in a Multiple-Server Environment”
Section 4.2.6, “Using Option Files”
Section 4.2.4, “Using Options on the Command Line”

--hostname

Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--howto

Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--html

Section 4.5.1.1, “mysql Options”

I

[index top]

-I

Section 23.8.4.1, “Building C API Client Programs”
Section 16.2.2.1, “memcached Command-Line Options”
Section 16.2.5, “memcached FAQ”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.8.1, “perror — Explain Error Codes”
Section 4.8.2, “replace — A String-Replacement Utility”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”

-i

Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 7.6.2, “How to Check MyISAM Tables for Errors”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysql Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.4, “mysqldump — A Database Backup Program”

Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 24.5.1.3, “Using WER with PDB to create a Windows crashdump”

--i-am-a-dummy

Section 4.5.1.1, “mysql Options”
Using the --safe-updates Option

--id

Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--ignore

Section 4.5.5, “mysqlimport — A Data Import Program”

--ignore-builtin-innodb

Section 14.17, “InnoDB Startup Options and System Variables”
Section 1.4, “What Is New in MySQL 5.5”

--ignore-lines

Section 4.5.5, “mysqlimport — A Data Import Program”

--ignore-spaces

Section 4.5.1.1, “mysql Options”

--ignore-table

Section 4.5.4, “mysqldump — A Database Backup Program”

--in_file

Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--include

Section 4.7.2, “mysql_config — Display Options for Compiling Clients”

--include-*

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--include-databases

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--include-master-host-port

Section 4.5.4, “mysqldump — A Database Backup Program”

--include-tables

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--info

Section 4.8.1, “perror — Explain Error Codes”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”

--Information

Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”

--information

Section 4.6.3.2, “myisamchk Check Options”

--init-command

Section 4.5.1.1, “mysql Options”
Section 17.4.1.26, “Replication of Server-Side Help Tables”

--init-file

Section 22.4, “Performance Schema Runtime Configuration”
Resetting the Root Password: Unix and Unix-Like Systems
Resetting the Root Password: Windows Systems
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 15.4, “The MEMORY Storage Engine”

--init_connect

Section 10.1.5, “Configuring Application Character Set and Collation”

--initial

Section 18.5.13.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 18.1.6.10, “Limitations Relating to Multiple NDB Cluster Nodes”
Section 18.3.3, “NDB Cluster Configuration Files”
Section 18.3.2.1, “NDB Cluster Data Node Configuration Parameters”
Section 18.5.12.3, “NDB Cluster Disk Data Storage Requirements”
Section 18.3.2.2, “NDB Cluster Management Node Configuration Parameters”
Section 18.3.2.3, “NDB Cluster SQL Node and API Node Configuration Parameters”
Section 18.4.7, “`ndb_config` — Extract NDB Cluster Configuration Information”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”
Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”
Section 18.4.3, “`ndbmtd` — The NDB Cluster Data Node Daemon (Multi-Threaded)”
Section 18.3.2.4, “Other NDB Cluster Configuration Parameters”
Section 18.3.2, “Overview of NDB Cluster Configuration Parameters, Options, and Variables”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Restoring to Fewer Nodes Than the Original
Section 18.5.1, “Summary of NDB Cluster Start Phases”

--initial-start

Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”

--innodb

Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.1.6, “Turning Off InnoDB”

--innodb-status-file

Section 14.17, “InnoDB Startup Options and System Variables”

innodb-status-file

Section 14.20.2, “Enabling InnoDB Monitors”

--innodb-xxx
Section 5.1.4, “Server Command Options”

--innodb_checksums
Section 14.17, “InnoDB Startup Options and System Variables”

--innodb_file_per_table
Section 14.10.4.1, “Enabling and Disabling File-Per-Table Tablespaces”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 5.1.4, “Server Command Options”
Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”

innodb_file_per_table
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 5.1.4, “Server Command Options”

--innodb_rollback_on_timeout
Section 14.23.4, “InnoDB Error Handling”
Section 14.17, “InnoDB Startup Options and System Variables”

--innodb_support_xa
Section 5.4.4, “The Binary Log”

--insert-ignore
Section 4.5.4, “`mysqldump` — A Database Backup Program”

--install
Section 4.2.7, “Command-Line Options that Affect Option-File Handling”
Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”
Section 5.1.4, “Server Command Options”
Section 5.6.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 2.3.7.7, “Starting MySQL as a Windows Service”

--install-manual
Section 5.1.4, “Server Command Options”
Section 5.6.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 2.3.7.7, “Starting MySQL as a Windows Service”

INSTALL_LAYOUT
Section 2.9.4, “MySQL Source-Configuration Options”
Section 5.1.5, “Server System Variables”

INSTALL_SECURE_FILE_PRIV_EMBEDDEDDIR
Section 2.9.4, “MySQL Source-Configuration Options”
Section 5.1.5, “Server System Variables”

INSTALL_SECURE_FILE_PRIVDIR
Section 5.1.5, “Server System Variables”

--interactive
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”

--iterations
Section 4.5.7, “mysqlslap — Load Emulation Client”

J

[index top]

-j
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--join
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”

K

[index top]

-K
Section 4.5.4, “mysqldump — A Database Backup Program”

-k
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

--keep_files_on_create
Section 13.1.17, “CREATE TABLE Syntax”

--keepold
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--key_buffer_size
Section 5.1.4, “Server Command Options”

--keys
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

--keys-used
Section 4.6.3.3, “myisamchk Repair Options”

L

[index top]

-L
Section 23.8.4.1, “Building C API Client Programs”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.5.1.1, “mysql Options”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 2.12.3, “Problems Using the Perl DBI/DBD Interface”
Section 10.2, “Setting the Error Message Language”

-I

Section 23.8.4.1, “Building C API Client Programs”
Section 23.8.13, “C API Embedded Server Function Descriptions”
Section 23.8.6, “C API Function Overview”
Section 16.2.2.1, “`memcached` Command-Line Options”
Section 4.6.2, “`myisam_ftdump` — Display Full-Text Index information”
Section 4.6.3.3, “myisamchk Repair Options”
Section 23.8.7.39, “mysql_library_end()”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.8, “`mysqldumpslow` — Summarize Slow Query Log Files”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 18.4.15, “`ndb_move_data` — NDB Data Copy Utility”
Section 18.4.20, “`ndb_redo_log_reader` — Check and Print Content of Cluster Redo Log”
Section 18.4.22, “`ndb_select_all` — Print Rows from an NDB Table”
Section 18.4.24, “`ndb_show_tables` — Display List of NDB Tables”
Section 18.4.2, “`ndbinfo_select_all` — Select From ndbinfo Tables”
Section 5.1.4, “Server Command Options”
Section 5.4.3, “The General Query Log”

--language

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 10.2, “Setting the Error Message Language”
Section 1.4, “What Is New in MySQL 5.5”

--large-pages

Section 8.12.4.2, “Enabling Large Page Support”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

--lc-messages

Section 5.1.4, “Server Command Options”

--lc-messages-dir

Section 5.1.4, “Server Command Options”

--ldata

Section 4.4.3, “`mysql_install_db` — Initialize MySQL Data Directory”

--ledir

Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”

--length

Section 4.6.2, “`myisam_ftdump` — Display Full-Text Index information”

--libmysqld-libs

Section 4.7.2, “`mysql_config` — Display Options for Compiling Clients”

--libs

Section 4.7.2, “`mysql_config` — Display Options for Compiling Clients”

--libs_r

Section 4.7.2, “`mysql_config` — Display Options for Compiling Clients”

--line-numbers

Section 4.5.1.1, “mysql Options”

--lines-terminated-by

Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”

--loadqueries

Section 18.4.25, “`ndb_size.pl` — NDBCLUSTER Size Requirement Estimator”

--local

Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

--local-infile

Section 13.2.7, “LOAD XML Syntax”
Section 4.5.1.1, “mysql Options”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

--local-load

Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”

--local-service

Section 5.1.4, “Server Command Options”
Section 2.3.7.7, “Starting MySQL as a Windows Service”

--lock

Section 18.4.22, “`ndb_select_all` — Print Rows from an NDB Table”

--lock-all-tables

Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 1.4, “What Is New in MySQL 5.5”

--lock-tables

Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”

--log

Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 5.1.4, “Server Command Options”
Section 5.4.3, “The General Query Log”

--log-bin

Section 7.3.3, “Backup Strategy Summary”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 20.7, “Binary Logging of Stored Programs”
Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 7.2, “Database Backup Methods”
Section 7.3.1, “Establishing a Backup Policy”
Section 17.4.5, “How to Report Replication Bugs or Problems”
Section B.5.7, “Known Issues in MySQL”

Section 18.1.6.1, “Noncompliance with SQL Syntax in NDB Cluster”
Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”
Section 13.4.1.1, “PURGE BINARY LOGS Syntax”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 17.3.6, “Switching Masters During Failover”
Section 5.4.4, “The Binary Log”
Section 17.4.4, “Troubleshooting Replication”
Section 17.4.3, “Upgrading a Replication Setup”
Section 7.3.2, “Using Backups for Recovery”

--log-bin-index

Section 17.1.3.4, “Binary Log Options and Variables”
Section 18.1.6.1, “Noncompliance with SQL Syntax in NDB Cluster”
Section 5.4.4, “The Binary Log”

--log-bin-trust-function-creators

Section 17.1.3.4, “Binary Log Options and Variables”
Section 20.7, “Binary Logging of Stored Programs”
Section 1.4, “What Is New in MySQL 5.5”

--log-bin-trust-routine-creators

Section 1.4, “What Is New in MySQL 5.5”

--log-bin-use-v1-events

Section 17.1.3.4, “Binary Log Options and Variables”

--log-bin-use-v1-row-events

Section 17.1.3.4, “Binary Log Options and Variables”
MySQL Server Options for NDB Cluster
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

--log-error

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 5.4.2.2, “Error Logging on Unix and Unix-Like Systems”
Section 5.4.2.1, “Error Logging on Windows”
Section 5.4.2.3, “Error Logging to the System Log”
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.2.9, “Option Defaults, Options Expecting Values, and the = Sign”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.1.4, “Server Command Options”
Section 5.4.7, “Server Log Maintenance”
Section 2.3.7.5, “Starting MySQL from the Windows Command Line”
Section 2.3.7.4, “Starting the Server for the First Time”

--log-isam

Section 4.6.4, “`myisamlog` — Display MyISAM Log File Contents”
Section 5.1.4, “Server Command Options”

--log-long-format

Section 5.1.4, “Server Command Options”

Section 1.4, “What Is New in MySQL 5.5”

--log-name

Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

--log-output

Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section 5.4.3, “The General Query Log”
Section 5.4.5, “The Slow Query Log”

--log-queries-not-using-indexes

Section 5.1.4, “Server Command Options”

--log-short-format

Section 5.1.4, “Server Command Options”
Section 5.4.5, “The Slow Query Log”

--log-slave-updates

Section 17.4.5, “How to Report Replication Bugs or Problems”
Section 17.3.5, “Improving Replication Performance”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
MySQL Server Options for NDB Cluster
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
NDB Cluster System Variables
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.3.6, “Switching Masters During Failover”
Section 5.4.4, “The Binary Log”

--log-slow-admin-statements

Section 5.1.4, “Server Command Options”
Section 5.4.5, “The Slow Query Log”

--log-slow-queries

Section 5.1.4, “Server Command Options”
Section 5.4.5, “The Slow Query Log”

--log-slow-slave-statements

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.4.5, “The Slow Query Log”

--log-tc

Section 5.1.4, “Server Command Options”

--log-tc-size

Section 5.1.4, “Server Command Options”
Section 5.1.7, “Server Status Variables”

--log-update

Section 1.4, “What Is New in MySQL 5.5”

--log-warnings

Section B.5.2.11, “Communication Errors and Aborted Connections”
Section 5.4.2.4, “Error Log Filtering”

Section 5.4.4.3, “Mixed Binary Logging Format”
Section B.5.2.9, “MySQL server has gone away”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--loops

Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 18.4.2, “ndbinfo_select_all — Select From ndbinfo Tables”

--loose

Section 4.2.5, “Program Option Modifiers”

--loose-opt_name

Section 4.2.6, “Using Option Files”

--lossy-conversions

Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--low-priority

Section 4.5.5, “mysqlimport — A Data Import Program”

--low-priority-updates

Section 8.11.3, “Concurrent Inserts”
Section 13.2.5, “INSERT Syntax”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section 5.1.4, “Server Command Options”
Section 8.11.2, “Table Locking Issues”

--lower-case-table-names

Section 9.2.2, “Identifier Case Sensitivity”

M

[index top]

-M

Section 16.2.2.1, “memcached Command-Line Options”

-m

Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--malloc-lib

Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

--master-connect-retry

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”

Section 1.4, “What Is New in MySQL 5.5”

--master-data

Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”
Section 7.3.1, “Establishing a Backup Policy”
Section 5.4, “MySQL Server Logs”
Section 4.5.4, “`mysqldump` — A Database Backup Program”

--master-host

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 1.4, “What Is New in MySQL 5.5”

--master-info-file

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.2.2.2, “Slave Status Logs”

--master-password

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 1.4, “What Is New in MySQL 5.5”

--master-port

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 1.4, “What Is New in MySQL 5.5”

--master-retry-count

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 17.1.3.3, “Replication Slave Options and Variables”

--master-ssl

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-ca

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-capath

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-cert

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-cipher

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 1.4, “What Is New in MySQL 5.5”

--master-ssl-key

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 1.4, “What Is New in MySQL 5.5”

--master-user

Section 17.1.3.3, “Replication Slave Options and Variables”

Section 1.4, “What Is New in MySQL 5.5”

--master-xxx
Section 1.4, “What Is New in MySQL 5.5”

--max
Section 4.2.8, “Using Options to Set Program Variables”

--max-binlog-dump-events
Section 17.1.3.4, “Binary Log Options and Variables”

--max-binlog-size
Section 17.1.3.3, “Replication Slave Options and Variables”

--max-record-length
Section 4.6.3.3, “myisamchk Repair Options”
Section 13.7.2.5, “REPAIR TABLE Syntax”

--max-relay-log-size
Section 17.1.3.3, “Replication Slave Options and Variables”

--max-seeks-for-key
Section 8.2.1.16, “Avoiding Full Table Scans”
Section B.5.5, “Optimizer-Related Issues”

--max_a
Section 4.2.8, “Using Options to Set Program Variables”

--max_join_size
Using the --safe-updates Option

--maximum
Section 4.2.5, “Program Option Modifiers”

--maximum-back_log
Section 4.2.5, “Program Option Modifiers”

--maximum-innodb_log_file_size
Section 5.1.6, “Using System Variables”

--maximum-max_heap_table_size
Section 4.2.5, “Program Option Modifiers”

--maximum-query_cache_size
Section 8.10.3.3, “Query Cache Configuration”

--maximum-var_name
Section 5.1.4, “Server Command Options”
Section 5.1.6, “Using System Variables”

--medium-check
Section 4.6.3.2, “myisamchk Check Options”

Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--memlock

Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 14.10.3, “Using Raw Disk Partitions for the System Tablespace”

--method

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--min-examined-row-limit

Section 5.1.4, “Server Command Options”

--mount

Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

--my-plugin

Section 5.5.1, “Installing and Uninstalling Plugins”

--my-print-defaults

Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”

--my_plugin

Section 5.5.1, “Installing and Uninstalling Plugins”

--mycnf

Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

--myisam-block-size

Section 8.10.2.5, “Key Cache Block Size”
Section 5.1.4, “Server Command Options”

--myisam-recover

Section 5.1.4, “Server Command Options”

--myisam-recover-options

Section 15.3.1, “MyISAM Startup Options”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section B.5.2.19, “Table-Corruption Issues”
Section 15.3, “The MyISAM Storage Engine”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”

--myisam_sort_buffer_size

Section 4.6.3.6, “myisamchk Memory Usage”

MYSQL_ALLOW_EMPTY_PASSWORD

Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_DATABASE

Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_LOG_CONSOLE
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_MAINTAINER_MODE
Section 2.9.5, “Dealing with Problems Compiling MySQL”

MYSQL_PASSWORD
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_RANDOM_ROOT_PASSWORD
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_ROOT_HOST
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_ROOT_PASSWORD
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

MYSQL_TCP_PORT
Section 2.9.3, “Installing MySQL Using a Development Source Tree”
Section 2.9.4, “MySQL Source-Configuration Options”

MYSQL_UNIX_ADDR
Section B.5.3.6, “How to Protect or Change the MySQL Unix Socket File”
Section 2.9.3, “Installing MySQL Using a Development Source Tree”
Section 2.9.4, “MySQL Source-Configuration Options”

MYSQL_USER
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

--mysqladmin
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”

--mysqld
Section 4.4.4, “`mysql_plugin` — Configure MySQL Server Plugins”
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”

--mysqld-version
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”

N

[index top]

-N
Section 4.4.1, “`comp_err` — Compile MySQL Error Message File”
Section 4.5.1.1, “mysql Options”
Section 4.5.4, “`mysqldump` — A Database Backup Program”

-n
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 16.2.2.1, “`memcached` Command-Line Options”

Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.5.1.1, “mysql Options”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”

--name

Section 2.5.3.1, “Basic Steps for MySQL Server Deployment with Docker”

--name_file

Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--named-commands

Section 4.5.1.1, “mysql Options”

--ndb

Section 4.8.1, “perror — Explain Error Codes”

--ndb-batch-size

MySQL Server Options for NDB Cluster

--ndb-blob-read-batch-bytes

MySQL Server Options for NDB Cluster

--ndb-blob-write-batch-bytes

MySQL Server Options for NDB Cluster

--ndb-cluster

Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”

--ndb-cluster-connection-pool

MySQL Server Options for NDB Cluster

--ndb-connectstring

Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Server Options for NDB Cluster
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 18.6.5, “Preparing the NDB Cluster for Replication”
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”
Restoring to Fewer Nodes Than the Original
Restoring to More Nodes Than the Original

--ndb-deferred-constraints

MySQL Server Options for NDB Cluster

--ndb-distribution

MySQL Server Options for NDB Cluster

--ndb-force-send

Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”

--ndb-index-stat-enable

Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”

--ndb-log-apply-status

MySQL Server Options for NDB Cluster
NDB Cluster System Variables

--ndb-log-empty-epochs

MySQL Server Options for NDB Cluster
Section 18.6.4, “NDB Cluster Replication Schema and Tables”

--ndb-log-empty-update

MySQL Server Options for NDB Cluster

--ndb-log-orig

MySQL Server Options for NDB Cluster
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
NDB Cluster System Variables

--ndb-log-transaction-id

Section 17.1.3.4, “Binary Log Options and Variables”
MySQL Server Options for NDB Cluster
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
NDB Cluster System Variables

--ndb-log-update-as-write

Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
Section 5.4.4, “The Binary Log”

--ndb-log-updated-only

Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

--ndb-mgmd-host

MySQL Server Options for NDB Cluster
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

--ndb-nodegroup-map

Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”

--ndb-nodeid

MySQL Server Options for NDB Cluster
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”

Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

--ndb-optimized-node-selection

Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

--ndb-transid-mysql-connection-map

Section 21.29.2, “The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table”

ndb-transid-mysql-connection-map

MySQL Server Options for NDB Cluster

--ndb-use-exact-count

Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”

--ndb-wait-connected

MySQL Server Options for NDB Cluster

--ndb-wait-setup

MySQL Server Options for NDB Cluster

--ndb_optimization_delay

MySQL Server Options for NDB Cluster
Section 13.7.2.4, “OPTIMIZE TABLE Syntax”

--ndbcluster

Section 18.3, “Configuration of NDB Cluster”
Section 18.2.2.1, “Installing NDB Cluster on Windows from a Binary Release”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Server Options for NDB Cluster
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 18.1.1, “NDB Cluster Core Concepts”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 18.3.3.2, “Recommended Starting Configuration for NDB Cluster”
Section 13.7.5.17, “SHOW ENGINES Syntax”

--ndbinfo-database

NDB Cluster System Variables

--ndbinfo-table-prefix

NDB Cluster System Variables

net_retry_count

Section 17.2.1, “Replication Implementation Details”

net_write_timeout

Section 17.2.1, “Replication Implementation Details”

--network

Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”

--nice
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

--no-auto-rehash
Section 4.5.1.1, “mysql Options”

--no-autocommit
Section 4.5.4, “mysqldump — A Database Backup Program”

--no-beep
Section 4.5.1.1, “mysql Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

--no-binlog
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--no-contact
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--no-create-db
Section 4.5.4, “mysqldump — A Database Backup Program”

--no-create-info
Section 7.4.5.4, “Dumping Table Definitions and Content Separately”
Section 4.5.4, “mysqldump — A Database Backup Program”

--no-data
Section 7.4.5.4, “Dumping Table Definitions and Content Separately”
Section 4.5.4, “mysqldump — A Database Backup Program”

--no-defaults
Section 4.2.7, “Command-Line Options that Affect Option-File Handling”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Options”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 5.1.4, “Server Command Options”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 4.2.6, “Using Option Files”

--no-drop
Section 4.5.7, “mysqlslap — Load Emulation Client”

--no-log

Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”

--no-named-commands

Section 4.5.1.1, “mysql Options”
Section 1.4, “What Is New in MySQL 5.5”

--no-nodeid-checks

Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

--no-pager

Section 4.5.1.1, “mysql Options”
Section 1.4, “What Is New in MySQL 5.5”

--no-restore-disk-objects

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--no-set-names

Section 4.5.4, “mysqldump — A Database Backup Program”

--no-symlinks

Section 4.6.3.3, “myisamchk Repair Options”

--no-tablespaces

Section 4.5.4, “mysqldump — A Database Backup Program”

--no-tee

Section 4.5.1.1, “mysql Options”
Section 1.4, “What Is New in MySQL 5.5”

--no-upgrade

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--nodaemon

Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--nodata

Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--nodeid

Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to Fewer Nodes Than the Original
Restoring to More Nodes Than the Original

--nodes

Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--noindices

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--nostart

Section 18.5.2, “Commands in the NDB Cluster Management Client”

Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--not-started

Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--nowait-nodes

Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”
Section 18.4.1, “ndbd — The NDB Cluster Data Node Daemon”

--number-char-cols

Section 4.5.7, “mysqlslap — Load Emulation Client”

--number-int-cols

Section 4.5.7, “mysqlslap — Load Emulation Client”

--number-of-queries

Section 4.5.7, “mysqlslap — Load Emulation Client”

--numeric-dump-file

Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”

O

[index top]

-O

Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 1.4, “What Is New in MySQL 5.5”

-o

Section 23.7.1, “Compiling Programs with libmysqld”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysql Options”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 8.12.2, “Optimizing Disk I/O”

--offset

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--old-alter-table

Section 5.1.4, “Server Command Options”

--old-style-user-limits

Section 5.1.4, “Server Command Options”
Section 6.3.4, “Setting Account Resource Limits”

--old_server

Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

ON

Section 3.3.4.9, “Using More Than one Table”

--one-database

Section 4.5.1.1, “mysql Options”

--one-thread

Section 5.1.4, “Server Command Options”

--only-print

Section 4.5.7, “mysqlslap — Load Emulation Client”

--open-files-limit

Section B.5.2.18, “File Not Found and Similar Errors”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

open-files-limit

Section B.5.2.7, “Too many connections”

--opt

Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 4.5.4, “mysqldump — A Database Backup Program”

--opt_name

Section 4.2.6, “Using Option Files”

--optimize

Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--order

Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--order-by-primary

Section 4.5.4, “mysqldump — A Database Backup Program”

--out_dir

Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--out_file

Section 4.4.1, “comp_err — Compile MySQL Error Message File”

P

[index top]

-P

Section 4.2.2, “Connecting to the MySQL Server”
Section 4.2.1, “Invoking MySQL Programs”

Section 16.2.2.1, “memcached Command-Line Options”
Section 4.5.1.1, “mysql Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 5.1.4, “Server Command Options”

-p

Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 6.3.2, “Adding User Accounts”
Section 4.2.2, “Connecting to the MySQL Server”
Section 2.11.2, “Downgrading MySQL”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
Section 4.2.1, “Invoking MySQL Programs”
Section 19.2.5, “KEY Partitioning”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysql Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section B.5.2.5, “Password Fails When Entered Interactively”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 2.3.7.7, “Starting MySQL as a Windows Service”
Section 2.3.7.5, “Starting MySQL from the Windows Command Line”
Section 2.3.7.8, “Testing The MySQL Installation”
Section 2.10.3, “Testing the Server”
Section 18.5.10.4, “The ndbinfo cluster_operations Table”
Section 18.5.10.15, “The ndbinfo server_operations Table”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 2.11.1, “Upgrading MySQL”
Section 2.3.10, “Upgrading MySQL on Windows”
Section 6.3.1, “User Names and Passwords”

Section 4.2.4, “Using Options on the Command Line”
Section 2.3.9, “Windows Postinstallation Procedures”

--pager

Section 4.5.1.2, “mysql Commands”
Section 4.5.1.1, “mysql Options”

--parallel-recover

Section 4.6.3.3, “myisamchk Repair Options”

--parallelism

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

parallelism

Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--parsable

Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”

--partition

Section 5.1.4, “Server Command Options”

--password

Section 6.3.2, “Adding User Accounts”
Section 4.2.2, “Connecting to the MySQL Server”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 7.3, “Example Backup and Recovery Strategy”
Section 4.2.1, “Invoking MySQL Programs”
Section 4.5.1.1, “mysql Options”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.6.13, “mysql_setpermission — Interactively Set Permissions in Grant Tables”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section B.5.2.5, “Password Fails When Entered Interactively”
Section 6.5.1.7, “Test Pluggable Authentication”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 6.3.1, “User Names and Passwords”
Section 4.2.4, “Using Options on the Command Line”

--performance_schema_max_mutex_classes

Section 22.7, “Performance Schema Status Monitoring”

--performance_schema_max_mutex_instances

Section 22.7, “Performance Schema Status Monitoring”

--pid-file

Section 5.4.2.1, “Error Logging on Windows”

Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

pid-file

Section 4.3.3, “mysql.server — MySQL Server Startup Script”

--pipe

Section 4.2.2, “Connecting to the MySQL Server”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 2.3.7.8, “Testing The MySQL Installation”

--plan

Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--plugin

Section 5.1.4, “Server Command Options”

--plugin-dir

Section 23.8.14, “C API Client Plugin Functions”
Client Plugin Descriptors
Section 4.5.1.1, “mysql Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 6.3.6, “Pluggable Authentication”
Section C.9, “Restrictions on Pluggable Authentication”
Using the Authentication Plugins

--plugin-ini

Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”

--plugin-innodb_file_per_table

Section 5.1.4, “Server Command Options”

--plugin-load

Section 6.5.2.7, “Audit Log Options and System Variables”
Section 13.7.3.3, “INSTALL PLUGIN Syntax”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 6.5.2.1, “Installing MySQL Enterprise Audit”

Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 6.5.1.4, “PAM Pluggable Authentication”
Section 24.2.3, “Plugin API Components”
Section 24.2.4.2, “Plugin Data Structures”
Section 5.1.4, “Server Command Options”
Server Plugin Library and Plugin Descriptors
Section 6.5.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.5.1.7, “Test Pluggable Authentication”
Section 24.2, “The MySQL Plugin API”
Section 5.5.3.2, “Thread Pool Installation”
Using the Authentication Plugins
Section 6.5.1.5, “Windows Pluggable Authentication”

--plugin-sql-mode

Section 5.1.4, “Server Command Options”

--plugin-xxx

Section 5.1.4, “Server Command Options”

--plugin_dir

Section 2.9.4, “MySQL Source-Configuration Options”
Section 24.2.3, “Plugin API Components”

--plugin_name

Section 5.5.1, “Installing and Uninstalling Plugins”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”

--plugindir

Section 4.7.2, “mysql_config — Display Options for Compiling Clients”

--port

Section 4.2.2, “Connecting to the MySQL Server”
Section 4.2.1, “Invoking MySQL Programs”
Section 4.5.1.1, “mysql Options”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.7.2, “mysql_config — Display Options for Compiling Clients”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.6.13, “mysql_setpermission — Interactively Set Permissions in Grant Tables”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”
Section 5.6.4, “Using Client Programs in a Multiple-Server Environment”

--port-open-timeout
Section 5.1.4, “Server Command Options”

--position
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 1.4, “What Is New in MySQL 5.5”

--post-query
Section 4.5.7, “mysqlslap — Load Emulation Client”

--post-system
Section 4.5.7, “mysqlslap — Load Emulation Client”

--pre-query
Section 4.5.7, “mysqlslap — Load Emulation Client”

--pre-system
Section 4.5.7, “mysqlslap — Load Emulation Client”

PREFIX
Section 18.2.1.4, “Building NDB Cluster from Source on Linux”

--prefix
Section 16.2.1, “Installing memcached”

--preserve-trailing-spaces
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--preview
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--print
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--print-defaults
Section 4.2.7, “Command-Line Options that Affect Option-File Handling”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Options”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 5.1.4, “Server Command Options”
Section 2.11.1, “Upgrading MySQL”

--print-full-config
Section 18.4.4, “ndb_mgmd — The NDB Cluster Management Server Daemon”

--print_*
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--print_data
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--print_log
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--print_meta
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--progress-frequency
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--promote-attributes
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--prompt
Section 4.5.1.2, “mysql Commands”
Section 4.5.1.1, “mysql Options”

--protocol
Section 4.2.2, “Connecting to the MySQL Server”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 2.3.7.4, “Starting the Server for the First Time”
Section 2.3.7.8, “Testing The MySQL Installation”
Section 1.3.2, “The Main Features of MySQL”
Section 5.6.4, “Using Client Programs in a Multiple-Server Environment”

Q

[index top]

-Q
Section 4.5.4, “mysqldump — A Database Backup Program”

-q
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.5.1.1, “mysql Options”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”

--query

Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--query-cache-size

Section 8.11.5, “External Locking”

--quick

Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.5.1.1, “mysql Options”
Section 4.5.1, “mysql — The MySQL Command-Line Tool”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section B.5.2.8, “Out of memory”
Section 7.6.1, “Using myisamchk for Crash Recovery”
Section 4.2.6, “Using Option Files”

--quiet

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--quote-names

Section 4.5.4, “mysqldump — A Database Backup Program”

R

[index top]

-R

Section 16.2.2.1, “memcached Command-Line Options”
Section 16.2.4.1, “memcached General Statistics”
Section 7.6.4, “MyISAM Table Optimization”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.3.4, “Other myisamchk Options”

-r

Section 24.4.2, “Adding a New User-Defined Function”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysql Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 5.1.4, “Server Command Options”

--raw

Section 4.5.1.1, “mysql Options”

--read-from-remote-server

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--read-only

Section 4.6.3.2, “myisamchk Check Options”

--rebuild-indexes

Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--reconnect

Section 4.5.1.1, “mysql Options”

--record_log_pos

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--recover

Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”

--regexp

Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--relative

Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

--relay-log

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 17.3.5, “Improving Replication Performance”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
Section 4.2.9, “Option Defaults, Options Expecting Values, and the = Sign”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.2.2.1, “The Slave Relay Log”

--relay-log-index

Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.2.2.1, “The Slave Relay Log”

--relay-log-info-file

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.2.2.2, “Slave Status Logs”

--relay-log-purge

Section 17.1.3.3, “Replication Slave Options and Variables”

--relay-log-recovery

Section 17.1.3.3, “Replication Slave Options and Variables”

--relay-log-space-limit

Section 17.1.3.3, “Replication Slave Options and Variables”

--relnotes

Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”

--reload

Section 18.5.13.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.1.6.10, “Limitations Relating to Multiple NDB Cluster Nodes”
Section 18.3.3, “NDB Cluster Configuration Files”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”

--remove

Section 18.2.2.4, “Installing NDB Cluster Processes as Windows Services”
Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”
Section 18.4.1, “`ndbd` — The NDB Cluster Data Node Daemon”
Section 5.1.4, “Server Command Options”
Section 5.6.2.2, “Starting Multiple MySQL Instances as Windows Services”
Section 2.3.7.7, “Starting MySQL as a Windows Service”

--repair

Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”

--replace

Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”

--replicate-*

Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”

--replicate-*-db

Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section C.1, “Restrictions on Stored Programs”

--replicate-*-table

Section 17.2.3.3, “Replication Rule Application”

--replicate-do-*

Section 18.6.3, “Known Issues in NDB Cluster Replication”

--replicate-do-db

Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 18.6.3, “Known Issues in NDB Cluster Replication”

Section 17.3.4, “Replicating Different Databases to Different Slaves”
Section 17.4.1.25, “Replication and Reserved Words”
Section 17.4.1.31, “Replication and Temporary Tables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 5.4.4, “The Binary Log”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-do-table

Section 17.2.3.2, “Evaluation of Table-Level Replication Options”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.4.1.25, “Replication and Reserved Words”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.31, “Replication and Temporary Tables”
Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-ignore-*

Section 18.6.3, “Known Issues in NDB Cluster Replication”

--replicate-ignore-db

Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.4.1.25, “Replication and Reserved Words”
Section 17.4.1.14, “Replication and System Functions”
Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 5.4.4, “The Binary Log”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-ignore-table

Section 17.2.3.2, “Evaluation of Table-Level Replication Options”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.4.1.25, “Replication and Reserved Words”
Section 17.4.1.31, “Replication and Temporary Tables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-rewrite-db

Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

--replicate-same-server-id

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 17.1.3.3, “Replication Slave Options and Variables”

--replicate-wild-do-table

Section 17.2.3.2, “Evaluation of Table-Level Replication Options”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 17.3.4, “Replicating Different Databases to Different Slaves”
Section 17.4.1.31, “Replication and Temporary Tables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section C.1, “Restrictions on Stored Programs”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”

--replicate-wild-ignore-table

Section 17.2.3.2, “Evaluation of Table-Level Replication Options”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section 17.4.1.31, “Replication and Temporary Tables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”

replication-ignore-table

Section 17.4.1.39, “Replication and Views”

--replication-rewrite-db

Section 17.1.3.3, “Replication Slave Options and Variables”

--report-host

Section 17.1.4.1, “Checking Replication Status”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.5.34, “SHOW SLAVE HOSTS Syntax”

--report-password

Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.5.34, “SHOW SLAVE HOSTS Syntax”

--report-port

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.5.34, “SHOW SLAVE HOSTS Syntax”

--report-user

Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.5.34, “SHOW SLAVE HOSTS Syntax”

--resetmaster

Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”

--resetslave

Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”

--restore-privilege-tables

Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--restore_data

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to Fewer Nodes Than the Original

--restore_epoch

Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”

--restore_meta

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Restoring to More Nodes Than the Original

--result-file

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”

--retries

Section 18.4.10, “ndb_desc — Describe NDB Tables”

--rewrite-database

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--rhost

Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--rollback

Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--routines

Section 7.4.5.3, “Dumping Stored Programs”
Section 7.4.5.4, “Dumping Table Definitions and Content Separately”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 2.11.1, “Upgrading MySQL”

--rowid

Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--rows

Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

--rpm

Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

S

[index top]

-S

Section 4.4.1, “comp_err — Compile MySQL Error Message File”

Section 4.2.2, “Connecting to the MySQL Server”
Section 4.2.1, “Invoking MySQL Programs”
Section 7.6.4, “MyISAM Table Optimization”
Section 4.5.1.2, “mysql Commands”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 4.6.3.4, “Other myisamchk Options”

-s

Section 7.6.2, “How to Check MyISAM Tables for Errors”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 4.6.1, “innochecksum — Offline InnoDB File Checksum Utility”
Section 2.2, “Installing MySQL on Unix/Linux Using Generic Binaries”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 4.8.1, “perror — Explain Error Codes”
Section 4.8.2, “replace — A String-Replacement Utility”
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”
Section 5.1.4, “Server Command Options”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”

--safe-mode

Section 5.1.4, “Server Command Options”

--safe-recover

Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”

--safe-show-database

Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--safe-updates

Section 4.5.1.2, “mysql Commands”
Section 4.5.1.1, “mysql Options”

Using the --safe-updates Option

--safe-user-create

Section 5.1.4, “Server Command Options”

--savequeries

Section 18.4.25, “ndb_size.pl — NDBCLUSTER Size Requirement Estimator”

--secure-auth

Section 4.5.1.1, “mysql Options”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 5.1.4, “Server Command Options”

--secure-file-priv

Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

--select_limit

Using the --safe-updates Option

--server-id

Section 18.6.2, “General Requirements for NDB Cluster Replication”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 17.1.3, “Replication and Binary Logging Options and Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.5.34, “SHOW SLAVE HOSTS Syntax”
Section 17.4.4, “Troubleshooting Replication”

server-id

Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
Section 17.1, “Replication Configuration”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.1.1.1, “Setting the Replication Master Configuration”
Section 17.1.1.2, “Setting the Replication Slave Configuration”
Section 17.1.1.8, “Setting Up Replication with Existing Data”

--server-id-bits

MySQL Server Options for NDB Cluster
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
NDB Cluster System Variables

service-startup-timeout

Section 4.3.3, “mysql.server — MySQL Server Startup Script”

--set-auto-increment

Section 4.6.3.4, “Other myisamchk Options”

--set-charset

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”

--set-collation

Section 4.6.3.3, “myisamchk Repair Options”

--set-variable

Section 4.5.1.1, “mysql Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 1.4, “What Is New in MySQL 5.5”

--shared-memory

Section 4.2.2, “Connecting to the MySQL Server”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 5.1.4, “Server Command Options”
Section 5.6.2.1, “Starting Multiple MySQL Instances at the Windows Command Line”
Section 2.3.7.4, “Starting the Server for the First Time”
Section 1.3.2, “The Main Features of MySQL”

--shared-memory-base-name

Section 4.2.2, “Connecting to the MySQL Server”
Section 4.5.1.1, “mysql Options”
Section 23.8.7.49, “mysql_options()”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.1.4, “Server Command Options”
Section 5.6.2.1, “Starting Multiple MySQL Instances at the Windows Command Line”
Section 5.6.4, “Using Client Programs in a Multiple-Server Environment”

--short-form

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”

--show-slave-auth-info

Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.34, “SHOW SLAVE HOSTS Syntax”

--show-table-type

Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

--show-temp-status

Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”

--show-warnings

Section 4.5.1.1, “mysql Options”

--sigint-ignore

Section 4.5.1.1, “mysql Options”

--silent

Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 4.8.1, “perror — Explain Error Codes”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”

--single-transaction

Section 7.2, “Database Backup Methods”
Section 7.3.1, “Establishing a Backup Policy”
Section 14.21.1, “InnoDB Backup”
Section 4.5.4, “mysqldump — A Database Backup Program”

--single-user

Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--skip

Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.2.5, “Program Option Modifiers”
Section 5.1.4, “Server Command Options”

--skip-add-drop-table

Section 4.5.4, “mysqldump — A Database Backup Program”

--skip-add-locks

Section 4.5.4, “mysqldump — A Database Backup Program”

--skip-auto-rehash

Section 4.5.1.1, “mysql Options”
Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”

--skip-broken-objects

Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--skip-character-set-client-handshake

Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
The cp932 Character Set

--skip-column-names

Section 4.5.1.1, “mysql Options”

--skip-comments

Section 4.5.1.1, “mysql Options”
Section 4.5.4, “mysqldump — A Database Backup Program”

--skip-compact

Section 4.5.4, “mysqldump — A Database Backup Program”

--skip-concurrent-insert

Section 5.1.4, “Server Command Options”

--skip-config-cache

Section 18.4.4, “`ndb_mgmd` — The NDB Cluster Management Server Daemon”

--skip-disable-keys

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--skip-dump-date

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--skip-engine_name

Section 13.7.5.17, “SHOW ENGINES Syntax”

--skip-event-scheduler

Section 5.1.4, “Server Command Options”

--skip-events

Section 7.4.5.3, “Dumping Stored Programs”

--skip-extended-insert

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--skip-external-locking

Section 8.11.5, “External Locking”
Section 8.14.2, “General Thread States”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 8.12.1, “System Factors”
Section 1.4, “What Is New in MySQL 5.5”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”

--skip-grant-tables

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”
Section 20.4.2, “Event Scheduler Configuration”
Section 13.7.3.3, “INSTALL PLUGIN Syntax”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 6.3.6, “Pluggable Authentication”
Resetting the Root Password: Generic Instructions
Section 5.1.4, “Server Command Options”
Section 5.3, “The mysql System Database”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 24.4.2.5, “UDF Compiling and Installing”
Section 4.2.4, “Using Options on the Command Line”
Section 6.2.6, “When Privilege Changes Take Effect”

--skip-host-cache

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section 5.1.4, “Server Command Options”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”

--skip-innodb

Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 14.1.6, “Turning Off InnoDB”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”

--skip-innodb-checksums

Section 14.17, “InnoDB Startup Options and System Variables”

--skip-innodb_adaptive_hash_index

Section 14.17, “InnoDB Startup Options and System Variables”

--skip-innodb_checksums

Section 14.17, “InnoDB Startup Options and System Variables”

--skip-innodb_doublewrite

Section 14.17, “InnoDB Startup Options and System Variables”

--skip-kill-mysqld

Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”

--skip-line-numbers

Section 4.5.1.1, “mysql Options”

--skip-lock-tables

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--skip-locking

Section 1.4, “What Is New in MySQL 5.5”

--skip-name-resolve

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section 4.4.3, “`mysql_install_db` — Initialize MySQL Data Directory”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 2.3.7.8, “Testing The MySQL Installation”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”

--skip-named-commands

Section 4.5.1.1, “mysql Options”
Section 1.4, “What Is New in MySQL 5.5”

--skip-ndbcluster

MySQL Server Options for NDB Cluster
Section 18.3.2.5, “NDB Cluster mysqld Option and Variable Reference”
NDB Cluster System Variables

--skip-networking

Section B.5.2.2, “Can't connect to [local] MySQL server”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section B.5.2.9, “MySQL server has gone away”
Section 6.3.6, “Pluggable Authentication”
Resetting the Root Password: Generic Instructions
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 17.4.3, “Upgrading a Replication Setup”

skip-networking

Section A.13, “MySQL 5.5 FAQ: Replication”
Section 17.1.1.1, “Setting the Replication Master Configuration”
Section 17.4.4, “Troubleshooting Replication”

--skip-new

Section 24.5.1, “Debugging a MySQL Server”
Section 13.7.2.4, “OPTIMIZE TABLE Syntax”
Section 5.1.5, “Server System Variables”

--skip-nodegroup

Section 18.4.13, “`ndb_error_reporter` — NDB Error-Reporting Utility”

--skip-opt

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--skip-pager

Section 4.5.1.1, “mysql Options”
Section 1.4, “What Is New in MySQL 5.5”

--skip-partition

Chapter 19, *Partitioning*
Section 5.1.4, “Server Command Options”

--skip-plugin-innodb_file_per_table

Section 5.1.4, “Server Command Options”

--skip-plugin_name

Section 5.5.1, “Installing and Uninstalling Plugins”

--skip-quick

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--skip-quote-names

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--skip-reconnect

Section 23.8.20, “C API Automatic Reconnection Control”
Disabling mysql Auto-Reconnect
Section 4.5.1.1, “mysql Options”

--skip-routines

Section 7.4.5.3, “Dumping Stored Programs”

--skip-safemalloc

Section 5.1.4, “Server Command Options”

--skip-set-charset

Section 4.5.4, “`mysqldump` — A Database Backup Program”

--skip-show-database

Section 6.2.1, “Privileges Provided by MySQL”
Section 5.1.4, “Server Command Options”
Section 13.7.5.15, “SHOW DATABASES Syntax”
Section 1.8.5, “Supporters of MySQL”

--skip-slave-start

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.6.5, “Preparing the NDB Cluster for Replication”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”
Section 17.1.1.8, “Setting Up Replication with Existing Data”
Section 13.4.2.5, “START SLAVE Syntax”
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”
Section 17.4.4, “Troubleshooting Replication”
Section 17.4.3, “Upgrading a Replication Setup”

--skip-ssl

Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”

--skip-stack-trace

Section 24.5.1.4, “Debugging mysqld under gdb”
Section 5.1.4, “Server Command Options”

--skip-super-large-pages

Section 8.12.4.2, “Enabling Large Page Support”
Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--skip-symbolic-links

Section 13.1.17, “CREATE TABLE Syntax”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”
Section 1.4, “What Is New in MySQL 5.5”

--skip-symlink

Section 1.4, “What Is New in MySQL 5.5”

--skip-syslog

Section 5.4.2.3, “Error Logging to the System Log”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”

--skip-table-check

Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”

--skip-tee

Section 4.5.1.1, “mysql Options”
Section 1.4, “What Is New in MySQL 5.5”

--skip-thread-priority
Section 5.1.4, “Server Command Options”

--skip-triggers
Section 7.4.5.3, “Dumping Stored Programs”
Section 4.5.4, “mysqldump — A Database Backup Program”

--skip-tz-utc
Section 4.5.4, “mysqldump — A Database Backup Program”

--skip-unknown-objects
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”

--skip-use-db
Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”

--skip-version-check
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”

--skip-write-binlog
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--skip-xxx
Section 4.5.4, “mysqldump — A Database Backup Program”

--skip_grant_tables
Section 4.2.4, “Using Options on the Command Line”

--slave-load-tmpdir
Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 7.2, “Database Backup Methods”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section B.5.3.5, “Where MySQL Stores Temporary Files”

--slave-max-allowed-packet
Section 17.1.3.3, “Replication Slave Options and Variables”

slave-max-allowed-packet
Section 17.1.3.3, “Replication Slave Options and Variables”

--slave-net-timeout
Section 17.1.3.3, “Replication Slave Options and Variables”

--slave-skip-errors
Section 18.6.8, “Implementing Failover with NDB Cluster Replication”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.4.1.29, “Slave Errors During Replication”

--slave_compressed_protocol
Section 17.1.3.3, “Replication Slave Options and Variables”

--sleep
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

--slow-query-log

Section 5.1.4, “Server Command Options”

--slow-start-timeout

Section 5.1.4, “Server Command Options”

--slow_query_log

Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

--slow_query_log_file

Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.1.4, “Server Command Options”
Section 5.4.5, “The Slow Query Log”

--socket

Section B.5.2.2, “Can't connect to [local] MySQL server”
Section 4.2.2, “Connecting to the MySQL Server”
Section B.5.3.6, “How to Protect or Change the MySQL Unix Socket File”
Section 4.2.1, “Invoking MySQL Programs”
Section 4.5.1.1, “mysql Options”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.7.2, “`mysql_config` — Display Options for Compiling Clients”
Section 4.6.10, “`mysql_convert_table_format` — Convert Tables to Use a Given Storage Engine”
Section 4.6.13, “`mysql_setpermission` — Interactively Set Permissions in Grant Tables”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.6.3, “Running Multiple MySQL Instances on Unix”
Section 5.1.4, “Server Command Options”
Server Plugin Library and Plugin Descriptors
Section 2.3.7.8, “Testing The MySQL Installation”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 5.6.4, “Using Client Programs in a Multiple-Server Environment”

--sort-index

Section 7.6.4, “MyISAM Table Optimization”
Section 4.6.3.4, “Other myisamchk Options”

--sort-records

Section 7.6.4, “MyISAM Table Optimization”
Section 4.6.3.4, “Other myisamchk Options”

--sort-recover

Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3.6, “myisamchk Memory Usage”

Section 4.6.3.3, “myisamchk Repair Options”

--spassword

Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”

--sporadic-binlog-dump-fail

Section 17.1.3.4, “Binary Log Options and Variables”

--sql-bin-update-same

Section 1.4, “What Is New in MySQL 5.5”

--sql-mode

Chapter 12, *Functions and Operators*
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”
Section 5.1.4, “Server Command Options”
Section 5.1.8, “Server SQL Modes”

sql-mode

Section 5.1.8, “Server SQL Modes”

--srcdir

Section 4.4.3, “`mysql_install_db` — Initialize MySQL Data Directory”

--ssl

Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 4.2.2, “Connecting to the MySQL Server”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 5.1.4, “Server Command Options”

--ssl*

Section 4.2.2, “Connecting to the MySQL Server”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 5.1.4, “Server Command Options”

--ssl-ca

Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 6.4.3, “Creating SSL Certificates and Keys Using openssl”
Section 13.7.1.3, “GRANT Syntax”

Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”

--ssl-capath

Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 13.7.1.3, “GRANT Syntax”
Section 6.4.4, “OpenSSL Versus yaSSL”
Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”

--ssl-cert

Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 6.4.3, “Creating SSL Certificates and Keys Using openssl”
Section 13.7.1.3, “GRANT Syntax”
Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”

--ssl-cipher

Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.4, “OpenSSL Versus yaSSL”

--ssl-key

Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 6.4.3, “Creating SSL Certificates and Keys Using openssl”
Section 13.7.1.3, “GRANT Syntax”
Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”

--ssl-mode

Section 23.8.15, “C API Encrypted Connection Support”
Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 23.8.7.49, “mysql_options()”

--ssl-verify-server-cert

Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”

--ssl-xxx

Section 6.4.5, “Building MySQL with Support for Encrypted Connections”
Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 5.1.5, “Server System Variables”

--staging-tries

Section 18.4.15, “`ndb_move_data` — NDB Data Copy Utility”

--standalone

Section 24.5.1.2, “Creating Trace Files”
Section 5.1.4, “Server Command Options”
Section 2.3.7.5, “Starting MySQL from the Windows Command Line”

--start-datetime

Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 7.5.1, “Point-in-Time Recovery Using Event Times”

--start-position

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 7.5.2, “Point-in-Time Recovery Using Event Positions”
Section 1.4, “What Is New in MySQL 5.5”

--start_row

Section 4.6.11, “mysql_find_rows — Extract SQL Statements from Files”

--statefile

Section 4.4.1, “comp_err — Compile MySQL Error Message File”

--stats

Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”

--status

Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”

--stop-datetime

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 7.5.1, “Point-in-Time Recovery Using Event Times”

--stop-position

Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 7.5.2, “Point-in-Time Recovery Using Event Positions”

--suffix

Section 4.6.9, “mysqlhotcopy — A Database Backup Program”

--super-large-pages

Section 8.12.4.2, “Enabling Large Page Support”
Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--superuser

Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

--symbolic-links

Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--symbols-file

Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”

--sys-*

Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-check

Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-create

Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

sys-create-if-not-exist

Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-create-if-not-valid
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-drop
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-skip-events
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--sys-skip-tables
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

SYSCONFDIR
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.2.6, “Using Option Files”

--sysdate-is-now
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 12.7, “Date and Time Functions”
Section 17.4.1.14, “Replication and System Functions”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

--syslog
Section 5.4.2.3, “Error Logging to the System Log”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

--syslog-tag
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”

--system
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”

T

[index top]

-T
Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 5.1.4, “Server Command Options”

-t
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 2.3.6.13, “MySQL Server Instance Config Wizard: Creating an Instance from the Command Line”

Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.15, “mysql_zap — Kill Processes That Match a Pattern”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 18.4.9, “ndb_delete_all — Delete All Rows from an NDB Table”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.20, “ndb_redo_log_reader — Check and Print Content of Cluster Redo Log”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”
Section 5.1.4, “Server Command Options”

--tab

Section 7.1, “Backup and Recovery Types”
Section 7.2, “Database Backup Methods”
Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 7.4, “Using mysqldump for Backups”

--table

Section 4.5.1.1, “mysql Options”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 18.4.10, “ndb_desc — Describe NDB Tables”

--table_open_cache

Section 8.4.3.1, “How MySQL Opens and Closes Tables”

--tables

Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”

--tc-heuristic-recover

Section 5.1.4, “Server Command Options”

--tcp-ip

Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”

--tee

Section 4.5.1.2, “mysql Commands”
Section 4.5.1.1, “mysql Options”

--temp-pool

Section 5.1.4, “Server Command Options”

--test

Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”

Text

Section 1.2, “Typographical and Syntax Conventions”

--thread_cache_size

Section 24.5.1.4, “Debugging mysqld under gdb”

--thread_handling

Section 5.1.4, “Server Command Options”

--thread_stack

Section 8.12.5.1, “How MySQL Uses Threads for Client Connections”

--timeout

Section 18.4.26, “`ndb_waiter` — Wait for NDB Cluster to Reach a Given Status”

--timezone

Section 10.6, “MySQL Server Time Zone Support”
Section 4.3.2, “`mysqld_safe` — MySQL Server Startup Script”
Section 17.4.1.34, “Replication and Time Zones”
Section 5.1.5, “Server System Variables”
Section B.5.3.7, “Time Zone Problems”

--tmpdir

Section B.5.2.13, “Can't create/write to file”
Section 4.6.3.6, “myisamchk Memory Usage”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 5.6, “Running Multiple MySQL Instances on One Machine”
Section 5.1.4, “Server Command Options”
Section 2.3.7.7, “Starting MySQL as a Windows Service”
Section B.5.3.5, “Where MySQL Stores Temporary Files”

tmpdir

Section 2.3, “Installing MySQL on Microsoft Windows”

--to-last-log

Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”

--transaction-isolation

Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 13.3.6, “SET TRANSACTION Syntax”
Section 14.8.2.1, “Transaction Isolation Levels”

--transactional

Section 18.4.9, “`ndb_delete_all` — Delete All Rows from an NDB Table”

--triggers

Section 7.4.5.3, “Dumping Stored Programs”
Section 4.5.4, “`mysqldump` — A Database Backup Program”

--try-reconnect

Section 18.4.5, “`ndb_mgm` — The NDB Cluster Management Client”

--tupscan

Section 18.4.22, “`ndb_select_all` — Print Rows from an NDB Table”

--type

Section 4.6.10, “`mysql_convert_table_format` — Convert Tables to Use a Given Storage Engine”

Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”

--tz-utc

Section 4.5.4, “mysqldump — A Database Backup Program”

U

[index top]

-U

Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.2, “myisamchk Check Options”
Section 4.5.1.1, “mysql Options”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”

-u

Section 4.2.2, “Connecting to the MySQL Server”
Section 2.11.2, “Downgrading MySQL”
Section 4.2.1, “Invoking MySQL Programs”
Section 16.2.2.1, “memcached Command-Line Options”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”
Section 5.1.4, “Server Command Options”
Section 2.3.7.8, “Testing The MySQL Installation”
Section 2.10.3, “Testing the Server”
Section 2.11.1, “Upgrading MySQL”
Section 6.3.1, “User Names and Passwords”
Section 2.3.9, “Windows Postinstallation Procedures”

--unbuffered

Section 4.5.1.1, “mysql Options”

--unpack

Section 15.3.3, “MyISAM Table Storage Formats”
Section 4.6.3.3, “myisamchk Repair Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”

--unqualified

Section 18.4.10, “ndb_desc — Describe NDB Tables”
Section 18.4.24, “ndb_show_tables — Display List of NDB Tables”

--update

Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”

--update-state

Section 7.6.3, “How to Repair MyISAM Tables”
Section 4.6.3.2, “myisamchk Check Options”
Section 15.3, “The MyISAM Storage Engine”

--upgrade-system-tables

Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”

--usage

Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”

--use-frm

Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

--use-symbolic-links

Section 1.4, “What Is New in MySQL 5.5”

--use-threads

Section 4.5.5, “mysqlimport — A Data Import Program”

--useHexFormat

Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--user

Section 4.2.2, “Connecting to the MySQL Server”
Section 7.3, “Example Backup and Recovery Strategy”
Section B.5.2.18, “File Not Found and Similar Errors”
Section 6.1.5, “How to Run MySQL as a Normal User”
Section 2.10.1, “Initializing the Data Directory”
Section 4.2.1, “Invoking MySQL Programs”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 4.5.1.1, “mysql Options”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.6.13, “mysql_setpermission — Interactively Set Permissions in Grant Tables”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.3.2, “mysqld_safe — MySQL Server Startup Script”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 4.2.9, “Option Defaults, Options Expecting Values, and the = Sign”
Resetting the Root Password: Unix and Unix-Like Systems

Section 5.1.4, “Server Command Options”
Section 6.5.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 2.10.2, “Starting the Server”
Section 6.5.1.7, “Test Pluggable Authentication”
Section 6.3.1, “User Names and Passwords”
Section 4.2.6, “Using Option Files”

V

[index top]

-V

Section 4.4.1, “`comp_err` — Compile MySQL Error Message File”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.4, “`myisamlog` — Display MyISAM Log File Contents”
Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.4.4, “`mysql_plugin` — Configure MySQL Server Plugins”
Section 4.6.14, “`mysql_waitpid` — Kill Process and Wait for Its Termination”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 18.4.7, “`ndb_config` — Extract NDB Cluster Configuration Information”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 4.8.1, “`perror` — Explain Error Codes”
Section 4.8.2, “`replace` — A String-Replacement Utility”
Section 4.7.4, “`resolve_stack_dump` — Resolve Numeric Stack Trace Dump to Symbols”
Section 4.8.3, “`resolveip` — Resolve Host name to IP Address or Vice Versa”
Section 5.1.4, “Server Command Options”
Section 4.2.4, “Using Options on the Command Line”

-v

Section 7.6.2, “How to Check MyISAM Tables for Errors”
Section 4.6.1, “`innochecksum` — Offline InnoDB File Checksum Utility”
Section 16.2.2.1, “`memcached` Command-Line Options”
Section 16.2.2.9, “`memcached` Logs”
Section 4.7.3, “`my_print_defaults` — Display Options from Option Files”
Section 4.6.2, “`myisam_ftdump` — Display Full-Text Index information”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.4, “`myisamlog` — Display MyISAM Log File Contents”
Section 4.6.5, “`myisampack` — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.4.4, “`mysql_plugin` — Configure MySQL Server Plugins”
Section 4.6.14, “`mysql_waitpid` — Kill Process and Wait for Its Termination”
Section 4.6.6, “`mysqlaccess` — Client for Checking Access Privileges”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7.2, “mysqlbinlog Row Event Display”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.8, “`mysqldumpslow` — Summarize Slow Query Log Files”
Section 4.5.5, “`mysqlimport` — A Data Import Program”

Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.17, “ndb_print_file — Print NDB Disk Data File Contents”
Section 4.6.3.5, “Obtaining Table Information with myisamchk”
Section 4.8.1, “perror — Explain Error Codes”
Section 4.8.2, “replace — A String-Replacement Utility”
Section 5.1.4, “Server Command Options”
Section 4.2.4, “Using Options on the Command Line”

--var_name

Section 14.17, “InnoDB Startup Options and System Variables”
Section 4.6.3.1, “myisamchk General Options”
Section 4.5.1.1, “mysql Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 5.1.4, “Server Command Options”
Section 1.4, “What Is New in MySQL 5.5”

--variable

Section 4.7.2, “mysql_config — Display Options for Compiling Clients”

--verbose

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 4.5.1.5, “Executing SQL Statements from a Text File”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.2, “myisam_ftdump — Display Full-Text Index information”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7.2, “mysqlbinlog Row Event Display”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.6.8, “mysqldumpslow — Summarize Slow Query Log Files”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.6, “ndb_blob_tool — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”
Section 18.4.14, “ndb_index_stat — NDB Index Statistics Utility”
Section 18.4.15, “ndb_move_data — NDB Data Copy Utility”
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 4.6.3.4, “Other myisamchk Options”
Section 4.8.1, “perror — Explain Error Codes”
Section 5.1.4, “Server Command Options”
Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”
Section 4.2.6, “Using Option Files”
Section 4.2.4, “Using Options on the Command Line”

--version

Section 4.4.1, “comp_err — Compile MySQL Error Message File”
Section 4.7.3, “my_print_defaults — Display Options from Option Files”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.7.2, “mysql_config — Display Options for Compiling Clients”
Section 4.6.10, “mysql_convert_table_format — Convert Tables to Use a Given Storage Engine”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 4.6.14, “mysql_waitpid — Kill Process and Wait for Its Termination”
Section 4.6.6, “mysqlaccess — Client for Checking Access Privileges”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.6.7, “mysqlbinlog — Utility for Processing Binary Log Files”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.3.4, “mysqld_multi — Manage Multiple MySQL Servers”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 18.4.27, “Options Common to NDB Cluster Programs — Options Common to NDB Cluster Programs”
Section 4.8.1, “perror — Explain Error Codes”
Section 4.7.4, “resolve_stack_dump — Resolve Numeric Stack Trace Dump to Symbols”
Section 4.8.3, “resolveip — Resolve Host name to IP Address or Vice Versa”
Section 5.1.4, “Server Command Options”
Section 4.2.4, “Using Options on the Command Line”

--version-check

Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”

--vertical

Section 1.6, “How to Report Bugs or Problems”
Section 4.5.1.1, “mysql Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

W

[index top]

-W

Section 4.2.2, “Connecting to the MySQL Server”
Section 4.5.1.1, “mysql Options”
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.5, “mysqlimport — A Data Import Program”
Section 4.5.6, “mysqlshow — Display Database, Table, and Column Information”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 5.1.4, “Server Command Options”

-w

Section 4.6.3.1, “myisamchk General Options”
Section 4.6.4, “myisamlog — Display MyISAM Log File Contents”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”

Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--wait

Section 4.6.3.1, “myisamchk General Options”
Section 4.6.5, “myisampack — Generate Compressed, Read-Only MyISAM Tables”
Section 4.5.1.1, “mysql Options”
Section 4.5.2, “mysqladmin — Client for Administering a MySQL Server”

--wait-nodes

Section 18.4.26, “ndb_waiter — Wait for NDB Cluster to Reach a Given Status”

--warnings

Section 1.4, “What Is New in MySQL 5.5”

--where

Section 4.5.4, “mysqldump — A Database Backup Program”

--windows

Section 4.4.3, “mysql_install_db — Initialize MySQL Data Directory”

--with-libevent

Section 16.2.1, “Installing memcached”

--with-pstack

Section 1.4, “What Is New in MySQL 5.5”

WITH_BUNDLED_MEMCACHED

Section 2.9.4, “MySQL Source-Configuration Options”

WITH_CLASSPATH

Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”

WITH_DEBUG

Section 14.17, “InnoDB Startup Options and System Variables”
Section 4.5.1.1, “mysql Options”
Section 2.9.4, “MySQL Source-Configuration Options”

WITH_NDB_JAVA

Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”

WITH_NDBCLUSTER

Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”

WITH_NDBCLUSTER_STORAGE_ENGINE

Section 18.2.1.4, “Building NDB Cluster from Source on Linux”
Section 18.2.2.2, “Compiling and Installing NDB Cluster from Source on Windows”
Section 2.9.4, “MySQL Source-Configuration Options”

WITH_PERFSCHEMA_STORAGE_ENGINE

Section 22.2, “Performance Schema Build Configuration”

WITH_ZLIB
Section 2.9.4, “MySQL Source-Configuration Options”

--write-binlog
Section 4.4.7, “mysql_upgrade — Check and Upgrade MySQL Tables”
Section 4.5.3, “mysqlcheck — A Table Maintenance Program”

X

[index top]

-X
Section 4.5.1.2, “mysql Commands”
Section 4.5.1.1, “mysql Options”
Section 4.5.4, “mysqldump — A Database Backup Program”

-x
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

--xml
Section 13.2.7, “LOAD XML Syntax”
Section 4.5.1.1, “mysql Options”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.4.7, “ndb_config — Extract NDB Cluster Configuration Information”
Section 12.11, “XML Functions”

Y

[index top]

-Y
Section 4.5.4, “mysqldump — A Database Backup Program”

-y
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 4.5.7, “mysqlslap — Load Emulation Client”

Z

[index top]

-z
Section 18.4.21, “ndb_restore — Restore an NDB Cluster Backup”
Section 18.4.22, “ndb_select_all — Print Rows from an NDB Table”

Privileges Index

A | C | D | E | F | G | I | L | P | R | S | T | U

A

[index top]

ALL
Section 13.7.1.3, “GRANT Syntax”

Section 6.2.1, “Privileges Provided by MySQL”

ALL PRIVILEGES

Section 6.2.1, “Privileges Provided by MySQL”

ALTER

Section 13.1.1, “ALTER DATABASE Syntax”
Section 13.1.7, “ALTER TABLE Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.1.32, “RENAME TABLE Syntax”
Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”

ALTER ROUTINE

Section 13.1.3, “ALTER FUNCTION Syntax”
Section 13.1.5, “ALTER PROCEDURE Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 5.1.5, “Server System Variables”
Section 20.2.2, “Stored Routines and MySQL Privileges”

C

[index top]

CREATE

Section 13.1.7, “ALTER TABLE Syntax”
Section 13.1.10, “CREATE DATABASE Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.1.32, “RENAME TABLE Syntax”

CREATE ROUTINE

Section 20.7, “Binary Logging of Stored Programs”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 6.2.1, “Privileges Provided by MySQL”
Section 5.1.5, “Server System Variables”
Section 20.2.2, “Stored Routines and MySQL Privileges”

CREATE TABLESPACE

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”

CREATE TEMPORARY TABLES

Section 13.1.17.3, “CREATE TEMPORARY TABLE Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”

CREATE USER

Section 6.3.2, “Adding User Accounts”

Section 6.3.5, “Assigning Account Passwords”
Section 13.7.1.1, “CREATE USER Syntax”
Section 13.7.1.2, “DROP USER Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.1.4, “RENAME USER Syntax”
Section 13.7.1.5, “REVOKE Syntax”

CREATE VIEW

Section 13.1.9, “ALTER VIEW Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section C.5, “Restrictions on Views”
Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”

D

[index top]

DELETE

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 13.1.17, “CREATE TABLE Syntax”
Section 13.2.2, “DELETE Syntax”
Section 13.7.3.2, “DROP FUNCTION Syntax”
Section 13.7.1.2, “DROP USER Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.2.8, “REPLACE Syntax”
Section 15.8, “The MERGE Storage Engine”
Section 24.4.2.5, “UDF Compiling and Installing”
Section 24.4.2.6, “UDF Security Precautions”
Section 13.7.3.4, “UNINSTALL PLUGIN Syntax”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”

DROP

Section 13.1.7, “ALTER TABLE Syntax”
Section 13.1.9, “ALTER VIEW Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 13.1.21, “DROP DATABASE Syntax”
Section 13.1.28, “DROP TABLE Syntax”
Section 13.1.31, “DROP VIEW Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 22.8, “Performance Schema General Table Characteristics”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.1.32, “RENAME TABLE Syntax”
Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”
Section 6.2, “The MySQL Access Privilege System”
Section 13.1.33, “TRUNCATE TABLE Syntax”

E

[index top]

EVENT

Section 13.1.2, “ALTER EVENT Syntax”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.1.22, “DROP EVENT Syntax”
Section 20.4.1, “Event Scheduler Overview”
Section 20.4.3, “Event Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.5.9, “SHOW CREATE EVENT Syntax”
Section 13.7.5.19, “SHOW EVENTS Syntax”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

EXECUTE

Section 20.6, “Access Control for Stored Programs and Views”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 5.1.5, “Server System Variables”
Section 20.2.2, “Stored Routines and MySQL Privileges”

F

[index top]

FILE

Section 13.1.17, “CREATE TABLE Syntax”
Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 13.2.7, “LOAD XML Syntax”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.2.9.1, “SELECT ... INTO Syntax”
Section 5.1.5, “Server System Variables”
Section 12.5, “String Functions”
Section 11.4.3, “The BLOB and TEXT Types”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”

G

[index top]

GRANT OPTION

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.1.5, “REVOKE Syntax”
Section 21.5, “The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table”

I

[index top]

INDEX

Section 13.1.7, “ALTER TABLE Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”

INSERT

Section 20.6, “Access Control for Stored Programs and Views”
Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 13.1.7, “ALTER TABLE Syntax”
Section 13.7.2.1, “ANALYZE TABLE Syntax”
Section 6.3.5, “Assigning Account Passwords”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 13.7.1.1, “CREATE USER Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 13.2.5, “INSERT Syntax”
Section 13.7.3.3, “INSTALL PLUGIN Syntax”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 13.7.2.4, “OPTIMIZE TABLE Syntax”
Section 15.2.1, “Pluggable Storage Engine Architecture”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.1.32, “RENAME TABLE Syntax”
Section 13.7.2.5, “REPAIR TABLE Syntax”
Section 13.2.8, “REPLACE Syntax”
Section 5.1.4, “Server Command Options”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 21.5, “The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table”
Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”
Section 24.4.2.5, “UDF Compiling and Installing”
Section 24.4.2.6, “UDF Security Precautions”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”

L

[index top]

LOCK TABLES

Section 13.7.6.3, “FLUSH Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 6.2.1, “Privileges Provided by MySQL”

P

[index top]

PROCESS

Section 6.3.2, “Adding User Accounts”
Section 14.20.2, “Enabling InnoDB Monitors”
Section 20.4.2, “Event Scheduler Configuration”
Section 8.14, “Examining Thread Information”
Section 13.7.1.3, “GRANT Syntax”

Chapter 21, *INFORMATION_SCHEMA Tables*
Section 13.7.6.4, “KILL Syntax”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.5.16, “SHOW ENGINE Syntax”
Section 13.7.5.30, “SHOW PROCESSLIST Syntax”
Section 21.28.1, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table”
Section 21.28.2, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table”
Section 21.28.3, “The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table”
Section 21.28.4, “The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables”
Section 21.28.5, “The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables”
Section 21.28.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”
Section 21.28.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”
Section 21.28.8, “The INFORMATION_SCHEMA INNODB_TRX Table”
Section 21.14, “The INFORMATION_SCHEMA PROCESSLIST Table”
Section 22.9.6.2, “The threads Table”
Section B.5.2.7, “Too many connections”

PROXY

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Implementing Proxy User Support in Authentication Plugins
Section 6.5.1.4, “PAM Pluggable Authentication”
Section 6.2.1, “Privileges Provided by MySQL”
Section 6.3.7, “Proxy Users”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 6.5.1.5, “Windows Pluggable Authentication”

PROXY ... WITH GRANT OPTION

Section 6.3.7, “Proxy Users”

R

[index top]

REFERENCES

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 21.5, “The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table”
Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”

RELOAD

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 6.3.2, “Adding User Accounts”
Section 12.13, “Encryption and Compression Functions”
Section 13.7.6.3, “FLUSH Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 23.8.7.55, “mysql_refresh()”
Section 23.8.7.56, “mysql_reload()”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.6.6, “RESET Syntax”

REPLICATION CLIENT

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.5.2, “SHOW BINARY LOGS Syntax”
Section 13.7.5.24, “SHOW MASTER STATUS Syntax”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”

REPLICATION SLAVE

Section 17.1.1.3, “Creating a User for Replication”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”

S

[index top]

SELECT

Section 20.6, “Access Control for Stored Programs and Views”
Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 13.7.2.1, “ANALYZE TABLE Syntax”
Section 13.7.2.3, “CHECKSUM TABLE Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.17.4, “CREATE TABLE ... LIKE Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 13.2.2, “DELETE Syntax”
Section 13.8.2, “EXPLAIN Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 13.2.5, “INSERT Syntax”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 13.7.2.4, “OPTIMIZE TABLE Syntax”
Section 22.8, “Performance Schema General Table Characteristics”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.2.5, “REPAIR TABLE Syntax”
Section C.5, “Restrictions on Views”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 13.7.5.22, “SHOW GRANTS Syntax”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 21.5, “The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table”
Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”
Section 15.8, “The MERGE Storage Engine”
Section 6.2, “The MySQL Access Privilege System”
Section 20.3.1, “Trigger Syntax and Examples”
Section 13.2.11, “UPDATE Syntax”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”

SHOW DATABASES

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 5.1.5, “Server System Variables”
Section 13.7.5.15, “SHOW DATABASES Syntax”

SHOW VIEW

Section 13.8.2, “EXPLAIN Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 6.2.1, “Privileges Provided by MySQL”
Section C.5, “Restrictions on Views”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”

SHUTDOWN

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 23.8.7.65, “mysql_shutdown()”
Section 4.3.4, “`mysqld_multi` — Manage Multiple MySQL Servers”
Section 6.2.1, “Privileges Provided by MySQL”
Section 5.1.12, “The Server Shutdown Process”

SUPER

Section 20.6, “Access Control for Stored Programs and Views”
Section 13.7.1, “Account Management Statements”
Section 13.1.3, “ALTER FUNCTION Syntax”
Section 13.1.6, “ALTER SERVER Syntax”
Section 13.1.9, “ALTER VIEW Syntax”
Section 6.3.5, “Assigning Account Passwords”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 20.7, “Binary Logging of Stored Programs”
Section 13.7.6.1, “BINLOG Syntax”
Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 10.1.5, “Configuring Application Character Set and Collation”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.16, “CREATE SERVER Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.7.1.1, “CREATE USER Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 13.1.27, “DROP SERVER Syntax”
Section 13.7.1.2, “DROP USER Syntax”
Section 12.13, “Encryption and Compression Functions”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 13.7.1.3, “GRANT Syntax”
Section 17.1.1, “How to Set Up Replication”
Section 13.7.6.4, “KILL Syntax”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 10.7, “MySQL Server Locale Support”
Section 10.6, “MySQL Server Time Zone Support”
Section 23.8.7.12, “mysql_dump_debug_info()”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.1.4, “RENAME USER Syntax”
Section 17.1.2, “Replication Formats”
Section 13.7.1.5, “REVOKE Syntax”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”

Section 13.7.1.6, “SET PASSWORD Syntax”
Section 13.4.1.3, “SET sql_log_bin Syntax”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 13.3.6, “SET TRANSACTION Syntax”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 13.7.5.2, “SHOW BINARY LOGS Syntax”
Section 13.7.5.22, “SHOW GRANTS Syntax”
Section 13.7.5.24, “SHOW MASTER STATUS Syntax”
Section 13.7.5.30, “SHOW PROCESSLIST Syntax”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 13.4.2.5, “START SLAVE Syntax”
Section 13.4.2.6, “STOP SLAVE Syntax”
Section 5.4.4, “The Binary Log”
Section 24.5.3, “The DBUG Package”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section B.5.2.7, “Too many connections”
Section 5.1.6, “Using System Variables”

T

[index top]

TRIGGER

Section 20.6, “Access Control for Stored Programs and Views”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.1.30, “DROP TRIGGER Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.5.13, “SHOW CREATE TRIGGER Syntax”
Section 13.7.5.39, “SHOW TRIGGERS Syntax”
Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”

U

[index top]

UPDATE

Section 20.6, “Access Control for Stored Programs and Views”
Section 6.3.5, “Assigning Account Passwords”
Section 13.1.17, “CREATE TABLE Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 13.2.5, “INSERT Syntax”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 22.8, “Performance Schema General Table Characteristics”
Section 22.4, “Performance Schema Runtime Configuration”
Section 22.9.2, “Performance Schema Setup Tables”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.1.4, “RENAME USER Syntax”
Section 13.7.1.5, “REVOKE Syntax”
Section 21.5, “The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table”
Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”
Section 15.8, “The MERGE Storage Engine”
Section 20.3.1, “Trigger Syntax and Examples”
Section 13.2.11, “UPDATE Syntax”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”

USAGE

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”

SQL Modes Index

A | D | E | H | I | M | N | O | P | R | S | T

A

[index top]

ALLOW_INVALID_DATES

Section 12.7, “Date and Time Functions”
Section 11.3, “Date and Time Types”
Section B.5.4.2, “Problems Using DATE Columns”
Section 5.1.8, “Server SQL Modes”
Section 11.3.1, “The DATE, DATETIME, and TIMESTAMP Types”

ANSI

Section 9.2.4, “Function Name Parsing and Resolution”
Section 5.1.8, “Server SQL Modes”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”

ANSI_QUOTES

Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 9.2, “Schema Object Names”
Section 5.1.8, “Server SQL Modes”
Section 9.1.1, “String Literals”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”

D

[index top]

DB2

Section 5.1.8, “Server SQL Modes”

E

[index top]

ERROR_FOR_DIVISION_BY_ZERO

Section 12.18.3, “Expression Handling”
Section 12.18.5, “Precision Math Examples”
Section 5.1.8, “Server SQL Modes”

H

[index top]

HIGH_NOT_PRECEDENCE

Section 9.5, “Expression Syntax”
Section 12.3.1, “Operator Precedence”

Section 5.1.8, “Server SQL Modes”

I

[index top]

IGNORE_SPACE

Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 9.2.4, “Function Name Parsing and Resolution”
Section 4.5.1.1, “mysql Options”
Section 5.1.8, “Server SQL Modes”

M

[index top]

MAXDB

Section 11.1.2, “Date and Time Type Overview”
Section 5.1.8, “Server SQL Modes”
Section 11.3.1, “The DATE, DATETIME, and TIMESTAMP Types”

MSSQL

Section 5.1.8, “Server SQL Modes”

MYSQL323

Section 5.1.8, “Server SQL Modes”

MYSQL40

Section 5.1.8, “Server SQL Modes”

N

[index top]

NO_AUTO_CREATE_USER

Section 13.7.1.3, “GRANT Syntax”
Section 5.1.8, “Server SQL Modes”

NO_AUTO_VALUE_ON_ZERO

Section 13.1.17, “CREATE TABLE Syntax”
Section 11.2.5, “Numeric Type Attributes”
Section 5.1.8, “Server SQL Modes”
Section 3.6.9, “Using AUTO_INCREMENT”

NO_BACKSLASH_ESCAPES

Section 5.1.8, “Server SQL Modes”
Section 12.5.1, “String Comparison Functions”
Section 9.1.1, “String Literals”

NO_DIR_IN_CREATE

Section 13.1.17, “CREATE TABLE Syntax”
Section 17.4.1.10, “Replication and DIRECTORY Table Options”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.8, “Server SQL Modes”
Section 19.2.6, “Subpartitioning”
Section 5.4.4, “The Binary Log”

NO_ENGINE_SUBSTITUTION

Section 13.1.7, “ALTER TABLE Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 5.1.8, “Server SQL Modes”
Section 15.1, “Setting the Storage Engine”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”

NO_FIELD_OPTIONS

Section 5.1.8, “Server SQL Modes”

NO_KEY_OPTIONS

Section 5.1.8, “Server SQL Modes”

NO_TABLE_OPTIONS

Section 5.1.8, “Server SQL Modes”

NO_UNSIGNED_SUBTRACTION

Section 12.6.1, “Arithmetic Operators”
Section 12.10, “Cast Functions and Operators”
Section 11.1.1, “Numeric Type Overview”
Section 11.2.6, “Out-of-Range and Overflow Handling”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.8, “Server SQL Modes”

NO_ZERO_DATE

Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.10, “Cast Functions and Operators”
Section 12.7, “Date and Time Functions”
Section 11.3, “Date and Time Types”
Section B.5.4.2, “Problems Using DATE Columns”
Section 5.1.8, “Server SQL Modes”

NO_ZERO_IN_DATE

Section 13.1.17, “CREATE TABLE Syntax”
Section 12.7, “Date and Time Functions”
Section 11.3, “Date and Time Types”
Section B.5.4.2, “Problems Using DATE Columns”
Section 5.1.8, “Server SQL Modes”

O

[index top]

ONLY_FULL_GROUP_BY

Section 3.3.4.8, “Counting Rows”
Section 12.16.2, “GROUP BY Modifiers”
Section 12.16.3, “MySQL Handling of GROUP BY”
Section 5.1.8, “Server SQL Modes”

ORACLE

Section 5.1.8, “Server SQL Modes”

P

[index top]

PAD_CHAR_TO_FULL_LENGTH
Section 5.1.8, “Server SQL Modes”
Section 11.1.3, “String Type Overview”
Section 11.4.1, “The CHAR and VARCHAR Types”

PIPES_AS_CONCAT
Section 9.5, “Expression Syntax”
Section 12.3.1, “Operator Precedence”
Section 5.1.8, “Server SQL Modes”

POSTGRESQL
Section 5.1.8, “Server SQL Modes”

R

[index top]

REAL_AS_FLOAT
Section 11.1.1, “Numeric Type Overview”
Section 11.2, “Numeric Types”
Section 5.1.8, “Server SQL Modes”

S

[index top]

STRICT_ALL_TABLES
Section 1.7.3.3, “Constraints on Invalid Data”
Section 12.18.3, “Expression Handling”
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”
Section 5.1.8, “Server SQL Modes”

STRICT_TRANS_TABLES
Section 1.7.3.3, “Constraints on Invalid Data”
Section 12.18.3, “Expression Handling”
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”
Section 5.1.8, “Server SQL Modes”

T

[index top]

TRADITIONAL
Section 11.3.5, “Automatic Initialization and Updating for TIMESTAMP”
Section 12.18.3, “Expression Handling”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”
Section 5.1.8, “Server SQL Modes”

Statement/Syntax Index

A | B | C | D | E | F | G | H | I | K | L | O | P | R | S | T | U | W | X

A

[index top]

ALTER DATABASE

Section 13.1.1, “ALTER DATABASE Syntax”
Section 10.1.3.3, “Database Character Set and Collation”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 17.1.3.3, “Replication Slave Options and Variables”

ALTER EVENT

Section 13.1.2, “ALTER EVENT Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 13.1.11, “CREATE EVENT Syntax”
Section 20.4.4, “Event Metadata”
Section 20.4.1, “Event Scheduler Overview”
Section 20.4.3, “Event Syntax”
Section 12.14, “Information Functions”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.15, “Replication of Invoked Features”
Section C.1, “Restrictions on Stored Programs”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”

ALTER EVENT event_name ENABLE

Section 17.4.1.15, “Replication of Invoked Features”

ALTER FUNCTION

Section 13.1.3, “ALTER FUNCTION Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.2.1, “Stored Routine Syntax”

ALTER LOGFILE GROUP

Section 13.1.4, “ALTER LOGFILE GROUP Syntax”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”

ALTER ONLINE TABLE

Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”

ALTER ONLINE TABLE ... REORGANIZE PARTITION

Section 18.5.13.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 18.5.13.1, “Adding NDB Cluster Data Nodes Online: General Issues”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 18.2.7, “Upgrading and Downgrading NDB Cluster”

ALTER PROCEDURE

Section 13.1.5, “ALTER PROCEDURE Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.2.1, “Stored Routine Syntax”

ALTER SCHEMA

Section 13.1.1, “ALTER DATABASE Syntax”

ALTER SERVER

Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.5, “Replication of CREATE SERVER, ALTER SERVER, and DROP SERVER”
Section 13.3.3, “Statements That Cause an Implicit Commit”

ALTER TABLE

Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 13.1.7.3, “ALTER TABLE Examples”
Section 13.1.7.2, “ALTER TABLE Online Operations in NDB Cluster 7.2”
Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 13.1.7, “ALTER TABLE Syntax”
Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 13.7.2.2, “CHECK TABLE Syntax”
Section 10.1.3.5, “Column Character Set and Collation”
Section 10.1.7, “Column Character Set Conversion”
Section 8.3.4, “Column Indexes”
Section 14.16.4, “Concurrency Considerations for Fast Index Creation”
Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 10.1.9.7, “Converting Between 3-Byte and 4-Byte Unicode Character Sets”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 13.1.13, “CREATE INDEX Syntax”
Section 13.1.17.1, “CREATE TABLE Statement Retention”
Section 13.1.17, “CREATE TABLE Syntax”
Section 3.3.2, “Creating a Table”
Section 14.11.1.1, “Creating InnoDB Tables”
Section 11.5.4, “Creating Spatial Columns”
Section 11.5.8, “Creating Spatial Indexes”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 14.15.4, “Defragmenting a Table”
Section 13.1.24, “DROP INDEX Syntax”
Section 14.12.2, “Enabling Compression for a Table”
Section 14.16.2, “Examples of Fast Index Creation”
Section 8.8.2, “EXPLAIN Output Format”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 14.23.2, “Forcing InnoDB Recovery”
Section 1.7.3.2, “FOREIGN KEY Constraints”
Section 12.9, “Full-Text Search Functions”
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Syntax”
Section 14.12.5, “How Compression Works for InnoDB Tables”
Section 14.16.5, “How Crash Recovery Works with Fast Index Creation”
Section B.5.3.4, “How MySQL Handles a Full Disk”
Section 8.10.3.1, “How the Query Cache Operates”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 12.14, “Information Functions”
Section 18.2.3, “Initial Configuration of NDB Cluster”
Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.2.5.3, “INSERT DELAYED Syntax”

Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 13.7.6.4, “KILL Syntax”
Section B.5.7, “Known Issues in MySQL”
Section 14.16.6, “Limitations of Fast Index Creation”
Section 18.1.6.10, “Limitations Relating to Multiple NDB Cluster Nodes”
Section 18.1.6.2, “Limits and Differences of NDB Cluster from Standard MySQL Limits”
Section C.10.3, “Limits on Table Size”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
Section 19.3.3, “Maintenance of Partitions”
Section 19.3.2, “Management of HASH and KEY Partitions”
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 15.3.1, “MyISAM Startup Options”
Section 15.3.3, “MyISAM Table Storage Formats”
Section 4.6.3.1, “myisamchk General Options”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Glossary
Section 23.8.7.35, “mysql_info()”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.3.3.1, “NDB Cluster Configuration: Basic Example”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.2.5, “NDB Cluster Example with Tables and Data”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
NDB Cluster System Variables
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”
Section 18.1.6.1, “Noncompliance with SQL Syntax in NDB Cluster”
Section 13.7.2.4, “OPTIMIZE TABLE Syntax”
Section 11.2.6, “Out-of-Range and Overflow Handling”
Section 19.1, “Overview of Partitioning in MySQL”
Section 14.12.1, “Overview of Table Compression”
Section 19.3, “Partition Management”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”
Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”
Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 6.2.1, “Privileges Provided by MySQL”
Section B.5.6.1, “Problems with ALTER TABLE”
Section 19.2.3.1, “RANGE COLUMNS partitioning”
Section 19.2.1, “RANGE Partitioning”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 13.1.32, “RENAME TABLE Syntax”
Section 17.4.1.1, “Replication and AUTO_INCREMENT”
Section 17.4.1.25, “Replication and Reserved Words”
Replication with More Columns on Master or Slave
Section 19.5, “Restrictions and Limitations on Partitioning”
Section C.5, “Restrictions on Views”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section B.3, “Server Error Codes and Messages”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 15.1, “Setting the Storage Engine”
Section 13.7.5.16, “SHOW ENGINE Syntax”
Section 13.7.5.23, “SHOW INDEX Syntax”

Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section 13.1.17.7, “Silent Column Specification Changes”
Section 14.14.2, “Specifying the Row Format for a Table”
Section 14.12.6, “SQL Compression Syntax Warnings and Errors”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 11.1.3, “String Type Overview”
Section 10.1.3.4, “Table Character Set and Collation”
Section B.5.6.2, “TEMPORARY Table Problems”
Section 5.4.6, “The DDL Log”
Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”
Section 15.4, “The MEMORY Storage Engine”
Section 15.3, “The MyISAM Storage Engine”
Section 5.4.5, “The Slow Query Log”
Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”
Section 18.1.6.6, “Unsupported or Missing Features in NDB Cluster”
Section 3.6.9, “Using AUTO_INCREMENT”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”
Section 14.13.2, “Verifying File Format Compatibility”
Section 1.4, “What Is New in MySQL 5.5”
Section B.5.3.3, “What to Do If MySQL Keeps Crashing”
Section B.5.3.5, “Where MySQL Stores Temporary Files”
Section 11.3.4, “YEAR(2) Limitations and Migrating to YEAR(4)”

ALTER TABLE ... ADD PARTITION

Section 19.3.1, “Management of RANGE and LIST Partitions”

ALTER TABLE ... CHANGE

Section 14.16.6, “Limitations of Fast Index Creation”

ALTER TABLE ... DISCARD TABLESPACE

MySQL Glossary

ALTER TABLE ... DROP PARTITION

Section 17.4.1.23, “Replication and Partitioning”

ALTER TABLE ... ENGINE = MEMORY

Section 17.4.1.20, “Replication and MEMORY Tables”

ALTER TABLE ... ENGINE = NDB

Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”

ALTER TABLE ... IMPORT TABLESPACE

Section 13.1.7, “ALTER TABLE Syntax”
MySQL Glossary

ALTER TABLE ... OPTIMIZE PARTITION

Section 19.3.3, “Maintenance of Partitions”
Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”

ALTER TABLE ... PARTITION BY

Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”

ALTER TABLE ... PARTITION BY ...

Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 19.5, “Restrictions and Limitations on Partitioning”

ALTER TABLE ... PARTITION BY ALGORITHM=1 KEY ()

Section 2.11.2.1, “Changes Affecting Downgrades from MySQL 5.5”

ALTER TABLE ... PARTITION BY ALGORITHM=2 KEY ()

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”

ALTER TABLE ... RENAME

Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

ALTER TABLE ... REORGANIZE PARTITION

Section 18.5.13.1, “Adding NDB Cluster Data Nodes Online: General Issues”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”

ALTER TABLE ... REPAIR PARTITION

Section 19.3.3, “Maintenance of Partitions”

ALTER TABLE ... TRUNCATE PARTITION

Section 19.3.3, “Maintenance of Partitions”
Section 19.3, “Partition Management”
Section 1.4, “What Is New in MySQL 5.5”

ALTER TABLE mysql.ndb_apply_status ENGINE=MyISAM

Section 18.6.3, “Known Issues in NDB Cluster Replication”

ALTER TABLE t3 DROP PARTITION p2

Section 5.4.6, “The DDL Log”

ALTER TABLE table_name REORGANIZE PARTITION

Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”

ALTER TABLE tbl_name TABLESPACE tablespace_name

MySQL Glossary

ALTER TABLESPACE

Section 13.1.8, “ALTER TABLESPACE Syntax”
Section 13.1.18, “CREATE TABLESPACE Syntax”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”

ALTER VIEW

Section 13.1.9, “ALTER VIEW Syntax”
Section 12.14, “Information Functions”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section C.1, “Restrictions on Stored Programs”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.5.2, “View Processing Algorithms”
Section 20.5.1, “View Syntax”

ANALYZE TABLE

Section 13.1.7, “ALTER TABLE Syntax”
Section 13.7.2.1, “ANALYZE TABLE Syntax”
Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”
Section 14.9.11.1, “Estimating ANALYZE TABLE Complexity for InnoDB Tables”

Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Syntax”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 8.14.2, “General Thread States”
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section 14.17, “InnoDB Startup Options and System Variables”
Section B.5.7, “Known Issues in MySQL”
Section 14.11.1.7, “Limits on InnoDB Tables”
Section 19.3.3, “Maintenance of Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”
Section 4.6.3.1, “myisamchk General Options”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Glossary
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 8.8.1, “Optimizing Queries with EXPLAIN”
Section 8.2.1, “Optimizing SELECT Statements”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.13, “Replication and FLUSH”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 13.7.5.23, “SHOW INDEX Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 5.4.5, “The Slow Query Log”

B

[index top]

BEGIN

Section 14.8.2.2, “autocommit, Commit, and Rollback”
Section 13.6.1, “BEGIN ... END Compound-Statement Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 14.23.4, “InnoDB Error Handling”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 17.4.1.35, “Replication and Transactions”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section C.1, “Restrictions on Stored Programs”
Section 5.1.5, “Server System Variables”
Section 13.3.3, “Statements That Cause an Implicit Commit”

BEGIN ... END

Section 13.6.1, “BEGIN ... END Compound-Statement Syntax”
Section 13.6.5.1, “CASE Syntax”
Section 13.6, “Compound-Statement Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.6.6.1, “Cursor CLOSE Syntax”
Section 13.6.6.3, “Cursor FETCH Syntax”
Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
Section 13.6.3, “DECLARE Syntax”
Section 20.1, “Defining Stored Programs”
Section 20.4.1, “Event Scheduler Overview”
Section 13.6.5.4, “LEAVE Syntax”
Section 13.6.4.1, “Local Variable DECLARE Syntax”
Section 13.6.4.2, “Local Variable Scope and Resolution”
Section C.1, “Restrictions on Stored Programs”

Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 13.6.2, “Statement Label Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.3.1, “Trigger Syntax and Examples”

BINLOG

Section 13.7.6.1, “BINLOG Syntax”
Section 4.6.7.2, “mysqlbinlog Row Event Display”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 6.2.1, “Privileges Provided by MySQL”

C

[index top]

CACHE INDEX

Section 13.7.6.2, “CACHE INDEX Syntax”
Section 8.10.2.4, “Index Preloading”
Section 13.7.6.5, “LOAD INDEX INTO CACHE Syntax”
Section 8.10.2.2, “Multiple Key Caches”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 1.4, “What Is New in MySQL 5.5”

CALL

Section 20.6, “Access Control for Stored Programs and Views”
Section 20.7, “Binary Logging of Stored Programs”
Section 23.8.5, “C API Data Structures”
Section 23.8.16, “C API Multiple Statement Execution Support”
Section 23.8.18, “C API Prepared CALL Statement Support”
Section 23.8.19, “C API Prepared Statement Problems”
Section 13.2.1, “CALL Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.37, “mysql_insert_id()”
Section 23.8.7.45, “mysql_more_results()”
Section 23.8.7.46, “mysql_next_result()”
Section 23.8.7.52, “mysql_real_connect()”
Section 23.8.7.64, “mysql_set_server_option()”
Section 23.8.11.17, “mysql_stmt_next_result()”
Section 13.5, “Prepared SQL Statement Syntax”
Chapter 20, *Stored Programs and Views*
Section 20.2.1, “Stored Routine Syntax”
Section 20.3.1, “Trigger Syntax and Examples”

CALL p()

RESIGNAL with a Condition Value and Optional New Signal Information

CALL stored_procedure()

Section 19.5.4, “Partitioning and Table-Level Locking”

CASE

Section 13.6.5.1, “CASE Syntax”
Section 12.4, “Control Flow Functions”
Section 13.6.5, “Flow Control Statements”

CHANGE MASTER TO

Section 6.3.5, “Assigning Account Passwords”
Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”
Section 13.7.1.3, “GRANT Syntax”
Section 18.6.8, “Implementing Failover with NDB Cluster Replication”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
Section 18.6.5, “Preparing the NDB Cluster for Replication”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.28, “Replication and Master or Slave Shutdowns”
Section 17.1, “Replication Configuration”
Section 8.14.8, “Replication Slave Connection Thread States”
Section 8.14.6, “Replication Slave I/O Thread States”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.4.2.3, “RESET SLAVE Syntax”
Section 5.1.7, “Server Status Variables”
Section 17.1.1.10, “Setting the Master Configuration on the Slave”
Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”
Section 17.1.1.8, “Setting Up Replication with Existing Data”
Section 17.1.1.7, “Setting Up Replication with New Master and Slaves”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 17.2.2.2, “Slave Status Logs”
Section 17.3.6, “Switching Masters During Failover”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”
Section 1.4, “What Is New in MySQL 5.5”

CHECK TABLE

Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 13.7.2.2, “CHECK TABLE Syntax”
Section 15.3.4.1, “Corrupted MyISAM Tables”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 8.11.5, “External Locking”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 1.6, “How to Report Bugs or Problems”
Section 4.6.1, “`innochecksum` — Offline InnoDB File Checksum Utility”
Section 14.21.2, “InnoDB Recovery”
Section 14.23, “InnoDB Troubleshooting”
Section 19.3.3, “Maintenance of Partitions”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”
Section 4.6.3, “`myisamchk` — MyISAM Table-Maintenance Utility”
Section A.6, “MySQL 5.5 FAQ: Views”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section B.5.2.9, “MySQL server has gone away”
Section 23.8.7.69, “mysql_store_result()”
Section 4.4.7, “`mysql_upgrade` — Check and Upgrade MySQL Tables”
Section 23.8.7.71, “mysql_use_result()”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 15.3.4.2, “Problems from Tables Not Being Closed Properly”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section C.3, “Restrictions on Server-Side Cursors”
Section C.1, “Restrictions on Stored Programs”

Section C.5, “Restrictions on Views”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 15.6, “The ARCHIVE Storage Engine”
Section 15.8, “The MERGE Storage Engine”
Section 5.4.5, “The Slow Query Log”

CHECK TABLE ... EXTENDED

Section 13.7.2.2, “CHECK TABLE Syntax”

CHECK TABLE ... FOR UPGRADE

Section 13.7.2.5, “REPAIR TABLE Syntax”

CHECK TABLE QUICK

Section 13.7.2.2, “CHECK TABLE Syntax”

CHECKSUM TABLE

Section 13.7.2.3, “CHECKSUM TABLE Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 17.4.1.4, “Replication and CHECKSUM TABLE”

COMMIT

Section 14.8.2.2, “autocommit, Commit, and Rollback”
Section 20.7, “Binary Logging of Stored Programs”
Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 14.5, “InnoDB and the ACID Model”
Section 14.23.4, “InnoDB Error Handling”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.11.1.7, “Limits on InnoDB Tables”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
NDB Cluster System Variables
Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”
Section 17.4.1.35, “Replication and Transactions”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Syntax”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 5.4.4, “The Binary Log”
Section 13.3, “Transactional and Locking Statements”
Section 20.3.1, “Trigger Syntax and Examples”

CREATE DATABASE

Section 7.1, “Backup and Recovery Types”
Section 23.8.6, “C API Function Overview”
Section 10.1.5, “Configuring Application Character Set and Collation”
Section 7.4.5.2, “Copy a Database from one Server to Another”
Section 13.1.10, “CREATE DATABASE Syntax”
Section 10.1.3.3, “Database Character Set and Collation”
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 9.2.2, “Identifier Case Sensitivity”

Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 23.8.7.8, “mysql_create_db()”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 7.4.2, “Reloading SQL-Format Backups”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 10.1.3.2, “Server Character Set and Collation”
Section B.3, “Server Error Codes and Messages”
Section 13.7.5.8, “SHOW CREATE DATABASE Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”

CREATE DATABASE dbx

Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”

CREATE DATABASE IF NOT EXISTS

Section 17.4.1.6, “Replication of CREATE ... IF NOT EXISTS Statements”

CREATE EVENT

Section 13.1.2, “ALTER EVENT Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 13.1.11, “CREATE EVENT Syntax”
Section 20.4.4, “Event Metadata”
Section 20.4.3, “Event Syntax”
Section 12.14, “Information Functions”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.15, “Replication of Invoked Features”
Section C.1, “Restrictions on Stored Programs”
Section 13.7.5.9, “SHOW CREATE EVENT Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”

CREATE EVENT IF NOT EXISTS

Section 17.4.1.6, “Replication of CREATE ... IF NOT EXISTS Statements”

CREATE FUNCTION

Section 24.4, “Adding New Functions to MySQL”
Section 13.1.3, “ALTER FUNCTION Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 1.8.1, “Contributors to MySQL”
Section 13.1.12, “CREATE FUNCTION Syntax”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.7.3.2, “DROP FUNCTION Syntax”
Section 9.2.4, “Function Name Parsing and Resolution”
Section 12.14, “Information Functions”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.15, “Replication of Invoked Features”
Section C.1, “Restrictions on Stored Programs”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.2.1, “Stored Routine Syntax”
Section 24.4.2.1, “UDF Calling Sequences for Simple Functions”
Section 24.4.2.5, “UDF Compiling and Installing”

Section 24.4.2.6, “UDF Security Precautions”
Section 2.11.1, “Upgrading MySQL”

CREATE INDEX

Section 13.1.7.2, “ALTER TABLE Online Operations in NDB Cluster 7.2”
Section 8.3.4, “Column Indexes”
Section 14.16.4, “Concurrency Considerations for Fast Index Creation”
Section 13.1.13, “CREATE INDEX Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 11.5.8, “Creating Spatial Indexes”
Section 14.12.2, “Enabling Compression for a Table”
Section 14.16.2, “Examples of Fast Index Creation”
Section 12.9, “Full-Text Search Functions”
Section 14.12.5, “How Compression Works for InnoDB Tables”
Section 14.16.5, “How Crash Recovery Works with Fast Index Creation”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 8.7, “Optimizing for MEMORY Tables”
Section 14.16.1, “Overview of Fast Index Creation”
Section 5.1.4, “Server Command Options”
Section B.3, “Server Error Codes and Messages”
Section 5.1.5, “Server System Variables”
Section 13.7.5.23, “SHOW INDEX Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 5.4.5, “The Slow Query Log”
Section 18.1.6.6, “Unsupported or Missing Features in NDB Cluster”

CREATE LOGFILE GROUP

Section 13.1.4, “ALTER LOGFILE GROUP Syntax”
Section 13.1.14, “CREATE LOGFILE GROUP Syntax”
Section 13.1.18, “CREATE TABLESPACE Syntax”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”
Section 18.5.10.14, “The ndbinfo resources Table”

CREATE OR REPLACE VIEW

Section 13.1.20, “CREATE VIEW Syntax”
Section C.5, “Restrictions on Views”

CREATE PROCEDURE

Section 13.1.5, “ALTER PROCEDURE Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 13.2.1, “CALL Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 12.14, “Information Functions”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.15, “Replication of Invoked Features”
Section C.1, “Restrictions on Stored Programs”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.2.1, “Stored Routine Syntax”

CREATE SCHEMA

Section 13.1.10, “CREATE DATABASE Syntax”

Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”

CREATE SERVER

Section 13.1.6, “ALTER SERVER Syntax”
Section 15.9.2.2, “Creating a FEDERATED Table Using CREATE SERVER”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 13.7.6.3, “FLUSH Syntax”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 15.9.2, “How to Create FEDERATED Tables”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.5, “Replication of CREATE SERVER, ALTER SERVER, and DROP SERVER”
Section 13.3.3, “Statements That Cause an Implicit Commit”

CREATE TABLE

Section 13.1.7.3, “ALTER TABLE Examples”
Section 13.1.7.2, “ALTER TABLE Online Operations in NDB Cluster 7.2”
Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 13.1.7, “ALTER TABLE Syntax”
Chapter 15, *Alternative Storage Engines*
Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 7.1, “Backup and Recovery Types”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 10.1.3.5, “Column Character Set and Collation”
Section 8.3.4, “Column Indexes”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.1.13, “CREATE INDEX Syntax”
Section 13.1.16, “CREATE SERVER Syntax”
Section 13.1.17.4, “CREATE TABLE ... LIKE Syntax”
Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”
Section 13.1.17.1, “CREATE TABLE Statement Retention”
Section 13.1.17, “CREATE TABLE Syntax”
Section 13.1.17.3, “CREATE TEMPORARY TABLE Syntax”
Section 15.9.2.1, “Creating a FEDERATED Table Using CONNECTION”
Section 3.3.2, “Creating a Table”
Section 14.11.1.1, “Creating InnoDB Tables”
Section 11.5.4, “Creating Spatial Columns”
Section 11.5.8, “Creating Spatial Indexes”
Section 7.2, “Database Backup Methods”
Section 10.1.3.3, “Database Character Set and Collation”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 14.12.2, “Enabling Compression for a Table”
Section 14.20.2, “Enabling InnoDB Monitors”
Section 1.7.3.2, “FOREIGN KEY Constraints”
Section 12.9, “Full-Text Search Functions”
Section 3.4, “Getting Information About Databases and Tables”
Section 19.2.4, “HASH Partitioning”
Section 13.8.3, “HELP Syntax”
Section 14.12.5, “How Compression Works for InnoDB Tables”
Section 19.2.7, “How MySQL Partitioning Handles NULL”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 9.2.2, “Identifier Case Sensitivity”
Section 12.14, “Information Functions”
Section 18.2.3, “Initial Configuration of NDB Cluster”

Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”
Section 14.22, “InnoDB and MySQL Replication”
Section 14.14, “InnoDB Row Storage and Row Formats”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.23, “InnoDB Troubleshooting”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 14.1, “Introduction to InnoDB”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 19.2.5, “KEY Partitioning”
Section C.10.3, “Limits on Table Size”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 19.2.2, “LIST Partitioning”
Section 13.2.7, “LOAD XML Syntax”
Section 3.3.3, “Loading Data into a Table”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 15.3.3, “MyISAM Table Storage Formats”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Glossary
Section 4.5.1.1, “mysql Options”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.5.15, “NDB API Statistics Counters and Variables”
Section 18.3.3.1, “NDB Cluster Configuration: Basic Example”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.4.6, “`ndb_blob_tool` — Check and Repair BLOB and TEXT columns of NDB Cluster Tables”
Section 18.1.6.1, “Noncompliance with SQL Syntax in NDB Cluster”
Section 8.4.1, “Optimizing Data Size”
Section 8.5.6, “Optimizing InnoDB DDL Operations”
Section 19.1, “Overview of Partitioning in MySQL”
Section 14.12.1, “Overview of Table Compression”
Section 19.3, “Partition Management”
Section 19.5.1, “Partitioning Keys, Primary Keys, and Unique Keys”
Section 19.5.3, “Partitioning Limitations Relating to Functions”
Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”
Section 19.2, “Partitioning Types”
Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 6.2.1, “Privileges Provided by MySQL”
Section 19.2.3.1, “RANGE COLUMNS partitioning”
Section 19.2.1, “RANGE Partitioning”
Section 7.4.4, “Reloading Delimited-Text Format Backups”
Section 13.2.8, “REPLACE Syntax”
Section 17.4.1.1, “Replication and AUTO_INCREMENT”
Section 17.4.1.3, “Replication and Character Sets”
Section 17.4.1.10, “Replication and DIRECTORY Table Options”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.7, “Replication of CREATE TABLE ... SELECT Statements”
Replication with More Columns on Master or Slave
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section B.3, “Server Error Codes and Messages”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 15.1, “Setting the Storage Engine”

Section 13.7.5.6, “SHOW COLUMNS Syntax”
Section 13.7.5.12, “SHOW CREATE TABLE Syntax”
Section 13.7.5.16, “SHOW ENGINE Syntax”
Section 13.7.5.23, “SHOW INDEX Syntax”
Section 13.7.5.37, “SHOW TABLE STATUS Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section 13.1.17.7, “Silent Column Specification Changes”
Section B.1, “Sources of Error Information”
Section 14.14.2, “Specifying the Row Format for a Table”
Section 14.12.6, “SQL Compression Syntax Warnings and Errors”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 11.1.3, “String Type Overview”
Section 19.2.6, “Subpartitioning”
Section 10.1.3.4, “Table Character Set and Collation”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”
Section 15.6, “The ARCHIVE Storage Engine”
Section 11.4.4, “The ENUM Type”
Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”
Section 15.4, “The MEMORY Storage Engine”
Section 15.3, “The MyISAM Storage Engine”
Section 13.2.10.1, “The Subquery as Scalar Operand”
Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”
Section 13.1.33, “TRUNCATE TABLE Syntax”
Section 13.7.3.4, “UNINSTALL PLUGIN Syntax”
Section 18.1.6.6, “Unsupported or Missing Features in NDB Cluster”
Section 3.6.9, “Using AUTO_INCREMENT”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”
Section 3.3.4.9, “Using More Than one Table”
Section 7.4, “Using mysqldump for Backups”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”
Section 1.4, “What Is New in MySQL 5.5”
Section C.10.6, “Windows Platform Limitations”

CREATE TABLE ... LIKE

Section 13.1.17.4, “CREATE TABLE ... LIKE Syntax”
Section 17.4.1.1, “Replication and AUTO_INCREMENT”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”
Section 15.8, “The MERGE Storage Engine”

CREATE TABLE ... SELECT

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 20.7, “Binary Logging of Stored Programs”
Section 12.10, “Cast Functions and Operators”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”
Section B.5.7, “Known Issues in MySQL”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 17.4.2, “Replication Compatibility Between MySQL Versions”
Section 17.4.1.7, “Replication of CREATE TABLE ... SELECT Statements”
Section 1.7.2.1, “SELECT INTO TABLE Differences”
Section 13.3.3, “Statements That Cause an Implicit Commit”

CREATE TABLE ... SELECT ...

Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 19.3.1, “Management of RANGE and LIST Partitions”

CREATE TABLE IF NOT EXISTS

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”
Section 17.4.1.6, “Replication of CREATE ... IF NOT EXISTS Statements”

CREATE TABLE IF NOT EXISTS ... LIKE

Section 17.4.1.6, “Replication of CREATE ... IF NOT EXISTS Statements”

CREATE TABLE IF NOT EXISTS ... SELECT

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”
Section 17.4.1.6, “Replication of CREATE ... IF NOT EXISTS Statements”

CREATE TABLE tbl_name ... TABLESPACE tablespace_name

MySQL Glossary

CREATE TABLE...AS SELECT

Section 8.2.1, “Optimizing SELECT Statements”

CREATE TABLESPACE

Section 13.1.8, “ALTER TABLESPACE Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 13.1.18, “CREATE TABLESPACE Syntax”
Section 18.3.3.6, “Defining NDB Cluster Data Nodes”
Section 13.1.29, “DROP TABLESPACE Syntax”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
MySQL Glossary
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”

CREATE TEMPORARY TABLE

Section 13.7.1.3, “GRANT Syntax”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section B.5.6.2, “TEMPORARY Table Problems”

CREATE TRIGGER

Section 20.7, “Binary Logging of Stored Programs”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 12.14, “Information Functions”
Section A.5, “MySQL 5.5 FAQ: Triggers”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.15, “Replication of Invoked Features”
Section C.1, “Restrictions on Stored Programs”
Section 13.7.5.13, “SHOW CREATE TRIGGER Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 8.2.2, “Subquery Optimization”
Section 20.3.1, “Trigger Syntax and Examples”

CREATE USER

Section 6.3.2, “Adding User Accounts”

Section 6.3.5, “Assigning Account Passwords”
Section 5.1.9.3, “Connecting Using the IPv6 Local Host Address”
Section 13.7.1.1, “CREATE USER Syntax”
Section 17.1.1.3, “Creating a User for Replication”
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 13.7.6.3, “FLUSH Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Implementing Proxy User Support in Authentication Plugins
Section 5.1.9, “IPv6 Support”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 6.5.1.4, “PAM Pluggable Authentication”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 6.1.2.3, “Passwords and Logging”
Section 6.2.1, “Privileges Provided by MySQL”
Section 2.10.1.1, “Problems Running mysql_install_db”
Section 6.3.7, “Proxy Users”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 6.2.3, “Specifying Account Names”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 6.2, “The MySQL Access Privilege System”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 6.3.1, “User Names and Passwords”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”
Section 6.5.1.5, “Windows Pluggable Authentication”

CREATE VIEW

Section 13.1.9, “ALTER VIEW Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 8.14.2, “General Thread States”
Section 12.14, “Information Functions”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section C.5, “Restrictions on Views”
Section 9.2, “Schema Object Names”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”
Section 20.5.1, “View Syntax”

D

[index top]

DEALLOCATE PREPARE

Section 13.5.3, “DEALLOCATE PREPARE Syntax”
Section 13.5.1, “PREPARE Syntax”
Section 13.5, “Prepared SQL Statement Syntax”
Section C.1, “Restrictions on Stored Programs”
Section 5.1.7, “Server Status Variables”

DECLARE

Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.6.3, “DECLARE Syntax”
Section 13.6.7.4, “SIGNAL Syntax”
Section 13.6.4, “Variables in Stored Programs”

DECLARE ... CONDITION

Section 13.6.7, “Condition Handling”
Section 13.6.7.1, “DECLARE ... CONDITION Syntax”
Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
Section 13.6.7.4, “SIGNAL Syntax”

DECLARE ... HANDLER

Section 13.6.7, “Condition Handling”
Section 13.6.7.1, “DECLARE ... CONDITION Syntax”
Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
Effect of Signals on Handlers, Cursors, and Statements

DELETE

Section 6.3.2, “Adding User Accounts”
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 23.8.6, “C API Function Overview”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 14.7.2, “Change Buffer”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 14.9.4, “Configuring InnoDB Change Buffering”
Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 13.2.2, “DELETE Syntax”
Section B.5.4.6, “Deleting Rows from Related Tables”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 14.23.2, “Forcing InnoDB Recovery”
Chapter 12, *Functions and Operators*
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.14, “Information Functions”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 14.22, “InnoDB and MySQL Replication”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 8.11.1, “Internal Locking Methods”
Section 13.2.9.2, “JOIN Syntax”
Section 9.3, “Keywords and Reserved Words”
Section 13.7.6.4, “KILL Syntax”
Section B.5.7, “Known Issues in MySQL”
Section 18.1.6.2, “Limits and Differences of NDB Cluster from Standard MySQL Limits”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 19.2.2, “LIST Partitioning”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”

Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Glossary
Section 4.5.1.1, “mysql Options”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.48, “mysql_num_rows()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.13, “mysql_stmt_field_count()”
Section 23.8.11.18, “mysql_stmt_num_rows()”
Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.4.9, “`ndb_delete_all` — Delete All Rows from an NDB Table”
Section 8.2.4, “Optimizing Data Change Statements”
Section 8.2.1, “Optimizing SELECT Statements”
Section 19.4, “Partition Pruning”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 6.2.1, “Privileges Provided by MySQL”
Section 8.14.4, “Query Cache Thread States”
Section 19.2.1, “RANGE Partitioning”
Section 14.15.5, “Reclaiming Disk Space with TRUNCATE TABLE”
Section 17.4.1.16, “Replication and LIMIT”
Section 17.4.1.20, “Replication and MEMORY Tables”
Section 17.4.1.22, “Replication and the Query Optimizer”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.2.10.11, “Rewriting Subqueries as Joins”
Section 3.3.4.1, “Selecting All Data”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”
Section 5.7.1.12, “Statement Probes”
Section 13.2.10.9, “Subquery Errors”
Section 13.2.10, “Subquery Syntax”
Section 8.11.2, “Table Locking Issues”
Section 15.6, “The ARCHIVE Storage Engine”
Section 5.4.4, “The Binary Log”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 1.3.2, “The Main Features of MySQL”
Section 15.4, “The MEMORY Storage Engine”
Section 15.8, “The MERGE Storage Engine”
Section 6.2, “The MySQL Access Privilege System”
Section 14.8.2.1, “Transaction Isolation Levels”
Section 20.3.1, “Trigger Syntax and Examples”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 13.1.33, “TRUNCATE TABLE Syntax”
Section 20.5.3, “Updatable and Insertable Views”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”
Using the --safe-updates Option
Section 23.8.21.2, “What Results You Can Get from a Query”
Section 6.2.6, “When Privilege Changes Take Effect”
Section 8.2.1.1, “WHERE Clause Optimization”
Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”
Section 24.2.4.8, “Writing Audit Plugins”

DELETE FROM ... WHERE ...

Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”

DELETE FROM a.t

Section 17.1.3.3, “Replication Slave Options and Variables”

DELETE FROM t1,t2

Section 5.7.1.12, “Statement Probes”

DESCRIBE

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 13.1.17.1, “CREATE TABLE Statement Retention”
Section 3.3.2, “Creating a Table”
Section 13.8.1, “DESCRIBE Syntax”
Section 13.8.2, “EXPLAIN Syntax”
Section 21.31, “Extensions to SHOW Statements”
Section 3.4, “Getting Information About Databases and Tables”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 23.8.11.28, “mysql_stmt_store_result()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Section 13.7.5.6, “SHOW COLUMNS Syntax”
Section 13.1.17.7, “Silent Column Specification Changes”
Section 21.28.1, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table”
Section 21.28.2, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table”
Section 21.28.3, “The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table”
Section 21.28.4, “The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables”
Section 21.28.5, “The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables”
Section 21.28.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”
Section 21.28.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”
Section 21.28.8, “The INFORMATION_SCHEMA INNODB_TRX Table”
Section 3.6.6, “Using Foreign Keys”
Section 10.1.2.2, “UTF-8 for Metadata”

DO

Section 13.1.2, “ALTER EVENT Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.2.3, “DO Syntax”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 12.17, “Miscellaneous Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section C.1, “Restrictions on Stored Programs”
Section 13.2.10, “Subquery Syntax”
Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”

DROP DATABASE

Section 23.8.6, “C API Function Overview”
Section 13.1.21, “DROP DATABASE Syntax”
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 8.10.3.1, “How the Query Cache Operates”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 1.7.1, “MySQL Extensions to Standard SQL”

Section 23.8.7.11, “mysql_drop_db()”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 7.5, “Point-in-Time (Incremental) Recovery Using the Binary Log”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section C.10.6, “Windows Platform Limitations”

DROP DATABASE IF EXISTS

Section 17.4.1.11, “Replication of DROP ... IF EXISTS Statements”

DROP EVENT

Section 20.7, “Binary Logging of Stored Programs”
Section 20.4.3, “Event Syntax”
Section 17.4.1.15, “Replication of Invoked Features”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

DROP FUNCTION

Section 24.4, “Adding New Functions to MySQL”
Section 13.1.3, “ALTER FUNCTION Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 1.8.1, “Contributors to MySQL”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 13.1.23, “DROP FUNCTION Syntax”
Section 13.7.3.2, “DROP FUNCTION Syntax”
Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Syntax”
Section 9.2.4, “Function Name Parsing and Resolution”
Section 17.4.1.15, “Replication of Invoked Features”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.2.1, “Stored Routine Syntax”
Section 24.4.2.5, “UDF Compiling and Installing”
Section 24.4.2.6, “UDF Security Precautions”
Section 2.11.1, “Upgrading MySQL”

DROP INDEX

Section 13.1.7.2, “ALTER TABLE Online Operations in NDB Cluster 7.2”
Section 13.1.7, “ALTER TABLE Syntax”
Section 11.5.8, “Creating Spatial Indexes”
Section 13.1.24, “DROP INDEX Syntax”
Section 14.16.2, “Examples of Fast Index Creation”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Glossary
Section 14.16.1, “Overview of Fast Index Creation”
Section 5.1.4, “Server Command Options”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 5.4.5, “The Slow Query Log”

DROP LOGFILE GROUP

Section 13.1.25, “DROP LOGFILE GROUP Syntax”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”

DROP PROCEDURE

Section 13.1.5, “ALTER PROCEDURE Syntax”
Section 20.7, “Binary Logging of Stored Programs”
Section 17.4.1.15, “Replication of Invoked Features”

Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.2.1, “Stored Routine Syntax”

DROP SCHEMA

Section 13.1.21, “DROP DATABASE Syntax”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 5.1.5, “Server System Variables”

DROP SERVER

Section 13.7.6.3, “FLUSH Syntax”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.5, “Replication of CREATE SERVER, ALTER SERVER, and DROP SERVER”
Section 13.3.3, “Statements That Cause an Implicit Commit”

DROP TABLE

Section 18.5.13.1, “Adding NDB Cluster Data Nodes Online: General Issues”
Section 13.1.7, “ALTER TABLE Syntax”
Section 6.5.2.3, “Audit Log File Formats”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.1.28, “DROP TABLE Syntax”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.14, “Information Functions”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 18.1.6.2, “Limits and Differences of NDB Cluster from Standard MySQL Limits”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
Section 15.8.2, “MERGE Table Problems”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Glossary
Section 4.5.1.1, “mysql Options”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.4.11, “`ndb_drop_index` — Drop Index from an NDB Table”
Section 18.4.12, “`ndb_drop_table` — Drop an NDB Table”
Section 8.5.6, “Optimizing InnoDB DDL Operations”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Section C.5, “Restrictions on Views”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 13.6.7.4, “SIGNAL Syntax”
Section 13.4.2.5, “START SLAVE Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 5.4.6, “The DDL Log”
Section 15.4, “The MEMORY Storage Engine”
Section 15.8, “The MERGE Storage Engine”
Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”
Section 13.1.33, “TRUNCATE TABLE Syntax”
Section 24.2.1, “Types of Plugins”
Section 13.7.3.4, “UNINSTALL PLUGIN Syntax”

Section 13.1.17.6, “Using FOREIGN KEY Constraints”

DROP TABLE IF EXISTS

Section 17.4.1.11, “Replication of DROP ... IF EXISTS Statements”

DROP TABLE IF EXISTS mysql.user mysql.db mysql.tables_priv mysql.columns_priv mysql.procs_priv

Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”

DROP TABLESPACE

Section 13.1.29, “DROP TABLESPACE Syntax”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”

DROP TEMPORARY TABLE IF EXISTS

Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

DROP TRIGGER

Section 13.1.30, “DROP TRIGGER Syntax”
Section A.5, “MySQL 5.5 FAQ: Triggers”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 17.4.1.15, “Replication of Invoked Features”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.3.1, “Trigger Syntax and Examples”

DROP USER

Section 13.7.1.2, “DROP USER Syntax”
Section 13.7.6.3, “FLUSH Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 12.14, “Information Functions”
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 6.2.1, “Privileges Provided by MySQL”
Section 6.3.3, “Removing User Accounts”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 13.7.1.5, “REVOKE Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 6.3.1, “User Names and Passwords”

DROP USER 'x'@'localhost'

Using the Authentication Plugins

DROP VIEW

Section 13.1.31, “DROP VIEW Syntax”
Section C.5, “Restrictions on Views”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”
Section 20.5.1, “View Syntax”

DROP VIEW IF EXISTS

Section 17.4.1.11, “Replication of DROP ... IF EXISTS Statements”

E

[index top]

EXECUTE

Section 23.8.18, “C API Prepared CALL Statement Support”
Section 13.2.1, “CALL Syntax”
Section 13.5.2, “EXECUTE Syntax”
Section 13.5.1, “PREPARE Syntax”
Section 13.5, “Prepared SQL Statement Syntax”
Section C.1, “Restrictions on Stored Programs”
Section C.5, “Restrictions on Views”
Section 5.1.7, “Server Status Variables”

EXPLAIN

Section 13.1.7, “ALTER TABLE Syntax”
Section 8.2.1.16, “Avoiding Full Table Scans”
Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 8.3.4, “Column Indexes”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 24.5.1, “Debugging a MySQL Server”
Section 13.2.10.8, “Derived Tables (Subqueries in the FROM Clause)”
Section 13.8.1, “DESCRIBE Syntax”
Section 8.2.1.12, “DISTINCT Optimization”
Section 8.2.1.4, “Engine Condition Pushdown Optimization”
Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Syntax”
Section 8.8.3, “Extended EXPLAIN Output Format”
Section 8.2.1.11, “GROUP BY Optimization”
Section 8.9.3, “Index Hints”
Section 8.2.1.3, “Index Merge Optimization”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 8.2.1.9, “IS NULL Optimization”
Chapter 22, *MySQL Performance Schema*
Section 23.8.11.28, “mysql_stmt_store_result()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
NDB Cluster Status Variables
NDB Cluster System Variables
Section 19.3.4, “Obtaining Information About Partitions”
Section B.5.5, “Optimizer-Related Issues”
Section 8.2.3, “Optimizing INFORMATION_SCHEMA Queries”
Section 8.8.1, “Optimizing Queries with EXPLAIN”
Section 8.2.1, “Optimizing SELECT Statements”
Section 13.2.10.10, “Optimizing Subqueries”
Section 8.2.1.10, “ORDER BY Optimization”
Section 6.2.1, “Privileges Provided by MySQL”
Section 8.2.1.2, “Range Optimization”
Section C.1, “Restrictions on Stored Programs”
Section 13.2.9, “SELECT Syntax”
Section B.3, “Server Error Codes and Messages”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section B.5.4.7, “Solving Problems with No Matching Rows”
Section 8.2.2, “Subquery Optimization”
Section 1.3.2, “The Main Features of MySQL”
Section 8.8, “Understanding the Query Execution Plan”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”
Section 11.5.9, “Using Spatial Indexes”

Section 8.3.6, “Verifying Index Usage”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

EXPLAIN ... SELECT

Section 19.3.4, “Obtaining Information About Partitions”

EXPLAIN EXTENDED

Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Syntax”
Section 8.8.1, “Optimizing Queries with EXPLAIN”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section 8.2.2, “Subquery Optimization”

EXPLAIN PARTITIONS

Section 13.8.2, “EXPLAIN Syntax”
Section 19.3.4, “Obtaining Information About Partitions”
Section 8.8.1, “Optimizing Queries with EXPLAIN”

EXPLAIN PARTITIONS SELECT

Section 19.3.4, “Obtaining Information About Partitions”

EXPLAIN PARTITIONS SELECT COUNT()

Section 19.2.1, “RANGE Partitioning”

EXPLAIN SELECT

Section 13.2.10.8, “Derived Tables (Subqueries in the FROM Clause)”
Section 8.8.2, “EXPLAIN Output Format”
Section 14.8.5.3, “How to Minimize and Handle Deadlocks”
Section 1.6, “How to Report Bugs or Problems”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 19.3.4, “Obtaining Information About Partitions”

EXPLAIN SELECT ... ORDER BY

Section 8.2.1.10, “ORDER BY Optimization”

EXPLAIN tbl_name

Section 8.8.1, “Optimizing Queries with EXPLAIN”

F

[index top]

FETCH

Section 13.6.6.2, “Cursor DECLARE Syntax”
Section 13.6.6.3, “Cursor FETCH Syntax”
Section C.1, “Restrictions on Stored Programs”

FETCH ... INTO var_list

Section 13.6.4, “Variables in Stored Programs”

FLUSH

Section 7.3.1, “Establishing a Backup Policy”
Section 13.7.6.3, “FLUSH Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.5.4, “`mysqldump` — A Database Backup Program”

Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.13, “Replication and FLUSH”
Section 13.7.6.6, “RESET Syntax”
Section C.1, “Restrictions on Stored Programs”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 5.1.11, “Server Response to Signals”
Section 13.3.3, “Statements That Cause an Implicit Commit”

FLUSH BINARY LOGS

Section 13.7.6.3, “FLUSH Syntax”
Section 5.4.7, “Server Log Maintenance”

FLUSH DES_KEY_FILE

Section 12.13, “Encryption and Compression Functions”
Section 13.7.6.3, “FLUSH Syntax”

FLUSH ENGINE LOGS

Section 13.7.6.3, “FLUSH Syntax”

FLUSH ERROR LOGS

Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 13.7.6.3, “FLUSH Syntax”

FLUSH GENERAL LOGS

Section 13.7.6.3, “FLUSH Syntax”

FLUSH HOSTS

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section 13.7.6.3, “FLUSH Syntax”
Section B.5.2.6, “Host 'host_name' is blocked”
Section 23.8.7.55, “mysql_refresh()”
Section 5.1.5, “Server System Variables”

FLUSH LOGS

Section 7.3.3, “Backup Strategy Summary”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 7.2, “Database Backup Methods”
Section 5.4.2.5, “Error Log File Flushing and Renaming”
Section 7.3.1, “Establishing a Backup Policy”
Section 13.7.6.3, “FLUSH Syntax”
Section 5.4, “MySQL Server Logs”
Section 23.8.7.55, “mysql_refresh()”
Section 17.4.1.13, “Replication and FLUSH”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.4.7, “Server Log Maintenance”
Section 5.1.7, “Server Status Variables”
Section 17.2.2.1, “The Slave Relay Log”

FLUSH MASTER

Section 13.7.6.3, “FLUSH Syntax”
Section 17.4.1.13, “Replication and FLUSH”

FLUSH PRIVILEGES

Section 18.5.14, “Distributed MySQL Privileges for NDB Cluster”
Section 13.7.6.3, “FLUSH Syntax”
Section 6.2.2, “Grant Tables”
Section 8.12.4.1, “How MySQL Uses Memory”

Section 23.8.7.55, “mysql_refresh()”
Section 23.8.7.56, “mysql_reload()”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.5.11.3, “NDB Cluster and MySQL Security Procedures”
Section 17.4.1.13, “Replication and FLUSH”
Section 5.1.4, “Server Command Options”
Section 6.3.4, “Setting Account Resource Limits”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 1.2, “Typographical and Syntax Conventions”
Section 6.2.6, “When Privilege Changes Take Effect”

FLUSH QUERY CACHE

Section 13.7.6.3, “FLUSH Syntax”
Section 8.10.3.4, “Query Cache Status and Maintenance”

FLUSH RELAY LOGS

Section 13.7.6.3, “FLUSH Syntax”

FLUSH SLAVE

Section 13.7.6.3, “FLUSH Syntax”
Section 17.4.1.13, “Replication and FLUSH”

FLUSH SLOW LOGS

Section 13.7.6.3, “FLUSH Syntax”

FLUSH STATUS

Section 13.7.6.3, “FLUSH Syntax”
Section 23.8.7.55, “mysql_refresh()”
Section 5.1.7, “Server Status Variables”

FLUSH TABLE

Section 13.7.6.3, “FLUSH Syntax”

FLUSH TABLES

Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 13.7.6.3, “FLUSH Syntax”
Section 8.14.2, “General Thread States”
Section 13.2.4, “HANDLER Syntax”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 15.8.2, “MERGE Table Problems”
Section 4.6.3, “myisamchk — MyISAM Table-Maintenance Utility”
Section 23.8.7.55, “mysql_refresh()”
Section 4.6.9, “mysqlhotcopy — A Database Backup Program”
Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”
Section 15.3.4.2, “Problems from Tables Not Being Closed Properly”
Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 17.4.1.13, “Replication and FLUSH”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

FLUSH TABLES ... FOR EXPORT

MySQL Glossary

FLUSH TABLES tbl_list WITH READ LOCK

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”

FLUSH TABLES tbl_name ...

Section 13.7.6.3, “FLUSH Syntax”

FLUSH TABLES tbl_name ... WITH READ LOCK

Section 13.7.6.3, “FLUSH Syntax”

FLUSH TABLES tbl_name WITH READ LOCK

Section 13.2.4, “HANDLER Syntax”

FLUSH TABLES WITH READ LOCK

Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”
Section 7.2, “Database Backup Methods”
Section 7.3.1, “Establishing a Backup Policy”
Section 13.7.6.3, “FLUSH Syntax”
Section 8.14.2, “General Thread States”
Section 13.3.5.1, “Interaction of Table Locking and Transactions”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
MySQL Glossary
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”
Section 17.4.1.13, “Replication and FLUSH”
Section C.6, “Restrictions on XA Transactions”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.5, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”

FLUSH USER_RESOURCES

Section 13.7.6.3, “FLUSH Syntax”
Section 6.3.4, “Setting Account Resource Limits”

G

[index top]

GRANT

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 6.3.2, “Adding User Accounts”
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 6.3.5, “Assigning Account Passwords”
Section 6.4.2, “Command Options for Encrypted Connections”
Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 5.1.9.3, “Connecting Using the IPv6 Local Host Address”
Section 13.7.1.1, “CREATE USER Syntax”
Section 17.1.1.3, “Creating a User for Replication”
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 13.7.6.3, “FLUSH Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Implementing Proxy User Support in Authentication Plugins
Section 12.14, “Information Functions”

Section 5.1.9, “IPv6 Support”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section A.13, “MySQL 5.5 FAQ: Replication”
MySQL Glossary
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 8.2.5, “Optimizing Database Privileges”
Section 6.5.1.4, “PAM Pluggable Authentication”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 6.1.2.3, “Passwords and Logging”
Section 18.6.5, “Preparing the NDB Cluster for Replication”
Section 6.2.1, “Privileges Provided by MySQL”
Section 2.10.1.1, “Problems Running mysql_install_db”
Section 6.3.7, “Proxy Users”
Section 17.4.1.13, “Replication and FLUSH”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.21, “Replication of the mysql System Database”
Section 13.7.1.5, “REVOKE Syntax”
Section 6.1.1, “Security Guidelines”
Section 5.1.4, “Server Command Options”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”
Section 6.3.4, “Setting Account Resource Limits”
Section 13.7.5.22, “SHOW GRANTS Syntax”
Section 6.2.3, “Specifying Account Names”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 6.2, “The MySQL Access Privilege System”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 6.3.1, “User Names and Passwords”
Section 6.4, “Using Encrypted Connections”
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”
Section 6.2.6, “When Privilege Changes Take Effect”
Section 6.5.1.5, “Windows Pluggable Authentication”

GRANT ALL

Section 13.7.1.3, “GRANT Syntax”

GRANT EVENT

Section 20.4.6, “The Event Scheduler and MySQL Privileges”

GRANT USAGE

Section 6.3.5, “Assigning Account Passwords”
Section 13.7.1.3, “GRANT Syntax”
Section 6.3.4, “Setting Account Resource Limits”

H

[index top]

HANDLER

Section 23.8.20, “C API Automatic Reconnection Control”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 13.7.6.3, “FLUSH Syntax”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 1.7, “MySQL Standards Compliance”
Section 23.8.7.3, “mysql_change_user()”

Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.5, “Server System Variables”

HANDLER ... CLOSE

Section 13.7.5.25, “SHOW OPEN TABLES Syntax”

HANDLER ... OPEN

Section 13.7.5.25, “SHOW OPEN TABLES Syntax”

HANDLER ... READ

Section C.1, “Restrictions on Stored Programs”

HANDLER OPEN

Section 13.2.4, “HANDLER Syntax”
Section 13.1.33, “TRUNCATE TABLE Syntax”

HELP

Section 13.8.3, “HELP Syntax”
Section 17.4.1.26, “Replication of Server-Side Help Tables”
Section 5.1.10, “Server-Side Help”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”

I

[index top]

IF

Section 12.4, “Control Flow Functions”
Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.2, “IF Syntax”

INSERT

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 6.3.2, “Adding User Accounts”
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 14.8.2.2, “autocommit, Commit, and Rollback”
Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 7.1, “Backup and Recovery Types”
Section 20.7, “Binary Logging of Stored Programs”
Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 23.8.6, “C API Function Overview”
Section 23.8.16, “C API Multiple Statement Execution Support”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 14.7.2, “Change Buffer”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 10.1.7, “Column Character Set Conversion”
Section 8.11.3, “Concurrent Inserts”
Section 14.9.4, “Configuring InnoDB Change Buffering”
Section 1.7.3.3, “Constraints on Invalid Data”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 13.1.13, “CREATE INDEX Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”
Section 13.1.17.3, “CREATE TEMPORARY TABLE Syntax”

Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 15.9.2.1, “Creating a FEDERATED Table Using CONNECTION”
Section 11.6, “Data Type Default Values”
Section 11.1.2, “Date and Time Type Overview”
Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
Section 13.2.2, “DELETE Syntax”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 7.3.1, “Establishing a Backup Policy”
Section 12.18.3, “Expression Handling”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 14.23.2, “Forcing InnoDB Recovery”
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 8.10.3.1, “How the Query Cache Operates”
Section 23.8.21.3, “How to Get the Unique ID for the Last Inserted Row”
Section 12.14, “Information Functions”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 14.8.1, “InnoDB Locking”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 13.2.5.1, “INSERT ... SELECT Syntax”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section 8.11.1, “Internal Locking Methods”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 19.2.2, “LIST Partitioning”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 3.3.3, “Loading Data into a Table”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 12.17, “Miscellaneous Functions”
Section A.1, “MySQL 5.5 FAQ: General”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section A.5, “MySQL 5.5 FAQ: Triggers”
Section A.6, “MySQL 5.5 FAQ: Views”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Glossary
Section 4.5.1.1, “mysql Options”
Section B.5.2.9, “MySQL server has gone away”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.37, “mysql_insert_id()”
Section 23.8.7.48, “mysql_num_rows()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.13, “mysql_stmt_field_count()”
Section 23.8.11.16, “mysql_stmt_insert_id()”
Section 23.8.11.18, “mysql_stmt_num_rows()”
Section 23.8.11.21, “mysql_stmt_prepare()”
Section 23.8.7.69, “mysql_store_result()”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.5.15, “NDB API Statistics Counters and Variables”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.2.5, “NDB Cluster Example with Tables and Data”

Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
Section 13.7.2.4, “OPTIMIZE TABLE Syntax”
Section 8.2.4, “Optimizing Data Change Statements”
Section 8.2.4.1, “Optimizing INSERT Statements”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 11.2.6, “Out-of-Range and Overflow Handling”
Section 19.4, “Partition Pruning”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 11.5.5, “Populating Spatial Columns”
Section 1.7.3.1, “PRIMARY KEY and UNIQUE Index Constraints”
Section 6.2.1, “Privileges Provided by MySQL”
Section 8.14.4, “Query Cache Thread States”
Section 19.2.1, “RANGE Partitioning”
Section 13.2.8, “REPLACE Syntax”
Section 17.4.1.1, “Replication and AUTO_INCREMENT”
Section 17.4.1.30, “Replication and Server SQL Mode”
Section 17.4.1.14, “Replication and System Functions”
Section 17.4.1.38, “Replication and Variables”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.2.3.3, “Replication Rule Application”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section C.1, “Restrictions on Stored Programs”
Section 5.7.1.7, “Row-Level Probes”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section B.3, “Server Error Codes and Messages”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”
Section 13.7.5.28, “SHOW PROCEDURE CODE Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section 17.4.1.29, “Slave Errors During Replication”
Section 5.7.1.12, “Statement Probes”
Section 13.2.10, “Subquery Syntax”
Section 8.11.2, “Table Locking Issues”
Section 15.6, “The ARCHIVE Storage Engine”
Section 10.1.8.5, “The binary Collation Compared to _bin Collations”
Section 5.4.4, “The Binary Log”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 1.3.2, “The Main Features of MySQL”
Section 15.8, “The MERGE Storage Engine”
Section 15.3, “The MyISAM Storage Engine”
Section 6.2, “The MySQL Access Privilege System”
Section 8.10.3, “The MySQL Query Cache”
Section 5.1.12, “The Server Shutdown Process”
Section 20.3.1, “Trigger Syntax and Examples”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 20.5.3, “Updatable and Insertable Views”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”
Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”
Section 20.3, “Using Triggers”
Section 23.8.21.2, “What Results You Can Get from a Query”
Section 6.2.6, “When Privilege Changes Take Effect”
Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”

INSERT ... ()

Section 5.7.1.12, “Statement Probes”

INSERT ... ON DUPLICATE KEY UPDATE

Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 12.14, “Information Functions”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 15.8.2, “MERGE Table Problems”
Section 12.17, “Miscellaneous Functions”
MySQL Glossary
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.37, “mysql_insert_id()”
Section 19.5.4, “Partitioning and Table-Level Locking”

INSERT ... SELECT

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 8.11.3, “Concurrent Inserts”
Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 13.2.5.1, “INSERT ... SELECT Syntax”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section B.5.7, “Known Issues in MySQL”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 23.8.7.37, “mysql_insert_id()”
NDB Cluster System Variables
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 17.4.1.16, “Replication and LIMIT”
Section 5.1.5, “Server System Variables”
Section 5.7.1.12, “Statement Probes”
Section 5.4.4, “The Binary Log”

INSERT ... SELECT ON DUPLICATE KEY UPDATE

Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 13.2.5.1, “INSERT ... SELECT Syntax”

INSERT ... SET

Section 13.2.5, “INSERT Syntax”

INSERT ... VALUES

Section 13.2.5, “INSERT Syntax”
Section 23.8.7.35, “mysql_info()”

INSERT DELAYED

Section 13.1.7, “ALTER TABLE Syntax”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 8.14.3, “Delayed-Insert Thread States”

Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section 13.7.6.4, “KILL Syntax”
Section B.5.7, “Known Issues in MySQL”
Section 15.8.2, “MERGE Table Problems”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 24.1.1, “MySQL Threads”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section C.1, “Restrictions on Stored Programs”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”
Section 8.11.2, “Table Locking Issues”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”
Section 15.6, “The ARCHIVE Storage Engine”
Section 15.4, “The MEMORY Storage Engine”
Section 20.5.3, “Updatable and Insertable Views”

INSERT IGNORE

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 1.7.3.3, “Constraints on Invalid Data”
Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”
Section 1.7.3.4, “ENUM and SET Constraints”
Section 12.14, “Information Functions”
Section 13.2.5, “INSERT Syntax”
Section 4.5.4, “mysqldump — A Database Backup Program”
Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 5.1.8, “Server SQL Modes”

INSERT IGNORE ... SELECT

Section 13.2.5.1, “INSERT ... SELECT Syntax”

INSERT INTO ... SELECT

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 1.7.3.3, “Constraints on Invalid Data”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.2.5, “INSERT Syntax”
Section 17.4.1.7, “Replication of CREATE TABLE ... SELECT Statements”
Section 1.7.2.1, “SELECT INTO TABLE Differences”
Section 15.4, “The MEMORY Storage Engine”

INSERT INTO ... SELECT ...

Section 23.8.7.35, “mysql_info()”
Section 23.8.21.2, “What Results You Can Get from a Query”

INSERT INTO ... SELECT FROM memory_table

Section 17.4.1.20, “Replication and MEMORY Tables”

INSERT INTO...SELECT

Section 8.2.1, “Optimizing SELECT Statements”

INSTALL PLUGIN

Section 6.5.2.7, “Audit Log Options and System Variables”

Section 13.7.6.3, “FLUSH Syntax”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”
Section 13.7.3.3, “INSTALL PLUGIN Syntax”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 6.5.2.1, “Installing MySQL Enterprise Audit”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 4.4.4, “`mysql_plugin` — Configure MySQL Server Plugins”
Section 5.5.2, “Obtaining Server Plugin Information”
Section 6.5.1.4, “PAM Pluggable Authentication”
Section 15.2.1, “Pluggable Storage Engine Architecture”
Section 24.2.3, “Plugin API Components”
Section 24.2.4.2, “Plugin Data Structures”
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 5.1.4, “Server Command Options”
Server Plugin Library and Plugin Descriptors
Section 5.1.5, “Server System Variables”
Section 13.7.5.26, “SHOW PLUGINS Syntax”
Section 6.5.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.5.1.7, “Test Pluggable Authentication”
Section 21.13, “The INFORMATION_SCHEMA PLUGINS Table”
Section 24.2, “The MySQL Plugin API”
Section 13.7.3.4, “UNINSTALL PLUGIN Syntax”
Section 6.5.1.5, “Windows Pluggable Authentication”
Section 24.2.4.8, “Writing Audit Plugins”
Section 24.2.4.5, “Writing Daemon Plugins”
Section 24.2.4.4, “Writing Full-Text Parser Plugins”
Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”
Writing the Server-Side Authentication Plugin

ITERATE

Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.3, “ITERATE Syntax”
Section 13.6.2, “Statement Label Syntax”

K

[index top]

KILL

Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Syntax”
Section 13.7.6.4, “KILL Syntax”
Section B.5.2.9, “MySQL server has gone away”
Section 23.8.7.38, “mysql_kill()”
Section 4.6.15, “`mysql_zap` — Kill Processes That Match a Pattern”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.5.30, “SHOW PROCESSLIST Syntax”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”

KILL CONNECTION

Section 13.7.6.4, “KILL Syntax”
Section 13.4.2.6, “STOP SLAVE Syntax”
Section 5.1.12, “The Server Shutdown Process”

KILL QUERY

Section 13.7.6.4, “KILL Syntax”
Section 12.17, “Miscellaneous Functions”
Section 13.4.2.6, “STOP SLAVE Syntax”
Section 5.1.12, “The Server Shutdown Process”

L

[index top]

LEAVE

Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.4, “LEAVE Syntax”
Section 13.6.5.5, “LOOP Syntax”
Section C.1, “Restrictions on Stored Programs”
Section 13.6.5.7, “RETURN Syntax”
Section 13.6.2, “Statement Label Syntax”

LOAD DATA

Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 8.11.3, “Concurrent Inserts”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 10.1.3.3, “Database Character Set and Collation”
Section B.5.7, “Known Issues in MySQL”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 13.2.7, “LOAD XML Syntax”
Section 3.3.3, “Loading Data into a Table”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 23.8.7.49, “mysql_options()”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section C.1, “Restrictions on Stored Programs”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 3.3.4.1, “Selecting All Data”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 11.4.4, “The ENUM Type”
Section 9.4, “User-Defined Variables”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”
Section 20.3, “Using Triggers”

LOAD DATA INFILE

Section 6.5.2.3, “Audit Log File Formats”
Section 6.5.2.8, “Audit Log Restrictions”
Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section 7.1, “Backup and Recovery Types”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 8.11.3, “Concurrent Inserts”
Section 7.2, “Database Backup Methods”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”
Section B.5.3.4, “How MySQL Handles a Full Disk”
Section 12.14, “Information Functions”
Section B.5.7, “Known Issues in MySQL”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”

Section 15.3.1, “MyISAM Startup Options”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.5.1.1, “mysql Options”
Section 4.6.7.1, “mysqlbinlog Hex Dump Format”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.5, “`mysqlimport` — A Data Import Program”
Section 18.4.24, “`ndb_show_tables` — Display List of NDB Tables”
Section 9.1.7, “NULL Values”
Section 8.2.4.1, “Optimizing INSERT Statements”
Section 11.2.6, “Out-of-Range and Overflow Handling”
Section 4.1, “Overview of MySQL Programs”
Section 18.5.5, “Performing a Rolling Restart of an NDB Cluster”
Section 6.2.1, “Privileges Provided by MySQL”
Section B.5.4.3, “Problems with NULL Values”
Section 7.4.4, “Reloading Delimited-Text Format Backups”
Section 17.4.1.17, “Replication and LOAD DATA INFILE”
Section 17.4.2, “Replication Compatibility Between MySQL Versions”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 8.14.7, “Replication Slave SQL Thread States”
Section C.7, “Restrictions on Character Sets”
Section 13.2.9.1, “SELECT ... INTO Syntax”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 13.2.10, “Subquery Syntax”
Section 15.4, “The MEMORY Storage Engine”
Section 6.2, “The MySQL Access Privilege System”
Section 13.2.10.1, “The Subquery as Scalar Operand”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section B.5.3.5, “Where MySQL Stores Temporary Files”
Section C.10.6, “Windows Platform Limitations”

LOAD DATA INFILE ...

Section 23.8.7.35, “mysql_info()”
Section 23.8.21.2, “What Results You Can Get from a Query”

LOAD DATA LOCAL

Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 23.8.7.49, “mysql_options()”
Section 23.8.7.52, “mysql_real_connect()”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 5.1.5, “Server System Variables”

LOAD DATA LOCAL INFILE

Section 23.8.6, “C API Function Overview”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 23.8.7.49, “mysql_options()”
Section 23.8.7.62, “mysql_set_local_infile_default()”
Section 23.8.7.63, “mysql_set_local_infile_handler()”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”

LOAD INDEX INTO CACHE

Section 13.7.6.2, “CACHE INDEX Syntax”

Section 8.10.2.4, “Index Preloading”
Section 13.7.6.5, “LOAD INDEX INTO CACHE Syntax”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 1.4, “What Is New in MySQL 5.5”

LOAD INDEX INTO CACHE ... IGNORE LEAVES

Section 13.7.6.5, “LOAD INDEX INTO CACHE Syntax”

LOAD XML

Section 13.2.7, “LOAD XML Syntax”

LOAD XML INFILE

Section 13.2.7, “LOAD XML Syntax”
Section 1.4, “What Is New in MySQL 5.5”

LOAD XML LOCAL

Section 13.2.7, “LOAD XML Syntax”

LOAD XML LOCAL INFILE

Section 13.2.7, “LOAD XML Syntax”

LOCK TABLE

Section 8.11.3, “Concurrent Inserts”
Section 8.14.2, “General Thread States”
Section B.5.6.1, “Problems with ALTER TABLE”

LOCK TABLES

Section 14.1.2, “Best Practices for InnoDB Tables”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 13.1.10, “CREATE DATABASE Syntax”
Section 13.1.17.4, “CREATE TABLE ... LIKE Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 14.8.5.2, “Deadlock Detection and Rollback”
Section 14.8.5, “Deadlocks in InnoDB”
Section 13.7.6.3, “FLUSH Syntax”
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Syntax”
Section 14.8.5.3, “How to Minimize and Handle Deadlocks”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.3.5.1, “Interaction of Table Locking and Transactions”
Section 8.11.1, “Internal Locking Methods”
Section 18.1.6.10, “Limitations Relating to Multiple NDB Cluster Nodes”
Section 14.11.1.7, “Limits on InnoDB Tables”
Section 13.3.5.2, “LOCK TABLES and Triggers”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 15.8.2, “MERGE Table Problems”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.6.9, “`mysqlhotcopy` — A Database Backup Program”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 6.2.1, “Privileges Provided by MySQL”
Section 15.3.4.2, “Problems from Tables Not Being Closed Properly”
Section C.1, “Restrictions on Stored Programs”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.5, “Server System Variables”

Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 8.12.1, “System Factors”
Section 8.11.2, “Table Locking Issues”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”

LOCK TABLES ... READ

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 13.7.6.3, “FLUSH Syntax”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.11.1.7, “Limits on InnoDB Tables”

LOCK TABLES ... WRITE

Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.11.1.7, “Limits on InnoDB Tables”

LOOP

Section 13.6.5, “Flow Control Statements”
Section 13.6.5.3, “ITERATE Syntax”
Section 13.6.5.4, “LEAVE Syntax”
Section 13.6.5.5, “LOOP Syntax”
Section 13.6.2, “Statement Label Syntax”

O

[index top]

OPTIMIZE TABLE

Section 18.5.13.2, “Adding NDB Cluster Data Nodes Online: Basic procedure”
Section 18.5.13.3, “Adding NDB Cluster Data Nodes Online: Detailed Example”
Section 13.1.7.2, “ALTER TABLE Online Operations in NDB Cluster 7.2”
Section 24.5.1, “Debugging a MySQL Server”
Section 13.2.2, “DELETE Syntax”
Section 15.3.3.2, “Dynamic Table Characteristics”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 8.14.2, “General Thread States”
Section B.5.3.4, “How MySQL Handles a Full Disk”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 13.7.6.4, “KILL Syntax”
Section B.5.7, “Known Issues in MySQL”
Section 14.16.6, “Limitations of Fast Index Creation”
Section 18.1.6.2, “Limits and Differences of NDB Cluster from Standard MySQL Limits”
Section 19.3.3, “Maintenance of Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”
Section 7.6.4, “MyISAM Table Optimization”
Section 4.6.3.1, “myisamchk General Options”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Server Options for NDB Cluster
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 18.5.12.3, “NDB Cluster Disk Data Storage Requirements”
Section 13.7.2.4, “OPTIMIZE TABLE Syntax”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 8.2.4.2, “Optimizing UPDATE Statements”
Section 8.2.6, “Other Optimization Tips”
Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”

Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.13, “Replication and FLUSH”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 15.3.3.1, “Static (Fixed-Length) Table Characteristics”
Section 15.6, “The ARCHIVE Storage Engine”
Section 5.1.12, “The Server Shutdown Process”
Section 5.4.5, “The Slow Query Log”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

P

[index top]

PREPARE

Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 23.8.18, “C API Prepared CALL Statement Support”
Section 13.2.1, “CALL Syntax”
Section 13.5.3, “DEALLOCATE PREPARE Syntax”
Section 13.5.2, “EXECUTE Syntax”
Section 9.2.2, “Identifier Case Sensitivity”
Section 8.11.4, “Metadata Locking”
Section 13.5.1, “PREPARE Syntax”
Section 13.5, “Prepared SQL Statement Syntax”
Section C.1, “Restrictions on Stored Programs”
Section C.5, “Restrictions on Views”
Section 5.1.7, “Server Status Variables”

PURGE BINARY LOGS

Section 7.3.1, “Establishing a Backup Policy”
Section 13.7.1.3, “GRANT Syntax”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.4.1.1, “PURGE BINARY LOGS Syntax”
Section 13.4.1.2, “RESET MASTER Syntax”
Section 5.4.7, “Server Log Maintenance”
Section 5.1.5, “Server System Variables”
Section 5.4.4, “The Binary Log”

R

[index top]

RELEASE SAVEPOINT

Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Syntax”

RENAME TABLE

Section 13.1.7, “ALTER TABLE Syntax”
Section 13.2.2, “DELETE Syntax”
Section 8.14.2, “General Thread States”
Section 9.2.2, “Identifier Case Sensitivity”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.5.4, “`mysqldump` — A Database Backup Program”

Section 13.1.32, “RENAME TABLE Syntax”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section B.5.6.2, “TEMPORARY Table Problems”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

RENAME USER

Section 13.7.1.3, “GRANT Syntax”
Section 12.14, “Information Functions”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.1.4, “RENAME USER Syntax”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 6.2.6, “When Privilege Changes Take Effect”

REPAIR TABLE

Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 13.1.7, “ALTER TABLE Syntax”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 15.3.4.1, “Corrupted MyISAM Tables”
Section 7.2, “Database Backup Methods”
Section 8.11.5, “External Locking”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 8.14.2, “General Thread States”
Section 16.1.3, “Handling MySQL Recovery with ZFS”
Section B.5.3.4, “How MySQL Handles a Full Disk”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 1.6, “How to Report Bugs or Problems”
Section 13.7.6.4, “KILL Syntax”
Section B.5.7, “Known Issues in MySQL”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 19.3.3, “Maintenance of Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 15.3.1, “MyISAM Startup Options”
Section 7.6, “MyISAM Table Maintenance and Crash Recovery”
Section 4.6.3.1, “myisamchk General Options”
Section 4.6.3, “`myisamchk` — MyISAM Table-Maintenance Utility”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.5.3, “`mysqlcheck` — A Table Maintenance Program”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 6.2.1, “Privileges Provided by MySQL”
Section 15.3.4.2, “Problems from Tables Not Being Closed Properly”
Section B.5.6.1, “Problems with ALTER TABLE”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 13.7.2.5, “REPAIR TABLE Syntax”
Section 17.4.1.13, “Replication and FLUSH”
Section 17.4.1.24, “Replication and REPAIR TABLE”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 7.6.5, “Setting Up a MyISAM Table Maintenance Schedule”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 15.6, “The ARCHIVE Storage Engine”
Section 5.1.12, “The Server Shutdown Process”
Section 5.4.5, “The Slow Query Log”

Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

REPEAT

Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
Section 20.1, “Defining Stored Programs”
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.3, “ITERATE Syntax”
Section 13.6.5.4, “LEAVE Syntax”
Section 13.6.5.6, “REPEAT Syntax”
Section 13.6.2, “Statement Label Syntax”

REPLACE

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 11.6, “Data Type Default Values”
Section 12.14, “Information Functions”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section B.5.7, “Known Issues in MySQL”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 15.8.2, “MERGE Table Problems”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section B.5.2.9, “MySQL server has gone away”
Section 23.8.7.1, “mysql_affected_rows()”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 13.2.8, “REPLACE Syntax”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.4, “Server Command Options”
Section 13.2.10, “Subquery Syntax”
Section 15.6, “The ARCHIVE Storage Engine”
Section 1.3.2, “The Main Features of MySQL”

REPLACE ... SELECT

Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section B.5.7, “Known Issues in MySQL”

RESET

Section 13.7.6.3, “FLUSH Syntax”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 13.7.6.6, “RESET Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”

RESET MASTER

Section 13.7.6.3, “FLUSH Syntax”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 23.8.7.55, “mysql_refresh()”
Section 13.4.1.2, “RESET MASTER Syntax”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 17.3.6, “Switching Masters During Failover”
Section 5.4.4, “The Binary Log”

RESET QUERY CACHE

Section 8.14.4, “Query Cache Thread States”

RESET SLAVE

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 13.7.6.3, “FLUSH Syntax”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 23.8.7.55, “mysql_refresh()”
Section 13.4.1.2, “RESET MASTER Syntax”
Section 13.4.2.3, “RESET SLAVE Syntax”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”

RESET SLAVE ALL

Section 13.4.2.1, “CHANGE MASTER TO Syntax”

RESIGNAL

Section 13.6.7, “Condition Handling”
Section 13.6.7.1, “DECLARE ... CONDITION Syntax”
Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
RESIGNAL Alone
RESIGNAL Requires Condition Handler Context
Section 13.6.7.3, “RESIGNAL Syntax”
RESIGNAL with a Condition Value and Optional New Signal Information
RESIGNAL with New Signal Information
Section C.2, “Restrictions on Condition Handling”
Section C.1, “Restrictions on Stored Programs”
Signal Condition Information Items
Section 1.4, “What Is New in MySQL 5.5”

RETURN

Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.5, “LOOP Syntax”
Section C.1, “Restrictions on Stored Programs”
Section 13.6.5.7, “RETURN Syntax”

REVOKE

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.7.6.3, “FLUSH Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 12.14, “Information Functions”
Section 5.1.9, “IPv6 Support”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section 1.7.2, “MySQL Differences from Standard SQL”
MySQL Glossary
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 6.2.1, “Privileges Provided by MySQL”
Section 2.10.1.1, “Problems Running mysql_install_db”
Section 6.3.7, “Proxy Users”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Section 17.4.1.21, “Replication of the mysql System Database”
Section 13.7.1.5, “REVOKE Syntax”
Section 6.1.1, “Security Guidelines”

Section 5.1.5, “Server System Variables”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 6.2, “The MySQL Access Privilege System”
Section 6.3.1, “User Names and Passwords”
Section 6.2.6, “When Privilege Changes Take Effect”

REVOKE ALL PRIVILEGES

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”

ROLLBACK

Section 14.8.2.2, “autocommit, Commit, and Rollback”
Section 20.7, “Binary Logging of Stored Programs”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 14.8.5.2, “Deadlock Detection and Rollback”
Section 12.14, “Information Functions”
Section 14.5, “InnoDB and the ACID Model”
Section 14.23.4, “InnoDB Error Handling”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.3.5.1, “Interaction of Table Locking and Transactions”
Section 23.8.7.3, “mysql_change_user()”
Section 17.4.1.35, “Replication and Transactions”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section B.5.4.5, “Rollback Failure for Nontransactional Tables”
Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Syntax”
Section 5.1.5, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 13.3.2, “Statements That Cannot Be Rolled Back”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 5.4.4, “The Binary Log”
Section 13.3, “Transactional and Locking Statements”
Section 20.3.1, “Trigger Syntax and Examples”

ROLLBACK TO SAVEPOINT

Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Syntax”

ROLLBACK to SAVEPOINT

Section 20.3.1, “Trigger Syntax and Examples”

S

[index top]

SAVEPOINT

Section 13.3.4, “SAVEPOINT, ROLLBACK TO SAVEPOINT, and RELEASE SAVEPOINT Syntax”

SELECT

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 13.1.7, “ALTER TABLE Syntax”
Section 13.1.9, “ALTER VIEW Syntax”
Section 12.3.4, “Assignment Operators”
Section 6.5.2.3, “Audit Log File Formats”
Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 14.8.2.2, “autocommit, Commit, and Rollback”
Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 17.1.3.4, “Binary Log Options and Variables”

Section 20.7, “Binary Logging of Stored Programs”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 23.8.16, “C API Multiple Statement Execution Support”
Section 23.8.18, “C API Prepared CALL Statement Support”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 12.3.2, “Comparison Functions and Operators”
Section 8.3.8, “Comparison of B-Tree and Hash Indexes”
Section 8.11.3, “Concurrent Inserts”
Section 10.1.4, “Connection Character Sets and Collations”
Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.1.13, “CREATE INDEX Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.17.5, “CREATE TABLE ... SELECT Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 13.1.17.3, “CREATE TEMPORARY TABLE Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 15.9.2.1, “Creating a FEDERATED Table Using CONNECTION”
Section 3.3.1, “Creating and Selecting a Database”
Section 13.6.6.2, “Cursor DECLARE Syntax”
Section 13.6.6.3, “Cursor FETCH Syntax”
Section 14.8.5.2, “Deadlock Detection and Rollback”
Section 13.2.2, “DELETE Syntax”
Section 13.2.10.8, “Derived Tables (Subqueries in the FROM Clause)”
Section 8.4.3.2, “Disadvantages of Creating Many Tables in the Same Database”
Section 13.2.3, “DO Syntax”
Section 5.1.6.2, “Dynamic System Variables”
Section 3.2, “Entering Queries”
Section 20.4.2, “Event Scheduler Configuration”
Section 10.1.8.6, “Examples of the Effect of Collation”
Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Syntax”
Section 8.8.3, “Extended EXPLAIN Output Format”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 14.23.2, “Forcing InnoDB Recovery”
Section 8.2.1.14, “Function Call Optimization”
Chapter 12, *Functions and Operators*
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Syntax”
Section 13.2.4, “HANDLER Syntax”
Section 19.2.7, “How MySQL Partitioning Handles NULL”
Section 8.10.3.1, “How the Query Cache Operates”
Section 14.8.5.3, “How to Minimize and Handle Deadlocks”
Section 1.6, “How to Report Bugs or Problems”
Section 8.9.3, “Index Hints”
Section 12.14, “Information Functions”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 2.10.1, “Initializing the Data Directory”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 13.2.5.1, “INSERT ... SELECT Syntax”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section 8.11.1, “Internal Locking Methods”

Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 13.2.9.2, “JOIN Syntax”
Section 9.3, “Keywords and Reserved Words”
Section 13.7.6.4, “KILL Syntax”
Section B.5.7, “Known Issues in MySQL”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 13.2.7, “LOAD XML Syntax”
Section 13.6.4.2, “Local Variable Scope and Resolution”
Section 14.8.2.4, “Locking Reads”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 15.8.2, “MERGE Table Problems”
Section 8.3.5, “Multiple-Column Indexes”
Section 7.6.4, “MyISAM Table Optimization”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Glossary
Section 4.5.1.1, “mysql Options”
Chapter 22, *MySQL Performance Schema*
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.17, “mysql_fetch_field()”
Section 23.8.7.22, “mysql_field_count()”
Section 23.8.7.47, “mysql_num_fields()”
Section 23.8.7.48, “mysql_num_rows()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.11, “mysql_stmt_fetch()”
Section 23.8.11.18, “mysql_stmt_num_rows()”
Section 23.8.11.28, “mysql_stmt_store_result()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 4.5.7, “`mysqlslap` — Load Emulation Client”
Section 12.9.1, “Natural Language Full-Text Searches”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.2.5, “NDB Cluster Example with Tables and Data”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
NDB Cluster System Variables
Section 18.4.22, “`ndb_select_all` — Print Rows from an NDB Table”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 19.3.4, “Obtaining Information About Partitions”
Section 8.3, “Optimization and Indexes”
Section B.5.5, “Optimizer-Related Issues”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 8.8.1, “Optimizing Queries with EXPLAIN”
Section 8.2.1, “Optimizing SELECT Statements”
Section 8.2.4.2, “Optimizing UPDATE Statements”
Section 4.6.3.4, “Other myisamchk Options”
Section 19.4, “Partition Pruning”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 14.8.4, “Phantom Rows”
Section 6.2.1, “Privileges Provided by MySQL”
Section B.5.4.2, “Problems Using DATE Columns”
Section B.5.4.8, “Problems with Floating-Point Values”
Section 8.10.3.2, “Query Cache SELECT Options”

Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 8.14.4, “Query Cache Thread States”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”
Section 19.2.3.1, “RANGE COLUMNS partitioning”
Section 8.2.1.2, “Range Optimization”
Section 15.5.1, “Repairing and Checking CSV Tables”
Section 13.2.8, “REPLACE Syntax”
Section 17.2, “Replication Implementation”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.4.1.6, “Replication of CREATE ... IF NOT EXISTS Statements”
Section 17.4.1.15, “Replication of Invoked Features”
Section C.1, “Restrictions on Stored Programs”
Section 3.3.4, “Retrieving Information from a Table”
Section 3.6.7, “Searching on Two Keys”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 13.2.9.1, “SELECT ... INTO Syntax”
Section 13.2.9, “SELECT Syntax”
Section 3.3.4.1, “Selecting All Data”
Section 3.3.4.2, “Selecting Particular Rows”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 13.7.5.3, “SHOW BINLOG EVENTS Syntax”
Section 13.7.5.11, “SHOW CREATE PROCEDURE Syntax”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 13.7.5.18, “SHOW ERRORS Syntax”
Section 13.7.5.28, “SHOW PROCEDURE CODE Syntax”
Section 13.7.5.30, “SHOW PROCESSLIST Syntax”
Section 13.7.5.33, “SHOW RELAYLOG EVENTS Syntax”
Section 13.7.5, “SHOW Syntax”
Section 13.7.5.40, “SHOW VARIABLES Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section B.5.4.7, “Solving Problems with No Matching Rows”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 5.7.1.12, “Statement Probes”
Section 20.2.1, “Stored Routine Syntax”
Section 9.1.1, “String Literals”
Section 13.2.10.6, “Subqueries with EXISTS or NOT EXISTS”
Section 13.2.10.9, “Subquery Errors”
Section 8.2.2, “Subquery Optimization”
Section 13.2.10, “Subquery Syntax”
Section 8.11.2, “Table Locking Issues”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”
Section 15.6, “The ARCHIVE Storage Engine”
Section 5.4.4, “The Binary Log”
Section 11.4.4, “The ENUM Type”
Section 21.4, “The INFORMATION_SCHEMA COLUMNS Table”
Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”
Section 21.9, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 1.3.2, “The Main Features of MySQL”
Section 15.8, “The MERGE Storage Engine”
Section 6.2, “The MySQL Access Privilege System”
Section 8.10.3, “The MySQL Query Cache”
Section 18.5.10.13, “The ndbinfo nodes Table”
Section 13.2.10.1, “The Subquery as Scalar Operand”
Section 14.8.2.1, “Transaction Isolation Levels”

Section 20.3.1, “Trigger Syntax and Examples”
Section 1.2, “Typographical and Syntax Conventions”
Section 13.2.9.3, “UNION Syntax”
Section 13.2.11, “UPDATE Syntax”
Section 9.4, “User-Defined Variables”
Section 14.18.2.1, “Using InnoDB Transaction and Locking Information”
Section 8.4.2.4, “Using PROCEDURE ANALYSE”
Section 24.5.1.6, “Using Server Logs to Find Causes of Errors in mysqld”
Section 11.5.9, “Using Spatial Indexes”
Section 5.1.6, “Using System Variables”
Using the --safe-updates Option
Section 10.1.2.2, “UTF-8 for Metadata”
Section 20.5.1, “View Syntax”
Section 12.8, “What Calendar Is Used By MySQL?”
Section 8.2.1.1, “WHERE Clause Optimization”
Section B.5.3.5, “Where MySQL Stores Temporary Files”
Section 24.2.4.8, “Writing Audit Plugins”

SELECT *

Section 11.4.3, “The BLOB and TEXT Types”

SELECT * INTO OUTFILE 'file_name' FROM tbl_name

Section 7.2, “Database Backup Methods”

SELECT ... FOR UPDATE

Section 14.8.5, “Deadlocks in InnoDB”
Section 14.8.5.3, “How to Minimize and Handle Deadlocks”
Section 14.8.1, “InnoDB Locking”
Section 14.8.2.4, “Locking Reads”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”

SELECT ... FROM

Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”

SELECT ... FROM ... FOR UPDATE

Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”

SELECT ... FROM ... LOCK IN SHARE MODE

Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”

SELECT ... INTO

Section 13.1.11, “CREATE EVENT Syntax”
Section 13.6.4.2, “Local Variable Scope and Resolution”
Section 17.4.1.14, “Replication and System Functions”
Section 13.2.9.1, “SELECT ... INTO Syntax”
Section 1.7.2.1, “SELECT INTO TABLE Differences”
Section 13.2.9, “SELECT Syntax”

SELECT ... INTO DUMPFILE

Section 2.10.1, “Initializing the Data Directory”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 5.1.5, “Server System Variables”

SELECT ... INTO OUTFILE

Section 7.1, “Backup and Recovery Types”

Section 7.4.3, “Dumping Data in Delimited-Text Format with mysqldump”
Section 14.23.2, “Forcing InnoDB Recovery”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 9.1.7, “NULL Values”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.2.9.1, “SELECT ... INTO Syntax”
Section 1.7.2.1, “SELECT INTO TABLE Differences”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 1.2, “Typographical and Syntax Conventions”
Section C.10.6, “Windows Platform Limitations”

SELECT ... INTO OUTFILE 'file_name'

Section 13.2.9.1, “SELECT ... INTO Syntax”

SELECT ... INTO var_list

Section C.1, “Restrictions on Stored Programs”
Section 13.6.4, “Variables in Stored Programs”

SELECT ... LOCK IN SHARE MODE

Section 14.8.1, “InnoDB Locking”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 14.8.2.4, “Locking Reads”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 14.8.2.1, “Transaction Isolation Levels”

SELECT DISTINCT

Section 8.14.2, “General Thread States”
Section C.4, “Restrictions on Subqueries”

SET

Section 12.3.4, “Assignment Operators”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 20.7, “Binary Logging of Stored Programs”
Section 20.1, “Defining Stored Programs”
Section 5.1.6.2, “Dynamic System Variables”
Section 20.4.2, “Event Scheduler Configuration”
Section 12.1, “Function and Operator Reference”
Chapter 12, *Functions and Operators*
Section 12.14, “Information Functions”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 4.6.11, “`mysql_find_rows` — Extract SQL Statements from Files”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 12.3, “Operators”
Section 8.10.3.3, “Query Cache Configuration”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.4, “Server Command Options”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”
Section 13.7.4, “SET Syntax”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 13.7.5.40, “SHOW VARIABLES Syntax”
Section 13.2.10, “Subquery Syntax”

Section 20.3.1, “Trigger Syntax and Examples”
Section 9.4, “User-Defined Variables”
Section 4.2.8, “Using Options to Set Program Variables”
Section 5.1.6, “Using System Variables”
Using the --safe-updates Option
Section 13.6.4, “Variables in Stored Programs”
Section 1.4, “What Is New in MySQL 5.5”

SET autocommit

Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 13.3, “Transactional and Locking Statements”

SET autocommit = 0

Section 17.3.8, “Semisynchronous Replication”

SET CHARACTER SET

Section 10.1.4, “Connection Character Sets and Collations”
Section 23.8.7.53, “mysql_real_escape_string()”
Section C.7, “Restrictions on Character Sets”
Section 5.1.5, “Server System Variables”
Section 13.7.4, “SET Syntax”
Section 10.1.9, “Unicode Support”

SET CHARACTER SET charset_name

Section 10.1.4, “Connection Character Sets and Collations”

SET GLOBAL

Section 14.9.4, “Configuring InnoDB Change Buffering”
Section 5.1.6.2, “Dynamic System Variables”
Section 13.7.1.3, “GRANT Syntax”
Section 8.10.2.2, “Multiple Key Caches”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 5.1.6, “Using System Variables”

SET GLOBAL sql_slave_skip_counter

Section 13.4.2.4, “SET GLOBAL sql_slave_skip_counter Syntax”

SET NAMES

Section 23.8.20, “C API Automatic Reconnection Control”
Section 10.1.3.6, “Character String Literal Character Set and Collation”
Section 10.1.5, “Configuring Application Character Set and Collation”
Section 10.1.4, “Connection Character Sets and Collations”
Section 10.1.6, “Error Message Character Set”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 4.5.1.2, “mysql Commands”
Section 23.8.7.53, “mysql_real_escape_string()”
Section 23.8.7.61, “mysql_set_character_set()”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section C.7, “Restrictions on Character Sets”
Section 5.1.5, “Server System Variables”
Section 13.7.4.3, “SET NAMES Syntax”
Section 13.7.4, “SET Syntax”
Section 12.2, “Type Conversion in Expression Evaluation”
Section 10.1.9, “Unicode Support”

Section 10.1.2.2, “UTF-8 for Metadata”

SET NAMES 'charset_name'

Section 10.1.4, “Connection Character Sets and Collations”

SET NAMES 'cp1251'

Section 10.1.4, “Connection Character Sets and Collations”

SET NAMES charset_name

Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”

SET NAMES default_character_set

Section 4.5.4, “`mysqldump` — A Database Backup Program”

SET PASSWORD

Section 6.3.5, “Assigning Account Passwords”
Section B.5.2.4, “Client does not support authentication protocol”
Section 13.7.1.1, “CREATE USER Syntax”
Section 6.1.2.1, “End-User Guidelines for Password Security”
Section 12.14, “Information Functions”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 6.1.2.3, “Passwords and Logging”
Section 17.4.1.38, “Replication and Variables”
Section 17.4.1.8, “Replication of CURRENT_USER()”
Resetting the Root Password: Generic Instructions
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 17.4.1.27, “SET PASSWORD and Row-Based Replication”
Section 13.7.1.6, “SET PASSWORD Syntax”
Section 13.7.4, “SET Syntax”
Section 6.2.3, “Specifying Account Names”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 6.2.6, “When Privilege Changes Take Effect”

SET PASSWORD ... = PASSWORD()

Section 6.3.5, “Assigning Account Passwords”

SET SESSION

Section 5.1.6.2, “Dynamic System Variables”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 5.1.6, “Using System Variables”

SET sql_mode='modes'

Section A.3, “MySQL 5.5 FAQ: Server SQL Mode”

SET TIMESTAMP = value

Section 8.14, “Examining Thread Information”

SET TRANSACTION

Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 14.8.2.1, “Transaction Isolation Levels”

SET TRANSACTION ISOLATION LEVEL

Section 13.7.4, “SET Syntax”
Section 13.3.6, “SET TRANSACTION Syntax”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”

SET var_name = value

Section 13.7.4, “SET Syntax”

SHOW

Section 23.8.5, “C API Data Structures”
Section 23.8.6, “C API Function Overview”
Section 13.1.11, “CREATE EVENT Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 3.3, “Creating and Using a Database”
Section 13.6.6.2, “Cursor DECLARE Syntax”
Section 21.31, “Extensions to SHOW Statements”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 9.2.3, “Mapping of Identifiers to File Names”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section 1.7.1, “MySQL Extensions to Standard SQL”
Section 23.8.11.28, “mysql_stmt_store_result()”
Section 23.8.7.69, “mysql_store_result()”
Section 23.8.7.71, “mysql_use_result()”
Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 22.1, “Performance Schema Quick Start”
Section C.1, “Restrictions on Stored Programs”
Section 13.7.5.6, “SHOW COLUMNS Syntax”
Section 13.7.5, “SHOW Syntax”
Section 13.7.5.38, “SHOW TABLES Syntax”
Section 13.4.1, “SQL Statements for Controlling Master Servers”
Section 5.4.4, “The Binary Log”
Section 21.1, “The INFORMATION_SCHEMA CHARACTER_SETS Table”
Section 21.3, “The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table”
Section 21.2, “The INFORMATION_SCHEMA COLLATIONS Table”
Section 21.5, “The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table”
Section 21.4, “The INFORMATION_SCHEMA COLUMNS Table”
Section 21.6, “The INFORMATION_SCHEMA ENGINES Table”
Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”
Section 21.29.1, “The INFORMATION_SCHEMA FILES Table”
Section 21.8, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”
Section 21.9, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”
Section 21.10, “The INFORMATION_SCHEMA KEY_COLUMN_USAGE Table”
Section 21.29.2, “The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table”
Section 21.12, “The INFORMATION_SCHEMA PARTITIONS Table”
Section 21.13, “The INFORMATION_SCHEMA PLUGINS Table”
Section 21.14, “The INFORMATION_SCHEMA PROCESSLIST Table”
Section 21.15, “The INFORMATION_SCHEMA PROFILING Table”
Section 21.16, “The INFORMATION_SCHEMA REFERENTIAL_CONSTRAINTS Table”
Section 21.19, “The INFORMATION_SCHEMA SCHEMA_PRIVILEGES Table”
Section 21.18, “The INFORMATION_SCHEMA SCHEMATA Table”
Section 21.20, “The INFORMATION_SCHEMA STATISTICS Table”
Section 21.23, “The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table”
Section 21.24, “The INFORMATION_SCHEMA TABLE_PRIVILEGES Table”
Section 21.21, “The INFORMATION_SCHEMA TABLES Table”

Section 21.22, “The INFORMATION_SCHEMA TABLESPACES Table”
Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”
Section 21.26, “The INFORMATION_SCHEMA USER_PRIVILEGES Table”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 1.3.2, “The Main Features of MySQL”
Section 10.1.2.2, “UTF-8 for Metadata”

SHOW AUTHORS

Section 13.7.5.1, “SHOW AUTHORS Syntax”

SHOW BINARY LOGS

Section 6.2.1, “Privileges Provided by MySQL”
Section 13.4.1.1, “PURGE BINARY LOGS Syntax”
Section 13.7.5.2, “SHOW BINARY LOGS Syntax”
Section 13.4.1, “SQL Statements for Controlling Master Servers”

SHOW BINLOG EVENTS

Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section C.3, “Restrictions on Server-Side Cursors”
Section 13.7.5.3, “SHOW BINLOG EVENTS Syntax”
Section 13.4.1, “SQL Statements for Controlling Master Servers”
Section 13.4.2.5, “START SLAVE Syntax”

SHOW CHARACTER SET

Section 13.1.1, “ALTER DATABASE Syntax”
Section 10.1.3.8, “Character Set Introducers”
Section 10.1.2, “Character Sets and Collations in MySQL”
Section 10.1.3.6, “Character String Literal Character Set and Collation”
Section 10.1.3.5, “Column Character Set and Collation”
Section 10.1.3.3, “Database Character Set and Collation”
Section 21.31, “Extensions to SHOW Statements”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 13.7.5.4, “SHOW CHARACTER SET Syntax”
Section 10.1.10, “Supported Character Sets and Collations”
Section 10.1.3.4, “Table Character Set and Collation”

SHOW COLLATION

Section 13.1.1, “ALTER DATABASE Syntax”
Section 23.8.5, “C API Data Structures”
Section 10.5, “Character Set Configuration”
Section 10.1.2, “Character Sets and Collations in MySQL”
Section 10.4.2, “Choosing a Collation ID”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 13.7.5.5, “SHOW COLLATION Syntax”
Section 21.3, “The INFORMATION_SCHEMA COLLATION_CHARACTER_SET_APPLICABILITY Table”
Section 21.2, “The INFORMATION_SCHEMA COLLATIONS Table”

SHOW COLUMNS

Section 13.8.2, “EXPLAIN Syntax”
Section 21.31, “Extensions to SHOW Statements”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 22.1, “Performance Schema Quick Start”
Section 13.7.5.6, “SHOW COLUMNS Syntax”
Section 21.28.1, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE Table”
Section 21.28.2, “The INFORMATION_SCHEMA INNODB_BUFFER_PAGE_LRU Table”

Section 21.28.3, “The INFORMATION_SCHEMA INNODB_BUFFER_POOL_STATS Table”
Section 21.28.4, “The INFORMATION_SCHEMA INNODB_CMP and INNODB_CMP_RESET Tables”
Section 21.28.5, “The INFORMATION_SCHEMA INNODB_CMPMEM and INNODB_CMPMEM_RESET Tables”
Section 21.28.7, “The INFORMATION_SCHEMA INNODB_LOCK_WAITS Table”
Section 21.28.6, “The INFORMATION_SCHEMA INNODB_LOCKS Table”
Section 21.28.8, “The INFORMATION_SCHEMA INNODB_TRX Table”

SHOW COLUMNS FROM tbl_name LIKE 'enum_col'

Section 11.4.4, “The ENUM Type”

SHOW CONTRIBUTORS

Section 13.7.5.7, “SHOW CONTRIBUTORS Syntax”

SHOW COUNT()

Section 13.7.5.18, “SHOW ERRORS Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”

SHOW CREATE DATABASE

Section 5.1.5, “Server System Variables”
Section 13.7.5.8, “SHOW CREATE DATABASE Syntax”

SHOW CREATE EVENT

Section 20.4.4, “Event Metadata”
Section 13.7.5.19, “SHOW EVENTS Syntax”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

SHOW CREATE FUNCTION

Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 1.6, “How to Report Bugs or Problems”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 13.7.5.11, “SHOW CREATE PROCEDURE Syntax”
Section 20.2.3, “Stored Routine Metadata”

SHOW CREATE PROCEDURE

Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 1.6, “How to Report Bugs or Problems”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 13.7.5.10, “SHOW CREATE FUNCTION Syntax”
Section 20.2.3, “Stored Routine Metadata”

SHOW CREATE SCHEMA

Section 13.7.5.8, “SHOW CREATE DATABASE Syntax”

SHOW CREATE TABLE

Section 13.1.7.1, “ALTER TABLE Partition Operations”
Section 13.1.7, “ALTER TABLE Syntax”
Section 13.1.17.1, “CREATE TABLE Statement Retention”
Section 13.1.17, “CREATE TABLE Syntax”
Section 11.6, “Data Type Default Values”
Section 13.8.2, “EXPLAIN Syntax”
Section 3.4, “Getting Information About Databases and Tables”
Section 15.9.2, “How to Create FEDERATED Tables”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 19.2.5, “KEY Partitioning”
Section 19.3.1, “Management of RANGE and LIST Partitions”

Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 18.1.6.1, “Noncompliance with SQL Syntax in NDB Cluster”
Section 19.3.4, “Obtaining Information About Partitions”
Section 22.1, “Performance Schema Quick Start”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”
Section 13.7.5.6, “SHOW COLUMNS Syntax”
Section 13.7.5.12, “SHOW CREATE TABLE Syntax”
Section 13.1.17.7, “Silent Column Specification Changes”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”
Section 3.6.6, “Using Foreign Keys”

SHOW CREATE TRIGGER

Section 13.7.5.13, “SHOW CREATE TRIGGER Syntax”
Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”
Section 20.3.2, “Trigger Metadata”

SHOW CREATE VIEW

Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section C.5, “Restrictions on Views”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 20.5.5, “View Metadata”

SHOW DATABASES

Section 13.1.10, “CREATE DATABASE Syntax”
Section 3.3, “Creating and Using a Database”
Section 21.31, “Extensions to SHOW Statements”
Section 3.4, “Getting Information About Databases and Tables”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 9.2.2, “Identifier Case Sensitivity”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 18.5.11.2, “NDB Cluster and MySQL Privileges”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 22.2, “Performance Schema Build Configuration”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 13.7.5.15, “SHOW DATABASES Syntax”

SHOW ENGINE

Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.5.16, “SHOW ENGINE Syntax”

SHOW ENGINE INNODB MUTEX

Section 13.7.5.16, “SHOW ENGINE Syntax”
Section 1.4, “What Is New in MySQL 5.5”

SHOW ENGINE INNODB STATUS

Section 14.7.3, “Adaptive Hash Index”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 14.8.5, “Deadlocks in InnoDB”
Section 14.20.2, “Enabling InnoDB Monitors”
Section 14.8.5.3, “How to Minimize and Handle Deadlocks”

Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 14.18.3, “InnoDB INFORMATION_SCHEMA Buffer Pool Tables”
Section 14.8.1, “InnoDB Locking”
Section 14.20.3, “InnoDB Standard Monitor and Lock Monitor Output”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.9.2.6, “Monitoring the Buffer Pool Using the InnoDB Standard Monitor”
MySQL Glossary
Section 8.5.7, “Optimizing InnoDB Disk I/O”
Section 13.7.5.16, “SHOW ENGINE Syntax”
Section B.1, “Sources of Error Information”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”
Section 1.4, “What Is New in MySQL 5.5”

SHOW ENGINE NDB STATUS

Section 18.2.2.3, “Initial Startup of NDB Cluster on Windows”
Section 18.5, “Management of NDB Cluster”
Section 18.6.4, “NDB Cluster Replication Schema and Tables”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”
Section 13.7.5.16, “SHOW ENGINE Syntax”

SHOW ENGINE NDBCLUSTER STATUS

MySQL Server Options for NDB Cluster
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”

SHOW ENGINE PERFORMANCE_SCHEMA STATUS

Section 22.7, “Performance Schema Status Monitoring”
Section 13.7.5.16, “SHOW ENGINE Syntax”

SHOW ENGINES

Chapter 15, *Alternative Storage Engines*
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
NDB Cluster System Variables
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 22.2, “Performance Schema Build Configuration”
Section 22.1, “Performance Schema Quick Start”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”
Section 2.3.7.3, “Selecting a MySQL Server Type”
Section 5.1.5, “Server System Variables”
Section 13.7.5.17, “SHOW ENGINES Syntax”
Section 15.6, “The ARCHIVE Storage Engine”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 1.4, “What Is New in MySQL 5.5”

SHOW ERRORS

Section 14.11.1.6, “InnoDB and FOREIGN KEY Constraints”
RESIGNAL with a Condition Value and Optional New Signal Information
Section 5.1.5, “Server System Variables”
Section 13.7.5.18, “SHOW ERRORS Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Signal Condition Information Items
Section B.1, “Sources of Error Information”

SHOW EVENTS

Section 20.4.4, “Event Metadata”
Section 17.4.1.15, “Replication of Invoked Features”

Section 13.7.5.19, “SHOW EVENTS Syntax”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”
Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”

SHOW FULL COLUMNS

Section 13.1.17, “CREATE TABLE Syntax”
Section 21.5, “The INFORMATION_SCHEMA COLUMN_PRIVILEGES Table”

SHOW FULL PROCESSLIST

Section 8.14, “Examining Thread Information”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”

SHOW FULL TABLES

Section 4.5.6, “`mysqlshow` — Display Database, Table, and Column Information”

SHOW FUNCTION CODE

Section 13.7.5.28, “SHOW PROCEDURE CODE Syntax”

SHOW FUNCTION STATUS

Section 13.7.5.29, “SHOW PROCEDURE STATUS Syntax”
Section 20.2.3, “Stored Routine Metadata”

SHOW GLOBAL STATUS

NDB Cluster Status Variables
Section 5.1.5, “Server System Variables”
Section 21.8, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”

SHOW GLOBAL VARIABLES

Section 21.9, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”

SHOW GRANTS

Section 6.3.2, “Adding User Accounts”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.1.5, “REVOKE Syntax”
Section 6.1.1, “Security Guidelines”
Section 13.7.5.22, “SHOW GRANTS Syntax”
Section 13.7.5.27, “SHOW PRIVILEGES Syntax”
Section 6.2, “The MySQL Access Privilege System”

SHOW INDEX

Section 13.7.2.1, “ANALYZE TABLE Syntax”
Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”
Section 8.8.2, “EXPLAIN Output Format”
Section 13.8.2, “EXPLAIN Syntax”
Section 8.9.3, “Index Hints”
Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.11.1.7, “Limits on InnoDB Tables”
Section 18.4.14, “`ndb_index_stat` — NDB Index Statistics Utility”
Section 4.6.3.4, “Other myisamchk Options”
Section 13.7.5.6, “SHOW COLUMNS Syntax”
Section 13.7.5.23, “SHOW INDEX Syntax”
Section 21.20, “The INFORMATION_SCHEMA STATISTICS Table”

Section 21.23, “The INFORMATION_SCHEMA TABLE_CONSTRAINTS Table”

SHOW MASTER LOGS

Section 13.7.5.2, “SHOW BINARY LOGS Syntax”

SHOW MASTER STATUS

Section 17.1.1.5, “Creating a Data Snapshot Using mysqldump”
Section 17.4.5, “How to Report Replication Bugs or Problems”
Section 18.6.9, “NDB Cluster Backups With NDB Cluster Replication”
Section 17.1.1.4, “Obtaining the Replication Master Binary Log Coordinates”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.4.1, “SQL Statements for Controlling Master Servers”
Section 17.4.4, “Troubleshooting Replication”

SHOW OPEN TABLES

Section 13.7.5.25, “SHOW OPEN TABLES Syntax”

SHOW PLUGINS

Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”
Section 13.7.3.3, “INSTALL PLUGIN Syntax”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 6.5.2.1, “Installing MySQL Enterprise Audit”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
MySQL Server Options for NDB Cluster
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 5.5.2, “Obtaining Server Plugin Information”
Section 6.5.1.4, “PAM Pluggable Authentication”
Chapter 19, *Partitioning*
Section 24.2.2, “Plugin API Characteristics”
Section 24.2.3, “Plugin API Components”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Server Plugin Library and Plugin Descriptors
Section 5.1.5, “Server System Variables”
Section 13.7.5.26, “SHOW PLUGINS Syntax”
Section 6.5.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.5.1.7, “Test Pluggable Authentication”
Section 21.29.2, “The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table”
Section 21.13, “The INFORMATION_SCHEMA PLUGINS Table”
Section 5.5.3.2, “Thread Pool Installation”
Section 1.4, “What Is New in MySQL 5.5”
Section 6.5.1.5, “Windows Pluggable Authentication”
Section 24.2.4.8, “Writing Audit Plugins”
Section 24.2.4.5, “Writing Daemon Plugins”
Section 24.2.4.4, “Writing Full-Text Parser Plugins”
Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”
Writing the Server-Side Authentication Plugin

SHOW PRIVILEGES

Section 13.7.5.27, “SHOW PRIVILEGES Syntax”

SHOW PROCEDURE CODE

Section 13.7.5.20, “SHOW FUNCTION CODE Syntax”

SHOW PROCEDURE STATUS

Section 13.7.5.21, “SHOW FUNCTION STATUS Syntax”
Section 20.2.3, “Stored Routine Metadata”

SHOW PROCESSLIST

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 17.1.4.1, “Checking Replication Status”
Section 5.7.1.2, “Command Probes”
Section 5.7.1.1, “Connection Probes”
Section 20.4.2, “Event Scheduler Configuration”
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Syntax”
Section 12.14, “Information Functions”
Section 14.23.4, “InnoDB Error Handling”
Section 13.7.6.4, “KILL Syntax”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section 18.5.4, “MySQL Server Usage for NDB Cluster”
Section 23.8.7.43, “mysql_list_processes()”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 6.2.1, “Privileges Provided by MySQL”
Section 5.7.1.6, “Query Execution Probes”
Section 5.7.1.3, “Query Probes”
Section 17.2.1, “Replication Implementation Details”
Section 5.1.5, “Server System Variables”
Section 13.7.5.30, “SHOW PROCESSLIST Syntax”
Section 13.7.5.31, “SHOW PROFILE Syntax”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 17.3.6, “Switching Masters During Failover”
Section 21.29.2, “The INFORMATION_SCHEMA ndb_transid_mysql_connection_map Table”
Section 18.5.10.15, “The ndbinfo server_operations Table”
Section 18.5.10.16, “The ndbinfo server_transactions Table”
Section 22.9.6.2, “The threads Table”
Section B.5.2.7, “Too many connections”
Section 17.4.4, “Troubleshooting Replication”

SHOW PROFILE

Section 8.14, “Examining Thread Information”
Section 8.14.2, “General Thread States”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 5.1.5, “Server System Variables”
Section 13.7.5.31, “SHOW PROFILE Syntax”
Section 13.7.5.32, “SHOW PROFILES Syntax”
Section 21.15, “The INFORMATION_SCHEMA PROFILING Table”

SHOW PROFILES

Section 2.9.4, “MySQL Source-Configuration Options”
Section 5.1.5, “Server System Variables”
Section 13.7.5.31, “SHOW PROFILE Syntax”
Section 13.7.5.32, “SHOW PROFILES Syntax”
Section 21.15, “The INFORMATION_SCHEMA PROFILING Table”

SHOW RELAYLOG EVENTS

Section 13.7.5.3, “SHOW BINLOG EVENTS Syntax”
Section 13.7.5.33, “SHOW RELAYLOG EVENTS Syntax”
Section 13.4.2, “SQL Statements for Controlling Slave Servers”

SHOW SCHEMAS

Section 13.7.5.15, “SHOW DATABASES Syntax”

SHOW SESSION STATUS

NDB Cluster Status Variables
Section 21.8, “The INFORMATION_SCHEMA GLOBAL_STATUS and SESSION_STATUS Tables”

SHOW SESSION VARIABLES

Section 21.9, “The INFORMATION_SCHEMA GLOBAL_VARIABLES and SESSION_VARIABLES Tables”

SHOW SLAVE HOSTS

Section 17.1.4.1, “Checking Replication Status”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.4.1, “SQL Statements for Controlling Master Servers”

SHOW SLAVE STATUS

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 17.1.4.1, “Checking Replication Status”
Section 17.4.5, “How to Report Replication Bugs or Problems”
Section 18.6.8, “Implementing Failover with NDB Cluster Replication”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.4.1.1, “PURGE BINARY LOGS Syntax”
Section 17.2.1, “Replication Implementation Details”
Section 8.14.6, “Replication Slave I/O Thread States”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.3.7, “Setting Up Replication to Use Encrypted Connections”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 17.4.1.29, “Slave Errors During Replication”
Section 17.2.2.2, “Slave Status Logs”
Section B.1, “Sources of Error Information”
Section 13.4.2, “SQL Statements for Controlling Slave Servers”
Section 13.4.2.5, “START SLAVE Syntax”
Section 17.4.4, “Troubleshooting Replication”

SHOW STATUS

Section 18.3.3.7, “Defining SQL and Other API Nodes in an NDB Cluster”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 18.5, “Management of NDB Cluster”
MySQL Server Options for NDB Cluster
Section 18.5.15, “NDB API Statistics Counters and Variables”
Section 18.6, “NDB Cluster Replication”
Section 24.2.2, “Plugin API Characteristics”
Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 18.5.9, “Quick Reference: NDB Cluster SQL Statements”
Section 17.4.1.31, “Replication and Temporary Tables”
Section 17.2.1, “Replication Implementation Details”
Section 17.4.1.32, “Replication Retries and Timeouts”
Section C.1, “Restrictions on Stored Programs”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Server Plugin Library and Plugin Descriptors
Server Plugin Status and System Variables
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.5.36, “SHOW STATUS Syntax”
Section 24.2.4.8, “Writing Audit Plugins”

Section 24.2.4.4, “Writing Full-Text Parser Plugins”
Section 24.2.4, “Writing Plugins”

SHOW STATUS LIKE 'perf%'

Section 22.7, “Performance Schema Status Monitoring”

SHOW TABLE STATUS

Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”
Section 13.1.17.1, “CREATE TABLE Statement Retention”
Section 13.1.17, “CREATE TABLE Syntax”
Section 14.11.1.1, “Creating InnoDB Tables”
Section 13.8.2, “EXPLAIN Syntax”
Section 14.15.2, “File Space Management”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.11.1.7, “Limits on InnoDB Tables”
MySQL Glossary
Section 19.3.4, “Obtaining Information About Partitions”
Section 13.7.5.6, “SHOW COLUMNS Syntax”
Section 13.7.5.37, “SHOW TABLE STATUS Syntax”
Section 15.6, “The ARCHIVE Storage Engine”
Section 21.21, “The INFORMATION_SCHEMA TABLES Table”
Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table”

SHOW TABLES

Section 3.3.2, “Creating a Table”
Section 21.31, “Extensions to SHOW Statements”
Section 9.2.2, “Identifier Case Sensitivity”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 14.18, “InnoDB INFORMATION_SCHEMA Tables”
Section 9.2.3, “Mapping of Identifiers to File Names”
MySQL Glossary
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 5.1.4, “Server Command Options”
Section 13.7.5.37, “SHOW TABLE STATUS Syntax”
Section 13.7.5.38, “SHOW TABLES Syntax”
Section B.5.2.16, “Table 'tbl_name' doesn't exist”
Section B.5.6.2, “TEMPORARY Table Problems”

SHOW TABLES FROM some_ndb_database

Section 18.5.11.2, “NDB Cluster and MySQL Privileges”

SHOW TRIGGERS

Section A.5, “MySQL 5.5 FAQ: Triggers”
Section 13.7.5.39, “SHOW TRIGGERS Syntax”
Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”
Section 20.3.2, “Trigger Metadata”

SHOW VARIABLES

Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 20.4.2, “Event Scheduler Configuration”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Chapter 19, *Partitioning*
Section 24.2.2, “Plugin API Characteristics”
Section 5.6, “Running Multiple MySQL Instances on One Machine”

Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 13.7.5.40, “SHOW VARIABLES Syntax”
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”
Section 5.1.6, “Using System Variables”
Section 24.2.4, “Writing Plugins”

SHOW WARNINGS

Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 13.1.7, “ALTER TABLE Syntax”
Section 13.6.7, “Condition Handling”
Section 13.1.26, “DROP PROCEDURE and DROP FUNCTION Syntax”
Section 13.1.28, “DROP TABLE Syntax”
Effect of Signals on Handlers, Cursors, and Statements
Section 8.8.2, “EXPLAIN Output Format”
Section 8.8.3, “Extended EXPLAIN Output Format”
Section 9.2.4, “Function Name Parsing and Resolution”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 1.7.3.1, “PRIMARY KEY and UNIQUE Index Constraints”
Section B.3, “Server Error Codes and Messages”
Section 5.1.5, “Server System Variables”
Section 13.7.5.18, “SHOW ERRORS Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Signal Condition Information Items
Section 13.6.7.4, “SIGNAL Syntax”
Section B.1, “Sources of Error Information”
Section 8.2.2, “Subquery Optimization”

SIGNAL

Section 13.6.7, “Condition Handling”
Section 13.6.7.1, “DECLARE ... CONDITION Syntax”
Section 13.6.7.2, “DECLARE ... HANDLER Syntax”
Effect of Signals on Handlers, Cursors, and Statements
Section 12.14, “Information Functions”
Section 13.6.7.3, “RESIGNAL Syntax”
Section C.2, “Restrictions on Condition Handling”
Section C.1, “Restrictions on Stored Programs”
Signal Condition Information Items
Section 13.6.7.4, “SIGNAL Syntax”
Section 1.4, “What Is New in MySQL 5.5”

START SLAVE

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 18.6.8, “Implementing Failover with NDB Cluster Replication”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
Section 18.4.21, “`ndb_restore` — Restore an NDB Cluster Backup”
Section 17.1.4.2, “Pausing Replication on the Slave”
Section 17.3.4, “Replicating Different Databases to Different Slaves”
Section 17.2.1, “Replication Implementation Details”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.4.2.3, “RESET SLAVE Syntax”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”

Section 17.4.1.29, “Slave Errors During Replication”
Section 13.4.2.5, “START SLAVE Syntax”
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”
Section 13.4.2.6, “STOP SLAVE Syntax”
Section 17.3.6, “Switching Masters During Failover”
Section 17.4.4, “Troubleshooting Replication”
Section 18.6.7, “Using Two Replication Channels for NDB Cluster Replication”

START TRANSACTION

Section 14.8.2.2, “autocommit, Commit, and Rollback”
Section 13.6.1, “BEGIN ... END Compound-Statement Syntax”
Section 13.7.6.3, “FLUSH Syntax”
Section 14.8.5.3, “How to Minimize and Handle Deadlocks”
Section 14.23.4, “InnoDB Error Handling”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.3.5.1, “Interaction of Table Locking and Transactions”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
Section 14.8.2.4, “Locking Reads”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section C.1, “Restrictions on Stored Programs”
Section 17.3.8, “Semisynchronous Replication”
Section 5.1.5, “Server System Variables”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 13.3, “Transactional and Locking Statements”
Section 20.3.1, “Trigger Syntax and Examples”
Section 13.3.7.2, “XA Transaction States”

START TRANSACTION READ ONLY

MySQL Glossary

START TRANSACTION WITH CONSISTENT SNAPSHOT

Section 14.8.2.3, “Consistent Nonlocking Reads”

STOP SLAVE

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 17.1.4.1, “Checking Replication Status”
Section 17.1.1.9, “Introducing Additional Slaves to an Existing Replication Environment”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 17.1.4.2, “Pausing Replication on the Slave”
Section 13.4.1.2, “RESET MASTER Syntax”
Section 13.4.2.3, “RESET SLAVE Syntax”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 13.4.2.5, “START SLAVE Syntax”
Section 13.4.2.6, “STOP SLAVE Syntax”
Section 17.3.6, “Switching Masters During Failover”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

STOP SLAVE SQL_THREAD

Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

T

[index top]

TRUNCATE TABLE

Section 18.5.13.1, “Adding NDB Cluster Data Nodes Online: General Issues”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”

Section 18.5.2, “Commands in the NDB Cluster Management Client”
Section 15.3.3.3, “Compressed Table Characteristics”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.2.2, “DELETE Syntax”
Section 22.4.3, “Event Pre-Filtering”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 22.9.5.2, “File I/O Summary Tables”
Section 13.2.4, “HANDLER Syntax”
Section 8.10.3.1, “How the Query Cache Operates”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 18.1.6.2, “Limits and Differences of NDB Cluster from Standard MySQL Limits”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 19.3.3, “Maintenance of Partitions”
Section 19.3.1, “Management of RANGE and LIST Partitions”
Section 15.8.2, “MERGE Table Problems”
MySQL Glossary
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.4.9, “`ndb_delete_all` — Delete All Rows from an NDB Table”
Section 8.5.6, “Optimizing InnoDB DDL Operations”
Section 22.4.1, “Performance Schema Event Timing”
Section 22.8, “Performance Schema General Table Characteristics”
Section 22.9.5, “Performance Schema Summary Tables”
Section 18.6.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.20, “Replication and MEMORY Tables”
Section 17.4.1.37, “Replication and TRUNCATE TABLE”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.5, “Server System Variables”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 22.9.3.1, “The cond_instances Table”
Section 22.9.4.1, “The events_waits_current Table”
Section 22.9.4.2, “The events_waits_history Table”
Section 22.9.4.3, “The events_waits_history_long Table”
Section 22.9.3.2, “The file_instances Table”
Section 15.4, “The MEMORY Storage Engine”
Section 22.9.3.3, “The mutex_instances Table”
Section 22.9.6.1, “The performance_timers Table”
Section 22.9.3.4, “The rwlock_instances Table”
Section 22.9.2.1, “The setup_consumers Table”
Section 22.9.2.2, “The setup_instruments Table”
Section 22.9.2.3, “The setup_timers Table”
Section 22.9.6.2, “The threads Table”
Section 13.1.33, “TRUNCATE TABLE Syntax”
Section 22.9.5.1, “Wait Event Summary Tables”
Section 23.8.21.2, “What Results You Can Get from a Query”

U

[index top]

UNINSTALL PLUGIN

Section 13.7.6.3, “FLUSH Syntax”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 13.7.3.3, “INSTALL PLUGIN Syntax”

Section 5.5.1, “Installing and Uninstalling Plugins”
Section 4.4.4, “mysql_plugin — Configure MySQL Server Plugins”
Section 6.5.1.4, “PAM Pluggable Authentication”
Section 22.13, “Performance Schema and Plugins”
Section 15.2.1, “Pluggable Storage Engine Architecture”
Section 24.2.3, “Plugin API Components”
Server Plugin Library and Plugin Descriptors
Section 13.7.5.26, “SHOW PLUGINS Syntax”
Section 6.5.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.5.1.7, “Test Pluggable Authentication”
Section 21.13, “The INFORMATION_SCHEMA PLUGINS Table”
Section 13.7.3.4, “UNINSTALL PLUGIN Syntax”
Section 6.5.1.5, “Windows Pluggable Authentication”
Section 24.2.4.8, “Writing Audit Plugins”
Section 24.2.4.5, “Writing Daemon Plugins”
Section 24.2.4.4, “Writing Full-Text Parser Plugins”
Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”
Writing the Server-Side Authentication Plugin

UNION

Section 23.8.5, “C API Data Structures”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 13.1.17, “CREATE TABLE Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 8.8.2, “EXPLAIN Output Format”
Section 12.14, “Information Functions”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 11.2.5, “Numeric Type Attributes”
Section 8.2.1.2, “Range Optimization”
Section 3.6.7, “Searching on Two Keys”
Section 13.2.9, “SELECT Syntax”
Section 5.1.7, “Server Status Variables”
Section 13.2.10, “Subquery Syntax”
Section 15.8, “The MERGE Storage Engine”
Section 13.2.9.3, “UNION Syntax”
Section 20.5.3, “Updatable and Insertable Views”
Section 8.4.2.4, “Using PROCEDURE ANALYSE”
Section 20.5.2, “View Processing Algorithms”
Section 20.5.1, “View Syntax”
Section 12.11, “XML Functions”

UNION ALL

Section 12.14, “Information Functions”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 13.2.9.3, “UNION Syntax”
Section 20.5.3, “Updatable and Insertable Views”
Section 20.5.2, “View Processing Algorithms”

UNION DISTINCT

Section 13.2.9.3, “UNION Syntax”

UNLOCK TABLES

Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 7.2, “Database Backup Methods”
Section 13.7.6.3, “FLUSH Syntax”

Section 14.8.5.3, “How to Minimize and Handle Deadlocks”
Section 13.3.5.1, “Interaction of Table Locking and Transactions”
Section 14.11.1.7, “Limits on InnoDB Tables”
Section 13.3.5, “LOCK TABLES and UNLOCK TABLES Syntax”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section C.1, “Restrictions on Stored Programs”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 13.3.3, “Statements That Cause an Implicit Commit”
Section 8.12.1, “System Factors”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”

UPDATE

Section 6.2.5, “Access Control, Stage 2: Request Verification”
Section 6.3.2, “Adding User Accounts”
Section 17.1.2.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication”
Section 12.3.4, “Assignment Operators”
Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 13.5.4, “Automatic Prepared Statement Repreparation”
Section 17.1.3.4, “Binary Log Options and Variables”
Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 23.8.6, “C API Function Overview”
Section 23.8.16, “C API Multiple Statement Execution Support”
Section 23.8.10, “C API Prepared Statement Function Overview”
Section 14.7.2, “Change Buffer”
Section 13.7.2.2, “CHECK TABLE Syntax”
Section 10.1.7, “Column Character Set Conversion”
Section 14.9.4, “Configuring InnoDB Change Buffering”
Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 1.7.3.3, “Constraints on Invalid Data”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 13.1.17.3, “CREATE TEMPORARY TABLE Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Section 13.1.20, “CREATE VIEW Syntax”
Section 15.9.2.1, “Creating a FEDERATED Table Using CONNECTION”
Section 11.6, “Data Type Default Values”
Section 11.1.2, “Date and Time Type Overview”
Section 14.8.5, “Deadlocks in InnoDB”
Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 14.23.2, “Forcing InnoDB Recovery”
Section 12.1, “Function and Operator Reference”
Section 8.2.1.14, “Function Call Optimization”
Chapter 12, *Functions and Operators*
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.2, “Grant Tables”
Section 8.10.3.1, “How the Query Cache Operates”
Section 12.14, “Information Functions”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 14.8.1, “InnoDB Locking”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.2.5.2, “INSERT ... ON DUPLICATE KEY UPDATE Syntax”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 13.2.5, “INSERT Syntax”
Section 8.11.1, “Internal Locking Methods”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 13.2.9.2, “JOIN Syntax”
Section 13.7.6.4, “KILL Syntax”
Section B.5.7, “Known Issues in MySQL”

Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 14.8.2.4, “Locking Reads”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 12.17, “Miscellaneous Functions”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 1.7.1, “MySQL Extensions to Standard SQL”
MySQL Glossary
Section 4.5.1.1, “mysql Options”
Section 23.8.7.1, “mysql_affected_rows()”
Section 23.8.7.35, “mysql_info()”
Section 23.8.7.37, “mysql_insert_id()”
Section 23.8.7.48, “mysql_num_rows()”
Section 23.8.7.49, “mysql_options()”
Section 23.8.11.10, “mysql_stmt_execute()”
Section 23.8.11.16, “mysql_stmt_insert_id()”
Section 23.8.11.18, “mysql_stmt_num_rows()”
Section 4.6.7.2, “mysqlbinlog Row Event Display”
Section 18.5.12.1, “NDB Cluster Disk Data Objects”
Section 12.3, “Operators”
Section 8.2.4, “Optimizing Data Change Statements”
Section 11.2.6, “Out-of-Range and Overflow Handling”
Section 19.4, “Partition Pruning”
Section 19.5.4, “Partitioning and Table-Level Locking”
Section 1.7.3.1, “PRIMARY KEY and UNIQUE Index Constraints”
Section 6.2.1, “Privileges Provided by MySQL”
Section B.5.4.2, “Problems Using DATE Columns”
Section 17.4.1.16, “Replication and LIMIT”
Section 17.4.1.22, “Replication and the Query Optimizer”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 13.2.10.11, “Rewriting Subqueries as Joins”
Section 2.10.4, “Securing the Initial MySQL Accounts”
Section 3.3.4.1, “Selecting All Data”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section 5.1.8, “Server SQL Modes”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.1.6, “SET PASSWORD Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section 17.4.1.29, “Slave Errors During Replication”
Section 5.7.1.12, “Statement Probes”
Section 13.2.10.9, “Subquery Errors”
Section 13.2.10, “Subquery Syntax”
Section 8.11.2, “Table Locking Issues”
Section 13.3.5.3, “Table-Locking Restrictions and Conditions”
Section 15.6, “The ARCHIVE Storage Engine”
Section 10.1.8.5, “The binary Collation Compared to _bin Collations”
Section 5.4.4, “The Binary Log”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 1.3.2, “The Main Features of MySQL”
Section 15.8, “The MERGE Storage Engine”
Section 15.3, “The MyISAM Storage Engine”
Section 6.2, “The MySQL Access Privilege System”
Section 5.1.12, “The Server Shutdown Process”

Section 14.8.2.1, “Transaction Isolation Levels”
Section 20.3.1, “Trigger Syntax and Examples”
Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
Section 20.5.3, “Updatable and Insertable Views”
Section 1.7.2.2, “UPDATE Differences”
Section 13.2.11, “UPDATE Syntax”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”
Using the --safe-updates Option
Section 23.8.21.2, “What Results You Can Get from a Query”
Section 6.2.6, “When Privilege Changes Take Effect”
Section 8.2.1.1, “WHERE Clause Optimization”
Section 23.8.21.1, “Why mysql_store_result() Sometimes Returns NULL After mysql_query() Returns Success”

UPDATE ... ()

Section 14.8.2.3, “Consistent Nonlocking Reads”

UPDATE ... WHERE

Section 14.8.5, “Deadlocks in InnoDB”

UPDATE ... WHERE ...

Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”

UPDATE IGNORE

Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 5.1.8, “Server SQL Modes”
Section 13.2.11, “UPDATE Syntax”

UPDATE t1,t2 ...

Section 5.7.1.12, “Statement Probes”

USE

Section 17.1.3.4, “Binary Log Options and Variables”
Section 7.4.5.2, “Copy a Database from one Server to Another”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 3.3.1, “Creating and Selecting a Database”
Section 3.3, “Creating and Using a Database”
Section 7.4.1, “Dumping Data in SQL Format with mysqldump”
Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Chapter 21, *INFORMATION_SCHEMA Tables*
Section 4.5.1.1, “mysql Options”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 18.5.10, “ndbinfo: The NDB Cluster Information Database”
Section 7.4.2, “Reloading SQL-Format Backups”
Section 17.2.3.3, “Replication Rule Application”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 20.2.1, “Stored Routine Syntax”
Section 13.8.4, “USE Syntax”

USE db2

Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”

USE db_name

Section 4.5.1.1, “mysql Options”

USE test
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”

W

[index top]

WHILE
Section 13.6.5, “Flow Control Statements”
Section 13.6.5.3, “ITERATE Syntax”
Section 13.6.5.4, “LEAVE Syntax”
Section 13.6.2, “Statement Label Syntax”
Section 13.6.5.8, “WHILE Syntax”

X

[index top]

XA COMMIT
Section 2.11.2, “Downgrading MySQL”
Section 5.1.5, “Server System Variables”
Section 2.11.1, “Upgrading MySQL”
Section 13.3.7.2, “XA Transaction States”

XA END
Section C.6, “Restrictions on XA Transactions”
Section 13.3.7.1, “XA Transaction SQL Syntax”
Section 13.3.7.2, “XA Transaction States”

XA PREPARE
Section 13.3.7.2, “XA Transaction States”

XA RECOVER
Section 2.11.2, “Downgrading MySQL”
Section 2.11.1, “Upgrading MySQL”
Section 13.3.7.1, “XA Transaction SQL Syntax”
Section 13.3.7.2, “XA Transaction States”

XA ROLLBACK
Section 2.11.2, “Downgrading MySQL”
Section 5.1.5, “Server System Variables”
Section 2.11.1, “Upgrading MySQL”
Section 13.3.7.2, “XA Transaction States”

XA START
Section C.6, “Restrictions on XA Transactions”
Section 13.3.7.1, “XA Transaction SQL Syntax”
Section 13.3.7.2, “XA Transaction States”

XA START xid
Section 13.3.7.1, “XA Transaction SQL Syntax”

Status Variable Index

A | B | C | D | F | H | I | K | L | M | N | O | P | Q | R | S | T | U

A

[index top]

Aborted_clients
Section B.5.2.11, “Communication Errors and Aborted Connections”
Section 5.1.7, “Server Status Variables”

Aborted_connects
Section B.5.2.11, “Communication Errors and Aborted Connections”
Section 5.1.7, “Server Status Variables”

B

[index top]

Binlog_cache_disk_use
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.7, “Server Status Variables”
Section 5.4.4, “The Binary Log”

Binlog_cache_use
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.7, “Server Status Variables”
Section 5.4.4, “The Binary Log”

Binlog_stmt_cache_disk_use
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.7, “Server Status Variables”

Binlog_stmt_cache_use
Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.7, “Server Status Variables”

Bytes_received
Section 5.1.7, “Server Status Variables”

Bytes_sent
Section 5.1.7, “Server Status Variables”

C

[index top]

Com_flush
Section 5.1.7, “Server Status Variables”

Com_stmt_reprepare
Section 13.5.4, “Automatic Prepared Statement Repreparation”

Compression
Section 5.1.7, “Server Status Variables”

Connections
Section 5.1.7, “Server Status Variables”

Section 5.1.5, “Server System Variables”

Created_tmp_disk_tables

Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

Created_tmp_files

Section 5.1.7, “Server Status Variables”

Created_tmp_tables

Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.5.36, “SHOW STATUS Syntax”

D

[index top]

Delayed_errors

Section 5.1.7, “Server Status Variables”

Delayed_insert_threads

Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 5.1.7, “Server Status Variables”

Delayed_writes

Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 5.1.7, “Server Status Variables”

F

[index top]

Flush_commands

Section 5.1.7, “Server Status Variables”

H

[index top]

Handler_commit

Section 5.1.7, “Server Status Variables”

Handler_delete

Section 5.1.7, “Server Status Variables”

Handler_discover

NDB Cluster Status Variables

Handler_prepare

Section 5.1.7, “Server Status Variables”

Handler_read_first

Section 5.1.7, “Server Status Variables”

Handler_read_key
Section 5.1.7, “Server Status Variables”

Handler_read_last
Section 5.1.7, “Server Status Variables”

Handler_read_next
Section 5.1.7, “Server Status Variables”

Handler_read_prev
Section 5.1.7, “Server Status Variables”

Handler_read_rnd
Section 5.1.7, “Server Status Variables”

Handler_read_rnd_next
Section 5.1.7, “Server Status Variables”

Handler_rollback
Section 5.1.7, “Server Status Variables”

Handler_savepoint
Section 5.1.7, “Server Status Variables”

Handler_savepoint_rollback
Section 5.1.7, “Server Status Variables”

Handler_update
Section 5.1.7, “Server Status Variables”

Handler_write
Section 5.1.7, “Server Status Variables”

I

[index top]

Innodb_buffer_pool_bytes_data
Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_bytes_dirty
Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_pages_data
Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_pages_dirty
Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_pages_flushed
Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_pages_free
Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_pages_latched

Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_pages_misc

Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_pages_total

Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_read_ahead

Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.1.7, “Server Status Variables”
Section 1.4, “What Is New in MySQL 5.5”

Innodb_buffer_pool_read_ahead_evicted

Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.1.7, “Server Status Variables”
Section 1.4, “What Is New in MySQL 5.5”

Innodb_buffer_pool_read_ahead_rnd

Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”
Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_read_requests

Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_reads

Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_wait_free

Section 5.1.7, “Server Status Variables”

Innodb_buffer_pool_write_requests

Section 5.1.7, “Server Status Variables”

Innodb_data_fsyncs

Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.1.7, “Server Status Variables”

Innodb_data_pending_fsyncs

Section 5.1.7, “Server Status Variables”

Innodb_data_pending_reads

Section 5.1.7, “Server Status Variables”

Innodb_data_pending_writes

Section 5.1.7, “Server Status Variables”

Innodb_data_read

Section 5.1.7, “Server Status Variables”

Innodb_data_reads

Section 5.1.7, “Server Status Variables”

Innodb_data_writes
Section 5.1.7, “Server Status Variables”

Innodb_data_written
Section 5.1.7, “Server Status Variables”

Innodb_dblwr_pages_written
Section 5.1.7, “Server Status Variables”

Innodb_dblwr_writes
Section 5.1.7, “Server Status Variables”

Innodb_have_atomic_builtins
Section 5.1.7, “Server Status Variables”
Section 1.4, “What Is New in MySQL 5.5”

Innodb_log_waits
Section 5.1.7, “Server Status Variables”

Innodb_log_write_requests
Section 5.1.7, “Server Status Variables”

Innodb_log_writes
Section 5.1.7, “Server Status Variables”

Innodb_os_log_fsyncs
Section 5.1.7, “Server Status Variables”

Innodb_os_log_pending_fsyncs
Section 5.1.7, “Server Status Variables”

Innodb_os_log_pending_writes
Section 5.1.7, “Server Status Variables”

Innodb_os_log_written
Section 5.1.7, “Server Status Variables”

Innodb_page_size
Section 5.1.7, “Server Status Variables”

Innodb_pages_created
Section 5.1.7, “Server Status Variables”

Innodb_pages_read
Section 5.1.7, “Server Status Variables”

Innodb_pages_written
Section 5.1.7, “Server Status Variables”

Innodb_row_lock_current_waits
Section 5.1.7, “Server Status Variables”

Innodb_row_lock_time
Section 5.1.7, “Server Status Variables”

Innodb_row_lock_time_avg
Section 5.1.7, “Server Status Variables”

Innodb_row_lock_time_max
Section 5.1.7, “Server Status Variables”

Innodb_row_lock_waits
Section 5.1.7, “Server Status Variables”

Innodb_rows_deleted
Section 5.1.7, “Server Status Variables”

Innodb_rows_inserted
Section 5.1.7, “Server Status Variables”

Innodb_rows_read
Section 5.1.7, “Server Status Variables”

Innodb_rows_updated
Section 5.1.7, “Server Status Variables”

Innodb_truncated_status_writes
Section 5.1.7, “Server Status Variables”

K

[index top]

Key_blocks_not_flushed
Section 5.1.7, “Server Status Variables”

Key_blocks_unused
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

Key_blocks_used
Section 5.1.7, “Server Status Variables”

Key_read_requests
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

Key_reads
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

Key_write_requests
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

Key_writes
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

L

[index top]

Last_query_cost
Section 5.1.7, “Server Status Variables”

M

[index top]

Max_used_connections
Section 13.7.6.3, “FLUSH Syntax”
Section 5.1.7, “Server Status Variables”

N

[index top]

Ndb_api_bytes_received_count
Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_bytes_received_count_session
Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_bytes_received_count_slave
Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_bytes_sent_count
Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_bytes_sent_count_session
Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_bytes_sent_count_slave
Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_event_bytes_count
Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_event_bytes_count_injector
Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_event_data_count
Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_event_data_count_injector

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_event_nondata_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_event_nondata_count_injector

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_pk_op_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_pk_op_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_pk_op_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_pruned_scan_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_pruned_scan_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_pruned_scan_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_range_scan_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_range_scan_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_range_scan_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_read_row_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_read_row_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_read_row_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_scan_batch_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_scan_batch_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_scan_batch_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_table_scan_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_table_scan_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_table_scan_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_abort_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_abort_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_abort_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_close_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_close_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_close_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_commit_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_commit_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_commit_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_local_read_row_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_local_read_row_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_local_read_row_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_start_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_start_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_trans_start_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_uk_op_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_uk_op_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_uk_op_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_exec_complete_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_exec_complete_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_exec_complete_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”

NDB Cluster Status Variables

Ndb_api_wait_meta_request_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_meta_request_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_meta_request_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_nanos_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_nanos_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_nanos_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_scan_result_count

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_scan_result_count_session

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_api_wait_scan_result_count_slave

Section 18.5.15, “NDB API Statistics Counters and Variables”
NDB Cluster Status Variables

Ndb_cluster_node_id

NDB Cluster Status Variables

Ndb_config_from_host

NDB Cluster Status Variables

Ndb_config_from_port

NDB Cluster Status Variables

Ndb_conflict_fn_epoch

Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

Ndb_conflict_fn_epoch_trans

Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
NDB Cluster Status Variables

Ndb_conflict_fn_max
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

Ndb_conflict_fn_old
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

Ndb_conflict_trans_conflict_commit_count
NDB Cluster Status Variables

Ndb_conflict_trans_row_conflict_count
NDB Cluster Status Variables

Ndb_conflict_trans_row_reject_count
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”

Ndb_execute_count
NDB Cluster Status Variables

Ndb_number_of_data_nodes
NDB Cluster Status Variables

Ndb_pruned_scan_count
NDB Cluster Status Variables

Ndb_pushed_queries_defined
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

Ndb_pushed_queries_dropped
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

Ndb_pushed_queries_executed
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

Ndb_pushed_reads
NDB Cluster Status Variables
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

Ndb_scan_count
NDB Cluster Status Variables

Not_flushed_delayed_rows
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 5.1.7, “Server Status Variables”

O

[index top]

Open_files
Section 5.1.7, “Server Status Variables”

Open_streams
Section 5.1.7, “Server Status Variables”

Open_table_definitions
Section 5.1.7, “Server Status Variables”

Open_tables
Section 5.1.7, “Server Status Variables”

Opened_files
Section 5.1.7, “Server Status Variables”

Opened_table_definitions
Section 5.1.7, “Server Status Variables”

Opened_tables
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

P

[index top]

Performance_schema_cond_classes_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_cond_instances_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_file_classes_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_file_handles_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_file_instances_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_locker_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_mutex_classes_lost
Section 22.7, “Performance Schema Status Monitoring”
Section 22.12, “Performance Schema Status Variables”

Performance_schema_mutex_instances_lost
Section 22.7, “Performance Schema Status Monitoring”

Section 22.12, “Performance Schema Status Variables”

Performance_schema_rwlock_classes_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_rwlock_instances_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_table_handles_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_table_instances_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_thread_classes_lost
Section 22.12, “Performance Schema Status Variables”

Performance_schema_thread_instances_lost
Section 22.12, “Performance Schema Status Variables”
Section 22.11, “Performance Schema System Variables”

Prepared_stmt_count
Section 5.1.7, “Server Status Variables”

Q

[index top]

Qcache_free_blocks
Section 8.10.3.3, “Query Cache Configuration”
Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 5.1.7, “Server Status Variables”

Qcache_free_memory
Section 5.1.7, “Server Status Variables”

Qcache_hits
Section 8.10.3.1, “How the Query Cache Operates”
Section 5.1.7, “Server Status Variables”

Qcache_inserts
Section 5.1.7, “Server Status Variables”

Qcache_lowmem_prunes
Section 8.10.3.3, “Query Cache Configuration”
Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 5.1.7, “Server Status Variables”

Qcache_not_cached
Section 5.1.7, “Server Status Variables”

Qcache_queries_in_cache
Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.7, “Server Status Variables”

Qcache_total_blocks
Section 8.10.3.3, “Query Cache Configuration”
Section 8.10.3.4, “Query Cache Status and Maintenance”
Section 5.1.7, “Server Status Variables”

Queries
Section 5.1.7, “Server Status Variables”

Questions
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 5.1.7, “Server Status Variables”

R

[index top]

Rpl_semi_sync_master_clients
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_net_avg_wait_time
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_net_wait_time
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_net_waits
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_no_times
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_no_tx
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_status
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_timefunc_failures
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_tx_avg_wait_time
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_tx_wait_time
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_tx_waits
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_wait_pos_backtraverse
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_wait_sessions
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_master_yes_tx
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.7, “Server Status Variables”

Rpl_semi_sync_slave_status
Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.7, “Server Status Variables”

Rpl_status
Section 5.1.7, “Server Status Variables”

S

[index top]

Select_full_join
Section 5.1.7, “Server Status Variables”

Select_full_range_join
Section 5.1.7, “Server Status Variables”

Select_range
Section 5.1.7, “Server Status Variables”

Select_range_check
Section 5.1.7, “Server Status Variables”

Select_scan
Section 5.1.7, “Server Status Variables”

Slave_heartbeat_period
Section 5.1.7, “Server Status Variables”

Slave_open_temp_tables
Section 17.4.1.31, “Replication and Temporary Tables”
Section 5.1.7, “Server Status Variables”

Slave_received_heartbeats
Section 5.1.7, “Server Status Variables”

Slave_retried_transactions
Section 5.1.7, “Server Status Variables”

Slave_running
Section 17.2.1, “Replication Implementation Details”

Section 5.1.7, “Server Status Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”

Slow_launch_threads

Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

Slow_queries

Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

Sort_merge_passes

Section 8.2.1.10, “ORDER BY Optimization”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

Sort_range

Section 5.1.7, “Server Status Variables”

Sort_rows

Section 5.1.7, “Server Status Variables”

Sort_scan

Section 5.1.7, “Server Status Variables”

Ssl_accept_renegotiates

Section 5.1.7, “Server Status Variables”

Ssl_accepts

Section 5.1.7, “Server Status Variables”

Ssl_callback_cache_hits

Section 5.1.7, “Server Status Variables”

Ssl_cipher

Section 6.4.1, “Configuring MySQL to Use Encrypted Connections”
Section 6.4.6, “Encrypted Connection Protocols and Ciphers”
Section 5.1.7, “Server Status Variables”

Ssl_cipher_list

Section 6.4.6, “Encrypted Connection Protocols and Ciphers”
Section 5.1.7, “Server Status Variables”

Ssl_client_connects

Section 5.1.7, “Server Status Variables”

Ssl_connect_renegotiates

Section 5.1.7, “Server Status Variables”

Ssl_ctx_verify_depth

Section 5.1.7, “Server Status Variables”

Ssl_ctx_verify_mode

Section 5.1.7, “Server Status Variables”

Ssl_default_timeout
Section 5.1.7, “Server Status Variables”

Ssl_finished_accepts
Section 5.1.7, “Server Status Variables”

Ssl_finished_connects
Section 5.1.7, “Server Status Variables”

Ssl_session_cache_hits
Section 5.1.7, “Server Status Variables”

Ssl_session_cache_misses
Section 5.1.7, “Server Status Variables”

Ssl_session_cache_mode
Section 5.1.7, “Server Status Variables”

Ssl_session_cache_overflows
Section 5.1.7, “Server Status Variables”

Ssl_session_cache_size
Section 5.1.7, “Server Status Variables”

Ssl_session_cache_timeouts
Section 5.1.7, “Server Status Variables”

Ssl_sessions_reused
Section 5.1.7, “Server Status Variables”

Ssl_used_session_cache_entries
Section 5.1.7, “Server Status Variables”

Ssl_verify_depth
Section 5.1.7, “Server Status Variables”

Ssl_verify_mode
Section 5.1.7, “Server Status Variables”

Ssl_version
Section 6.4.6, “Encrypted Connection Protocols and Ciphers”
Section 5.1.7, “Server Status Variables”

T

[index top]

Table_locks_immediate
Section 8.11.1, “Internal Locking Methods”
Section 5.1.7, “Server Status Variables”

Table_locks_waited
Section 8.11.1, “Internal Locking Methods”

Section 5.1.7, “Server Status Variables”

Tc_log_max_pages_used

Section 5.1.7, “Server Status Variables”

Tc_log_page_size

Section 5.1.7, “Server Status Variables”

Tc_log_page_waits

Section 5.1.7, “Server Status Variables”

Threads_cached

Section 8.12.5.1, “How MySQL Uses Threads for Client Connections”
Section 5.1.7, “Server Status Variables”

Threads_connected

Section 5.1.7, “Server Status Variables”

Threads_created

Section 8.12.5.1, “How MySQL Uses Threads for Client Connections”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

Threads_running

Section A.14, “MySQL 5.5 FAQ: MySQL Enterprise Thread Pool”
Section 5.1.7, “Server Status Variables”

U

[index top]

Uptime

Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 5.1.7, “Server Status Variables”

Uptime_since_flush_status

Section 5.1.7, “Server Status Variables”

System Variable Index

A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W

A

[index top]

audit_log_buffer_size

Section 6.5.2.4, “Audit Log Logging Control”
Section 6.5.2.7, “Audit Log Options and System Variables”

audit_log_file

Section 6.5.2.4, “Audit Log Logging Control”
Section 6.5.2.7, “Audit Log Options and System Variables”
Section 6.5.2, “MySQL Enterprise Audit”

Section 6.5.2.2, “MySQL Enterprise Audit Security Considerations”

audit_log_flush

Section 6.5.2.4, “Audit Log Logging Control”
Section 6.5.2.7, “Audit Log Options and System Variables”

audit_log_format

Section 6.5.2.3, “Audit Log File Formats”
Section 6.5.2.4, “Audit Log Logging Control”
Section 6.5.2.7, “Audit Log Options and System Variables”
Section 6.5.2, “MySQL Enterprise Audit”

audit_log_policy

Section 6.5.2.5, “Audit Log Filtering”
Section 6.5.2.7, “Audit Log Options and System Variables”
Section 6.5.2, “MySQL Enterprise Audit”

audit_log_rotate_on_size

Section 6.5.2.4, “Audit Log Logging Control”
Section 6.5.2.7, “Audit Log Options and System Variables”

audit_log_strategy

Section 6.5.2.4, “Audit Log Logging Control”
Section 6.5.2.7, “Audit Log Options and System Variables”

authentication_windows_log_level

Section 5.1.5, “Server System Variables”
Section 6.5.1.5, “Windows Pluggable Authentication”

authentication_windows_use_principal_name

Section 5.1.5, “Server System Variables”
Section 6.5.1.5, “Windows Pluggable Authentication”

auto_increment_increment

Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section A.1, “MySQL 5.5 FAQ: General”
Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 17.4.1.38, “Replication and Variables”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 3.6.9, “Using AUTO_INCREMENT”

auto_increment_offset

Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section A.1, “MySQL 5.5 FAQ: General”
Section 18.1.6.11, “Previous NDB Cluster Issues Resolved in MySQL 5.1, NDB Cluster 6.x, and NDB Cluster 7.x”
Section 17.4.1.38, “Replication and Variables”
Section 17.1.3.2, “Replication Master Options and Variables”
Section 3.6.9, “Using AUTO_INCREMENT”

AUTOCOMMIT

Section 17.4.1.35, “Replication and Transactions”

autocommit

Section 14.8.2.2, “autocommit, Commit, and Rollback”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 14.8.5.2, “Deadlock Detection and Rollback”
Section 13.2.2, “DELETE Syntax”
Section 14.8, “InnoDB Locking and Transaction Model”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 13.3.5.1, “Interaction of Table Locking and Transactions”
Section 14.11.1.7, “Limits on InnoDB Tables”
Section 14.8.2.4, “Locking Reads”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
NDB Cluster System Variables
Section 17.4.1.35, “Replication and Transactions”
Section 5.1.5, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 5.5.3.3, “Thread Pool Operation”
Section 14.8.2.1, “Transaction Isolation Levels”

automatic_sp_privileges

Section 13.1.5, “ALTER PROCEDURE Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 5.1.5, “Server System Variables”
Section 20.2.2, “Stored Routines and MySQL Privileges”

B

[index top]

back_log

Section 5.1.5, “Server System Variables”

basedir

Section 13.7.3.3, “INSTALL PLUGIN Syntax”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

big_tables

Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section 5.1.5, “Server System Variables”

binlog_cache_size

Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.7, “Server Status Variables”
Section 5.4.4, “The Binary Log”

binlog_checksum

MySQL Glossary

binlog_direct_non_transactional_updates

Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.4.1.35, “Replication and Transactions”

binlog_format

Section 17.1.3.4, “Binary Log Options and Variables”
Section 12.7, “Date and Time Functions”
Section 17.1.2.3, “Determination of Safe and Unsafe Statements in Binary Logging”

Section 17.2.3.1, “Evaluation of Database-Level Replication and Binary Logging Options”
Section 18.6.2, “General Requirements for NDB Cluster Replication”
Section 12.14, “Information Functions”
Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 5.4.4.4, “Logging Format for Changes to mysql Database Tables”
Section 12.6.2, “Mathematical Functions”
Section 12.17, “Miscellaneous Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section A.13, “MySQL 5.5 FAQ: Replication”
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.4.1.2, “Replication and BLACKHOLE Tables”
Section 17.4.1.20, “Replication and MEMORY Tables”
Section 17.4.1.31, “Replication and Temporary Tables”
Section 17.4.1.35, “Replication and Transactions”
Section 17.1.2, “Replication Formats”
Section 17.4.1.21, “Replication of the mysql System Database”
Section 5.1.4, “Server Command Options”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 15.7, “The BLACKHOLE Storage Engine”
Section 5.4.3, “The General Query Log”

binlog_stmt_cache_size

Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.1.7, “Server Status Variables”

bulk_insert_buffer_size

Section 15.3.1, “MyISAM Startup Options”
Section 8.2.4.1, “Optimizing INSERT Statements”
Section 5.1.5, “Server System Variables”

C

[index top]

character_set_client

Section 23.8.9.1, “C API Prepared Statement Type Codes”
Section 10.5, “Character Set Configuration”
Section 10.1.4, “Connection Character Sets and Collations”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.4.2, “SET CHARACTER SET Syntax”
Section 13.7.4.3, “SET NAMES Syntax”
Section 13.7.5.9, “SHOW CREATE EVENT Syntax”
Section 13.7.5.11, “SHOW CREATE PROCEDURE Syntax”
Section 13.7.5.13, “SHOW CREATE TRIGGER Syntax”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 13.7.5.19, “SHOW EVENTS Syntax”
Section 13.7.5.29, “SHOW PROCEDURE STATUS Syntax”
Section 13.7.5.39, “SHOW TRIGGERS Syntax”
Section 5.4.4, “The Binary Log”
Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”
Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”
Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”

Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”

character_set_connection

Section 12.10, “Cast Functions and Operators”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 10.1.3.8, “Character Set Introducers”
Section 10.1.2.1, “Character Set Repertoire”
Section 10.1.3.6, “Character String Literal Character Set and Collation”
Section 10.1.8.4, “Collation Coercibility in Expressions”
Section 10.1.4, “Connection Character Sets and Collations”
Section 12.7, “Date and Time Functions”
Section 12.13, “Encryption and Compression Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 10.7, “MySQL Server Locale Support”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.4.2, “SET CHARACTER SET Syntax”
Section 13.7.4.3, “SET NAMES Syntax”
Section 9.1.1, “String Literals”
Section 12.2, “Type Conversion in Expression Evaluation”

character_set_database

Section 10.1.4, “Connection Character Sets and Collations”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 10.1.3.3, “Database Character Set and Collation”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.4.2, “SET CHARACTER SET Syntax”

character_set_filesystem

Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 13.2.9.1, “SELECT ... INTO Syntax”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 12.5, “String Functions”

character_set_results

Section 23.8.5, “C API Data Structures”
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 10.1.4, “Connection Character Sets and Collations”
Section 10.1.6, “Error Message Character Set”
Section A.11, “MySQL 5.5 FAQ: MySQL Chinese, Japanese, and Korean Character Sets”
Section 5.1.5, “Server System Variables”
Section 13.7.4.2, “SET CHARACTER SET Syntax”
Section 13.7.4.3, “SET NAMES Syntax”
Section 10.1.2.2, “UTF-8 for Metadata”

character_set_server

Section 10.5, “Character Set Configuration”
Section 10.1.4, “Connection Character Sets and Collations”
Section 10.1.3.3, “Database Character Set and Collation”
Section 12.9.4, “Full-Text Stopwords”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.3, “Replication and Character Sets”

Section 17.4.1.38, “Replication and Variables”
Section 10.1.3.2, “Server Character Set and Collation”
Section 5.1.5, “Server System Variables”

character_set_system

Section 10.5, “Character Set Configuration”
Section 5.1.5, “Server System Variables”
Section 10.1.2.2, “UTF-8 for Metadata”

character_sets_dir

Section 10.4.3, “Adding a Simple Collation to an 8-Bit Character Set”
Section 10.4.4.1, “Defining a UCA Collation Using LDML Syntax”
Section 5.1.5, “Server System Variables”

collation_connection

Section 12.10, “Cast Functions and Operators”
Section 12.5.3, “Character Set and Collation of Function Results”
Section 10.1.3.8, “Character Set Introducers”
Section 10.1.3.6, “Character String Literal Character Set and Collation”
Section 10.1.8.4, “Collation Coercibility in Expressions”
Section 10.1.4, “Connection Character Sets and Collations”
Section 12.7, “Date and Time Functions”
Section 12.13, “Encryption and Compression Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 13.7.4.3, “SET NAMES Syntax”
Section 13.7.5.9, “SHOW CREATE EVENT Syntax”
Section 13.7.5.11, “SHOW CREATE PROCEDURE Syntax”
Section 13.7.5.13, “SHOW CREATE TRIGGER Syntax”
Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 13.7.5.19, “SHOW EVENTS Syntax”
Section 13.7.5.29, “SHOW PROCEDURE STATUS Syntax”
Section 13.7.5.39, “SHOW TRIGGERS Syntax”
Section 5.4.4, “The Binary Log”
Section 21.7, “The INFORMATION_SCHEMA EVENTS Table”
Section 21.17, “The INFORMATION_SCHEMA ROUTINES Table”
Section 21.25, “The INFORMATION_SCHEMA TRIGGERS Table”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 12.2, “Type Conversion in Expression Evaluation”

collation_database

Section 10.1.4, “Connection Character Sets and Collations”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 10.1.3.3, “Database Character Set and Collation”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 5.4.4, “The Binary Log”

collation_server

Section 10.1.4, “Connection Character Sets and Collations”
Section 10.1.3.3, “Database Character Set and Collation”
Section 12.9.4, “Full-Text Stopwords”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 10.1.3.2, “Server Character Set and Collation”

Section 5.1.5, “Server System Variables”
Section 5.4.4, “The Binary Log”

completion_type

Section 23.8.7.6, “mysql_commit()”
Section 23.8.7.57, “mysql_rollback()”
Section 5.1.5, “Server System Variables”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”

concurrent_insert

Section 8.11.3, “Concurrent Inserts”
Section 8.11.1, “Internal Locking Methods”
Section 8.6.1, “Optimizing MyISAM Queries”
Section 5.1.5, “Server System Variables”

connect_timeout

Section B.5.2.11, “Communication Errors and Aborted Connections”
Section B.5.2.3, “Lost connection to MySQL server”
Section 23.8.7.52, “mysql_real_connect()”
Section 5.1.5, “Server System Variables”

D

[index top]

datadir

Section 14.9.1, “InnoDB Startup Configuration”
Section 2.3, “Installing MySQL on Microsoft Windows”
MySQL Glossary
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

date_format

Section 5.1.5, “Server System Variables”

datetime_format

Section 5.1.5, “Server System Variables”

debug

Section 5.1.5, “Server System Variables”
Section 24.5.3, “The DBUG Package”

debug_sync

Section 5.1.5, “Server System Variables”

default_storage_engine

Section 13.1.14, “CREATE LOGFILE GROUP Syntax”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 15.1, “Setting the Storage Engine”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”
Section 1.4, “What Is New in MySQL 5.5”

default_week_format

Section 12.7, “Date and Time Functions”
Section 19.5.3, “Partitioning Limitations Relating to Functions”

Section 5.1.5, “Server System Variables”

delay_key_write

Section 13.1.17, “CREATE TABLE Syntax”
Section 5.1.5, “Server System Variables”

delayed_insert_limit

Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 5.1.5, “Server System Variables”

delayed_insert_timeout

Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 5.1.5, “Server System Variables”

delayed_queue_size

Section 13.2.5.3, “INSERT DELAYED Syntax”
Section 5.1.5, “Server System Variables”

div_precision_increment

Section 12.6.1, “Arithmetic Operators”
Section 5.1.5, “Server System Variables”

E

[index top]

engine_condition_pushdown

Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 1.4, “What Is New in MySQL 5.5”

error_count

Section 5.1.5, “Server System Variables”
Section 13.7.5.18, “SHOW ERRORS Syntax”
Section B.1, “Sources of Error Information”

event_scheduler

Section 20.4.2, “Event Scheduler Configuration”
Section 23.7.2, “Restrictions When Using the Embedded MySQL Server”
Section 5.1.5, “Server System Variables”
Section 20.4.6, “The Event Scheduler and MySQL Privileges”

expire_logs_days

Section 13.4.1.1, “PURGE BINARY LOGS Syntax”
Section 5.4.7, “Server Log Maintenance”
Section 5.1.5, “Server System Variables”

external_user

Implementing Proxy User Support in Authentication Plugins
Section 6.3.7, “Proxy Users”
Section 5.1.5, “Server System Variables”
Writing the Server-Side Authentication Plugin

F

[index top]

flush
Section 5.1.5, “Server System Variables”

flush_time
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

foreign_key_checks
Section 13.1.7, “ALTER TABLE Syntax”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”
Section 5.4.4, “The Binary Log”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”

ft_boolean_syntax
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 5.1.5, “Server System Variables”

ft_max_word_len
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 5.1.5, “Server System Variables”
Section 24.2.1, “Types of Plugins”

ft_min_word_len
Section 12.9.2, “Boolean Full-Text Searches”
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 5.1.5, “Server System Variables”
Section 24.2.1, “Types of Plugins”

ft_query_expansion_limit
Section 5.1.5, “Server System Variables”

ft_stopword_file
Section 17.1.1.6, “Creating a Data Snapshot Using Raw Data Files”
Section 12.9.6, “Fine-Tuning MySQL Full-Text Search”
Section 5.1.5, “Server System Variables”

G

[index top]

general_log
MySQL Glossary
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 5.4.3, “The General Query Log”

general_log_file
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”

Section 5.1.5, “Server System Variables”
Section 5.4.3, “The General Query Log”

group_concat_max_len

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section 5.1.5, “Server System Variables”

H

[index top]

have_compress

Section 5.1.5, “Server System Variables”

have_crypt

Section 5.1.5, “Server System Variables”

have_csv

Section 5.1.5, “Server System Variables”

have_dynamic_loading

Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 5.1.5, “Server System Variables”

have_geometry

Section 5.1.5, “Server System Variables”

have_innodb

Section B.5.4.5, “Rollback Failure for Nontransactional Tables”
Section 5.1.5, “Server System Variables”

have_ndbcluster

NDB Cluster System Variables

have_openssl

Section 5.1.5, “Server System Variables”

have_partitioning

Chapter 19, *Partitioning*
Section 5.1.5, “Server System Variables”

have_profiling

Section 5.1.5, “Server System Variables”

have_query_cache

Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.5, “Server System Variables”

have_rtree_keys

Section 5.1.5, “Server System Variables”

have_ssl

Section 6.4.5, “Building MySQL with Support for Encrypted Connections”
Section 5.1.5, “Server System Variables”

have_symlink
Section 5.1.5, “Server System Variables”
Section 8.12.3.3, “Using Symbolic Links for Databases on Windows”
Section 8.12.3.2, “Using Symbolic Links for MyISAM Tables on Unix”

hostname
Section 5.1.5, “Server System Variables”

I

[index top]

identity
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”

ignore_builtin_innodb
Section 1.4, “What Is New in MySQL 5.5”

init_connect
Section 10.1.5, “Configuring Application Character Set and Collation”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”

init_file
Section 5.1.5, “Server System Variables”

init_slave
Section 17.1.3.3, “Replication Slave Options and Variables”

innodb
Section 14.10.4.1, “Enabling and Disabling File-Per-Table Tablespaces”
Section A.15, “MySQL 5.5 FAQ: InnoDB Change Buffer”

innodb_adaptive_flushing
Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing”
Section 14.9.2.1, “The InnoDB Buffer Pool”

innodb_adaptive_hash_index
Section 14.7.3, “Adaptive Hash Index”
Section 14.9.5, “Configuring Thread Concurrency for InnoDB”
MySQL Glossary
Section 8.5.8, “Optimizing InnoDB Configuration Variables”
Section 13.1.33, “TRUNCATE TABLE Syntax”
Section 1.4, “What Is New in MySQL 5.5”

innodb_additional_mem_pool_size
Section 14.9.3, “Configuring the Memory Allocator for InnoDB”
Section 14.9.1, “InnoDB Startup Configuration”

innodb_autoextend_increment
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 14.9.1, “InnoDB Startup Configuration”

Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 14.10.1, “Resizing the InnoDB System Tablespace”

innodb_autoinc_lock_mode

Section 14.11.1.5, “AUTO_INCREMENT Handling in InnoDB”
Section 8.5.4, “Bulk Data Loading for InnoDB Tables”
Section 12.14, “Information Functions”
Section 14.8.1, “InnoDB Locking”
Section 14.11.1.7, “Limits on InnoDB Tables”
MySQL Glossary

innodb_buffer_pool_dump_at_shutdown

MySQL Glossary

innodb_buffer_pool_instances

Section 14.9.2.2, “Configuring Multiple Buffer Pool Instances”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 14.9.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 14.9.2.1, “The InnoDB Buffer Pool”

innodb_buffer_pool_load_at_startup

MySQL Glossary

innodb_buffer_pool_size

Section 14.9.2.2, “Configuring Multiple Buffer Pool Instances”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 14.9.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 8.5.7, “Optimizing InnoDB Disk I/O”
Section B.3, “Server Error Codes and Messages”
Section 14.9.2.1, “The InnoDB Buffer Pool”

innodb_change_buffer_max_size

MySQL Glossary

innodb_change_buffering

Section 14.7.2, “Change Buffer”
Section 14.9.4, “Configuring InnoDB Change Buffering”
MySQL Glossary
Section 8.5.2, “Optimizing InnoDB Transaction Management”

innodb_checksum_algorithm

MySQL Glossary

innodb_checksums

Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary

innodb_commit_concurrency

Section 14.17, “InnoDB Startup Options and System Variables”

innodb_compression_failure_threshold_pct

MySQL Glossary

innodb_compression_level

MySQL Glossary

innodb_compression_pad_pct_max

MySQL Glossary

innodb_concurrency_tickets

Section 14.9.5, “Configuring Thread Concurrency for InnoDB”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 8.5.8, “Optimizing InnoDB Configuration Variables”
Section 21.28.8, “The INFORMATION_SCHEMA INNODB_TRX Table”

innodb_data_file_path

Section 14.15.2, “File Space Management”
Section 14.9.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.10.1, “Resizing the InnoDB System Tablespace”
Section 14.7.5, “System Tablespace”
Section 14.23.1, “Troubleshooting InnoDB I/O Problems”
Section 14.10.3, “Using Raw Disk Partitions for the System Tablespace”

innodb_data_home_dir

Section 14.9.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.23.1, “Troubleshooting InnoDB I/O Problems”

innodb_deadlock_detect

MySQL Glossary

innodb_default_row_format

MySQL Glossary

innodb_doublewrite

Section 14.7.7, “Doublewrite Buffer”
Section 14.5, “InnoDB and the ACID Model”
Section 14.15.1, “InnoDB Disk I/O”
Section 14.9.1, “InnoDB Startup Configuration”
MySQL Glossary

innodb_fast_shutdown

Section 14.10.2, “Changing the Number or Size of InnoDB Redo Log Files”
Section 14.13.2.1, “Compatibility Check When InnoDB Is Started”
Section 2.11.2, “Downgrading MySQL”
Section 14.21.2, “InnoDB Recovery”
MySQL Glossary
Section 5.1.12, “The Server Shutdown Process”
Section 2.11.1, “Upgrading MySQL”

innodb_file_format

Section 14.13.2.2, “Compatibility Check When a Table Is Opened”
Section 14.13.2.1, “Compatibility Check When InnoDB Is Started”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”

Section 13.1.17, “CREATE TABLE Syntax”
Section 14.11.1.1, “Creating InnoDB Tables”
Section 14.14.3, “DYNAMIC and COMPRESSED Row Formats”
Section 14.12.2, “Enabling Compression for a Table”
Section 14.13.1, “Enabling File Formats”
Section 14.13.3, “Identifying the File Format in Use”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 14.12.6, “SQL Compression Syntax Warnings and Errors”
Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table”
Section 14.1.4, “Upward and Downward Compatibility”

innodb_file_format_check

Section 14.13.2.2, “Compatibility Check When a Table Is Opened”
Section 14.13.2.1, “Compatibility Check When InnoDB Is Started”
Section 14.17, “InnoDB Startup Options and System Variables”

innodb_file_format_max

Section 14.17, “InnoDB Startup Options and System Variables”

innodb_file_per_table

Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 13.1.17, “CREATE TABLE Syntax”
Section 14.11.1.1, “Creating InnoDB Tables”
Section 14.14.3, “DYNAMIC and COMPRESSED Row Formats”
Section 14.10.4.1, “Enabling and Disabling File-Per-Table Tablespaces”
Section 14.12.2, “Enabling Compression for a Table”
Section 14.13.1, “Enabling File Formats”
Section 14.15.2, “File Space Management”
Section 14.7.9, “File-Per-Table Tablespaces”
Section 13.1.17.2, “Files Created by CREATE TABLE”
Section 14.5, “InnoDB and the ACID Model”
Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.20.4, “InnoDB Tablespace Monitor Output”
MySQL Glossary
Section 13.7.2.4, “OPTIMIZE TABLE Syntax”
Section 14.15.5, “Reclaiming Disk Space with TRUNCATE TABLE”
Section 17.3.4, “Replicating Different Databases to Different Slaves”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 14.12.6, “SQL Compression Syntax Warnings and Errors”
Section 14.11.1.2, “The Physical Row Structure of an InnoDB Table”
Section 14.23.3, “Troubleshooting InnoDB Data Dictionary Operations”
Section 1.4, “What Is New in MySQL 5.5”

innodb_flush_log_at_timeout

Section 14.7.4, “Redo Log Buffer”

innodb_flush_log_at_trx_commit

Section 14.5, “InnoDB and the ACID Model”
Section 8.5.2, “Optimizing InnoDB Transaction Management”
Section 14.7.4, “Redo Log Buffer”

innodb_flush_method

Section 14.10.4, “InnoDB File-Per-Table Tablespaces”
Section 14.9.1, “InnoDB Startup Configuration”

Section 14.17, “InnoDB Startup Options and System Variables”
Section 2.3, “Installing MySQL on Microsoft Windows”
Section 8.5.7, “Optimizing InnoDB Disk I/O”

innodb_flush_neighbors

MySQL Glossary

innodb_force_load_corrupted

Section 14.17, “InnoDB Startup Options and System Variables”

innodb_force_recovery

Section 14.23.2, “Forcing InnoDB Recovery”
Section 1.6, “How to Report Bugs or Problems”
Section 14.21.2, “InnoDB Recovery”
Section 8.5.2, “Optimizing InnoDB Transaction Management”
Section 2.11.3, “Rebuilding or Repairing Tables or Indexes”

innodb_ft_cache_size

MySQL Glossary

innodb_io_capacity

Section 14.9.8, “Configuring the InnoDB Master Thread I/O Rate”
Section 14.17, “InnoDB Startup Options and System Variables”
Section A.15, “MySQL 5.5 FAQ: InnoDB Change Buffer”
Section 8.5.7, “Optimizing InnoDB Disk I/O”
Section 1.4, “What Is New in MySQL 5.5”

innodb_large_prefix

Section 2.11.2.1, “Changes Affecting Downgrades from MySQL 5.5”
Section 8.3.4, “Column Indexes”
Section 13.1.13, “CREATE INDEX Syntax”
Section 13.1.17, “CREATE TABLE Syntax”
Section 14.11.1.7, “Limits on InnoDB Tables”
MySQL Glossary

innodb_lock_wait_timeout

Section 14.8.5.2, “Deadlock Detection and Rollback”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 17.4.1.32, “Replication Retries and Timeouts”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section B.3, “Server Error Codes and Messages”
Section 1.4, “What Is New in MySQL 5.5”

innodb_locks_unsafe_for_binlog

Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 14.8.1, “InnoDB Locking”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
MySQL Glossary
Section 14.8.2.1, “Transaction Isolation Levels”

innodb_log_buffer_size

Section 14.9.1, “InnoDB Startup Configuration”
MySQL Glossary
Section 8.5.3, “Optimizing InnoDB Redo Logging”

Section 14.7.4, “Redo Log Buffer”

innodb_log_file_size

Section 14.9.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 8.5.7, “Optimizing InnoDB Disk I/O”
Section 8.5.3, “Optimizing InnoDB Redo Logging”
Section 5.1.6, “Using System Variables”

innodb_log_files_in_group

Section 14.9.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 8.5.3, “Optimizing InnoDB Redo Logging”

innodb_log_group_home_dir

Section 14.9.1, “InnoDB Startup Configuration”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary

innodb_max_dirty_pages_pct

Section 14.9.2.5, “Configuring InnoDB Buffer Pool Flushing”
Section 8.5.7, “Optimizing InnoDB Disk I/O”
Section 14.9.2.1, “The InnoDB Buffer Pool”

innodb_max_purge_lag

Section 14.6, “InnoDB Multi-Versioning”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary

innodb_old_blocks_pct

Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.9.2.3, “Making the Buffer Pool Scan Resistant”
MySQL Glossary
Section 14.9.2.1, “The InnoDB Buffer Pool”

innodb_old_blocks_time

Section 14.9.2.3, “Making the Buffer Pool Scan Resistant”
Section 14.9.2.6, “Monitoring the Buffer Pool Using the InnoDB Standard Monitor”
Section 14.9.2.1, “The InnoDB Buffer Pool”

innodb_online_alter_log_max_size

MySQL Glossary

innodb_page_cleaners

MySQL Glossary

innodb_page_size

MySQL Glossary

innodb_print_all_deadlocks

Section 14.8.5, “Deadlocks in InnoDB”
Section 14.8.5.3, “How to Minimize and Handle Deadlocks”
Section 14.23, “InnoDB Troubleshooting”

innodb_purge_batch_size

Section 14.9.10, “Configuring InnoDB Purge Scheduling”

innodb_purge_threads

Section 14.9.10, “Configuring InnoDB Purge Scheduling”
Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary

innodb_random_read_ahead

Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”
MySQL Glossary
Section 14.9.2.1, “The InnoDB Buffer Pool”
Section 1.4, “What Is New in MySQL 5.5”

innodb_read_ahead_threshold

Section 14.9.2.4, “Configuring InnoDB Buffer Pool Prefetching (Read-Ahead)”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.9.2.1, “The InnoDB Buffer Pool”

innodb_read_io_threads

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 14.9.6, “Configuring the Number of Background InnoDB I/O Threads”
Section 14.20.3, “InnoDB Standard Monitor and Lock Monitor Output”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 24.1.1, “MySQL Threads”
Section 14.9.7, “Using Asynchronous I/O on Linux”
Section 1.4, “What Is New in MySQL 5.5”

innodb_rollback_segments

Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.7.8, “Undo Logs”

innodb_sort_buffer_size

MySQL Glossary

innodb_spin_wait_delay

Section 14.9.9, “Configuring Spin Lock Polling”

innodb_stats_method

Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
MySQL Glossary

innodb_stats_on_metadata

Section 1.4, “What Is New in MySQL 5.5”

innodb_stats_sample_pages

Section 14.9.11, “Configuring Optimizer Statistics for InnoDB”
Section 14.9.11.1, “Estimating ANALYZE TABLE Complexity for InnoDB Tables”
Section 14.11.1.7, “Limits on InnoDB Tables”

innodb_strict_mode

Section 13.1.17, “CREATE TABLE Syntax”
Section 14.12.5, “How Compression Works for InnoDB Tables”
Section 14.2, “Installing the InnoDB Storage Engine”
Section C.10.4, “Limits on Table Column Count and Row Size”

MySQL Glossary
Section 5.1.8, “Server SQL Modes”
Section 14.12.6, “SQL Compression Syntax Warnings and Errors”
Section 1.4, “What Is New in MySQL 5.5”

innodb_support_xa

MySQL Glossary
Section 8.5.2, “Optimizing InnoDB Transaction Management”

innodb_table_locks

Section 14.17, “InnoDB Startup Options and System Variables”
Section 14.11.1.7, “Limits on InnoDB Tables”

innodb_temp_data_file_path

MySQL Glossary

innodb_thread_concurrency

Section 14.9.5, “Configuring Thread Concurrency for InnoDB”
Section 14.20.3, “InnoDB Standard Monitor and Lock Monitor Output”
Section 14.17, “InnoDB Startup Options and System Variables”
Section A.14, “MySQL 5.5 FAQ: MySQL Enterprise Thread Pool”
Section 8.5.8, “Optimizing InnoDB Configuration Variables”

innodb_thread_sleep_delay

Section 14.9.5, “Configuring Thread Concurrency for InnoDB”

innodb_undo_tablespaces

MySQL Glossary

innodb_use_native_aio

Section 14.17, “InnoDB Startup Options and System Variables”
MySQL Glossary
Section 8.5.7, “Optimizing InnoDB Disk I/O”
Section 14.9.7, “Using Asynchronous I/O on Linux”
Section 1.4, “What Is New in MySQL 5.5”

innodb_use_sys_malloc

Section 14.9.3, “Configuring the Memory Allocator for InnoDB”
Section 14.9.5, “Configuring Thread Concurrency for InnoDB”
Section 14.17, “InnoDB Startup Options and System Variables”

innodb_write_io_threads

Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 14.9.6, “Configuring the Number of Background InnoDB I/O Threads”
Section 14.20.3, “InnoDB Standard Monitor and Lock Monitor Output”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 24.1.1, “MySQL Threads”
Section 14.9.7, “Using Asynchronous I/O on Linux”
Section 1.4, “What Is New in MySQL 5.5”

insert_id

Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 5.1.5, “Server System Variables”

interactive_timeout

Section B.5.2.11, “Communication Errors and Aborted Connections”

Section 23.8.7.52, “mysql_real_connect()”
Section 5.1.5, “Server System Variables”

J

[index top]

join_buffer_size

Section 8.2.1.5, “Nested-Loop Join Algorithms”
Section 5.1.5, “Server System Variables”

K

[index top]

keep_files_on_create

Section 5.1.5, “Server System Variables”

key_buffer_size

Section 8.6.2, “Bulk Data Loading for MyISAM Tables”
Section 5.1.1, “Configuring the Server”
Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 8.8.4, “Estimating Query Performance”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 7.6.3, “How to Repair MyISAM Tables”
Section 14.9.1, “InnoDB Startup Configuration”
Section B.5.7, “Known Issues in MySQL”
Section 8.10.2.2, “Multiple Key Caches”
Section 8.2.4.3, “Optimizing DELETE Statements”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 8.10.2.6, “Restructuring a Key Cache”
Section 5.1.4, “Server Command Options”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”
Section 5.1.6.1, “Structured System Variables”
Section 8.10.2, “The MyISAM Key Cache”

key_cache_age_threshold

Section 8.10.2.3, “Midpoint Insertion Strategy”
Section 5.1.5, “Server System Variables”
Section 5.1.6.1, “Structured System Variables”

key_cache_block_size

Section 8.10.2.5, “Key Cache Block Size”
Section 8.10.2.6, “Restructuring a Key Cache”
Section 5.1.5, “Server System Variables”
Section 5.1.6.1, “Structured System Variables”

key_cache_division_limit

Section 8.10.2.3, “Midpoint Insertion Strategy”
Section 5.1.5, “Server System Variables”
Section 5.1.6.1, “Structured System Variables”

L

[index top]

language
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 5.1.5, “Server System Variables”

large_files_support
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.5, “Server System Variables”

large_page_size
Section 5.1.5, “Server System Variables”

large_pages
Section 5.1.5, “Server System Variables”

last_insert_id
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”

lc_messages
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 5.1.5, “Server System Variables”
Section 10.2, “Setting the Error Message Language”
Section 1.4, “What Is New in MySQL 5.5”

lc_messages_dir
Section 2.11.1.1, “Changes Affecting Upgrades to MySQL 5.5”
Section 5.1.5, “Server System Variables”
Section 10.2, “Setting the Error Message Language”
Section 1.4, “What Is New in MySQL 5.5”

lc_time_names
Section 12.7, “Date and Time Functions”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 10.7, “MySQL Server Locale Support”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 12.5, “String Functions”

license
Section 5.1.5, “Server System Variables”

local
Section 13.2.7, “LOAD XML Syntax”

local_infile
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 6.1.6, “Security Issues with LOAD DATA LOCAL”
Section 5.1.5, “Server System Variables”

lock_wait_timeout
Section 5.1.5, “Server System Variables”

locked_in_memory
Section 5.1.5, “Server System Variables”

log
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

log_bin
Section 17.1.3.4, “Binary Log Options and Variables”
NDB Cluster System Variables

log_bin_trust_function_creators
Section 17.1.3.4, “Binary Log Options and Variables”
Section 20.7, “Binary Logging of Stored Programs”
Section A.4, “MySQL 5.5 FAQ: Stored Procedures and Functions”
Section 5.1.5, “Server System Variables”
Section 1.4, “What Is New in MySQL 5.5”

log_bin_use_v
Section 17.1.3.4, “Binary Log Options and Variables”

log_error
Section 5.4.2.2, “Error Logging on Unix and Unix-Like Systems”
Section 5.4.2.1, “Error Logging on Windows”
Section 2.5.3.2, “More Topics on Deploying MySQL Server with Docker”
Section 5.1.5, “Server System Variables”

log_output
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.5, “Server System Variables”
Section 5.4.3, “The General Query Log”
Section 5.4.5, “The Slow Query Log”

log_queries_not_using_indexes
Section 5.1.5, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

log_slave_updates
Section 17.1.3.4, “Binary Log Options and Variables”

log_slow_queries
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

log_warnings
Section 5.4.2.4, “Error Log Filtering”
Section 5.1.5, “Server System Variables”

long_query_time
Section 5.4, “MySQL Server Logs”
Section 4.5.2, “`mysqladmin` — Client for Administering a MySQL Server”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.4, “Server Command Options”
Section 5.1.7, “Server Status Variables”

Section 5.1.5, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

low_priority_updates

Section 5.1.5, “Server System Variables”
Section 8.11.2, “Table Locking Issues”

lower_case_file_system

Section 5.1.5, “Server System Variables”

lower_case_table_names

Section 13.7.1.3, “GRANT Syntax”
Section 17.2.3, “How Servers Evaluate Replication Filtering Rules”
Section 1.6, “How to Report Bugs or Problems”
Section 9.2.2, “Identifier Case Sensitivity”
Section 22.1, “Performance Schema Quick Start”
Section 17.4.1.38, “Replication and Variables”
Section 13.7.1.5, “REVOKE Syntax”
Section 5.1.5, “Server System Variables”
Section 13.7.5.38, “SHOW TABLES Syntax”
Section 10.1.8.7, “Using Collation in INFORMATION_SCHEMA Searches”
Section 13.1.17.6, “Using FOREIGN KEY Constraints”

M

[index top]

master_verify_checksum

MySQL Glossary

max_allowed_packet

Section 12.16.1, “Aggregate (GROUP BY) Function Descriptions”
Section B.5.2.11, “Communication Errors and Aborted Connections”
Section 12.3.2, “Comparison Functions and Operators”
Section B.5.4.6, “Deleting Rows from Related Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section B.5.2.3, “Lost connection to MySQL server”
Section 23.8, “MySQL C API”
Section B.5.2.9, “MySQL server has gone away”
Section 23.8.11.26, “mysql_stmt_send_long_data()”
Section 23.8.7.71, “mysql_use_result()”
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
Section B.5.2.10, “Packet Too Large”
Section 17.4.1.19, “Replication and max_allowed_packet”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”
Section 12.5, “String Functions”
Section 11.4.3, “The BLOB and TEXT Types”

max_binlog_cache_size

Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.4.4, “The Binary Log”

max_binlog_size

Section 17.1.3.4, “Binary Log Options and Variables”
Section 5.4, “MySQL Server Logs”

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.4.7, “Server Log Maintenance”
Section 5.1.5, “Server System Variables”
Section 5.4.4, “The Binary Log”
Section 17.2.2.1, “The Slave Relay Log”

max_binlog_stmt_cache_size

Section 17.1.3.4, “Binary Log Options and Variables”

max_connect_errors

Section 8.12.5.2, “DNS Lookup Optimization and the Host Cache”
Section 13.7.6.3, “FLUSH Syntax”
Section B.5.2.6, “Host 'host_name' is blocked”
Section 5.1.5, “Server System Variables”

max_connections

Section 24.5.1.4, “Debugging mysqld under gdb”
Section B.5.2.18, “File Not Found and Similar Errors”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 8.12.5.1, “How MySQL Uses Threads for Client Connections”
Section 22.11, “Performance Schema System Variables”
Section 6.2.1, “Privileges Provided by MySQL”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 5.5.3.3, “Thread Pool Operation”
Section B.5.2.7, “Too many connections”

max_delayed_threads

Section 22.11, “Performance Schema System Variables”
Section 5.1.5, “Server System Variables”

max_error_count

Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 13.6.7.3, “RESIGNAL Syntax”
Section 5.1.5, “Server System Variables”
Section 13.7.5.18, “SHOW ERRORS Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”

max_heap_table_size

Section 8.12.4.1, “How MySQL Uses Memory”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section C.10.3, “Limits on Table Size”
Section 17.4.1.20, “Replication and MEMORY Tables”
Section 17.4.1.38, “Replication and Variables”
Section C.3, “Restrictions on Server-Side Cursors”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”
Section 15.4, “The MEMORY Storage Engine”

max_insert_delayed_threads

Section 5.1.5, “Server System Variables”

max_join_size

Section 8.8.2, “EXPLAIN Output Format”
Section 5.1.5, “Server System Variables”
Section 13.7.4.1, “SET Syntax for Variable Assignment”

Section 5.1.6, “Using System Variables”

max_length_for_sort_data

Section 8.2.1.10, “ORDER BY Optimization”
Section 5.1.5, “Server System Variables”

max_long_data_size

Section 23.8.11.26, “mysql_stmt_send_long_data()”
Section 5.1.5, “Server System Variables”

max_prepared_stmt_count

Section 13.5, “Prepared SQL Statement Syntax”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

max_relay_log_size

Section 17.1.3.4, “Binary Log Options and Variables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”
Section 17.2.2.1, “The Slave Relay Log”

max_seeks_for_key

Section 14.11.1.7, “Limits on InnoDB Tables”
Section 5.1.5, “Server System Variables”

max_sort_length

Section B.5.7, “Known Issues in MySQL”
Section 8.2.1.10, “ORDER BY Optimization”
Section 13.2.9, “SELECT Syntax”
Section 5.1.5, “Server System Variables”
Section 11.4.3, “The BLOB and TEXT Types”

max_sp_recursion_depth

Section 5.1.5, “Server System Variables”
Section 20.2.1, “Stored Routine Syntax”

max_tmp_tables

Section 5.1.5, “Server System Variables”

max_user_connections

Section 13.7.6.3, “FLUSH Syntax”
Section 13.7.1.3, “GRANT Syntax”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 5.1.5, “Server System Variables”
Section 6.3.4, “Setting Account Resource Limits”

max_write_lock_count

Section 5.1.5, “Server System Variables”
Section 8.11.2, “Table Locking Issues”

metadata_locks_cache_size

Section 5.1.5, “Server System Variables”

min_examined_row_limit

Section 5.1.5, “Server System Variables”

Section 5.4.5, “The Slow Query Log”

multi_range_count

Section 5.1.5, “Server System Variables”

myisam_data_pointer_size

Section 13.1.17, “CREATE TABLE Syntax”
Section C.10.3, “Limits on Table Size”
Section 5.1.5, “Server System Variables”

myisam_max_sort_file_size

Section 15.3.1, “MyISAM Startup Options”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.5, “Server System Variables”

myisam_mmap_size

Section 5.1.5, “Server System Variables”

myisam_recover_options

Section 5.1.5, “Server System Variables”

myisam_repair_threads

Section 5.1.5, “Server System Variables”

myisam_sort_buffer_size

Section 13.1.7, “ALTER TABLE Syntax”
Section 15.3.1, “MyISAM Startup Options”
Section 4.6.3.1, “myisamchk General Options”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 5.1.5, “Server System Variables”

myisam_stats_method

Section 8.3.7, “InnoDB and MyISAM Index Statistics Collection”
Section 5.1.5, “Server System Variables”

myisam_use_mmap

Section 8.12.4.1, “How MySQL Uses Memory”
Section 5.1.5, “Server System Variables”

N

[index top]

named_pipe

Section 5.1.5, “Server System Variables”

ndb_autoincrement_prefetch_sz

NDB Cluster System Variables

ndb_cache_check_time

NDB Cluster System Variables

ndb_deferred_constraints

NDB Cluster System Variables

ndb_distribution
NDB Cluster System Variables

ndb_eventbuffer_max_alloc
NDB Cluster System Variables

ndb_extra_logging
NDB Cluster System Variables

ndb_force_send
NDB Cluster System Variables

ndb_index_stat_cache_entries
NDB Cluster System Variables

ndb_index_stat_enable
NDB Cluster System Variables

ndb_index_stat_option
NDB Cluster System Variables

ndb_index_stat_update_freq
NDB Cluster System Variables

ndb_join_pushdown
Section 8.8.2, “EXPLAIN Output Format”
NDB Cluster System Variables
Section 18.1.4, “What is New in MySQL NDB Cluster 7.2”

ndb_log_apply_status
Section 18.6.10, “NDB Cluster Replication: Multi-Master and Circular Replication”
NDB Cluster System Variables

ndb_log_bin
NDB Cluster System Variables

ndb_log_binlog_index
NDB Cluster System Variables

ndb_log_empty_epochs
NDB Cluster System Variables

ndb_log_empty_update
NDB Cluster System Variables

ndb_log_orig
NDB Cluster System Variables

ndb_log_transaction_id
NDB Cluster System Variables

ndb_optimized_node_selection
NDB Cluster System Variables

Section 18.3.3.9, “NDB Cluster TCP/IP Connections”
Section 18.5.6.3, “Using CLUSTERLOG STATISTICS in the NDB Cluster Management Client”

ndb_report_thresh_binlog_epoch_slip

NDB Cluster System Variables

ndb_report_thresh_binlog_mem_usage

NDB Cluster System Variables

ndb_table_no_logging

NDB Cluster System Variables

ndb_table_temporary

NDB Cluster System Variables

ndb_use_copying_alter_table

NDB Cluster System Variables

ndb_use_exact_count

NDB Cluster System Variables

ndb_use_transactions

NDB Cluster System Variables

ndb_version

NDB Cluster System Variables

ndb_version_string

NDB Cluster System Variables

ndbinfo_database

NDB Cluster System Variables

ndbinfo_max_bytes

NDB Cluster System Variables

ndbinfo_max_rows

NDB Cluster System Variables

ndbinfo_offline

NDB Cluster System Variables

ndbinfo_show_hidden

NDB Cluster System Variables
Section 18.5.10.4, “The ndbinfo cluster_operations Table”
Section 18.5.10.5, “The ndbinfo cluster_transactions Table”
Section 18.5.10.15, “The ndbinfo server_operations Table”
Section 18.5.10.16, “The ndbinfo server_transactions Table”

ndbinfo_table_prefix

NDB Cluster System Variables

ndbinfo_version

NDB Cluster System Variables

net_buffer_length
Section 8.12.4.1, “How MySQL Uses Memory”
Section 23.8, “MySQL C API”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 5.1.5, “Server System Variables”

net_read_timeout
Section B.5.2.3, “Lost connection to MySQL server”
Section 5.1.5, “Server System Variables”

net_retry_count
Section 5.1.5, “Server System Variables”

net_write_timeout
Section 5.1.5, “Server System Variables”

new
Section 19.5.2, “Partitioning Limitations Relating to Storage Engines”
Section 5.1.5, “Server System Variables”

O

[index top]

old
Section 8.9.3, “Index Hints”
Section 5.1.5, “Server System Variables”

old_alter_table
Section 13.1.7, “ALTER TABLE Syntax”
Section 5.1.5, “Server System Variables”

old_passwords
Section 6.3.5, “Assigning Account Passwords”
Section B.5.2.4, “Client does not support authentication protocol”
Section 13.7.1.1, “CREATE USER Syntax”
Section 12.13, “Encryption and Compression Functions”
Section 6.1.2.5, “Implications of Password Hashing Changes in MySQL 4.1 for Application Programs”
Section 6.1.2.4, “Password Hashing in MySQL”
Section 5.1.5, “Server System Variables”
Section 13.7.1.6, “SET PASSWORD Syntax”

one_shot
Section 5.1.5, “Server System Variables”

open_files_limit
Section B.5.2.18, “File Not Found and Similar Errors”
Section 22.11, “Performance Schema System Variables”
Section 19.5, “Restrictions and Limitations on Partitioning”
Section 5.1.5, “Server System Variables”

optimizer_prune_level
Section 8.9.1, “Controlling Query Plan Evaluation”
Section 5.1.5, “Server System Variables”

optimizer_search_depth
Section 8.9.1, “Controlling Query Plan Evaluation”
Section 5.1.5, “Server System Variables”

optimizer_switch
Section 8.2.1.4, “Engine Condition Pushdown Optimization”
Section 8.2.1.3, “Index Merge Optimization”
Section 5.1.5, “Server System Variables”
Section 8.9.2, “Switchable Optimizations”
Section 1.4, “What Is New in MySQL 5.5”

P

[index top]

performance_schema
Section 22.1, “Performance Schema Quick Start”
Section 22.3, “Performance Schema Startup Configuration”
Section 22.11, “Performance Schema System Variables”

performance_schema_events_waits_history_long_size
Section 22.11, “Performance Schema System Variables”
Section 22.9, “Performance Schema Table Descriptions”
Section 13.7.5.16, “SHOW ENGINE Syntax”
Section 22.9.4.3, “The events_waits_history_long Table”

performance_schema_events_waits_history_size
Section 22.11, “Performance Schema System Variables”
Section 22.9, “Performance Schema Table Descriptions”
Section 13.7.5.16, “SHOW ENGINE Syntax”
Section 22.9.4.2, “The events_waits_history Table”

performance_schema_max_cond_classes
Section 22.11, “Performance Schema System Variables”

performance_schema_max_cond_instances
Section 22.11, “Performance Schema System Variables”

performance_schema_max_file_classes
Section 22.11, “Performance Schema System Variables”

performance_schema_max_file_handles
Section 22.11, “Performance Schema System Variables”

performance_schema_max_file_instances
Section 22.11, “Performance Schema System Variables”

performance_schema_max_mutex_classes
Section 22.7, “Performance Schema Status Monitoring”
Section 22.11, “Performance Schema System Variables”

performance_schema_max_mutex_instances
Section 22.11, “Performance Schema System Variables”

performance_schema_max_rwlock_classes

Section 22.11, “Performance Schema System Variables”

performance_schema_max_rwlock_instances

Section 22.11, “Performance Schema System Variables”

performance_schema_max_table_handles

Section 22.11, “Performance Schema System Variables”

performance_schema_max_table_instances

Section 22.11, “Performance Schema System Variables”

performance_schema_max_thread_classes

Section 22.11, “Performance Schema System Variables”

performance_schema_max_thread_instances

Section 22.12, “Performance Schema Status Variables”
Section 22.11, “Performance Schema System Variables”
Section 13.7.5.16, “SHOW ENGINE Syntax”

pid_file

Section 5.1.5, “Server System Variables”

plugin_dir

Section 6.1.2.2, “Administrator Guidelines for Password Security”
Section 24.2.4.3, “Compiling and Installing Plugin Libraries”
Section 13.7.3.1, “CREATE FUNCTION Syntax for User-Defined Functions”
Section 2.10.1, “Initializing the Data Directory”
Section 13.7.3.3, “INSTALL PLUGIN Syntax”
Section 5.5.1, “Installing and Uninstalling Plugins”
Section 6.5.2.1, “Installing MySQL Enterprise Audit”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 6.5.1.4, “PAM Pluggable Authentication”
Section 15.2.1, “Pluggable Storage Engine Architecture”
Section 24.2.3, “Plugin API Components”
Section C.9, “Restrictions on Pluggable Authentication”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 13.7.5.26, “SHOW PLUGINS Syntax”
Section 6.5.1.6, “Socket Peer-Credential Pluggable Authentication”
Section 6.5.1.7, “Test Pluggable Authentication”
Section 21.13, “The INFORMATION_SCHEMA PLUGINS Table”
Section 5.5.3.2, “Thread Pool Installation”
Section 24.4.2.5, “UDF Compiling and Installing”
Section 24.4.2.6, “UDF Security Precautions”
Using the Authentication Plugins
Section 6.5.1.5, “Windows Pluggable Authentication”
Section 24.2.4.8, “Writing Audit Plugins”
Section 24.2.4.5, “Writing Daemon Plugins”
Section 24.2.4.4, “Writing Full-Text Parser Plugins”
Section 24.2.4.6, “Writing INFORMATION_SCHEMA Plugins”
Section 24.2.4.7, “Writing Semisynchronous Replication Plugins”

port

Section B.5.2.2, “Can't connect to [local] MySQL server”

Section 5.1.5, “Server System Variables”

preload_buffer_size

Section 5.1.5, “Server System Variables”

profiling

Section 5.1.5, “Server System Variables”
Section 13.7.5.31, “SHOW PROFILE Syntax”
Section 21.15, “The INFORMATION_SCHEMA PROFILING Table”

profiling_history_size

Section 5.1.5, “Server System Variables”
Section 13.7.5.31, “SHOW PROFILE Syntax”

protocol_version

Section 5.1.5, “Server System Variables”

proxy_user

Section 6.3.7, “Proxy Users”
Section 5.1.5, “Server System Variables”

pseudo_slave_mode

Section 5.1.5, “Server System Variables”

pseudo_thread_id

Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”

Q

[index top]

query_alloc_block_size

Section 5.1.5, “Server System Variables”

query_cache_limit

Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.5, “Server System Variables”

query_cache_min_res_unit

Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.5, “Server System Variables”

query_cache_size

Section 8.10.3.3, “Query Cache Configuration”
Section 5.1.5, “Server System Variables”
Section 8.10.3, “The MySQL Query Cache”

query_cache_type

Section 8.10.3.3, “Query Cache Configuration”
Section 8.10.3.2, “Query Cache SELECT Options”
Section 13.2.9, “SELECT Syntax”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

query_cache_wlock_invalidate
Section 5.1.5, “Server System Variables”

query_prealloc_size
Section 5.1.5, “Server System Variables”

R

[index top]

rand_seed
Section 5.1.5, “Server System Variables”

range_alloc_block_size
Section 5.1.5, “Server System Variables”

read_buffer_size
Section 8.12.4.1, “How MySQL Uses Memory”
Section 8.6.3, “Optimizing REPAIR TABLE Statements”
Section 5.1.5, “Server System Variables”
Section 1.4, “What Is New in MySQL 5.5”

read_only
Section 13.7.1, “Account Management Statements”
Section 6.3.5, “Assigning Account Passwords”
Section 17.3.1.3, “Backing Up a Master or Slave by Making It Read Only”
Section 13.7.1.1, “CREATE USER Syntax”
Section 13.7.1.2, “DROP USER Syntax”
Section 8.14.2, “General Thread States”
Section 13.7.1.3, “GRANT Syntax”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.7.1.4, “RENAME USER Syntax”
Section 17.4.1.38, “Replication and Variables”
Section 13.7.1.5, “REVOKE Syntax”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.5, “Server System Variables”
Section 13.7.1.6, “SET PASSWORD Syntax”

read_rnd_buffer_size
Section 5.1.1, “Configuring the Server”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 8.2.1.10, “ORDER BY Optimization”
Section 5.1.5, “Server System Variables”

relay_log
Section 17.1.3.3, “Replication Slave Options and Variables”

relay_log_index
Section 17.1.3.3, “Replication Slave Options and Variables”

relay_log_info_file
Section 17.1.3.3, “Replication Slave Options and Variables”

relay_log_purge
Section 13.4.2.1, “CHANGE MASTER TO Syntax”

Section 5.1.5, “Server System Variables”

relay_log_recovery

Section 17.1.3.3, “Replication Slave Options and Variables”

relay_log_space_limit

Section 8.14.6, “Replication Slave I/O Thread States”
Section 5.1.5, “Server System Variables”

report_host

Section 5.1.5, “Server System Variables”

report_password

Section 5.1.5, “Server System Variables”

report_port

Section 5.1.5, “Server System Variables”

report_user

Section 5.1.5, “Server System Variables”

rpl_recovery_rank

Section 17.1.3.3, “Replication Slave Options and Variables”

rpl_semi_sync_master_enabled

Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 17.3.8.3, “Semisynchronous Replication Monitoring”
Section 5.1.5, “Server System Variables”

rpl_semi_sync_master_timeout

Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 5.1.5, “Server System Variables”

rpl_semi_sync_master_trace_level

Section 5.1.5, “Server System Variables”

rpl_semi_sync_master_wait_no_slave

Section 5.1.5, “Server System Variables”

rpl_semi_sync_slave_enabled

Section 17.3.8.1, “Semisynchronous Replication Administrative Interface”
Section 17.3.8.2, “Semisynchronous Replication Installation and Configuration”
Section 5.1.5, “Server System Variables”

rpl_semi_sync_slave_trace_level

Section 5.1.5, “Server System Variables”

S

[index top]

secure_auth

Section 6.1.2.4, “Password Hashing in MySQL”

Section 5.1.5, “Server System Variables”

secure_file_priv

Section 2.10.1, “Initializing the Data Directory”
Section 2.5.1, “Installing MySQL on Linux Using RPM Packages”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 6.1.3, “Making MySQL Secure Against Attackers”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 6.2.1, “Privileges Provided by MySQL”
Section 13.2.9.1, “SELECT ... INTO Syntax”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 12.5, “String Functions”

server_id

Section 6.5.2.3, “Audit Log File Formats”
Section 12.17, “Miscellaneous Functions”
MySQL Server Options for NDB Cluster
Section 4.6.7, “`mysqlbinlog` — Utility for Processing Binary Log Files”
Section 18.6.11, “NDB Cluster Replication Conflict Resolution”
NDB Cluster System Variables
Section 5.1.5, “Server System Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

server_id_bits

MySQL Server Options for NDB Cluster
NDB Cluster System Variables

shared_memory

Section 5.1.5, “Server System Variables”

shared_memory_base_name

Section 5.1.5, “Server System Variables”

skip_external_locking

Section 8.11.5, “External Locking”
Section 5.1.5, “Server System Variables”

skip_name_resolve

Section 5.1.5, “Server System Variables”

skip_networking

Section 5.1.5, “Server System Variables”

skip_show_database

Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

slave_allow_batching

NDB Cluster System Variables
Section 18.6.6, “Starting NDB Cluster Replication (Single Replication Channel)”

slave_compressed_protocol

Section 17.1.3.3, “Replication Slave Options and Variables”

slave_exec_mode

Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.4.1.20, “Replication and MEMORY Tables”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 17.1.2.2, “Usage of Row-Based Logging and Replication”

slave_load_tmpdir

Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”

slave_max_allowed_packet

Section 17.1.3.3, “Replication Slave Options and Variables”

slave_net_timeout

Section 13.4.2.1, “CHANGE MASTER TO Syntax”
Section 17.1.4.1, “Checking Replication Status”
Section 17.4.1.28, “Replication and Master or Slave Shutdowns”
Section 8.14.6, “Replication Slave I/O Thread States”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”

slave_skip_errors

Section 17.1.3.3, “Replication Slave Options and Variables”

slave_sql_verify_checksum

MySQL Glossary

slave_transaction_retries

Section 17.4.1.32, “Replication Retries and Timeouts”
Section 17.1.3.3, “Replication Slave Options and Variables”

slave_type_conversions

Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 17.1.3.3, “Replication Slave Options and Variables”

slow_launch_time

Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

slow_query_log

Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.5, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

slow_query_log_file

Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.5, “Server System Variables”
Section 5.4.5, “The Slow Query Log”

socket

Section 5.1.5, “Server System Variables”

sort_buffer_size

Section 7.6.3, “How to Repair MyISAM Tables”

Section 8.2.1.10, “ORDER BY Optimization”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

sql_auto_is_null

Section 12.3.2, “Comparison Functions and Operators”
Section 13.1.17, “CREATE TABLE Syntax”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 5.4.4, “The Binary Log”

sql_big_selects

Section 5.1.5, “Server System Variables”

sql_buffer_result

Section 5.1.5, “Server System Variables”

sql_log_bin

Section 17.1.3.4, “Binary Log Options and Variables”
Section 18.1.6.8, “Issues Exclusive to NDB Cluster”
Section 18.6.3, “Known Issues in NDB Cluster Replication”
Section 18.1.6.1, “Noncompliance with SQL Syntax in NDB Cluster”
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.1.3.1, “Replication and Binary Logging Option and Variable Reference”
Section 5.1.5, “Server System Variables”
Section 13.4.1.3, “SET sql_log_bin Syntax”
Section 13.7.4.1, “SET Syntax for Variable Assignment”
Section 17.4.3, “Upgrading a Replication Setup”
Section 5.1.6, “Using System Variables”

sql_log_off

Section 17.1.3.4, “Binary Log Options and Variables”
MySQL Glossary
Section 6.2.1, “Privileges Provided by MySQL”
Section 17.1.3.1, “Replication and Binary Logging Option and Variable Reference”
Section 5.4.1, “Selecting General Query and Slow Query Log Output Destinations”
Section 5.1.5, “Server System Variables”
Section 5.4.3, “The General Query Log”

sql_log_update

Section 5.1.5, “Server System Variables”

sql_mode

Section 13.1.11, “CREATE EVENT Syntax”
Section 13.1.15, “CREATE PROCEDURE and CREATE FUNCTION Syntax”
Section 13.1.19, “CREATE TRIGGER Syntax”
Effect of Signals on Handlers, Cursors, and Statements
Section 12.18.3, “Expression Handling”
Section 1.6, “How to Report Bugs or Problems”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 1.7, “MySQL Standards Compliance”
Section B.5.4.2, “Problems Using DATE Columns”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.8, “Server SQL Modes”
Section 5.1.5, “Server System Variables”

Section 13.7.5.14, “SHOW CREATE VIEW Syntax”
Section 5.4.4, “The Binary Log”
Section 21.27, “The INFORMATION_SCHEMA VIEWS Table”
Section 4.2.6, “Using Option Files”
Section 5.1.6, “Using System Variables”

sql_notes

Section 5.1.5, “Server System Variables”
Section 13.7.5.41, “SHOW WARNINGS Syntax”

sql_quote_show_create

Section 5.1.5, “Server System Variables”
Section 13.7.5.8, “SHOW CREATE DATABASE Syntax”
Section 13.7.5.12, “SHOW CREATE TABLE Syntax”

sql_safe_updates

Section 5.1.5, “Server System Variables”

sql_select_limit

Section 5.1.5, “Server System Variables”

sql_slave_skip_counter

Section 17.1.3.3, “Replication Slave Options and Variables”
Section 13.7.5.35, “SHOW SLAVE STATUS Syntax”

sql_warnings

Section 5.1.5, “Server System Variables”

ssl_ca

Section 5.1.5, “Server System Variables”

ssl_capath

Section 5.1.5, “Server System Variables”

ssl_cert

Section 5.1.5, “Server System Variables”

ssl_cipher

Section 5.1.5, “Server System Variables”

ssl_key

Section 5.1.5, “Server System Variables”

storage_engine

Section 13.1.14, “CREATE LOGFILE GROUP Syntax”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 17.3.2, “Using Replication with Different Master and Slave Storage Engines”
Section 1.4, “What Is New in MySQL 5.5”

stored_program_cache

Section 5.1.5, “Server System Variables”

sync_binlog

Section 17.1.3.4, “Binary Log Options and Variables”

Section 14.5, “InnoDB and the ACID Model”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 17.4.1.28, “Replication and Master or Slave Shutdowns”
Section 5.4.4, “The Binary Log”

sync_frm

Section 5.1.5, “Server System Variables”

sync_master_info

Section 17.1.3.3, “Replication Slave Options and Variables”

sync_relay_log

Section 17.1.3.3, “Replication Slave Options and Variables”

sync_relay_log_info

Section 17.4.1.28, “Replication and Master or Slave Shutdowns”
Section 17.1.3.3, “Replication Slave Options and Variables”

system_time_zone

Section 10.6, “MySQL Server Time Zone Support”
Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”

T

[index top]

table_definition_cache

Section 8.12.4.1, “How MySQL Uses Memory”
Section 5.1.5, “Server System Variables”

table_lock_wait_timeout

Section 5.1.5, “Server System Variables”

table_open_cache

Section 5.1.1, “Configuring the Server”
Section B.5.2.18, “File Not Found and Similar Errors”
Section 8.14.2, “General Thread States”
Section 8.4.3.1, “How MySQL Opens and Closes Tables”
Section 8.12.4.1, “How MySQL Uses Memory”
Section 5.1.4, “Server Command Options”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

table_type

Section 5.1.5, “Server System Variables”

thread_cache_size

Section 24.5.1.4, “Debugging mysqld under gdb”
Section 8.12.5.1, “How MySQL Uses Threads for Client Connections”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

thread_concurrency

Section 5.1.5, “Server System Variables”

thread_handling
Section 5.1.5, “Server System Variables”
Section 5.5.3.1, “Thread Pool Components”

thread_pool_algorithm
Section 5.1.5, “Server System Variables”
Section 21.30.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 5.5.3.1, “Thread Pool Components”

thread_pool_high_priority_connection
Section 5.1.5, “Server System Variables”
Section 5.5.3.1, “Thread Pool Components”
Section 5.5.3.3, “Thread Pool Operation”

thread_pool_max_unused_threads
Section 5.1.5, “Server System Variables”
Section 5.5.3.1, “Thread Pool Components”

thread_pool_prio_kickup_timer
Section 5.1.5, “Server System Variables”
Section 21.30.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 21.30.2, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table”
Section 5.5.3.1, “Thread Pool Components”
Section 5.5.3.3, “Thread Pool Operation”
Section 5.5.3.4, “Thread Pool Tuning”

thread_pool_size
Section 5.1.5, “Server System Variables”
Section 5.5.3.1, “Thread Pool Components”
Section 5.5.3.3, “Thread Pool Operation”
Section 5.5.3.4, “Thread Pool Tuning”

thread_pool_stall_limit
Section 5.1.5, “Server System Variables”
Section 21.30.1, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATE Table”
Section 21.30.2, “The INFORMATION_SCHEMA TP_THREAD_GROUP_STATS Table”
Section 5.5.3.1, “Thread Pool Components”
Section 5.5.3.3, “Thread Pool Operation”
Section 5.5.3.4, “Thread Pool Tuning”

thread_stack
Section 8.12.4.1, “How MySQL Uses Memory”
Section 5.1.5, “Server System Variables”
Section 20.2.1, “Stored Routine Syntax”

time_format
Section 5.1.5, “Server System Variables”

time_zone
Section 13.1.11, “CREATE EVENT Syntax”
Section 12.7, “Date and Time Functions”
Section 20.4.4, “Event Metadata”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 10.6, “MySQL Server Time Zone Support”
Section 17.4.1.38, “Replication and Variables”

Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 11.3.1, “The DATE, DATETIME, and TIMESTAMP Types”

timed_mutexes

Section 5.1.5, “Server System Variables”
Section 1.4, “What Is New in MySQL 5.5”

timestamp

Section 15.9.3, “FEDERATED Storage Engine Notes and Tips”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”

tmp_table_size

Section 8.12.4.1, “How MySQL Uses Memory”
Section 8.4.4, “Internal Temporary Table Use in MySQL”
Section C.3, “Restrictions on Server-Side Cursors”
Section 5.1.7, “Server Status Variables”
Section 5.1.5, “Server System Variables”

tmpdir

Section 17.3.1.2, “Backing Up Raw Data from a Slave”
Section B.5.2.13, “Can't create/write to file”
Section 7.2, “Database Backup Methods”
Section 14.16.6, “Limitations of Fast Index Creation”
Section 13.2.6, “LOAD DATA INFILE Syntax”
Section 2.9.4, “MySQL Source-Configuration Options”
Section 8.2.1.10, “ORDER BY Optimization”
Section 17.1.3.3, “Replication Slave Options and Variables”
Section 5.1.5, “Server System Variables”

transaction_alloc_block_size

Section 5.1.5, “Server System Variables”

transaction_allow_batching

NDB Cluster System Variables

transaction_prealloc_size

Section 5.1.5, “Server System Variables”

tx_isolation

Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 13.3.6, “SET TRANSACTION Syntax”

U

[index top]

unique_checks

Section 14.11.1.4, “Converting Tables from MyISAM to InnoDB”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 17.4.1.38, “Replication and Variables”
Section 5.1.5, “Server System Variables”
Section 5.4.4, “The Binary Log”

updatable_views_with_limit
Section 5.1.5, “Server System Variables”
Section 20.5.3, “Updatable and Insertable Views”

V

[index top]

version
Section 6.5.2.3, “Audit Log File Formats”
Section 12.14, “Information Functions”
Section 14.17, “InnoDB Startup Options and System Variables”
Section 5.1.5, “Server System Variables”

version_comment
Section 5.1.5, “Server System Variables”
Section 13.7.5.40, “SHOW VARIABLES Syntax”

version_compile_machine
Section 5.1.5, “Server System Variables”

version_compile_os
Section 5.1.5, “Server System Variables”

W

[index top]

wait_timeout
Section B.5.2.11, “Communication Errors and Aborted Connections”
Section B.5.2.9, “MySQL server has gone away”
Section 23.8.7.52, “mysql_real_connect()”
Section 5.1.5, “Server System Variables”

warning_count
Effect of Signals on Handlers, Cursors, and Statements
Section 5.1.5, “Server System Variables”
Section 13.7.5.18, “SHOW ERRORS Syntax”
Section 13.7.5.41, “SHOW WARNINGS Syntax”
Section B.1, “Sources of Error Information”

Transaction Isolation Level Index

R | S

R

[index top]

READ COMMITTED
Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 18.1.5.1, “Differences Between the NDB and InnoDB Storage Engines”
Section 14.8.5.3, “How to Minimize and Handle Deadlocks”
Section 14.8.1, “InnoDB Locking”
Section 14.17, “InnoDB Startup Options and System Variables”

Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section A.1, “MySQL 5.5 FAQ: General”
Section A.10, “MySQL FAQ: MySQL 5.5 and NDB Cluster”
Section 18.1.5.3, “NDB and InnoDB Feature Usage Summary”
Section 8.5.2, “Optimizing InnoDB Transaction Management”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 14.8.2.1, “Transaction Isolation Levels”
Section 13.1.33, “TRUNCATE TABLE Syntax”

READ UNCOMMITTED

Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 5.4.4.2, “Setting The Binary Log Format”
Section 14.8.2.1, “Transaction Isolation Levels”
Section 13.1.33, “TRUNCATE TABLE Syntax”

READ-COMMITTED

Section 5.1.4, “Server Command Options”
Section 13.3.6, “SET TRANSACTION Syntax”

READ-UNCOMMITTED

Section 5.1.4, “Server Command Options”
Section 13.3.6, “SET TRANSACTION Syntax”

REPEATABLE READ

Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 14.8.1, “InnoDB Locking”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 4.5.4, “`mysqldump` — A Database Backup Program”
Section 8.5.2, “Optimizing InnoDB Transaction Management”
Section 13.3.6, “SET TRANSACTION Syntax”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 14.8.2.1, “Transaction Isolation Levels”
Section 13.3.7, “XA Transactions”

REPEATABLE-READ

Section 5.1.4, “Server Command Options”
Section 5.1.5, “Server System Variables”
Section 13.3.6, “SET TRANSACTION Syntax”

S

[index top]

SERIALIZABLE

Section 14.8.2.3, “Consistent Nonlocking Reads”
Section 8.10.3.1, “How the Query Cache Operates”
Section 18.1.6.3, “Limits Relating to Transaction Handling in NDB Cluster”
Section 14.8.3, “Locks Set by Different SQL Statements in InnoDB”
Section 5.4.4.3, “Mixed Binary Logging Format”
Section 5.1.4, “Server Command Options”
Section 13.3.6, “SET TRANSACTION Syntax”
Section 13.3.1, “START TRANSACTION, COMMIT, and ROLLBACK Syntax”
Section 14.8.2.1, “Transaction Isolation Levels”

Section 13.3.7, “XA Transactions”

MySQL Glossary

These terms are commonly used in information about the MySQL database server. This glossary originated as a reference for terminology about the InnoDB storage engine, and the majority of definitions are InnoDB-related.

A

.ARM file
: Metadata for `ARCHIVE` tables. Contrast with **.ARZ file**. Files with this extension are always included in backups produced by the `mysqlbackup` command of the **MySQL Enterprise Backup** product.
See Also .ARZ file, MySQL Enterprise Backup, mysqlbackup command.

.ARZ file
: Data for ARCHIVE tables. Contrast with **.ARM file**. Files with this extension are always included in backups produced by the `mysqlbackup` command of the **MySQL Enterprise Backup** product.
See Also .ARM file, MySQL Enterprise Backup, mysqlbackup command.

ACID
: An acronym standing for atomicity, consistency, isolation, and durability. These properties are all desirable in a database system, and are all closely tied to the notion of a **transaction**. The transactional features of `InnoDB` adhere to the ACID principles.

  Transactions are **atomic** units of work that can be **committed** or **rolled back**. When a transaction makes multiple changes to the database, either all the changes succeed when the transaction is committed, or all the changes are undone when the transaction is rolled back.

  The database remains in a consistent state at all times — after each commit or rollback, and while transactions are in progress. If related data is being updated across multiple tables, queries see either all old values or all new values, not a mix of old and new values.

  Transactions are protected (isolated) from each other while they are in progress; they cannot interfere with each other or see each other's uncommitted data. This isolation is achieved through the **locking** mechanism. Experienced users can adjust the **isolation level**, trading off less protection in favor of increased performance and **concurrency**, when they can be sure that the transactions really do not interfere with each other.

  The results of transactions are durable: once a commit operation succeeds, the changes made by that transaction are safe from power failures, system crashes, race conditions, or other potential dangers that many non-database applications are vulnerable to. Durability typically involves writing to disk storage, with a certain amount of redundancy to protect against power failures or software crashes during write operations. (In `InnoDB`, the **doublewrite buffer** assists with durability.)
  See Also atomic, commit, concurrency, doublewrite buffer, isolation level, locking, rollback, transaction.

adaptive flushing
: An algorithm for **InnoDB** tables that smooths out the I/O overhead introduced by **checkpoints**. Instead of **flushing** all modified **pages** from the **buffer pool** to the **data files** at once, MySQL periodically flushes small sets of modified pages. The adaptive flushing algorithm extends this process by estimating the optimal rate to perform these periodic flushes, based on the rate of flushing and how fast **redo** information is generated.
  See Also buffer pool, checkpoint, data files, flush, InnoDB, page, redo log.

adaptive hash index
: An optimization for `InnoDB` tables that can speed up lookups using `=` and `IN` operators, by constructing a **hash index** in memory. MySQL monitors index searches for `InnoDB` tables, and if queries could benefit from a hash index, it builds one automatically for index **pages** that are frequently accessed.
  In a sense, the adaptive hash index configures MySQL at runtime to take advantage of ample main memory, coming closer to the architecture of main-memory databases. This feature is controlled by the `innodb_adaptive_hash_index` configuration option. Because this feature benefits some workloads and not others, and the memory used for the hash index is reserved in the **buffer pool**, typically you should benchmark with this feature both enabled and disabled.

The hash index is always built based on an existing `InnoDB` **secondary index**, which is organized as a **B-tree** structure. MySQL can build a hash index on a prefix of any length of the key defined for the B-tree, depending on the pattern of searches against the index. A hash index can be partial; the whole B-tree index does not need to be cached in the buffer pool.

In MySQL 5.6 and higher, another way to take advantage of fast single-value lookups with `InnoDB` tables is to use the `InnoDB` **memcached** plugin. See InnoDB memcached Plugin for details.
See Also B-tree, buffer pool, hash index, memcached, page, secondary index.

AHI

Acronym for **adaptive hash index**.
See Also adaptive hash index.

AIO

Acronym for **asynchronous I/O**. You might see this acronym in `InnoDB` messages or keywords.
See Also asynchronous I/O.

Antelope

The code name for the original `InnoDB` **file format**. It supports the **REDUNDANT** and **COMPACT** row formats, but not the newer **DYNAMIC** and **COMPRESSED** row formats available in the **Barracuda** file format.
See Also Barracuda, compact row format, compressed row format, dynamic row format, file format, innodb_file_format, redundant row format.

application programming interface (API)

A set of functions or procedures. An API provides a stable set of names and types for functions, procedures, parameters, and return values.

apply

When a backup produced by the **MySQL Enterprise Backup** product does not include the most recent changes that occurred while the backup was underway, the process of updating the backup files to include those changes is known as the **apply** step. It is specified by the `apply-log` option of the `mysqlbackup` command.

Before the changes are applied, we refer to the files as a **raw backup**. After the changes are applied, we refer to the files as a **prepared backup**. The changes are recorded in the **ibbackup_logfile** file; once the apply step is finished, this file is no longer necessary.
See Also hot backup, ibbackup_logfile, MySQL Enterprise Backup, prepared backup, raw backup.

asynchronous I/O

A type of I/O operation that allows other processing to proceed before the I/O is completed. Also known as **non-blocking I/O** and abbreviated as **AIO**. `InnoDB` uses this type of I/O for certain operations that can run in parallel without affecting the reliability of the database, such as reading pages into the **buffer pool** that have not actually been requested, but might be needed soon.

Historically, `InnoDB` used asynchronous I/O on Windows systems only. Starting with the InnoDB Plugin 1.1 and MySQL 5.5, `InnoDB` uses asynchronous I/O on Linux systems. This change introduces a dependency on `libaio`. Asynchronous I/O on Linux systems is configured using the `innodb_use_native_aio` option, which is enabled by default. On other Unix-like systems, InnoDB uses synchronous I/O only.
See Also buffer pool, non-blocking I/O.

atomic

In the SQL context, **transactions** are units of work that either succeed entirely (when **committed**) or have no effect at all (when **rolled back**). The indivisible ("atomic") property of transactions is the “A” in the acronym **ACID**.
See Also ACID, commit, rollback, transaction.

atomic DDL

An atomic *DDL* statement is one that combines the *data dictionary* updates, *storage engine* operations, and *binary log* writes associated with a DDL operation into a single, atomic transaction. The transaction is either fully committed or rolled back, even if the server halts during the operation. Atomic DDL support was added in MySQL 8.0. For more information, see Atomic Data Definition Statement Support.

See Also binary log, data dictionary, DDL, storage engine.

atomic instruction
Special instructions provided by the CPU, to ensure that critical low-level operations cannot be interrupted.

auto-increment
A property of a table column (specified by the `AUTO_INCREMENT` keyword) that automatically adds an ascending sequence of values in the column.

It saves work for the developer, not to have to produce new unique values when inserting new rows. It provides useful information for the query optimizer, because the column is known to be not null and with unique values. The values from such a column can be used as lookup keys in various contexts, and because they are auto-generated there is no reason to ever change them; for this reason, primary key columns are often specified as auto-incrementing.

Auto-increment columns can be problematic with statement-based replication, because replaying the statements on a slave might not produce the same set of column values as on the master, due to timing issues. When you have an auto-incrementing primary key, you can use statement-based replication only with the setting `innodb_autoinc_lock_mode=1`. If you have `innodb_autoinc_lock_mode=2`, which allows higher concurrency for insert operations, use **row-based replication** rather than **statement-based replication**. The setting `innodb_autoinc_lock_mode=0` should not be used except for compatibility purposes.

Consecutive lock mode (`innodb_autoinc_lock_mode=1`) is the default setting prior to MySQL 8.0.3. As of MySQL 8.0.3, interleaved lock mode (`innodb_autoinc_lock_mode=2`) is the default, which reflects the change from statement-based to row-based replication as the default replication type.
See Also auto-increment locking, innodb_autoinc_lock_mode, primary key, row-based replication, statement-based replication.

auto-increment locking
The convenience of an **auto-increment** primary key involves some tradeoff with concurrency. In the simplest case, if one transaction is inserting values into the table, any other transactions must wait to do their own inserts into that table, so that rows inserted by the first transaction receive consecutive primary key values. `InnoDB` includes optimizations and the `innodb_autoinc_lock_mode` option so that you can configure and optimal balance between predictable sequences of auto-increment values and maximum **concurrency** for insert operations.
See Also auto-increment, concurrency, innodb_autoinc_lock_mode.

autocommit
A setting that causes a **commit** operation after each **SQL** statement. This mode is not recommended for working with `InnoDB` tables with **transactions** that span several statements. It can help performance for **read-only transactions** on `InnoDB` tables, where it minimizes overhead from **locking** and generation of **undo** data, especially in MySQL 5.6.4 and up. It is also appropriate for working with `MyISAM` tables, where transactions are not applicable.
See Also commit, locking, read-only transaction, SQL, transaction, undo.

availability
The ability to cope with, and if necessary recover from, failures on the host, including failures of MySQL, the operating system, or the hardware and maintenance activity that may otherwise cause downtime. Often paired with **scalability** as critical aspects of a large-scale deployment.
See Also scalability.

B

B-tree
A tree data structure that is popular for use in database indexes. The structure is kept sorted at all times, enabling fast lookup for exact matches (equals operator) and ranges (for example, greater than, less than, and `BETWEEN` operators). This type of index is available for most storage engines, such as `InnoDB` and `MyISAM`.

Because B-tree nodes can have many children, a B-tree is not the same as a binary tree, which is limited to 2 children per node.

Contrast with **hash index**, which is only available in the `MEMORY` storage engine. The `MEMORY` storage engine can also use B-tree indexes, and you should choose B-tree indexes for `MEMORY` tables if some queries use range operators.

The use of the term B-tree is intended as a reference to the general class of index design. B-tree structures used by MySQL storage engines may be regarded as variants due to sophistications not present in a classic B-tree design. For related information, refer to the `InnoDB` Page Structure Fil Header section of the MySQL Internals Manual.
See Also hash index.

backticks
Identifiers within MySQL SQL statements must be quoted using the backtick character (`) if they contain special characters or reserved words. For example, to refer to a table named `FOO#BAR` or a column named `SELECT`, you would specify the identifiers as `` `FOO#BAR` `` and `` `SELECT` ``. Since the backticks provide an extra level of safety, they are used extensively in program-generated SQL statements, where the identifier names might not be known in advance.

Many other database systems use double quotation marks (") around such special names. For portability, you can enable `ANSI_QUOTES` mode in MySQL and use double quotation marks instead of backticks to qualify identifier names.
See Also SQL.

backup
The process of copying some or all table data and metadata from a MySQL instance, for safekeeping. Can also refer to the set of copied files. This is a crucial task for DBAs. The reverse of this process is the **restore** operation.

With MySQL, **physical backups** are performed by the **MySQL Enterprise Backup** product, and **logical backups** are performed by the `mysqldump` command. These techniques have different characteristics in terms of size and representation of the backup data, and speed (especially speed of the restore operation).

Backups are further classified as **hot**, **warm**, or **cold** depending on how much they interfere with normal database operation. (Hot backups have the least interference, cold backups the most.)
See Also cold backup, hot backup, logical backup, MySQL Enterprise Backup, mysqldump, physical backup, warm backup.

Barracuda
The code name for an `InnoDB` **file format** that supports the **COMPRESSED** row format that enables InnoDB table compression, and the **DYNAMIC** row format that improves the storage layout for long variable-length columns.

The **MySQL Enterprise Backup** product version 3.5 and above supports backing up tablespaces that use the Barracuda file format.
See Also Antelope, compact row format, compressed row format, dynamic row format, file format, file-per-table, general tablespace, innodb_file_format, MySQL Enterprise Backup, row format, system tablespace.

beta
An early stage in the life of a software product, when it is available only for evaluation, typically without a definite release number or a number less than 1. `InnoDB` does not use the beta designation, preferring an **early adopter** phase that can extend over several point releases, leading to a **GA** release.
See Also early adopter, GA.

binary log
A file containing a record of all statements that attempt to change table data. These statements can be replayed to bring slave servers up to date in a **replication** scenario, or to bring a database up to date after restoring table data from a backup. The binary logging feature can be turned on and off, although Oracle recommends always enabling it if you use replication or perform backups.

You can examine the contents of the binary log, or replay those statements during replication or recovery, by using the `mysqlbinlog` command. For full information about the binary log, see Section 5.4.4, “The Binary Log”. For MySQL configuration options related to the binary log, see Section 17.1.3.4, “Binary Log Options and Variables”.

For the **MySQL Enterprise Backup** product, the file name of the binary log and the current position within the file are important details. To record this information for the master server when taking a backup in a replication context, you can specify the `--slave-info` option.

Prior to MySQL 5.0, a similar capability was available, known as the update log. In MySQL 5.0 and higher, the binary log replaces the update log.
See Also binlog, MySQL Enterprise Backup, replication.

binlog
An informal name for the **binary log** file. For example, you might see this abbreviation used in e-mail messages or forum discussions.
See Also binary log.

blind query expansion
A special mode of **full-text search** enabled by the `WITH QUERY EXPANSION` clause. It performs the search twice, where the search phrase for the second search is the original search phrase concatenated with the few most highly relevant documents from the first search. This technique is mainly applicable for short search phrases, perhaps only a single word. It can uncover relevant matches where the precise search term does not occur in the document.
See Also full-text search.

bottleneck
A portion of a system that is constrained in size or capacity, that has the effect of limiting overall throughput. For example, a memory area might be smaller than necessary; access to a single required resource might prevent multiple CPU cores from running simultaneously; or waiting for disk I/O to complete might prevent the CPU from running at full capacity. Removing bottlenecks tends to improve **concurrency**. For example, the ability to have multiple `InnoDB` **buffer pool** instances reduces contention when multiple sessions read from and write to the buffer pool simultaneously.
See Also buffer pool, concurrency.

bounce
A **shutdown** operation immediately followed by a restart. Ideally with a relatively short **warmup** period so that performance and throughput quickly return to a high level.
See Also shutdown.

buddy allocator
A mechanism for managing different-sized **pages** in the InnoDB **buffer pool**.
See Also buffer pool, page, page size.

buffer
A memory or disk area used for temporary storage. Data is buffered in memory so that it can be written to disk efficiently, with a few large I/O operations rather than many small ones. Data is buffered on disk for greater reliability, so that it can be recovered even when a **crash** or other failure occurs at the worst possible time. The main types of buffers used by InnoDB are the **buffer pool**, the **doublewrite buffer**, and the **change buffer**.
See Also buffer pool, change buffer, crash, doublewrite buffer.

buffer pool
The memory area that holds cached `InnoDB` data for both tables and indexes. For efficiency of high-volume read operations, the buffer pool is divided into **pages** that can potentially hold multiple rows. For efficiency of cache management, the buffer pool is implemented as a linked list of pages; data that is rarely used is aged out of the cache, using a variation of the **LRU** algorithm. On systems with large memory, you can improve concurrency by dividing the buffer pool into multiple **buffer pool instances**.

Several `InnoDB` status variables, `INFORMATION_SCHEMA` tables, and `performance_schema` tables help to monitor the internal workings of the buffer pool. Starting in MySQL 5.6, you can avoid a lengthy warmup

period after restarting the server, particularly for instances with large buffer pools, by saving the buffer pool state at server shutdown and restoring the buffer pool to the same state at server startup. See Saving and Restoring the Buffer Pool State.
See Also buffer pool instance, LRU, page, warm up.

buffer pool instance
Any of the multiple regions into which the **buffer pool** can be divided, controlled by the `innodb_buffer_pool_instances` configuration option. The total memory size specified by `innodb_buffer_pool_size` is divided among all buffer pool instances. Typically, having multiple buffer pool instances is appropriate for systems that allocate multiple gigabytes to the `InnoDB` buffer pool, with each instance being one gigabyte or larger. On systems loading or looking up large amounts of data in the buffer pool from many concurrent sessions, having multiple buffer pool instances reduces contention for exclusive access to data structures that manage the buffer pool.
See Also buffer pool.

built-in
The built-in `InnoDB` storage engine within MySQL is the original form of distribution for the storage engine. Contrast with the **InnoDB Plugin**. Starting with MySQL 5.5, the InnoDB Plugin is merged back into the MySQL code base as the built-in `InnoDB` storage engine (known as InnoDB 1.1).

This distinction is important mainly in MySQL 5.1, where a feature or bug fix might apply to the InnoDB Plugin but not the built-in `InnoDB`, or vice versa.
See Also InnoDB.

business rules
The relationships and sequences of actions that form the basis of business software, used to run a commercial company. Sometimes these rules are dictated by law, other times by company policy. Careful planning ensures that the relationships encoded and enforced by the database, and the actions performed through application logic, accurately reflect the real policies of the company and can handle real-life situations.

For example, an employee leaving a company might trigger a sequence of actions from the human resources department. The human resources database might also need the flexibility to represent data about a person who has been hired, but not yet started work. Closing an account at an online service might result in data being removed from a database, or the data might be moved or flagged so that it could be recovered if the account is re-opened. A company might establish policies regarding salary maximums, minimums, and adjustments, in addition to basic sanity checks such as the salary not being a negative number. A retail database might not allow a purchase with the same serial number to be returned more than once, or might not allow credit card purchases above a certain value, while a database used to detect fraud might allow these kinds of things.
See Also relational.

C

.cfg file
A metadata file used with the `InnoDB` **transportable tablespace** feature. It is produced by the command `FLUSH TABLES ... FOR EXPORT`, puts one or more tables in a consistent state that can be copied to another server. The `.cfg` file is copied along with the corresponding **.ibd file**, and used to adjust the internal values of the `.ibd` file, such as the **space ID**, during the `ALTER TABLE ... IMPORT TABLESPACE` step.
See Also .ibd file, space ID, transportable tablespace.

cache
The general term for any memory area that stores copies of data for frequent or high-speed retrieval. In `InnoDB`, the primary kind of cache structure is the **buffer pool**.
See Also buffer, buffer pool.

cardinality
The number of different values in a table **column**. When queries refer to columns that have an associated **index**, the cardinality of each column influences which access method is most efficient. For example, for a

column with a **unique constraint**, the number of different values is equal to the number of rows in the table. If a table has a million rows but only 10 different values for a particular column, each value occurs (on average) 100,000 times. A query such as `SELECT c1 FROM t1 WHERE c1 = 50;` thus might return 1 row or a huge number of rows, and the database server might process the query differently depending on the cardinality of `c1`.

If the values in a column have a very uneven distribution, the cardinality might not be a good way to determine the best query plan. For example, `SELECT c1 FROM t1 WHERE c1 = x;` might return 1 row when `x=50` and a million rows when `x=30`. In such a case, you might need to use **index hints** to pass along advice about which lookup method is more efficient for a particular query.

Cardinality can also apply to the number of distinct values present in multiple columns, as in a **composite index**.
See Also column, composite index, index, index hint, persistent statistics, random dive, selectivity, unique constraint.

change buffer
A special data structure that records changes to **pages** in **secondary indexes**. These values could result from SQL `INSERT`, `UPDATE`, or `DELETE` statements (**DML**). The set of features involving the change buffer is known collectively as **change buffering**, consisting of **insert buffering**, **delete buffering**, and **purge buffering**.

Changes are only recorded in the change buffer when the relevant page from the secondary index is not in the **buffer pool**. When the relevant index page is brought into the buffer pool while associated changes are still in the change buffer, the changes for that page are applied in the buffer pool (**merged**) using the data from the change buffer. Periodically, the **purge** operation that runs during times when the system is mostly idle, or during a slow shutdown, writes the new index pages to disk. The purge operation can write the disk blocks for a series of index values more efficiently than if each value were written to disk immediately.

Physically, the change buffer is part of the **system tablespace**, so that the index changes remain buffered across database restarts. The changes are only applied (**merged**) when the pages are brought into the buffer pool due to some other read operation.

The kinds and amount of data stored in the change buffer are governed by the `innodb_change_buffering` and `innodb_change_buffer_max_size` configuration options. To see information about the current data in the change buffer, issue the `SHOW ENGINE INNODB STATUS` command.

Formerly known as the **insert buffer**.
See Also buffer pool, change buffering, delete buffering, DML, insert buffer, insert buffering, merge, page, purge, purge buffering, secondary index, system tablespace.

change buffering
The general term for the features involving the **change buffer**, consisting of **insert buffering**, **delete buffering**, and **purge buffering**. Index changes resulting from SQL statements, which could normally involve random I/O operations, are held back and performed periodically by a background **thread**. This sequence of operations can write the disk blocks for a series of index values more efficiently than if each value were written to disk immediately. Controlled by the `innodb_change_buffering` and `innodb_change_buffer_max_size` configuration options.
See Also change buffer, delete buffering, insert buffering, purge buffering.

checkpoint
As changes are made to data pages that are cached in the **buffer pool**, those changes are written to the **data files** sometime later, a process known as **flushing**. The checkpoint is a record of the latest changes (represented by an **LSN** value) that have been successfully written to the data files.
See Also buffer pool, data files, flush, fuzzy checkpointing, LSN.

checksum
In `InnoDB`, a validation mechanism to detect corruption when a **page** in a **tablespace** is read from disk into the `InnoDB` **buffer pool**. This feature is controlled by the `innodb_checksums`

configuration option in MySQL 5.5. `innodb_checksums` is deprecated in MySQL 5.6.3, replaced by `innodb_checksum_algorithm`.

The `innochecksum` command helps diagnose corruption problems by testing the checksum values for a specified **tablespace** file while the MySQL server is shut down.

MySQL also uses checksums for replication purposes. For details, see the configuration options `binlog_checksum`, `master_verify_checksum`, and `slave_sql_verify_checksum`.
See Also buffer pool, page, tablespace.

child table
In a **foreign key** relationship, a child table is one whose rows refer (or point) to rows in another table with an identical value for a specific column. This is the table that contains the `FOREIGN KEY ... REFERENCES` clause and optionally `ON UPDATE` and `ON DELETE` clauses. The corresponding row in the **parent table** must exist before the row can be created in the child table. The values in the child table can prevent delete or update operations on the parent table, or can cause automatic deletion or updates in the child table, based on the `ON CASCADE` option used when creating the foreign key.
See Also foreign key, parent table.

clean page
A **page** in the `InnoDB` **buffer pool** where all changes made in memory have also been written (**flushed**) to the data files. The opposite of a **dirty page**.
See Also buffer pool, data files, dirty page, flush, page.

clean shutdown
A **shutdown** that completes without errors and applies all changes to `InnoDB` tables before finishing, as opposed to a **crash** or a **fast shutdown**. Synonym for **slow shutdown**.
See Also crash, fast shutdown, shutdown, slow shutdown.

client
A type of program that sends requests to a **server**, and interprets or processes the results. The client software might run only some of the time (such as a mail or chat program), and might run interactively (such as the `mysql` command processor).
See Also mysql, server.

clustered index
The `InnoDB` term for a **primary key** index. `InnoDB` table storage is organized based on the values of the primary key columns, to speed up queries and sorts involving the primary key columns. For best performance, choose the primary key columns carefully based on the most performance-critical queries. Because modifying the columns of the clustered index is an expensive operation, choose primary columns that are rarely or never updated.

In the Oracle Database product, this type of table is known as an **index-organized table**.
See Also index, primary key, secondary index.

cold backup
A **backup** taken while the database is shut down. For busy applications and web sites, this might not be practical, and you might prefer a **warm backup** or a **hot backup**.
See Also backup, hot backup, warm backup.

column
A data item within a **row**, whose storage and semantics are defined by a data type. Each **table** and **index** is largely defined by the set of columns it contains.

Each column has a **cardinality** value. A column can be the **primary key** for its table, or part of the primary key. A column can be subject to a **unique constraint**, a **NOT NULL constraint**, or both. Values in different columns, even across different tables, can be linked by a **foreign key** relationship.

In discussions of MySQL internal operations, sometimes **field** is used as a synonym.
See Also cardinality, foreign key, index, NOT NULL constraint, primary key, row, table, unique constraint.

column index
An **index** on a single column.
See Also composite index, index.

column prefix
When an **index** is created with a length specification, such as `CREATE INDEX idx ON t1 (c1(N))`, only the first N characters of the column value are stored in the index. Keeping the index prefix small makes the index compact, and the memory and disk I/O savings help performance. (Although making the index prefix too small can hinder query optimization by making rows with different values appear to the query optimizer to be duplicates.)

For columns containing binary values or long text strings, where sorting is not a major consideration and storing the entire value in the index would waste space, the index automatically uses the first N (typically 768) characters of the value to do lookups and sorts.
See Also index.

commit
A **SQL** statement that ends a **transaction**, making permanent any changes made by the transaction. It is the opposite of **rollback**, which undoes any changes made in the transaction.

`InnoDB` uses an **optimistic** mechanism for commits, so that changes can be written to the data files before the commit actually occurs. This technique makes the commit itself faster, with the tradeoff that more work is required in case of a rollback.

By default, MySQL uses the **autocommit** setting, which automatically issues a commit following each SQL statement.
See Also autocommit, optimistic, rollback, SQL, transaction.

compact row format
The default `InnoDB` **row format** for `InnoDB` tables since MySQL 5.0.3. The **COMPACT** row format provides a more compact representation for nulls and variable-length columns than the prior default (**REDUNDANT** row format).

For additional information about `InnoDB` `COMPACT` row format, see Section 14.14.4, “COMPACT and REDUNDANT Row Formats”.
See Also Antelope, dynamic row format, file format, redundant row format, row format.

composite index
An **index** that includes multiple columns.
See Also index.

compressed backup
The compression feature of the **MySQL Enterprise Backup** product makes a compressed copy of each tablespace, changing the extension from `.ibd` to `.ibz`. Compressing backup data allows you to keep more backups on hand, and reduces the time to transfer backups to a different server. The data is uncompressed during the restore operation. When a compressed backup operation processes a table that is already compressed, it skips the compression step for that table, because compressing again would result in little or no space savings.

A set of files produced by the **MySQL Enterprise Backup** product, where each **tablespace** is compressed. The compressed files are renamed with a `.ibz` file extension.

Applying **compression** at the start of the backup process helps to avoid storage overhead during the compression process, and to avoid network overhead when transferring the backup files to another server. The process of **applying** the **binary log** takes longer, and requires uncompressing the backup files.
See Also apply, binary log, compression, hot backup, MySQL Enterprise Backup, tablespace.

compressed row format
A **row format** that enables data and index **compression** for `InnoDB` tables. It was introduced in the `InnoDB` Plugin, available as part of the **Barracuda** file format. Large fields are stored away from the page that holds

the rest of the row data, as in **dynamic row format**. Both index pages and large fields are compressed, yielding memory and disk savings. Depending on the structure of the data, the decrease in memory and disk usage might or might not outweigh the performance overhead of uncompressing the data as it is used. See Section 14.12, “InnoDB Table Compression” for usage details.

For additional information about `InnoDB COMPRESSED` row format, see Section 14.14.3, “DYNAMIC and COMPRESSED Row Formats”.
See Also Barracuda, compression, dynamic row format, row format.

compressed table
A table for which the data is stored in compressed form. For `InnoDB`, it is a table created with `ROW_FORMAT=COMPRESSED`. See Section 14.12, “InnoDB Table Compression” for more information.
See Also compressed row format, compression.

compression
A feature with wide-ranging benefits from using less disk space, performing less I/O, and using less memory for caching. `InnoDB` table and index data can be kept in a compressed format during database operation.

The data is uncompressed when needed for queries, and re-compressed when changes are made by **DML** operations. After you enable compression for a table, this processing is transparent to users and application developers. DBAs can consult `InnoDB INFORMATION_SCHEMA` tables to monitor how efficiently the compression parameters work for the MySQL instance and for particular compressed tables.

When `InnoDB` table data is compressed, the compression applies to the table itself, any associated index data, and the pages loaded into the **buffer pool**. Compression does not apply to pages in the **undo buffer**.

The table compression feature requires using MySQL 5.5 or higher, or the InnoDB Plugin in MySQL 5.1 or earlier, and creating the table using the **Barracuda** file format and **compressed row format**, with the **innodb_file_per_table** setting enabled.

Compression for each table is influenced by the `KEY_BLOCK_SIZE` clause of the `CREATE TABLE` and `ALTER TABLE` statements. In MySQL 5.6 and higher, compression is also affected by the server-wide configuration options `innodb_compression_failure_threshold_pct`, `innodb_compression_level`, and `innodb_compression_pad_pct_max`. See Section 14.12, “InnoDB Table Compression” for usage details.

Another type of compression is the **compressed backup** feature of the **MySQL Enterprise Backup** product.
See Also Barracuda, buffer pool, compressed backup, compressed row format, DML, transparent page compression.

compression failure
Not actually an error, rather an expensive operation that can occur when using **compression** in combination with **DML** operations. It occurs when: updates to a compressed **page** overflow the area on the page reserved for recording modifications; the page is compressed again, with all changes applied to the table data; the re-compressed data does not fit on the original page, requiring MySQL to split the data into two new pages and compress each one separately. To check the frequency of this condition, query the `INFORMATION_SCHEMA.INNODB_CMP` table and check how much the value of the `COMPRESS_OPS` column exceeds the value of the `COMPRESS_OPS_OK` column. Ideally, compression failures do not occur often; when they do, you can adjust the `innodb_compression_level`, `innodb_compression_failure_threshold_pct`, and `innodb_compression_pad_pct_max` configuration options.
See Also compression, DML, page.

concatenated index
See composite index.

concurrency
The ability of multiple operations (in database terminology, **transactions**) to run simultaneously, without interfering with each other. Concurrency is also involved with performance, because ideally the protection for multiple simultaneous transactions works with a minimum of performance overhead, using efficient mechanisms for **locking**.

See Also ACID, locking, transaction.

configuration file
: The file that holds the **option** values used by MySQL at startup. Traditionally, on Linux and Unix this file is named `my.cnf`, and on Windows it is named `my.ini`. You can set a number of options related to InnoDB under the `[mysqld]` section of the file.

  See Section 4.2.6, “Using Option Files” for information about where MySQL searches for configuration files.

  When you use the **MySQL Enterprise Backup** product, you typically use two configuration files: one that specifies where the data comes from and how it is structured (which could be the original configuration file for your server), and a stripped-down one containing only a small set of options that specify where the backup data goes and how it is structured. The configuration files used with the **MySQL Enterprise Backup** product must contain certain options that are typically left out of regular configuration files, so you might need to add options to your existing configuration file for use with **MySQL Enterprise Backup**.
  See Also my.cnf, MySQL Enterprise Backup, option, option file.

consistent read
: A read operation that uses **snapshot** information to present query results based on a point in time, regardless of changes performed by other transactions running at the same time. If queried data has been changed by another transaction, the original data is reconstructed based on the contents of the **undo log**. This technique avoids some of the **locking** issues that can reduce **concurrency** by forcing transactions to wait for other transactions to finish.

  With **REPEATABLE READ isolation level**, the snapshot is based on the time when the first read operation is performed. With **READ COMMITTED** isolation level, the snapshot is reset to the time of each consistent read operation.

  Consistent read is the default mode in which `InnoDB` processes `SELECT` statements in **READ COMMITTED** and **REPEATABLE READ** isolation levels. Because a consistent read does not set any locks on the tables it accesses, other sessions are free to modify those tables while a consistent read is being performed on the table.

  For technical details about the applicable isolation levels, see Section 14.8.2.3, “Consistent Nonlocking Reads”.
  See Also concurrency, isolation level, locking, READ COMMITTED, REPEATABLE READ, snapshot, transaction, undo log.

constraint
: An automatic test that can block database changes to prevent data from becoming inconsistent. (In computer science terms, a kind of assertion related to an invariant condition.) Constraints are a crucial component of the **ACID** philosophy, to maintain data consistency. Constraints supported by MySQL include **FOREIGN KEY constraints** and **unique constraints**.
  See Also ACID, foreign key, unique constraint.

counter
: A value that is incremented by a particular kind of `InnoDB` operation. Useful for measuring how busy a server is, troubleshooting the sources of performance issues, and testing whether changes (for example, to configuration settings or indexes used by queries) have the desired low-level effects. Different kinds of counters are available through **Performance Schema** tables and **INFORMATION_SCHEMA** tables, particularly `INFORMATION_SCHEMA.INNODB_METRICS`.
  See Also INFORMATION_SCHEMA, metrics counter, Performance Schema.

covering index
: An **index** that includes all the columns retrieved by a query. Instead of using the index values as pointers to find the full table rows, the query returns values from the index structure, saving disk I/O. `InnoDB` can apply this optimization technique to more indexes than MyISAM can, because `InnoDB` **secondary indexes** also include the **primary key** columns. `InnoDB` cannot apply this technique for queries against tables modified by a transaction, until that transaction ends.

Any **column index** or **composite index** could act as a covering index, given the right query. Design your indexes and queries to take advantage of this optimization technique wherever possible.
See Also column index, composite index, index, primary key, secondary index.

CPU-bound
A type of **workload** where the primary **bottleneck** is CPU operations in memory. Typically involves read-intensive operations where the results can all be cached in the **buffer pool**.
See Also bottleneck, buffer pool, workload.

crash
MySQL uses the term “crash” to refer generally to any unexpected **shutdown** operation where the server cannot do its normal cleanup. For example, a crash could happen due to a hardware fault on the database server machine or storage device; a power failure; a potential data mismatch that causes the MySQL server to halt; a **fast shutdown** initiated by the DBA; or many other reasons. The robust, automatic **crash recovery** for **InnoDB** tables ensures that data is made consistent when the server is restarted, without any extra work for the DBA.
See Also crash recovery, fast shutdown, InnoDB, shutdown.

crash recovery
The cleanup activities that occur when MySQL is started again after a **crash**. For **InnoDB** tables, changes from incomplete transactions are replayed using data from the **redo log**. Changes that were **committed** before the crash, but not yet written into the **data files**, are reconstructed from the **doublewrite buffer**. When the database is shut down normally, this type of activity is performed during shutdown by the **purge** operation.

During normal operation, committed data can be stored in the **change buffer** for a period of time before being written to the data files. There is always a tradeoff between keeping the data files up-to-date, which introduces performance overhead during normal operation, and buffering the data, which can make shutdown and crash recovery take longer.
See Also change buffer, commit, crash, data files, doublewrite buffer, InnoDB, purge, redo log.

CRUD
Acronym for “create, read, update, delete”, a common sequence of operations in database applications. Often denotes a class of applications with relatively simple database usage (basic **DDL**, **DML** and **query** statements in **SQL**) that can be implemented quickly in any language.
See Also DDL, DML, query, SQL.

cursor
An internal data structure that is used to represent the result set of a **query**, or other operation that performs a search using an SQL `WHERE` clause. It works like an iterator in other high-level languages, producing each value from the result set as requested.

Although SQL usually handles the processing of cursors for you, you might delve into the inner workings when dealing with performance-critical code.
See Also query.

D

data definition language
See DDL.

data dictionary
Metadata that keeps track of InnoDB-related objects such as **tables**, **indexes**, and table **columns**. This metadata is physically located in the `InnoDB` **system tablespace**. For historical reasons, it overlaps to some degree with information stored in the **.frm files**.

Because the **MySQL Enterprise Backup** product always backs up the system tablespace, all backups include the contents of the data dictionary.
See Also column, file-per-table, .frm file, index, MySQL Enterprise Backup, system tablespace, table.

data directory
The directory under which each MySQL **instance** keeps the **data files** for `InnoDB` and the directories representing individual databases. Controlled by the `datadir` configuration option.
See Also data files, instance.

data files
The files that physically contain **table** and **index** data.

The `InnoDB` **system tablespace**, which holds the `InnoDB` **data dictionary** and is capable of holding data for multiple `InnoDB` tables, is represented by one or more `.ibdata` data files.

File-per-table tablespaces, which hold data for a single `InnoDB` table, are represented by a `.ibd` data file.

General tablespaces (introduced in MySQL 5.7.6), which can hold data for multiple `InnoDB` tables, are also represented by a `.ibd` data file.
See Also data dictionary, file-per-table, general tablespace, .ibd file, ibdata file, index, system tablespace, table, tablespace.

data manipulation language
See DML.

data warehouse
A database system or application that primarily runs large **queries**. The read-only or read-mostly data might be organized in **denormalized** form for query efficiency. Can benefit from the optimizations for **read-only transactions** in MySQL 5.6 and higher. Contrast with **OLTP**.
See Also denormalized, OLTP, query, read-only transaction.

database
Within the MySQL **data directory**, each database is represented by a separate directory. The InnoDB **system tablespace**, which can hold table data from multiple databases within a MySQL **instance**, is kept in **data files** that reside outside of individual database directories. When **file-per-table** mode is enabled, the **.ibd files** representing individual InnoDB tables are stored inside the database directories unless created elsewhere using the `DATA DIRECTORY` clause. General tablespaces, introduced in MySQL 5.7.6, also hold table data in **.ibd files**. Unlike file-per-table **.ibd files**, general tablespace **.ibd files** can hold table data from multiple databases within a MySQL **instance**, and can be assigned to directories relative to or independent of the MySQL data directory.

For long-time MySQL users, a database is a familiar notion. Users coming from an Oracle Database background will find that the MySQL meaning of a database is closer to what Oracle Database calls a **schema**.
See Also data files, file-per-table, .ibd file, instance, schema, system tablespace.

DCL
Data control language, a set of **SQL** statements for managing privileges. In MySQL, consists of the `GRANT` and `REVOKE` statements. Contrast with **DDL** and **DML**.
See Also DDL, DML, SQL.

DDL
Data definition language, a set of **SQL** statements for manipulating the database itself rather than individual table rows. Includes all forms of the `CREATE`, `ALTER`, and `DROP` statements. Also includes the `TRUNCATE` statement, because it works differently than a `DELETE FROM` *`table_name`* statement, even though the ultimate effect is similar.

DDL statements automatically **commit** the current **transaction**; they cannot be **rolled back**.

The `InnoDB` online DDL feature enhances performance for `CREATE INDEX`, `DROP INDEX`, and many types of `ALTER TABLE` operations. See InnoDB and Online DDL for more information. Also, the `InnoDB` file-per-table setting can affect the behavior of `DROP TABLE` and `TRUNCATE TABLE` operations.

Contrast with **DML** and **DCL**.
See Also commit, DCL, DML, file-per-table, rollback, SQL, transaction.

deadlock

A situation where different **transactions** are unable to proceed, because each holds a **lock** that the other needs. Because both transactions are waiting for a resource to become available, neither will ever release the locks it holds.

A deadlock can occur when the transactions lock rows in multiple tables (through statements such as `UPDATE` or `SELECT ... FOR UPDATE`), but in the opposite order. A deadlock can also occur when such statements lock ranges of index records and **gaps**, with each transaction acquiring some locks but not others due to a timing issue.

For background information on how deadlocks are automatically detected and handled, see Section 14.8.5.2, "Deadlock Detection and Rollback". For tips on avoiding and recovering from deadlock conditions, see Section 14.8.5.3, "How to Minimize and Handle Deadlocks".
See Also gap, lock, transaction.

deadlock detection

A mechanism that automatically detects when a **deadlock** occurs, and automatically **rolls back** one of the **transactions** involved (the **victim**).
See Also deadlock, rollback, transaction, victim.

delete

When `InnoDB` processes a `DELETE` statement, the rows are immediately marked for deletion and no longer are returned by queries. The storage is reclaimed sometime later, during the periodic garbage collection known as the **purge** operation. For removing large quantities of data, related operations with their own performance characteristics are **TRUNCATE** and **DROP**.
See Also drop, purge, truncate.

delete buffering

The technique of storing changes to secondary index pages, resulting from `DELETE` operations, in the **change buffer** rather than writing the changes immediately, so that the physical writes can be performed to minimize random I/O. (Because delete operations are a two-step process, this operation buffers the write that normally marks an index record for deletion.) It is one of the types of **change buffering**; the others are **insert buffering** and **purge buffering**.
See Also change buffer, change buffering, insert buffer, insert buffering, purge buffering.

denormalized

A data storage strategy that duplicates data across different tables, rather than linking the tables with **foreign keys** and **join** queries. Typically used in **data warehouse** applications, where the data is not updated after loading. In such applications, query performance is more important than making it simple to maintain consistent data during updates. Contrast with **normalized**.
See Also data warehouse, foreign key, join, normalized.

descending index

A type of **index** available with some database systems, where index storage is optimized to process `ORDER BY` *`column`* `DESC` clauses. Currently, although MySQL allows the `DESC` keyword in the `CREATE TABLE` statement, it does not use any special storage layout for the resulting index.
See Also index.

dirty page

A **page** in the `InnoDB` **buffer pool** that has been updated in memory, where the changes are not yet written (**flushed**) to the **data files**. The opposite of a **clean page**.
See Also buffer pool, clean page, data files, flush, page.

dirty read

An operation that retrieves unreliable data, data that was updated by another transaction but not yet **committed**. It is only possible with the **isolation level** known as **read uncommitted**.

This kind of operation does not adhere to the **ACID** principle of database design. It is considered very risky, because the data could be **rolled back**, or updated further before being committed; then, the transaction doing the dirty read would be using data that was never confirmed as accurate.

Its opposite is **consistent read**, where `InnoDB` ensures that a transaction does not read information updated by another transaction, even if the other transaction commits in the meantime.
See Also ACID, commit, consistent read, isolation level, READ UNCOMMITTED, rollback.

disk-based
A kind of database that primarily organizes data on disk storage (hard drives or equivalent). Data is brought back and forth between disk and memory to be operated upon. It is the opposite of an **in-memory database**. Although `InnoDB` is disk-based, it also contains features such as he **buffer pool**, multiple buffer pool instances, and the **adaptive hash index** that allow certain kinds of workloads to work primarily from memory.
See Also adaptive hash index, buffer pool, in-memory database.

disk-bound
A type of **workload** where the primary **bottleneck** is disk I/O. (Also known as **I/O-bound**.) Typically involves frequent writes to disk, or random reads of more data than can fit into the **buffer pool**.
See Also bottleneck, buffer pool, workload.

DML
Data manipulation language, a set of **SQL** statements for performing `INSERT`, `UPDATE`, and `DELETE` operations. The `SELECT` statement is sometimes considered as a DML statement, because the `SELECT ... FOR UPDATE` form is subject to the same considerations for **locking** as `INSERT`, `UPDATE`, and `DELETE`.

DML statements for an `InnoDB` table operate in the context of a **transaction**, so their effects can be **committed** or **rolled back** as a single unit.

Contrast with **DDL** and **DCL**.
See Also commit, DCL, DDL, locking, rollback, SQL, transaction.

document id
In the `InnoDB` **full-text search** feature, a special column in the table containing the **FULLTEXT index**, to uniquely identify the document associated with each **ilist** value. Its name is `FTS_DOC_ID` (uppercase required). The column itself must be of `BIGINT UNSIGNED NOT NULL` type, with a unique index named `FTS_DOC_ID_INDEX`. Preferably, you define this column when creating the table. If `InnoDB` must add the column to the table while creating a `FULLTEXT` index, the indexing operation is considerably more expensive.
See Also full-text search, FULLTEXT index, ilist.

doublewrite buffer
`InnoDB` uses a file flush technique called doublewrite. Before writing **pages** to the **data files**, `InnoDB` first writes them to a contiguous area called the doublewrite buffer. Only after the write and the flush to the doublewrite buffer have completed, does `InnoDB` write the pages to their proper positions in the data file. If there is an operating system, storage subsystem, or `mysqld` process crash in the middle of a page write, `InnoDB` can later find a good copy of the page from the doublewrite buffer during **crash recovery**.

Although data is always written twice, the doublewrite buffer does not require twice as much I/O overhead or twice as many I/O operations. Data is written to the buffer itself as a large sequential chunk, with a single `fsync()` call to the operating system.

To turn off the doublewrite buffer, specify the option `innodb_doublewrite=0`.
See Also crash recovery, data files, page, purge.

drop
A kind of **DDL** operation that removes a schema object, through a statement such as `DROP TABLE` or `DROP INDEX`. It maps internally to an `ALTER TABLE` statement. From an `InnoDB` perspective, the performance considerations of such operations involve the time that the **data dictionary** is locked to ensure that interrelated objects are all updated, and the time to update memory structures such as the **buffer pool**. For a **table**, the drop operation has somewhat different characteristics than a **truncate** operation (`TRUNCATE TABLE` statement).
See Also buffer pool, data dictionary, DDL, table, truncate.

dynamic row format
A row format introduced in the `InnoDB` Plugin, available as part of the **Barracuda file format**. Because long variable-length column values are stored outside of the page that holds the row data, it is very efficient for

rows that include large objects. Since the large fields are typically not accessed to evaluate query conditions, they are not brought into the **buffer pool** as often, resulting in fewer I/O operations and better utilization of cache memory.

As of MySQL 5.7.9, the default row format is defined by `innodb_default_row_format`, which has a default value of `DYNAMIC`.

For additional information about `InnoDB` `DYNAMIC` row format, see Section 14.14.3, “DYNAMIC and COMPRESSED Row Formats”.
See Also Barracuda, buffer pool, file format, row format.

E

early adopter
A stage similar to **beta**, when a software product is typically evaluated for performance, functionality, and compatibility in a non-mission-critical setting.
See Also beta.

error log
A type of **log** showing information about MySQL startup and critical runtime errors and **crash** information. For details, see Section 5.4.2, “The Error Log”.
See Also crash, log.

eviction
The process of removing an item from a cache or other temporary storage area, such as the `InnoDB` **buffer pool**. Often, but not always, uses the **LRU** algorithm to determine which item to remove. When a **dirty page** is evicted, its contents are **flushed** to disk, and any dirty **neighbor pages** might be flushed also.
See Also buffer pool, dirty page, flush, LRU, neighbor page.

exclusive lock
A kind of **lock** that prevents any other **transaction** from locking the same row. Depending on the transaction **isolation level**, this kind of lock might block other transactions from writing to the same row, or might also block other transactions from reading the same row. The default `InnoDB` isolation level, **REPEATABLE READ**, enables higher **concurrency** by allowing transactions to read rows that have exclusive locks, a technique known as **consistent read**.
See Also concurrency, consistent read, isolation level, lock, REPEATABLE READ, shared lock, transaction.

extent
A group of **pages** within a **tablespace**. For the default **page size** of 16KB, an extent contains 64 pages. In MySQL 5.6, the page size for an `InnoDB` instance can be 4KB, 8KB, or 16KB, controlled by the `innodb_page_size` configuration option. For 4KB, 8KB, and 16KB pages sizes, the extent size is always 1MB (or 1048576 bytes).

Support for 32KB and 64KB `InnoDB` page sizes was added in MySQL 5.7.6. For a 32KB page size, the extent size is 2MB. For a 64KB page size, the extent size is 4MB.

`InnoDB` features such as **segments**, **read-ahead** requests and the **doublewrite buffer** use I/O operations that read, write, allocate, or free data one extent at a time.
See Also doublewrite buffer, page, page size, read-ahead, segment, tablespace.

F

.frm file
A file containing the metadata, such as the table definition, of a MySQL table.

For backups, you must always keep the full set of `.frm` files along with the backup data to be able to restore tables that are altered or dropped after the backup.

Although each `InnoDB` table has a `.frm` file, `InnoDB` maintains its own table metadata in the **system tablespace**; the `.frm` files are not needed for `InnoDB` to operate on `InnoDB` tables.

`.frm` files are backed up by the **MySQL Enterprise Backup** product. These files must not be modified by an `ALTER TABLE` operation while the backup is taking place, which is why backups that include non-`InnoDB` tables perform a `FLUSH TABLES WITH READ LOCK` operation to freeze such activity while backing up `.frm` files. Restoring a backup can result in `.frm` files being created, changed, or removed to match the state of the database at the time of the backup.
See Also data dictionary, MySQL Enterprise Backup, system tablespace.

fanout
The increase or decrease in number of rows from adding a table during join processing. Suppose that a query of the form `SELECT ... FROM t1 INNER JOIN t2 ...` selects rows from table `t1`, then `t2`.

- If the join selects one row from `t2` per row in `t1`, the fanout for `t2` is 1.
- If the join selects two rows from `t2` per row in `t1`, the fanout for `t2` is 2.
- If the join selects one row from `t2` per two rows in `t1`, the fanout for `t2` is .5.

Fast Index Creation
A capability first introduced in the InnoDB Plugin, now part of MySQL in 5.5 and higher, that speeds up creation of `InnoDB` **secondary indexes** by avoiding the need to completely rewrite the associated table. The speedup applies to dropping secondary indexes also.

Because index maintenance can add performance overhead to many data transfer operations, consider doing operations such as `ALTER TABLE ... ENGINE=INNODB` or `INSERT INTO ... SELECT * FROM ...` without any secondary indexes in place, and creating the indexes afterward.

In MySQL 5.6, this feature becomes more general. You can read and write to tables while an index is being created, and many more kinds of `ALTER TABLE` operations can be performed without copying the table, without blocking **DML** operations, or both. Thus in MySQL 5.6 and higher, this set of features is referred to as **online DDL** rather than Fast Index Creation.

For related information, see Section 14.16, “InnoDB Fast Index Creation”, and InnoDB and Online DDL.
See Also DML, index, online DDL, secondary index.

fast shutdown
The default **shutdown** procedure for `InnoDB`, based on the configuration setting `innodb_fast_shutdown=1`. To save time, certain **flush** operations are skipped. This type of shutdown is safe during normal usage, because the flush operations are performed during the next startup, using the same mechanism as in **crash recovery**. In cases where the database is being shut down for an upgrade or downgrade, do a **slow shutdown** instead to ensure that all relevant changes are applied to the **data files** during the shutdown.
See Also crash recovery, data files, flush, shutdown, slow shutdown.

file format
The file format for `InnoDB` tables, enabled using the `innodb_file_format` configuration option. Supported file formats are **Antelope** and **Barracuda**. Antelope is the original `InnoDB` file format and supports the **REDUNDANT** and **COMPACT** row formats. Barracuda is the newer `InnoDB` file format and supports the **COMPRESSED** and **DYNAMIC** row formats.
See Also Antelope, Barracuda, file-per-table, .ibd file, ibdata file, row format.

file-per-table
A general name for the setting controlled by the `innodb_file_per_table` option, which is an important configuration option that affects aspects of `InnoDB` file storage, availability of features, and I/O characteristics. As of MySQL 5.6.7, `innodb_file_per_table` is enabled by default.

With the `innodb_file_per_table` option enabled, you can create a table in its own **.ibd file** rather than in the shared **ibdata files** of the **system tablespace**. When table data is stored in an individual **.ibd file**, you have more flexibility to choose **row formats** required for features such as data **compression**. The `TRUNCATE TABLE` operation is also faster, and reclaimed space can be used by the operating system rather than remaining reserved for `InnoDB`.

The **MySQL Enterprise Backup** product is more flexible for tables that are in their own files. For example, tables can be excluded from a backup, but only if they are in separate files. Thus, this setting is suitable for tables that are backed up less frequently or on a different schedule.
See Also compressed row format, compression, file format, .ibd file, ibdata file, innodb_file_per_table, MySQL Enterprise Backup, row format, system tablespace.

fill factor
In an `InnoDB` **index**, the proportion of a **page** that is taken up by index data before the page is split. The unused space when index data is first divided between pages allows for rows to be updated with longer string values without requiring expensive index maintenance operations. If the fill factor is too low, the index consumes more space than needed, causing extra I/O overhead when reading the index. If the fill factor is too high, any update that increases the length of column values can cause extra I/O overhead for index maintenance. See Section 14.11.2.2, "The Physical Structure of an InnoDB Index" for more information.
See Also index, page.

fixed row format
This row format is used by the `MyISAM` storage engine, not by `InnoDB`. If you create an `InnoDB` table with the option `ROW_FORMAT=FIXED` in MySQL 5.7.6 or earlier, `InnoDB` uses the **compact row format** instead, although the `FIXED` value might still show up in output such as `SHOW TABLE STATUS` reports. As of MySQL 5.7.7, `InnoDB` returns an error if `ROW_FORMAT=FIXED` is specified.
See Also compact row format, row format.

flush
To write changes to the database files, that had been buffered in a memory area or a temporary disk storage area. The `InnoDB` storage structures that are periodically flushed include the **redo log**, the **undo log**, and the **buffer pool**.

Flushing can happen because a memory area becomes full and the system needs to free some space, because a **commit** operation means the changes from a transaction can be finalized, or because a **slow shutdown** operation means that all outstanding work should be finalized. When it is not critical to flush all the buffered data at once, `InnoDB` can use a technique called **fuzzy checkpointing** to flush small batches of pages to spread out the I/O overhead.
See Also buffer pool, commit, fuzzy checkpointing, redo log, slow shutdown, undo log.

flush list
An internal `InnoDB` data structure that tracks **dirty pages** in the **buffer pool**: that is, **pages** that have been changed and need to be written back out to disk. This data structure is updated frequently by `InnoDB` internal **mini-transactions**, and so is protected by its own **mutex** to allow concurrent access to the buffer pool.
See Also buffer pool, dirty page, LRU, mini-transaction, mutex, page, page cleaner.

foreign key
A type of pointer relationship, between rows in separate `InnoDB` tables. The foreign key relationship is defined on one column in both the **parent table** and the **child table**.

In addition to enabling fast lookup of related information, foreign keys help to enforce **referential integrity**, by preventing any of these pointers from becoming invalid as data is inserted, updated, and deleted. This enforcement mechanism is a type of **constraint**. A row that points to another table cannot be inserted if the associated foreign key value does not exist in the other table. If a row is deleted or its foreign key value changed, and rows in another table point to that foreign key value, the foreign key can be set up to prevent the deletion, cause the corresponding column values in the other table to become **null**, or automatically delete the corresponding rows in the other table.

One of the stages in designing a **normalized** database is to identify data that is duplicated, separate that data into a new table, and set up a foreign key relationship so that the multiple tables can be queried like a single table, using a **join** operation.
See Also child table, FOREIGN KEY constraint, join, normalized, NULL, parent table, referential integrity, relational.

FOREIGN KEY constraint
The type of **constraint** that maintains database consistency through a **foreign key** relationship. Like other kinds of constraints, it can prevent data from being inserted or updated if data would become inconsistent; in

this case, the inconsistency being prevented is between data in multiple tables. Alternatively, when a **DML** operation is performed, `FOREIGN KEY` constraints can cause data in **child rows** to be deleted, changed to different values, or set to **null**, based on the `ON CASCADE` option specified when creating the foreign key.
See Also child table, constraint, DML, foreign key, NULL.

FTS
In most contexts, an acronym for **full-text search**. Sometimes in performance discussions, an acronym for **full table scan**.
See Also full table scan, full-text search.

full backup
A **backup** that includes all the **tables** in each MySQL **database**, and all the databases in a MySQL **instance**. Contrast with **partial backup**.
See Also backup, database, instance, partial backup, table.

full table scan
An operation that requires reading the entire contents of a table, rather than just selected portions using an **index**. Typically performed either with small lookup tables, or in data warehousing situations with large tables where all available data is aggregated and analyzed. How frequently these operations occur, and the sizes of the tables relative to available memory, have implications for the algorithms used in query optimization and managing the **buffer pool**.

The purpose of indexes is to allow lookups for specific values or ranges of values within a large table, thus avoiding full table scans when practical.
See Also buffer pool, index.

full-text search
The MySQL feature for finding words, phrases, Boolean combinations of words, and so on within table data, in a faster, more convenient, and more flexible way than using the SQL `LIKE` operator or writing your own application-level search algorithm. It uses the SQL function `MATCH()` and **FULLTEXT indexes**.
See Also FULLTEXT index.

FULLTEXT index
The special kind of **index** that holds the **search index** in the MySQL **full-text search** mechanism. Represents the words from values of a column, omitting any that are specified as **stopwords**. Originally, only available for `MyISAM` tables. Starting in MySQL 5.6.4, it is also available for **InnoDB** tables.
See Also full-text search, index, InnoDB, search index, stopword.

fuzzy checkpointing
A technique that **flushes** small batches of **dirty pages** from the **buffer pool**, rather than flushing all dirty pages at once which would disrupt database processing.
See Also buffer pool, dirty page, flush.

G

GA
"Generally available", the stage when a software product leaves **beta** and is available for sale, official support, and production use.
See Also beta.

gap
A place in an `InnoDB` **index** data structure where new values could be inserted. When you lock a set of rows with a statement such as `SELECT ... FOR UPDATE`, `InnoDB` can create locks that apply to the gaps as well as the actual values in the index. For example, if you select all values greater than 10 for update, a gap lock prevents another transaction from inserting a new value that is greater than 10. The **supremum record** and **infimum record** represent the gaps containing all values greater than or less than all the current index values.
See Also concurrency, gap lock, index, infimum record, isolation level, supremum record.

gap lock
A **lock** on a **gap** between index records, or a lock on the gap before the first or after the last index record. For example, `SELECT c1 FROM t WHERE c1 BETWEEN 10 and 20 FOR UPDATE;` prevents other transactions from inserting a value of 15 into the column `t.c1`, whether or not there was already any such value in the column, because the gaps between all existing values in the range are locked. Contrast with **record lock** and **next-key lock**.

Gap locks are part of the tradeoff between performance and **concurrency**, and are used in some transaction **isolation levels** and not others.
See Also gap, infimum record, lock, next-key lock, record lock, supremum record.

general log
See general query log.

general query log
A type of **log** used for diagnosis and troubleshooting of SQL statements processed by the MySQL server. Can be stored in a file or in a database table. You must enable this feature through the `general_log` configuration option to use it. You can disable it for a specific connection through the `sql_log_off` configuration option.

Records a broader range of queries than the **slow query log**. Unlike the **binary log**, which is used for replication, the general query log contains `SELECT` statements and does not maintain strict ordering. For more information, see Section 5.4.3, “The General Query Log”.
See Also binary log, log, slow query log.

general tablespace
A shared `InnoDB` **tablespace** created using `CREATE TABLESPACE` syntax. General tablespaces can be created outside of the MySQL data directory, are capable of holding multiple **tables**, and support tables of all row formats. General tablespaces were introduced in MySQL 5.7.6.

Tables are added to a general tablespace using `CREATE TABLE` *`tbl_name`* `... TABLESPACE [=]` *`tablespace_name`* or `ALTER TABLE` *`tbl_name`* `TABLESPACE [=]` *`tablespace_name`* syntax.

Contrast with **system tablespace** and **file-per-table** tablespace.

For more information, see InnoDB General Tablespaces.
See Also file-per-table, system tablespace, table, tablespace.

global transaction
A type of **transaction** involved in **XA** operations. It consists of several actions that are transactional in themselves, but that all must either complete successfully as a group, or all be rolled back as a group. In essence, this extends **ACID** properties “up a level” so that multiple ACID transactions can be executed in concert as components of a global operation that also has ACID properties.
See Also ACID, transaction, XA.

group commit
An `InnoDB` optimization that performs some low-level I/O operations (log write) once for a set of **commit** operations, rather than flushing and syncing separately for each commit.
See Also binary log, commit.

H

hash index
A type of **index** intended for queries that use equality operators, rather than range operators such as greater-than or `BETWEEN`. It is available for `MEMORY` tables. Although hash indexes are the default for `MEMORY` tables for historic reasons, that storage engine also supports **B-tree** indexes, which are often a better choice for general-purpose queries.

MySQL includes a variant of this index type, the **adaptive hash index**, that is constructed automatically for `InnoDB` tables if needed based on runtime conditions.

See Also adaptive hash index, B-tree, index, InnoDB.

HDD
Acronym for “hard disk drive”. Refers to storage media using spinning platters, usually when comparing and contrasting with **SSD**. Its performance characteristics can influence the throughput of a **disk-based** workload.
See Also disk-based, SSD.

heartbeat
A periodic message that is sent to indicate that a system is functioning properly. In a **replication** context, if the **master** stops sending such messages, one of the **slaves** can take its place. Similar techniques can be used between the servers in a cluster environment, to confirm that all of them are operating properly.
See Also master server, replication.

high-water mark
A value representing an upper limit, either a hard limit that should not be exceeded at runtime, or a record of the maximum value that was actually reached. Contrast with **low-water mark**.
See Also low-water mark.

history list
A list of **transactions** with delete-marked records scheduled to be processed by the `InnoDB` **purge** operation. Recorded in the **undo log**. The length of the history list is reported by the command `SHOW ENGINE INNODB STATUS`. If the history list grows longer than the value of the `innodb_max_purge_lag` configuration option, each **DML** operation is delayed slightly to allow the purge operation to finish **flushing** the deleted records.

Also known as **purge lag**.
See Also DML, flush, purge, purge lag, rollback segment, transaction, undo log.

hole punching
Releasing empty blocks from a page. The `InnoDB` **transparent page compression** feature relies on hole punching support. For more information, see InnoDB Page Compression.
See Also sparse file, transparent page compression.

hot
A condition where a row, table, or internal data structure is accessed so frequently, requiring some form of locking or mutual exclusion, that it results in a performance or scalability issue.

Although “hot” typically indicates an undesirable condition, a **hot backup** is the preferred type of backup.
See Also hot backup.

hot backup
A backup taken while the database is running and applications are reading and writing to it. The backup involves more than simply copying data files: it must include any data that was inserted or updated while the backup was in process; it must exclude any data that was deleted while the backup was in process; and it must ignore any changes that were not committed.

The Oracle product that performs hot backups, of `InnoDB` tables especially but also tables from `MyISAM` and other storage engines, is known as **MySQL Enterprise Backup**.

The hot backup process consists of two stages. The initial copying of the data files produces a **raw backup**. The **apply** step incorporates any changes to the database that happened while the backup was running. Applying the changes produces a **prepared** backup; these files are ready to be restored whenever necessary.
See Also apply, MySQL Enterprise Backup, prepared backup, raw backup.

I

.ibd file
The data file for **file-per-table** tablespaces and general tablespaces. File-per-table tablespace `.idb` files contain a single table and associated index data. **General tablespace** `.idb` files may contain table and index data for multiple tables. General tablespaces were introduced in MySQL 5.7.6.

The `.ibd` file extension does not apply to the **system tablespace**, which consists of one or more **ibdata files**.

If a file-per-table tablespace or general tablespace is created with the `DATA DIRECTORY =` clause, the `.ibd` file is located at the specified path, outside the normal data directory, and is pointed to by a **.isl file**.

When a `.ibd` file is included in a compressed backup by the **MySQL Enterprise Backup** product, the compressed equivalent is a `.ibz` file.
See Also database, file-per-table, general tablespace, ibdata file, .ibz file, innodb_file_per_table, .isl file, MySQL Enterprise Backup, system tablespace.

.ibz file
When the **MySQL Enterprise Backup** product performs a **compressed backup**, it transforms each **tablespace** file that is created using the **file-per-table** setting from a `.ibd` extension to a `.ibz` extension.

The compression applied during backup is distinct from the **compressed row format** that keeps table data compressed during normal operation. A compressed backup operation skips the compression step for a tablespace that is already in compressed row format, as compressing a second time would slow down the backup but produce little or no space savings.
See Also compressed backup, compressed row format, file-per-table, .ibd file, MySQL Enterprise Backup, tablespace.

.isl file
A file that specifies the location of an **.ibd file** for an `InnoDB` table created with the `DATA DIRECTORY =` clause in MySQL 5.6 and higher, or with the `CREATE TABLESPACE ... ADD DATAFILE` clause in MySQL 5.7.8 and higher. It functions like a symbolic link, without the platform restrictions of the actual symbolic link mechanism. You can store `InnoDB` **tablespaces** outside the **database** directory, for example, on an especially large or fast storage device depending on the usage of the table. For details, see Creating File-Per-Table Tablespaces Outside the Data Directory, and InnoDB General Tablespaces.
See Also database, .ibd file, table, tablespace.

I/O-bound
See disk-bound.

ib-file set
The set of files managed by `InnoDB` within a MySQL database: the **system tablespace**, **file-per-table** tablespace files, and **redo log** files. Depending on MySQL version and `InnoDB` configuration, may also include **general tablespace**, **temporary tablespace**, and **undo tablespace** files. This term is sometimes used in detailed discussions of `InnoDB` file structures and formats to refer to the set of files managed by `InnoDB` within a MySQL database.
See Also database, file-per-table, general tablespace, redo log, system tablespace, temporary tablespace, undo tablespace.

ibbackup_logfile
A supplemental backup file created by the **MySQL Enterprise Backup** product during a **hot backup** operation. It contains information about any data changes that occurred while the backup was running. The initial backup files, including `ibbackup_logfile`, are known as a **raw backup**, because the changes that occurred during the backup operation are not yet incorporated. After you perform the **apply** step to the raw backup files, the resulting files do include those final data changes, and are known as a **prepared backup**. At this stage, the `ibbackup_logfile` file is no longer necessary.
See Also apply, hot backup, MySQL Enterprise Backup, prepared backup, raw backup.

ibdata file
A set of files with names such as `ibdata1`, `ibdata2`, and so on, that make up the InnoDB **system tablespace**. These files contain metadata about `InnoDB` tables, (the `InnoDB` **data dictionary**), and the storage areas for one or more **undo logs**, the **change buffer**, and the **doublewrite buffer**. They also can contain some or all of the table data also (depending on whether the **file-per-table** mode is in effect when each table is created). When the **innodb_file_per_table** option is enabled, data and indexes for newly created tables are stored in separate **.ibd files** rather than in the system tablespace.

The growth of the `ibdata` files is influenced by the `innodb_autoextend_increment` configuration option.
See Also change buffer, data dictionary, doublewrite buffer, file-per-table, .ibd file, innodb_file_per_table, system tablespace, undo log.

ibtmp file
The `InnoDB` **temporary tablespace data file** for non-compressed `InnoDB` **temporary tables** and related objects. The configuration file option, `innodb_temp_data_file_path`, allows users to define a relative path for the temporary tablespace data file. If `innodb_temp_data_file_path` is not specified, the default behavior is to create a single auto-extending 12MB data file named `ibtmp1` in the data directory, alongside `ibdata1`.
See Also data files, temporary table, temporary tablespace.

ib_logfile
A set of files, typically named `ib_logfile0` and `ib_logfile1`, that form the **redo log**. Also sometimes referred to as the **log group**. These files record statements that attempt to change data in `InnoDB` tables. These statements are replayed automatically to correct data written by incomplete transactions, on startup following a crash.

This data cannot be used for manual recovery; for that type of operation, use the **binary log**.
See Also binary log, log group, redo log.

ilist
Within an `InnoDB` **FULLTEXT index**, the data structure consisting of a document ID and positional information for a token (that is, a particular word).
See Also FULLTEXT index.

implicit row lock
A row lock that `InnoDB` acquires to ensure consistency, without you specifically requesting it.
See Also row lock.

in-memory database
A type of database system that maintains data in memory, to avoid overhead due to disk I/O and translation between disk blocks and memory areas. Some in-memory databases sacrifice durability (the “D” in the **ACID** design philosophy) and are vulnerable to hardware, power, and other types of failures, making them more suitable for read-only operations. Other in-memory databases do use durability mechanisms such as logging changes to disk or using non-volatile memory.

MySQL features that address the same kinds of memory-intensive processing include the `InnoDB` **buffer pool**, **adaptive hash index**, and **read-only transaction** optimization, the `MEMORY` storage engine, the `MyISAM` key cache, and the MySQL query cache.
See Also ACID, adaptive hash index, buffer pool, disk-based, read-only transaction.

incremental backup
A type of **hot backup**, performed by the **MySQL Enterprise Backup** product, that only saves data changed since some point in time. Having a full backup and a succession of incremental backups lets you reconstruct backup data over a long period, without the storage overhead of keeping several full backups on hand. You can restore the full backup and then apply each of the incremental backups in succession, or you can keep the full backup up-to-date by applying each incremental backup to it, then perform a single restore operation.

The granularity of changed data is at the **page** level. A page might actually cover more than one row. Each changed page is included in the backup.
See Also hot backup, MySQL Enterprise Backup, page.

index
A data structure that provides a fast lookup capability for **rows** of a **table**, typically by forming a tree structure (**B-tree)** representing all the values of a particular **column** or set of columns.

`InnoDB` tables always have a **clustered index** representing the **primary key**. They can also have one or more **secondary indexes** defined on one or more columns. Depending on their structure, secondary indexes can be classified as **partial**, **column**, or **composite** indexes.

Indexes are a crucial aspect of **query** performance. Database architects design tables, queries, and indexes to allow fast lookups for data needed by applications. The ideal database design uses a **covering index** where practical; the query results are computed entirely from the index, without reading the actual table data. Each **foreign key** constraint also requires an index, to efficiently check whether values exist in both the **parent** and **child** tables.

Although a B-tree index is the most common, a different kind of data structure is used for **hash indexes**, as in the `MEMORY` storage engine and the `InnoDB` **adaptive hash index**. **R-tree** indexes are used for spatial indexing of multi-dimensional information.
See Also adaptive hash index, B-tree, child table, clustered index, column index, composite index, covering index, foreign key, hash index, parent table, partial index, primary key, query, R-tree, row, secondary index, table.

index cache
A memory area that holds the token data for `InnoDB` **full-text search**. It buffers the data to minimize disk I/O when data is inserted or updated in columns that are part of a **FULLTEXT index**. The token data is written to disk when the index cache becomes full. Each `InnoDB` `FULLTEXT` index has its own separate index cache, whose size is controlled by the configuration option `innodb_ft_cache_size`.
See Also full-text search, FULLTEXT index.

index condition pushdown
Index condition pushdown (ICP) is an optimization that pushes part of a `WHERE` condition down to the storage engine if parts of the condition can be evaluated using fields from the **index**. ICP can reduce the number of times the **storage engine** must access the base table and the number of times the MySQL server must access the storage engine. For more information, see Index Condition Pushdown Optimization.
See Also index, storage engine.

index hint
Extended SQL syntax for overriding the **indexes** recommended by the optimizer. For example, the `FORCE INDEX`, `USE INDEX`, and `IGNORE INDEX` clauses. Typically used when indexed columns have unevenly distributed values, resulting in inaccurate **cardinality** estimates.
See Also cardinality, index.

index prefix
In an **index** that applies to multiple columns (known as a **composite index**), the initial or leading columns of the index. A query that references the first 1, 2, 3, and so on columns of a composite index can use the index, even if the query does not reference all the columns in the index.
See Also composite index, index.

index statistics
See statistics.

infimum record
A **pseudo-record** in an **index**, representing the **gap** below the smallest value in that index. If a transaction has a statement such as `SELECT ... FROM ... WHERE col < 10 FOR UPDATE;`, and the smallest value in the column is 5, it is a lock on the infimum record that prevents other transactions from inserting even smaller values such as 0, -10, and so on.
See Also gap, index, pseudo-record, supremum record.

INFORMATION_SCHEMA
The name of the **database** that provides a query interface to the MySQL **data dictionary**. (This name is defined by the ANSI SQL standard.) To examine information (metadata) about the database, you can query tables such as `INFORMATION_SCHEMA.TABLES` and `INFORMATION_SCHEMA.COLUMNS`, rather than using `SHOW` commands that produce unstructured output.

The `INFORMATION_SCHEMA` database also contains tables specific to **InnoDB** that provide a query interface to the `InnoDB` data dictionary. You use these tables not to see how the database is structured, but to get real-time information about the workings of `InnoDB` tables to help with performance monitoring, tuning, and troubleshooting.

See Also data dictionary, database, InnoDB.

InnoDB
: A MySQL component that combines high performance with **transactional** capability for reliability, robustness, and concurrent access. It embodies the **ACID** design philosophy. Represented as a **storage engine**; it handles tables created or altered with the `ENGINE=INNODB` clause. See Chapter 14, *The InnoDB Storage Engine* for architectural details and administration procedures, and Section 8.5, "Optimizing for InnoDB Tables" for performance advice.

  In MySQL 5.5 and higher, `InnoDB` is the default storage engine for new tables and the `ENGINE=INNODB` clause is not required.

  `InnoDB` tables are ideally suited for **hot backups**. See Section 25.2, "MySQL Enterprise Backup Overview" for information about the **MySQL Enterprise Backup** product for backing up MySQL servers without interrupting normal processing.
  See Also ACID, hot backup, MySQL Enterprise Backup, storage engine, transaction.

innodb_autoinc_lock_mode
: The `innodb_autoinc_lock_mode` option controls the algorithm used for **auto-increment locking**. When you have an auto-incrementing **primary key**, you can use statement-based replication only with the setting `innodb_autoinc_lock_mode=1`. This setting is known as *consecutive* lock mode, because multi-row inserts within a transaction receive consecutive auto-increment values. If you have `innodb_autoinc_lock_mode=2`, which allows higher concurrency for insert operations, use row-based replication rather than statement-based replication. This setting is known as *interleaved* lock mode, because multiple multi-row insert statements running at the same time can receive **auto-increment** values that are interleaved. The setting `innodb_autoinc_lock_mode=0` should not be used except for compatibility purposes.

  Consecutive lock mode (`innodb_autoinc_lock_mode=1`) is the default setting prior to MySQL 8.0.3. As of MySQL 8.0.3, interleaved lock mode (`innodb_autoinc_lock_mode=2`) is the default, which reflects the change from statement-based to row-based replication as the default replication type.
  See Also auto-increment, auto-increment locking, mixed-mode insert, primary key.

innodb_file_format
: The `innodb_file_format` option defines the **file format** to use for new `InnoDB` file-per-table **tablespaces**. Currently, you can specify the **Antelope** and **Barracuda** file formats.
  See Also Antelope, Barracuda, file format, file-per-table, general tablespace, innodb_file_per_table, system tablespace, tablespace.

innodb_file_per_table
: An important configuration option that affects many aspects of `InnoDB` file storage, availability of features, and I/O characteristics. In MySQL 5.6.7 and higher, it is enabled by default. The `innodb_file_per_table` option turns on **file-per-table** mode. With this mode enabled, a newly created `InnoDB` table and associated indexes can be stored in a file-per-table **.ibd file**, outside the **system tablespace**.

  This option affects the performance and storage considerations for a number of SQL statements, such as `DROP TABLE` and `TRUNCATE TABLE`.

  Enabling the `innodb_file_per_table` option allows you to take advantage of features such as table **compression** and named-table backups in **MySQL Enterprise Backup**.

  For more information, see `innodb_file_per_table`, and Section 14.10.4, "InnoDB File-Per-Table Tablespaces".
  See Also compression, file-per-table, .ibd file, MySQL Enterprise Backup, system tablespace.

innodb_lock_wait_timeout
: The `innodb_lock_wait_timeout` option sets the balance between **waiting** for shared resources to become available, or giving up and handling the error, retrying, or doing alternative processing in your application. Rolls back any `InnoDB` transaction that waits more than a specified time to acquire a **lock**.

Especially useful if **deadlocks** are caused by updates to multiple tables controlled by different storage engines; such deadlocks are not **detected** automatically.
See Also deadlock, deadlock detection, lock, wait.

innodb_strict_mode
The `innodb_strict_mode` option controls whether `InnoDB` operates in **strict mode**, where conditions that are normally treated as warnings, cause errors instead (and the underlying statements fail).
See Also strict mode.

insert
One of the primary **DML** operations in **SQL**. The performance of inserts is a key factor in **data warehouse** systems that load millions of rows into tables, and **OLTP** systems where many concurrent connections might insert rows into the same table, in arbitrary order. If insert performance is important to you, you should learn about **InnoDB** features such as the **insert buffer** used in **change buffering**, and **auto-increment** columns.
See Also auto-increment, change buffering, data warehouse, DML, InnoDB, insert buffer, OLTP, SQL.

insert buffer
The former name of the **change buffer**. In MySQL 5.5, support was added for buffering changes to secondary index pages for `DELETE` and `UPDATE` operations. Previously, only changes resulting from `INSERT` operations were buffered. The preferred term is now *change buffer*.
See Also change buffer, change buffering.

insert buffering
The technique of storing changes to secondary index pages, resulting from `INSERT` operations, in the **change buffer** rather than writing the changes immediately, so that the physical writes can be performed to minimize random I/O. It is one of the types of **change buffering**; the others are **delete buffering** and **purge buffering**.

Insert buffering is not used if the secondary index is **unique**, because the uniqueness of new values cannot be verified before the new entries are written out. Other kinds of change buffering do work for unique indexes.
See Also change buffer, change buffering, delete buffering, insert buffer, purge buffering, unique index.

insert intention lock
A type of **gap lock** that is set by `INSERT` operations prior to row insertion. This type of **lock** signals the intent to insert in such a way that multiple transactions inserting into the same index gap need not wait for each other if they are not inserting at the same position within the gap. For more information, see Section 14.8.1, “InnoDB Locking”.
See Also gap lock, lock, next-key lock.

instance
A single **mysqld** daemon managing a **data directory** representing one or more **databases** with a set of **tables**. It is common in development, testing, and some **replication** scenarios to have multiple instances on the same **server** machine, each managing its own data directory and listening on its own port or socket. With one instance running a **disk-bound** workload, the server might still have extra CPU and memory capacity to run additional instances.
See Also data directory, database, disk-bound, mysqld, replication, server, table.

instrumentation
Modifications at the source code level to collect performance data for tuning and debugging. In MySQL, data collected by instrumentation is exposed through an SQL interface using the `INFORMATION_SCHEMA` and `PERFORMANCE_SCHEMA` databases.
See Also INFORMATION_SCHEMA, Performance Schema.

intention exclusive lock
See intention lock.

intention lock
A kind of **lock** that applies to the table, used to indicate the kind of lock the **transaction** intends to acquire on rows in the table. Different transactions can acquire different kinds of intention locks on the same table,

but the first transaction to acquire an *intention exclusive* (IX) lock on a table prevents other transactions from acquiring any S or X locks on the table. Conversely, the first transaction to acquire an *intention shared* (IS) lock on a table prevents other transactions from acquiring any X locks on the table. The two-phase process allows the lock requests to be resolved in order, without blocking locks and corresponding operations that are compatible. For more information about this locking mechanism, see Section 14.8.1, “InnoDB Locking”.
See Also lock, lock mode, locking, transaction.

intention shared lock
See intention lock.

inverted index
A data structure optimized for document retrieval systems, used in the implementation of `InnoDB` **full-text search**. The `InnoDB` **FULLTEXT index**, implemented as an inverted index, records the position of each word within a document, rather than the location of a table row. A single column value (a document stored as a text string) is represented by many entries in the inverted index.
See Also full-text search, FULLTEXT index, ilist.

IOPS
Acronym for **I/O operations per second**. A common measurement for busy systems, particularly **OLTP** applications. If this value is near the maximum that the storage devices can handle, the application can become **disk-bound**, limiting **scalability**.
See Also disk-bound, OLTP, scalability.

isolation level
One of the foundations of database processing. Isolation is the **I** in the acronym **ACID**; the isolation level is the setting that fine-tunes the balance between performance and reliability, consistency, and reproducibility of results when multiple **transactions** are making changes and performing queries at the same time.

From highest amount of consistency and protection to the least, the isolation levels supported by InnoDB are: **SERIALIZABLE**, **REPEATABLE READ**, **READ COMMITTED**, and **READ UNCOMMITTED**.

With `InnoDB` tables, many users can keep the default isolation level (*REPEATABLE READ*) for all operations. Expert users might choose the **READ COMMITTED** level as they push the boundaries of scalability with **OLTP** processing, or during data warehousing operations where minor inconsistencies do not affect the aggregate results of large amounts of data. The levels on the edges (**SERIALIZABLE** and **READ UNCOMMITTED**) change the processing behavior to such an extent that they are rarely used.
See Also ACID, OLTP, READ COMMITTED, READ UNCOMMITTED, REPEATABLE READ, SERIALIZABLE, transaction.

J

join
A **query** that retrieves data from more than one table, by referencing columns in the tables that hold identical values. Ideally, these columns are part of an `InnoDB` **foreign key** relationship, which ensures **referential integrity** and that the join columns are **indexed**. Often used to save space and improve query performance by replacing repeated strings with numeric IDs, in a **normalized** data design.
See Also foreign key, index, normalized, query, referential integrity.

K

KEY_BLOCK_SIZE
An option to specify the size of data pages within an `InnoDB` table that uses **compressed row format**. The default is 8 kilobytes. Lower values risk hitting internal limits that depend on the combination of row size and compression percentage.

For `MyISAM` tables, `KEY_BLOCK_SIZE` optionally specifies the size in bytes to use for index key blocks. The value is treated as a hint; a different size could be used if necessary. A `KEY_BLOCK_SIZE` value specified for an individual index definition overrides a table-level `KEY_BLOCK_SIZE` value.

See Also compressed row format.

L

latch
: A lightweight structure used by `InnoDB` to implement a **lock** for its own internal memory structures, typically held for a brief time measured in milliseconds or microseconds. A general term that includes both **mutexes** (for exclusive access) and **rw-locks** (for shared access). Certain latches are the focus of `InnoDB` performance tuning. Statistics about latch use and contention are available through the **Performance Schema** interface.
See Also lock, locking, mutex, Performance Schema, rw-lock.

list
: The `InnoDB` **buffer pool** is represented as a list of memory **pages**. The list is reordered as new pages are accessed and enter the buffer pool, as pages within the buffer pool are accessed again and are considered newer, and as pages that are not accessed for a long time are **evicted** from the buffer pool. The buffer pool is divided into **sublists**, and the replacement policy is a variation of the familiar **LRU** technique.
See Also buffer pool, eviction, LRU, page, sublist.

lock
: The high-level notion of an object that controls access to a resource, such as a table, row, or internal data structure, as part of a **locking** strategy. For intensive performance tuning, you might delve into the actual structures that implement locks, such as **mutexes** and **latches**.
See Also latch, lock mode, locking, mutex.

lock escalation
: An operation used in some database systems that converts many **row locks** into a single **table lock**, saving memory space but reducing concurrent access to the table. `InnoDB` uses a space-efficient representation for row locks, so that **lock** escalation is not needed.
See Also locking, row lock, table lock.

lock mode
: A shared (S) **lock** allows a **transaction** to read a row. Multiple transactions can acquire an S lock on that same row at the same time.

  An exclusive (X) lock allows a transaction to update or delete a row. No other transaction can acquire any kind of lock on that same row at the same time.

  Intention locks apply to the table, and are used to indicate what kind of lock the transaction intends to acquire on rows in the table. Different transactions can acquire different kinds of intention locks on the same table, but the first transaction to acquire an intention exclusive (IX) lock on a table prevents other transactions from acquiring any S or X locks on the table. Conversely, the first transaction to acquire an intention shared (IS) lock on a table prevents other transactions from acquiring any X locks on the table. The two-phase process allows the lock requests to be resolved in order, without blocking locks and corresponding operations that are compatible.
  See Also intention lock, lock, locking, transaction.

locking
: The system of protecting a **transaction** from seeing or changing data that is being queried or changed by other transactions. The **locking** strategy must balance reliability and consistency of database operations (the principles of the **ACID** philosophy) against the performance needed for good **concurrency**. Fine-tuning the locking strategy often involves choosing an **isolation level** and ensuring all your database operations are safe and reliable for that isolation level.
See Also ACID, concurrency, isolation level, locking, transaction.

locking read
: A `SELECT` statement that also performs a **locking** operation on an `InnoDB` table. Either `SELECT ... FOR UPDATE` or `SELECT ... LOCK IN SHARE MODE`. It has the potential to produce a **deadlock**, depending on

the **isolation level** of the transaction. The opposite of a **non-locking read**. Not allowed for global tables in a **read-only transaction**.

`SELECT ... FOR SHARE` replaces `SELECT ... LOCK IN SHARE MODE` in MySQL 8.0.1, but `LOCK IN SHARE MODE` remains available for backward compatibility.

See Section 14.8.2.4, “Locking Reads”.
See Also deadlock, isolation level, locking, non-locking read, read-only transaction.

log

In the `InnoDB` context, “log” or “log files” typically refers to the **redo log** represented by the **ib_logfile*N*** files. Another type of `InnoDB` log is the **undo log**, which is a storage area that holds copies of data modified by active transactions.

Other kinds of logs that are important in MySQL are the **error log** (for diagnosing startup and runtime problems), **binary log** (for working with replication and performing point-in-time restores), the **general query log** (for diagnosing application problems), and the **slow query log** (for diagnosing performance problems).
See Also binary log, error log, general query log, ib_logfile, redo log, slow query log, undo log.

log buffer

The memory area that holds data to be written to the **log files** that make up the **redo log**. It is controlled by the `innodb_log_buffer_size` configuration option.
See Also log file, redo log.

log file

One of the **ib_logfile*N*** files that make up the **redo log**. Data is written to these files from the **log buffer** memory area.
See Also ib_logfile, log buffer, redo log.

log group

The set of files that make up the **redo log**, typically named `ib_logfile0` and `ib_logfile1`. (For that reason, sometimes referred to collectively as **ib_logfile**.)
See Also ib_logfile, redo log.

logical

A type of operation that involves high-level, abstract aspects such as tables, queries, indexes, and other SQL concepts. Typically, logical aspects are important to make database administration and application development convenient and usable. Contrast with **physical**.
See Also logical backup, physical.

logical backup

A **backup** that reproduces table structure and data, without copying the actual data files. For example, the **`mysqldump`** command produces a logical backup, because its output contains statements such as `CREATE TABLE` and `INSERT` that can re-create the data. Contrast with **physical backup**. A logical backup offers flexibility (for example, you could edit table definitions or insert statements before restoring), but can take substantially longer to **restore** than a physical backup.
See Also backup, mysqldump, physical backup, restore.

loose_

A prefix added to `InnoDB` configuration options after server **startup**, so any new configuration options not recognized by the current level of MySQL do not cause a startup failure. MySQL processes configuration options that start with this prefix, but gives a warning rather than a failure if the part after the prefix is not a recognized option.
See Also startup.

low-water mark

A value representing a lower limit, typically a threshold value at which some corrective action begins or becomes more aggressive. Contrast with **high-water mark**.
See Also high-water mark.

LRU
: An acronym for “least recently used”, a common method for managing storage areas. The items that have not been used recently are **evicted** when space is needed to cache newer items. `InnoDB` uses the LRU mechanism by default to manage the **pages** within the **buffer pool**, but makes exceptions in cases where a page might be read only a single time, such as during a **full table scan**. This variation of the LRU algorithm is called the **midpoint insertion strategy**. For more information, see Section 14.9.2.1, “The InnoDB Buffer Pool”.
See Also buffer pool, eviction, full table scan, midpoint insertion strategy, page.

LSN
: Acronym for “log sequence number”. This arbitrary, ever-increasing value represents a point in time corresponding to operations recorded in the **redo log**. (This point in time is regardless of **transaction** boundaries; it can fall in the middle of one or more transactions.) It is used internally by `InnoDB` during **crash recovery** and for managing the **buffer pool**.

  Prior to MySQL 5.6.3, the LSN was a 4-byte unsigned integer. The LSN became an 8-byte unsigned integer in MySQL 5.6.3 when the redo log file size limit increased from 4GB to 512GB, as additional bytes were required to store extra size information. Applications built on MySQL 5.6.3 or later that use LSN values should use 64-bit rather than 32-bit variables to store and compare LSN values.

  In the **MySQL Enterprise Backup** product, you can specify an LSN to represent the point in time from which to take an **incremental backup**. The relevant LSN is displayed by the output of the `mysqlbackup` command. Once you have the LSN corresponding to the time of a full backup, you can specify that value to take a subsequent incremental backup, whose output contains another LSN for the next incremental backup.
  See Also buffer pool, crash recovery, incremental backup, MySQL Enterprise Backup, redo log, transaction.

M

.MRG file
: A file containing references to other tables, used by the `MERGE` storage engine. Files with this extension are always included in backups produced by the `mysqlbackup` command of the **MySQL Enterprise Backup** product.
See Also MySQL Enterprise Backup, mysqlbackup command.

.MYD file
: A file that MySQL uses to store data for a `MyISAM` table.
See Also .MYI file, MySQL Enterprise Backup, mysqlbackup command.

.MYI file
: A file that MySQL uses to store indexes for a `MyISAM` table.
See Also .MYD file, MySQL Enterprise Backup, mysqlbackup command.

master server
: Frequently shortened to “master”. A database server machine in a **replication** scenario that processes the initial insert, update, and delete requests for data. These changes are propagated to, and repeated on, other servers known as **slave servers**.
See Also replication, slave server.

master thread
: An `InnoDB` **thread** that performs various tasks in the background. Most of these tasks are I/O related, such as writing changes from the **change buffer** to the appropriate secondary indexes.

  To improve **concurrency**, sometimes actions are moved from the master thread to separate background threads. For example, in MySQL 5.6 and higher, **dirty pages** are **flushed** from the **buffer pool** by the **page cleaner** thread rather than the master thread.
  See Also buffer pool, change buffer, concurrency, dirty page, flush, page cleaner, thread.

MDL
: Acronym for “metadata lock”.

See Also metadata lock.

memcached
A popular component of many MySQL and **NoSQL** software stacks, allowing fast reads and writes for single values and caching the results entirely in memory. Traditionally, applications required extra logic to write the same data to a MySQL database for permanent storage, or to read data from a MySQL database when it was not cached yet in memory. Now, applications can use the simple `memcached` protocol, supported by client libraries for many languages, to communicate directly with MySQL servers using `InnoDB` or `NDB` tables. These NoSQL interfaces to MySQL tables allow applications to achieve higher read and write performance than by issuing SQL statements directly, and can simplify application logic and deployment configurations for systems that already incorporate `memcached` for in-memory caching.

The `memcached` interface to `InnoDB` tables is available in MySQL 5.6 and higher; see InnoDB memcached Plugin for details. The `memcached` interface to `NDB` tables is available in NDB Cluster 7.2 and later; see http://dev.mysql.com/doc/ndbapi/en/ndbmemcache.html for details.
See Also InnoDB, NoSQL.

merge
To apply changes to data cached in memory, such as when a page is brought into the **buffer pool**, and any applicable changes recorded in the **change buffer** are incorporated into the page in the buffer pool. The updated data is eventually written to the **tablespace** by the **flush** mechanism.
See Also buffer pool, change buffer, flush, tablespace.

metadata lock
A type of **lock** that prevents **DDL** operations on a table that is being used at the same time by another **transaction**. For details, see Section 8.11.4, “Metadata Locking”.

Enhancements to **online** operations, particularly in MySQL 5.6 and higher, are focused on reducing the amount of metadata locking. The objective is for DDL operations that do not change the table structure (such as `CREATE INDEX` and `DROP INDEX` for `InnoDB` tables) to proceed while the table is being queried, updated, and so on by other transactions.
See Also DDL, lock, online, transaction.

metrics counter
A feature implemented by the `INNODB_METRICS` table in the **INFORMATION_SCEMA**, in MySQL 5.6 and higher. You can query **counts** and totals for low-level `InnoDB` operations, and use the results for performance tuning in combination with data from the **Performance Schema**.
See Also counter, INFORMATION_SCHEMA, Performance Schema.

midpoint insertion strategy
The technique of initially bringing **pages** into the `InnoDB` **buffer pool** not at the “newest” end of the list, but instead somewhere in the middle. The exact location of this point can vary, based on the setting of the `innodb_old_blocks_pct` option. The intent is that pages that are only read once, such as during a **full table scan**, can be aged out of the buffer pool sooner than with a strict **LRU** algorithm. For more information, see Section 14.9.2.1, “The InnoDB Buffer Pool”.
See Also buffer pool, full table scan, LRU, page.

mini-transaction
An internal phase of `InnoDB` processing, when making changes at the **physical** level to internal data structures during **DML** operations. A mini-transaction (mtr) has no notion of **rollback**; multiple mini-transactions can occur within a single **transaction**. Mini-transactions write information to the **redo log** that is used during **crash recovery**. A mini-transaction can also happen outside the context of a regular transaction, for example during **purge** processing by background threads.
See Also commit, crash recovery, DML, physical, purge, redo log, rollback, transaction.

mixed-mode insert
An `INSERT` statement where **auto-increment** values are specified for some but not all of the new rows. For example, a multi-value `INSERT` could specify a value for the auto-increment column in some cases and `NULL` in other cases. `InnoDB` generates auto-increment values for the rows where the column value was specified as `NULL`. Another example is an `INSERT ... ON DUPLICATE KEY UPDATE` statement, where

auto-increment values might be generated but not used, for any duplicate rows that are processed as `UPDATE` rather than `INSERT` statements.

Can cause consistency issues between **master** and **slave** servers in a **replication** configuration. Can require adjusting the value of the **innodb_autoinc_lock_mode** configuration option.
See Also auto-increment, innodb_autoinc_lock_mode, master server, replication, slave server.

mtr
See mini-transaction.

multi-core
A type of processor that can take advantage of multi-threaded programs, such as the MySQL server.

multiversion concurrency control
See MVCC.

mutex
Informal abbreviation for “mutex variable”. (Mutex itself is short for “mutual exclusion”.) The low-level object that `InnoDB` uses to represent and enforce exclusive-access **locks** to internal in-memory data structures. Once the lock is acquired, any other process, thread, and so on is prevented from acquiring the same lock. Contrast with **rw-locks**, which `InnoDB` uses to represent and enforce shared-access **locks** to internal in-memory data structures. Mutexes and rw-locks are known collectively as **latches**.
See Also latch, lock, Performance Schema, Pthreads, rw-lock.

MVCC
Acronym for “multiversion concurrency control”. This technique lets `InnoDB` **transactions** with certain **isolation levels** perform **consistent read** operations; that is, to query rows that are being updated by other transactions, and see the values from before those updates occurred. This is a powerful technique to increase **concurrency**, by allowing queries to proceed without waiting due to **locks** held by the other transactions.

This technique is not universal in the database world. Some other database products, and some other MySQL storage engines, do not support it.
See Also ACID, concurrency, consistent read, isolation level, lock, transaction.

my.cnf
The name, on Unix or Linux systems, of the MySQL **option file**.
See Also my.ini, option file.

my.ini
The name, on Windows systems, of the MySQL **option file**.
See Also my.cnf, option file.

mysql
The `mysql` program is the command-line interpreter for the MySQL database. It processes **SQL** statements, and also MySQL-specific commands such as `SHOW TABLES`, by passing requests to the `mysqld` daemon.
See Also mysqld, SQL.

MySQL Enterprise Backup
A licensed product that performs **hot backups** of MySQL databases. It offers the most efficiency and flexibility when backing up `InnoDB` tables, but can also back up `MyISAM` and other kinds of tables.
See Also hot backup, InnoDB.

mysqlbackup command
A command-line tool of the **MySQL Enterprise Backup** product. It performs a **hot backup** operation for `InnoDB` tables, and a warm backup for `MyISAM` and other kinds of tables. See Section 25.2, “MySQL Enterprise Backup Overview” for more information about this command.
See Also hot backup, MySQL Enterprise Backup, warm backup.

mysqld
The `mysqld` program is the database engine for the MySQL database. It runs as a Unix daemon or Windows service, constantly waiting for requests and performing maintenance work in the background.

See Also mysql.

mysqldump
: A command that performs a **logical backup** of some combination of databases, tables, and table data. The results are SQL statements that reproduce the original schema objects, data, or both. For substantial amounts of data, a **physical backup** solution such as **MySQL Enterprise Backup** is faster, particularly for the **restore** operation.
See Also logical backup, MySQL Enterprise Backup, physical backup, restore.

N

natural key
: An indexed column, typically a **primary key**, where the values have some real-world significance. Usually advised against because:

- If the value should ever change, there is potentially a lot of index maintenance to re-sort the **clustered index** and update the copies of the primary key value that are repeated in each **secondary index**.
- Even seemingly stable values can change in unpredictable ways that are difficult to represent correctly in the database. For example, one country can change into two or several, making the original country code obsolete. Or, rules about unique values might have exceptions. For example, even if taxpayer IDs are intended to be unique to a single person, a database might have to handle records that violate that rule, such as in cases of identity theft. Taxpayer IDs and other sensitive ID numbers also make poor primary keys, because they may need to be secured, encrypted, and otherwise treated differently than other columns.

Thus, it is typically better to use arbitrary numeric values to form a **synthetic key**, for example using an **auto-increment** column.
See Also auto-increment, clustered index, primary key, secondary index, synthetic key.

neighbor page
: Any **page** in the same **extent** as a particular page. When a page is selected to be **flushed**, any neighbor pages that are **dirty** are typically flushed as well, as an I/O optimization for traditional hard disks. In MySQL 5.6 and up, this behavior can be controlled by the configuration variable `innodb_flush_neighbors`; you might turn that setting off for SSD drives, which do not have the same overhead for writing smaller batches of data at random locations.
See Also dirty page, extent, flush, page.

next-key lock
: A combination of a **record lock** on the index record and a gap lock on the gap before the index record.
See Also gap lock, locking, record lock.

non-blocking I/O
: An industry term that means the same as **asynchronous I/O**.
See Also asynchronous I/O.

non-locking read
: A **query** that does not use the `SELECT ... FOR UPDATE` or `SELECT ... LOCK IN SHARE MODE` clauses. The only kind of query allowed for global tables in a **read-only transaction**. The opposite of a **locking read**. See Section 14.8.2.3, “Consistent Nonlocking Reads”.

`SELECT ... FOR SHARE` replaces `SELECT ... LOCK IN SHARE MODE` in MySQL 8.0.1, but `LOCK IN SHARE MODE` remains available for backward compatibility.
See Also locking read, query, read-only transaction.

non-repeatable read
: The situation when a query retrieves data, and a later query within the same **transaction** retrieves what should be the same data, but the queries return different results (changed by another transaction committing in the meantime).

This kind of operation goes against the **ACID** principle of database design. Within a transaction, data should be consistent, with predictable and stable relationships.

Among different **isolation levels**, non-repeatable reads are prevented by the **serializable read** and **repeatable read** levels, and allowed by the **consistent read**, and **read uncommitted** levels.
See Also ACID, consistent read, isolation level, READ UNCOMMITTED, REPEATABLE READ, SERIALIZABLE, transaction.

normalized
A database design strategy where data is split into multiple tables, and duplicate values condensed into single rows represented by an ID, to avoid storing, querying, and updating redundant or lengthy values. It is typically used in **OLTP** applications.

For example, an address might be given a unique ID, so that a census database could represent the relationship **lives at this address** by associating that ID with each member of a family, rather than storing multiple copies of a complex value such as **123 Main Street, Anytown, USA**.

For another example, although a simple address book application might store each phone number in the same table as a person's name and address, a phone company database might give each phone number a special ID, and store the numbers and IDs in a separate table. This normalized representation could simplify large-scale updates when area codes split apart.

Normalization is not always recommended. Data that is primarily queried, and only updated by deleting entirely and reloading, is often kept in fewer, larger tables with redundant copies of duplicate values. This data representation is referred to as **denormalized**, and is frequently found in data warehousing applications.
See Also denormalized, foreign key, OLTP, relational.

NoSQL
A broad term for a set of data access technologies that do not use the **SQL** language as their primary mechanism for reading and writing data. Some NoSQL technologies act as key-value stores, only accepting single-value reads and writes; some relax the restrictions of the **ACID** methodology; still others do not require a pre-planned **schema**. MySQL users can combine NoSQL-style processing for speed and simplicity with SQL operations for flexibility and convenience, by using the **memcached** API to directly access some kinds of MySQL tables. The `memcached` interface to `InnoDB` tables is available in MySQL 5.6 and higher; see InnoDB memcached Plugin for details. The `memcached` interface to `NDB` tables is available in NDB Cluster 7.2 and later; see ndbmemcache—Memcache API for NDB Cluster.
See Also ACID, InnoDB, memcached, schema, SQL.

NOT NULL constraint
A type of **constraint** that specifies that a **column** cannot contain any **NULL** values. It helps to preserve **referential integrity**, as the database server can identify data with erroneous missing values. It also helps in the arithmetic involved in query optimization, allowing the optimizer to predict the number of entries in an index on that column.
See Also column, constraint, NULL, primary key, referential integrity.

NULL
A special value in **SQL**, indicating the absence of data. Any arithmetic operation or equality test involving a `NULL` value, in turn produces a `NULL` result. (Thus it is similar to the IEEE floating-point concept of NaN, “not a number”.) Any aggregate calculation such as `AVG()` ignores rows with `NULL` values, when determining how many rows to divide by. The only test that works with `NULL` values uses the SQL idioms `IS NULL` or `IS NOT NULL`.

`NULL` values play a part in **index** operations, because for performance a database must minimize the overhead of keeping track of missing data values. Typically, `NULL` values are not stored in an index, because a query that tests an indexed column using a standard comparison operator could never match a row with a `NULL` value for that column. For the same reason, unique indexes do not prevent `NULL` values; those values simply are not represented in the index. Declaring a `NOT NULL` constraint on a column provides reassurance that there are no rows left out of the index, allowing for better query optimization (accurate counting of rows and estimation of whether to use the index).

Because the **primary key** must be able to uniquely identify every row in the table, a single-column primary key cannot contain any `NULL` values, and a multi-column primary key cannot contain any rows with `NULL` values in all columns.

Although the Oracle database allows a `NULL` value to be concatenated with a string, `InnoDB` treats the result of such an operation as `NULL`.
See Also index, primary key, SQL.

O

.OPT file
A file containing database configuration information. Files with this extension are included in backups produced by the `mysqlbackup` command of the **MySQL Enterprise Backup** product.
See Also MySQL Enterprise Backup, mysqlbackup command.

off-page column
A column containing variable-length data (such as `BLOB` and `VARCHAR`) that is too long to fit on a **B-tree** page. The data is stored in **overflow pages**. The **DYNAMIC** row format is more efficient for such storage than the older **COMPACT** row format.
See Also B-tree, compact row format, dynamic row format, overflow page.

OLTP
Acronym for “Online Transaction Processing”. A database system, or a database application, that runs a workload with many **transactions**, with frequent writes as well as reads, typically affecting small amounts of data at a time. For example, an airline reservation system or an application that processes bank deposits. The data might be organized in **normalized** form for a balance between **DML** (insert/update/delete) efficiency and **query** efficiency. Contrast with **data warehouse**.

With its **row-level locking** and **transactional** capability, **InnoDB** is the ideal storage engine for MySQL tables used in OLTP applications.
See Also data warehouse, DML, InnoDB, query, row lock, transaction.

online
A type of operation that involves no downtime, blocking, or restricted operation for the database. Typically applied to **DDL**. Operations that shorten the periods of restricted operation, such as **fast index creation**, have evolved into a wider set of **online DDL** operations in MySQL 5.6.

In the context of backups, a **hot backup** is an online operation and a **warm backup** is partially an online operation.
See Also DDL, Fast Index Creation, hot backup, online DDL, warm backup.

online DDL
A feature that improves the performance, concurrency, and availability of `InnoDB` tables during **DDL** (primarily `ALTER TABLE`) operations. See InnoDB and Online DDL for details.

The details vary according to the type of operation. In some cases, the table can be modified concurrently while the `ALTER TABLE` is in progress. The operation might be able to be performed without a table copy, or using a specially optimized type of table copy. Space usage is controlled by the `innodb_online_alter_log_max_size` configuration option.

This feature is an enhancement of the **Fast Index Creation** feature in MySQL 5.5.
See Also DDL, Fast Index Creation, online.

optimistic
A methodology that guides low-level implementation decisions for a relational database system. The requirements of performance and **concurrency** in a relational database mean that operations must be started or dispatched quickly. The requirements of consistency and **referential integrity** mean that any operation could fail: a transaction might be rolled back, a **DML** operation could violate a constraint, a request for a lock could cause a deadlock, a network error could cause a timeout. An optimistic strategy is one that assumes

most requests or attempts will succeed, so that relatively little work is done to prepare for the failure case. When this assumption is true, the database does little unnecessary work; when requests do fail, extra work must be done to clean up and undo changes.

`InnoDB` uses optimistic strategies for operations such as **locking** and **commits**. For example, data changed by a transaction can be written to the data files before the commit occurs, making the commit itself very fast, but requiring more work to undo the changes if the transaction is rolled back.

The opposite of an optimistic strategy is a **pessimistic** one, where a system is optimized to deal with operations that are unreliable and frequently unsuccessful. This methodology is rare in a database system, because so much care goes into choosing reliable hardware, networks, and algorithms.
See Also commit, concurrency, DML, locking, pessimistic, referential integrity.

optimizer
The MySQL component that determines the best **indexes** and **join** order to use for a **query**, based on characteristics and data distribution of the relevant **tables**.
See Also index, join, query, table.

option
A configuration parameter for MySQL, either stored in the **option file** or passed on the command line.

For the **options** that apply to **InnoDB** tables, each option name starts with the prefix `innodb_`.
See Also InnoDB, option, option file.

option file
The file that holds the configuration **options** for the MySQL instance. Traditionally, on Linux and Unix this file is named `my.cnf`, and on Windows it is named `my.ini`.
See Also configuration file, my.cnf, my.ini, option.

overflow page
Separately allocated disk **pages** that hold variable-length columns (such as `BLOB` and `VARCHAR`) that are too long to fit on a **B-tree** page. The associated columns are known as **off-page columns**.
See Also B-tree, off-page column, page.

P

.par file
A file containing partition definitions. Files with this extension are included in backups produced by the `mysqlbackup` command of the **MySQL Enterprise Backup** product.

With the introduction of native partitioning support for `InnoDB` tables in MySQL 5.7.6, `.par` files are no longer created for partitioned `InnoDB` tables. Partitioned `MyISAM` tables continue to use `.par` files in MySQL 5.7. In MySQL 8.0, partitioning support is only provided by the `InnoDB` storage engine. As such, `.par` files are no longer used as of MySQL 8.0.
See Also MySQL Enterprise Backup, mysqlbackup command.

page
A unit representing how much data `InnoDB` transfers at any one time between disk (the **data files**) and memory (the **buffer pool**). A page can contain one or more **rows**, depending on how much data is in each row. If a row does not fit entirely into a single page, `InnoDB` sets up additional pointer-style data structures so that the information about the row can be stored in one page.

One way to fit more data in each page is to use **compressed row format**. For tables that use BLOBs or large text fields, **compact row format** allows those large columns to be stored separately from the rest of the row, reducing I/O overhead and memory usage for queries that do not reference those columns.

When `InnoDB` reads or writes sets of pages as a batch to increase I/O throughput, it reads or writes an **extent** at a time.

All the `InnoDB` disk data structures within a MySQL instance share the same **page size**.

See Also buffer pool, compact row format, compressed row format, data files, extent, page size, row.

page cleaner
An `InnoDB` background **thread** that **flushes dirty pages** from the **buffer pool**. Prior to MySQL 5.6, this activity was performed by the **master thread**. The number of page cleaner threads is controlled by the `innodb_page_cleaners` configuration option, introduced in MySQL 5.7.4.
See Also buffer pool, dirty page, flush, master thread, thread.

page size
For releases up to and including MySQL 5.5, the size of each `InnoDB` **page** is fixed at 16 kilobytes. This value represents a balance: large enough to hold the data for most rows, yet small enough to minimize the performance overhead of transferring unneeded data to memory. Other values are not tested or supported.

Starting in MySQL 5.6, the page size for an `InnoDB` **instance** can be either 4KB, 8KB, or 16KB, controlled by the `innodb_page_size` configuration option. As of MySQL 5.7.6, `InnoDB` also supports 32KB and 64KB page sizes. For 32KB and 64KB page sizes, `ROW_FORMAT=COMPRESSED` is not supported and the maximum record size is 16KB.

Page size is set when creating the MySQL instance, and it remains constant afterward. The same page size applies to all `InnoDB` **tablespaces**, including the **system tablespace**, **file-per-table** tablespaces, and **general tablespaces**.

Smaller page sizes can help performance with storage devices that use small block sizes, particularly for **SSD** devices in **disk-bound** workloads, such as for **OLTP** applications. As individual rows are updated, less data is copied into memory, written to disk, reorganized, locked, and so on.
See Also disk-bound, file-per-table, general tablespace, instance, OLTP, page, SSD, system tablespace, tablespace.

parent table
The table in a **foreign key** relationship that holds the initial column values pointed to from the **child table**. The consequences of deleting, or updating rows in the parent table depend on the `ON UPDATE` and `ON DELETE` clauses in the foreign key definition. Rows with corresponding values in the child table could be automatically deleted or updated in turn, or those columns could be set to `NULL`, or the operation could be prevented.
See Also child table, foreign key.

partial backup
A **backup** that contains some of the **tables** in a MySQL database, or some of the databases in a MySQL instance. Contrast with **full backup**.
See Also backup, full backup, table.

partial index
An **index** that represents only part of a column value, typically the first N characters (the **prefix**) of a long `VARCHAR` value.
See Also index, index prefix.

Performance Schema
The `performance_schema` schema, in MySQL 5.5 and up, presents a set of tables that you can query to get detailed information about the performance characteristics of many internal parts of the MySQL server.
See Chapter 22, *MySQL Performance Schema*.
See Also INFORMATION_SCHEMA, latch, mutex, rw-lock.

persistent statistics
A feature in MySQL 5.6 that stores **index** statistics for `InnoDB` **tables** on disk, providing better **plan stability** for **queries**. For more information, see Configuring Persistent Optimizer Statistics Parameters.
See Also index, optimizer, plan stability, query, table.

pessimistic
A methodology that sacrifices performance or concurrency in favor of safety. It is appropriate if a high proportion of requests or attempts might fail, or if the consequences of a failed request are severe. `InnoDB`

uses what is known as a pessimistic **locking** strategy, to minimize the chance of **deadlocks**. At the application level, you might avoid deadlocks by using a pessimistic strategy of acquiring all locks needed by a transaction at the very beginning.

Many built-in database mechanisms use the opposite **optimistic** methodology.
See Also deadlock, locking, optimistic.

phantom
A row that appears in the result set of a query, but not in the result set of an earlier query. For example, if a query is run twice within a **transaction**, and in the meantime, another transaction commits after inserting a new row or updating a row so that it matches the `WHERE` clause of the query.

This occurrence is known as a phantom read. It is harder to guard against than a **non-repeatable read**, because locking all the rows from the first query result set does not prevent the changes that cause the phantom to appear.

Among different **isolation levels**, phantom reads are prevented by the **serializable read** level, and allowed by the **repeatable read**, **consistent read**, and **read uncommitted** levels.
See Also consistent read, isolation level, non-repeatable read, READ UNCOMMITTED, REPEATABLE READ, SERIALIZABLE, transaction.

physical
A type of operation that involves hardware-related aspects such as disk blocks, memory pages, files, bits, disk reads, and so on. Typically, physical aspects are important during expert-level performance tuning and problem diagnosis. Contrast with **logical**.
See Also logical, physical backup.

physical backup
A **backup** that copies the actual data files. For example, the **`mysqlbackup`** command of the **MySQL Enterprise Backup** product produces a physical backup, because its output contains data files that can be used directly by the `mysqld` server, resulting in a faster **restore** operation. Contrast with **logical backup**.
See Also backup, logical backup, MySQL Enterprise Backup, restore.

PITR
Acronym for **point-in-time recovery**.
See Also point-in-time recovery.

plan stability
A property of a **query execution plan**, where the optimizer makes the same choices each time for a given **query**, so that performance is consistent and predictable.
See Also query, query execution plan.

point-in-time recovery
The process of restoring a **backup** to recreate the state of the database at a specific date and time. Commonly abbreviated “PITR”. Because it is unlikely that the specified time corresponds exactly to the time of a backup, this technique usually requires a combination of a **physical backup** and a **logical backup**. For example, with the **MySQL Enterprise Backup** product, you restore the last backup that you took before the specified point in time, then replay changes from the **binary log** between the time of the backup and the PITR time.
See Also backup, binary log, logical backup, MySQL Enterprise Backup, physical backup.

prefix
See index prefix.

prepared backup
A set of backup files, produced by the **MySQL Enterprise Backup** product, after all the stages of applying **binary logs** and **incremental backups** are finished. The resulting files are ready to be **restored**. Prior to the apply steps, the files are known as a **raw backup**.
See Also binary log, hot backup, incremental backup, MySQL Enterprise Backup, raw backup, restore.

primary key
A set of columns—and by implication, the index based on this set of columns—that can uniquely identify every row in a table. As such, it must be a unique index that does not contain any `NULL` values.

`InnoDB` requires that every table has such an index (also called the **clustered index** or **cluster index**), and organizes the table storage based on the column values of the primary key.

When choosing primary key values, consider using arbitrary values (a **synthetic key**) rather than relying on values derived from some other source (a **natural key**).
See Also clustered index, index, natural key, synthetic key.

process
An instance of an executing program. The operating system switches between multiple running processes, allowing for a certain degree of **concurrency**. On most operating systems, processes can contain multiple **threads** of execution that share resources. Context-switching between threads is faster than the equivalent switching between processes.
See Also concurrency, thread.

pseudo-record
An artificial record in an index, used for **locking** key values or ranges that do not currently exist.
See Also infimum record, locking, supremum record.

Pthreads
The POSIX threads standard, which defines an API for threading and locking operations on Unix and Linux systems. On Unix and Linux systems, `InnoDB` uses this implementation for **mutexes**.
See Also mutex.

purge
A type of garbage collection that runs on a periodic schedule. Purge parses and processes **undo log** pages from the **history list** for the purpose of removing clustered and secondary index records that were marked for deletion (by previous `DELETE` statements) and are no longer required for **MVCC** or **rollback**. Purge frees undo log pages from the history list after processing them. By default, the purge operation is performed as part of the master thread, but it can be configured to run in a separate background thread using the `innodb_purge_threads` configuration option.
See Also history list, MVCC, rollback, undo log.

purge buffering
The technique of storing changes to secondary index pages, resulting from `DELETE` operations, in the **change buffer** rather than writing the changes immediately, so that the physical writes can be performed to minimize random I/O. (Because delete operations are a two-step process, this operation buffers the write that normally purges an index record that was previously marked for deletion.) It is one of the types of **change buffering**; the others are **insert buffering** and **delete buffering**.
See Also change buffer, change buffering, delete buffering, insert buffer, insert buffering.

purge lag
Another name for the `InnoDB` **history list**. Related to the `innodb_max_purge_lag` configuration option.
See Also history list, purge.

purge thread
A **thread** within the `InnoDB` process that is dedicated to performing the periodic **purge** operation. In MySQL 5.6 and higher, multiple purge threads are enabled by the `innodb_purge_threads` configuration option.
See Also purge, thread.

Q

query
In **SQL**, an operation that reads information from one or more **tables**. Depending on the organization of data and the parameters of the query, the lookup might be optimized by consulting an **index**. If multiple tables are involved, the query is known as a **join**.

For historical reasons, sometimes discussions of internal processing for statements use “query” in a broader sense, including other types of MySQL statements such as **DDL** and **DML** statements.
See Also DDL, DML, index, join, SQL, table.

query execution plan
The set of decisions made by the optimizer about how to perform a **query** most efficiently, including which **index** or indexes to use, and the order in which to **join** tables. **Plan stability** involves the same choices being made consistently for a given query.
See Also index, join, plan stability, query.

query log
See general query log.

quiesce
To reduce the amount of database activity, often in preparation for an operation such as an `ALTER TABLE`, a **backup**, or a **shutdown**. Might or might not involve doing as much **flushing** as possible, so that **InnoDB** does not continue doing background I/O.

In MySQL 5.6 and higher, the syntax `FLUSH TABLES ... FOR EXPORT` writes some data to disk for `InnoDB` tables that make it simpler to back up those tables by copying the data files.
See Also backup, flush, InnoDB, shutdown.

R

R-tree
A tree data structure used for spatial indexing of multi-dimensional data such as geographical coordinates, rectangles or polygons.
See Also B-tree.

RAID
Acronym for “Redundant Array of Inexpensive Drives”. Spreading I/O operations across multiple drives enables greater **concurrency** at the hardware level, and improves the efficiency of low-level write operations that otherwise would be performed in sequence.
See Also concurrency.

random dive
A technique for quickly estimating the number of different values in a column (the column's **cardinality**). `InnoDB` samples pages at random from the index and uses that data to estimate the number of different values.
See Also cardinality.

raw backup
The initial set of backup files produced by the **MySQL Enterprise Backup** product, before the changes reflected in the **binary log** and any **incremental backups** are applied. At this stage, the files are not ready to **restore**. After these changes are applied, the files are known as a **prepared backup**.
See Also binary log, hot backup, ibbackup_logfile, incremental backup, MySQL Enterprise Backup, prepared backup, restore.

READ COMMITTED
An **isolation level** that uses a **locking** strategy that relaxes some of the protection between **transactions**, in the interest of performance. Transactions cannot see uncommitted data from other transactions, but they can see data that is committed by another transaction after the current transaction started. Thus, a transaction never sees any bad data, but the data that it does see may depend to some extent on the timing of other transactions.

When a transaction with this isolation level performs `UPDATE ... WHERE` or `DELETE ... WHERE` operations, other transactions might have to wait. The transaction can perform `SELECT ... FOR UPDATE`, and `LOCK IN SHARE MODE` operations without making other transactions wait.

`SELECT ... FOR SHARE` replaces `SELECT ... LOCK IN SHARE MODE` in MySQL 8.0.1, but `LOCK IN SHARE MODE` remains available for backward compatibility.
See Also ACID, isolation level, locking, REPEATABLE READ, SERIALIZABLE, transaction.

read phenomena
Phenomena such as **dirty reads**, **non-repeatable reads**, and **phantom** reads which can occur when a transaction reads data that another transaction has modified.
See Also dirty read, non-repeatable read, phantom.

READ UNCOMMITTED
The **isolation level** that provides the least amount of protection between transactions. Queries employ a **locking** strategy that allows them to proceed in situations where they would normally wait for another transaction. However, this extra performance comes at the cost of less reliable results, including data that has been changed by other transactions and not committed yet (known as **dirty read**). Use this isolation level with great caution, and be aware that the results might not be consistent or reproducible, depending on what other transactions are doing at the same time. Typically, transactions with this isolation level only do queries, not insert, update, or delete operations.
See Also ACID, dirty read, isolation level, locking, transaction.

read view
An internal snapshot used by the **MVCC** mechanism of `InnoDB`. Certain **transactions**, depending on their **isolation level**, see the data values as they were at the time the transaction (or in some cases, the statement) started. Isolation levels that use a read view are **REPEATABLE READ**, **READ COMMITTED**, and **READ UNCOMMITTED**.
See Also isolation level, MVCC, READ COMMITTED, READ UNCOMMITTED, REPEATABLE READ, transaction.

read-ahead
A type of I/O request that prefetches a group of **pages** (an entire **extent**) into the **buffer pool** asynchronously, in anticipation that these pages will be needed soon. The linear read-ahead technique prefetches all the pages of one extent based on access patterns for pages in the preceding extent. The random read-ahead technique prefetches all the pages for an extent once a certain number of pages from the same extent are in the buffer pool. Random read-ahead is not part of MySQL 5.5, but is re-introduced in MySQL 5.6 under the control of the `innodb_random_read_ahead` configuration option.
See Also buffer pool, extent, page.

read-only transaction
A type of **transaction** that can be optimized for `InnoDB` tables by eliminating some of the bookkeeping involved with creating a **read view** for each transaction. Can only perform **non-locking read** queries. It can be started explicitly with the syntax `START TRANSACTION READ ONLY`, or automatically under certain conditions. See Optimizing InnoDB Read-Only Transactions for details.
See Also non-locking read, read view, transaction.

record lock
A lock on an index record. For example, `SELECT c1 FROM t WHERE c1 = 10 FOR UPDATE;` prevents any other transaction from inserting, updating, or deleting rows where the value of `t.c1` is 10. Contrast with **gap lock** and **next-key lock**.
See Also gap lock, lock, next-key lock.

redo
The data, in units of records, recorded in the **redo log** when DML statements make changes to `InnoDB` tables. It is used during **crash recovery** to correct data written by incomplete **transactions**. The ever-increasing **LSN** value represents the cumulative amount of redo data that has passed through the redo log.
See Also crash recovery, DML, LSN, redo log, transaction.

redo log
A disk-based data structure used during **crash recovery**, to correct data written by incomplete **transactions**. During normal operation, it encodes requests to change `InnoDB` table data, which result from SQL statements or low-level API calls through NoSQL interfaces. Modifications that did not finish updating the **data files** before an unexpected **shutdown** are replayed automatically.

The redo log is physically represented as a set of files, typically named `ib_logfile0` and `ib_logfile1`. The data in the redo log is encoded in terms of records affected; this data is collectively referred to as **redo**. The passage of data through the redo logs is represented by the ever-increasing **LSN** value. The original 4GB limit on maximum size for the redo log is raised to 512GB in MySQL 5.6.3.

The disk layout of the redo log is influenced by the configuration options `innodb_log_file_size`, `innodb_log_group_home_dir`, and (rarely) `innodb_log_files_in_group`. The performance of redo log operations is also affected by the **log buffer**, which is controlled by the `innodb_log_buffer_size` configuration option.
See Also crash recovery, data files, ib_logfile, log buffer, LSN, redo, shutdown, transaction.

redundant row format
The oldest `InnoDB` **row format**. Prior to MySQL 5.0.3, it was the only row format available in `InnoDB`. From MySQL 5.0.3 to MySQL 5.7.8, the default row format is **COMPACT**. As of MySQL 5.7.9, the default row format is defined by the `innodb_default_row_format` configuration option, which has a default setting of **DYNAMIC**. You can still specify the **REDUNDANT** row format for compatibility with older `InnoDB` tables.

For more information, see Section 14.14.4, “COMPACT and REDUNDANT Row Formats”.
See Also compact row format, dynamic row format, row format.

referential integrity
The technique of maintaining data always in a consistent format, part of the **ACID** philosophy. In particular, data in different tables is kept consistent through the use of **foreign key constraints**, which can prevent changes from happening or automatically propagate those changes to all related tables. Related mechanisms include the **unique constraint**, which prevents duplicate values from being inserted by mistake, and the **NOT NULL constraint**, which prevents blank values from being inserted by mistake.
See Also ACID, FOREIGN KEY constraint, NOT NULL constraint, unique constraint.

relational
An important aspect of modern database systems. The database server encodes and enforces relationships such as one-to-one, one-to-many, many-to-one, and uniqueness. For example, a person might have zero, one, or many phone numbers in an address database; a single phone number might be associated with several family members. In a financial database, a person might be required to have exactly one taxpayer ID, and any taxpayer ID could only be associated with one person.

The database server can use these relationships to prevent bad data from being inserted, and to find efficient ways to look up information. For example, if a value is declared to be unique, the server can stop searching as soon as the first match is found, and it can reject attempts to insert a second copy of the same value.

At the database level, these relationships are expressed through SQL features such as **columns** within a table, unique and `NOT NULL` **constraints**, **foreign keys**, and different kinds of join operations. Complex relationships typically involve data split between more than one table. Often, the data is **normalized**, so that duplicate values in one-to-many relationships are stored only once.

In a mathematical context, the relations within a database are derived from set theory. For example, the `OR` and `AND` operators of a `WHERE` clause represent the notions of union and intersection.
See Also ACID, column, constraint, foreign key, normalized.

relevance
In the **full-text search** feature, a number signifying the similarity between the search string and the data in the **FULLTEXT index**. For example, when you search for a single word, that word is typically more relevant for a row where it occurs several times in the text than a row where it appears only once.
See Also full-text search, FULLTEXT index.

REPEATABLE READ
The default **isolation level** for `InnoDB`. It prevents any rows that are queried from being changed by other **transactions**, thus blocking **non-repeatable reads** but not **phantom** reads. It uses a moderately strict **locking** strategy so that all queries within a transaction see data from the same snapshot, that is, the data as it was at the time the transaction started.

When a transaction with this isolation level performs `UPDATE ... WHERE`, `DELETE ... WHERE`, `SELECT ... FOR UPDATE`, and `LOCK IN SHARE MODE` operations, other transactions might have to wait.

`SELECT ... FOR SHARE` replaces `SELECT ... LOCK IN SHARE MODE` in MySQL 8.0.1, but `LOCK IN SHARE MODE` remains available for backward compatibility.
See Also ACID, consistent read, isolation level, locking, phantom, transaction.

replication
The practice of sending changes from a **master database**, to one or more **slave databases**, so that all databases have the same data. This technique has a wide range of uses, such as load-balancing for better scalability, disaster recovery, and testing software upgrades and configuration changes. The changes can be sent between the database by methods called **row-based replication** and **statement-based replication**.
See Also master server, row-based replication, slave server, statement-based replication.

restore
The process of putting a set of backup files from the **MySQL Enterprise Backup** product in place for use by MySQL. This operation can be performed to fix a corrupted database, to return to some earlier point in time, or (in a **replication** context) to set up a new **slave database**. In the **MySQL Enterprise Backup** product, this operation is performed by the `copy-back` option of the `mysqlbackup` command.
See Also hot backup, MySQL Enterprise Backup, mysqlbackup command, prepared backup, replication, slave server.

rollback
A **SQL** statement that ends a **transaction**, undoing any changes made by the transaction. It is the opposite of **commit**, which makes permanent any changes made in the transaction.

By default, MySQL uses the **autocommit** setting, which automatically issues a commit following each SQL statement. You must change this setting before you can use the rollback technique.
See Also ACID, autocommit, commit, SQL, transaction.

rollback segment
The storage area containing the **undo log**. Rollback segments have traditionally resided in the **system tablespace**. As of MySQL 5.6, rollback segments can reside in **undo tablespaces**. As of MySQL 5.7, rollback segments are also allocated to the *temporary tablespace*.
See Also system tablespace, temporary tablespace, undo log, undo tablespace.

row
The logical data structure defined by a set of **columns**. A set of rows makes up a **table**. Within `InnoDB` **data files**, each **page** can contain one or more rows.

Although `InnoDB` uses the term **row format** for consistency with MySQL syntax, the row format is a property of each table and applies to all rows in that table.
See Also column, data files, page, row format, table.

row format
The disk storage format for **rows** of an `InnoDB` **table**. As `InnoDB` gains new capabilities such as **compression**, new row formats are introduced to support the resulting improvements in storage efficiency and performance.

The row format of an `InnoDB` table is specified by the `ROW_FORMAT` option or by the `innodb_default_row_format` configuration option (introduced in MySQL 5.7.9). Row formats include `REDUNDANT`, `COMPACT`, `COMPRESSED`, and `DYNAMIC`. To view the row format of an `InnoDB` table, issue the `SHOW TABLE STATUS` statement or query `InnoDB` table metadata in the `INFORMATION_SCHEMA`.
See Also compact row format, compressed row format, compression, dynamic row format, redundant row format, row, table.

row lock
A **lock** that prevents a row from being accessed in an incompatible way by another **transaction**. Other rows in the same table can be freely written to by other transactions. This is the type of **locking** done by **DML** operations on **InnoDB** tables.

Contrast with **table locks** used by `MyISAM`, or during **DDL** operations on `InnoDB` tables that cannot be done with **online DDL**; those locks block concurrent access to the table.
See Also DDL, DML, InnoDB, lock, locking, online DDL, table lock, transaction.

row-based replication
A form of **replication** where events are propagated from the **master server** specifying how to change individual rows on the **slave server**. It is safe to use for all settings of the `innodb_autoinc_lock_mode` option.
See Also auto-increment locking, innodb_autoinc_lock_mode, master server, replication, slave server, statement-based replication.

row-level locking
The **locking** mechanism used for **InnoDB** tables, relying on **row locks** rather than **table locks**. Multiple **transactions** can modify the same table concurrently. Only if two transactions try to modify the same row does one of the transactions wait for the other to complete (and release its row locks).
See Also InnoDB, locking, row lock, table lock, transaction.

rw-lock
The low-level object that `InnoDB` uses to represent and enforce shared-access **locks** to internal in-memory data structures following certain rules. Contrast with **mutexes**, which `InnoDB` uses to represent and enforce exclusive access to internal in-memory data structures. Mutexes and rw-locks are known collectively as **latches**.

`rw-lock` types include `s-locks` (shared locks), `x-locks` (exclusive locks), and `sx-locks` (shared-exclusive locks).

- An `s-lock` provides read access to a common resource.
- An `x-lock` provides write access to a common resource while not permitting inconsistent reads by other threads.
- An `sx-lock` provides write access to a common resource while permitting inconsistent reads by other threads. `sx-locks` were introduced in MySQL 5.7 to optimize concurrency and improve scalability for read-write workloads.

The following matrix summarizes rw-lock type compatibility.

	S	***SX***	***X***
S	Compatible	Compatible	Conflict
SX	Compatible	Conflict	Conflict
X	Conflict	Conflict	Conflict

See Also latch, lock, mutex, Performance Schema.

S

savepoint
Savepoints help to implement nested **transactions**. They can be used to provide scope to operations on tables that are part of a larger transaction. For example, scheduling a trip in a reservation system might involve booking several different flights; if a desired flight is unavailable, you might **roll back** the changes involved in booking that one leg, without rolling back the earlier flights that were successfully booked.
See Also rollback, transaction.

scalability
The ability to add more work and issue more simultaneous requests to a system, without a sudden drop in performance due to exceeding the limits of system capacity. Software architecture, hardware configuration, application coding, and type of workload all play a part in scalability. When the system reaches its maximum

capacity, popular techniques for increasing scalability are **scale up** (increasing the capacity of existing hardware or software) and **scale out** (adding new servers and more instances of MySQL). Often paired with **availability** as critical aspects of a large-scale deployment.
See Also availability, scale out, scale up.

scale out
A technique for increasing **scalability** by adding new servers and more instances of MySQL. For example, setting up replication, NDB Cluster, connection pooling, or other features that spread work across a group of servers. Contrast with **scale up**.
See Also scalability, scale up.

scale up
A technique for increasing **scalability** by increasing the capacity of existing hardware or software. For example, increasing the memory on a server and adjusting memory-related parameters such as `innodb_buffer_pool_size` and `innodb_buffer_pool_instances`. Contrast with **scale out**.
See Also scalability, scale out.

schema
Conceptually, a schema is a set of interrelated database objects, such as tables, table columns, data types of the columns, indexes, foreign keys, and so on. These objects are connected through SQL syntax, because the columns make up the tables, the foreign keys refer to tables and columns, and so on. Ideally, they are also connected logically, working together as part of a unified application or flexible framework. For example, the **INFORMATION_SCHEMA** and **performance_schema** databases use “schema” in their names to emphasize the close relationships between the tables and columns they contain.

In MySQL, physically, a **schema** is synonymous with a **database**. You can substitute the keyword `SCHEMA` instead of `DATABASE` in MySQL SQL syntax, for example using `CREATE SCHEMA` instead of `CREATE DATABASE`.

Some other database products draw a distinction. For example, in the Oracle Database product, a **schema** represents only a part of a database: the tables and other objects owned by a single user.
See Also database, INFORMATION_SCHEMA, Performance Schema.

search index
In MySQL, **full-text search** queries use a special kind of index, the **FULLTEXT index**. In MySQL 5.6.4 and up, `InnoDB` and `MyISAM` tables both support `FULLTEXT` indexes; formerly, these indexes were only available for `MyISAM` tables.
See Also full-text search, FULLTEXT index.

secondary index
A type of `InnoDB` **index** that represents a subset of table columns. An `InnoDB` table can have zero, one, or many secondary indexes. (Contrast with the **clustered index**, which is required for each `InnoDB` table, and stores the data for all the table columns.)

A secondary index can be used to satisfy queries that only require values from the indexed columns. For more complex queries, it can be used to identify the relevant rows in the table, which are then retrieved through lookups using the clustered index.

Creating and dropping secondary indexes has traditionally involved significant overhead from copying all the data in the `InnoDB` table. The **fast index creation** feature makes both `CREATE INDEX` and `DROP INDEX` statements much faster for `InnoDB` secondary indexes.
See Also clustered index, Fast Index Creation, index.

segment
A division within an `InnoDB` **tablespace**. If a tablespace is analogous to a directory, the segments are analogous to files within that directory. A segment can grow. New segments can be created.

For example, within a **file-per-table** tablespace, table data is in one segment and each associated index is in its own segment. The **system tablespace** contains many different segments, because it can hold many

tables and their associated indexes. Prior to MySQL 8.0, the system tablespace also includes one or more **rollback segments** used for **undo logs**.

Segments grow and shrink as data is inserted and deleted. When a segment needs more room, it is extended by one **extent** (1 megabyte) at a time. Similarly, a segment releases one extent's worth of space when all the data in that extent is no longer needed.
See Also extent, file-per-table, rollback segment, system tablespace, tablespace, undo log.

selectivity
A property of data distribution, the number of distinct values in a column (its **cardinality**) divided by the number of records in the table. High selectivity means that the column values are relatively unique, and can retrieved efficiently through an index. If you (or the query optimizer) can predict that a test in a `WHERE` clause only matches a small number (or proportion) of rows in a table, the overall **query** tends to be efficient if it evaluates that test first, using an index.
See Also cardinality, query.

semi-consistent read
A type of read operation used for `UPDATE` statements, that is a combination of **READ COMMITTED** and **consistent read**. When an `UPDATE` statement examines a row that is already locked, `InnoDB` returns the latest committed version to MySQL so that MySQL can determine whether the row matches the `WHERE` condition of the `UPDATE`. If the row matches (must be updated), MySQL reads the row again, and this time `InnoDB` either locks it or waits for a lock on it. This type of read operation can only happen when the transaction has the READ COMMITTED **isolation level**, or when the `innodb_locks_unsafe_for_binlog` option is enabled. `innodb_locks_unsafe_for_binlog` was removed in MySQL 8.0.
See Also consistent read, isolation level, READ COMMITTED.

SERIALIZABLE
The **isolation level** that uses the most conservative locking strategy, to prevent any other **transactions** from inserting or changing data that was read by this transaction, until it is finished. This way, the same query can be run over and over within a transaction, and be certain to retrieve the same set of results each time. Any attempt to change data that was committed by another transaction since the start of the current transaction, cause the current transaction to wait.

This is the default isolation level specified by the SQL standard. In practice, this degree of strictness is rarely needed, so the default isolation level for `InnoDB` is the next most strict, **REPEATABLE READ**.
See Also ACID, consistent read, isolation level, locking, REPEATABLE READ, transaction.

server
A type of program that runs continuously, waiting to receive and act upon requests from another program (the **client**). Because often an entire computer is dedicated to running one or more server programs (such as a database server, a web server, an application server, or some combination of these), the term **server** can also refer to the computer that runs the server software.
See Also client, mysqld.

shared lock
A kind of **lock** that allows other **transactions** to read the locked object, and to also acquire other shared locks on it, but not to write to it. The opposite of **exclusive lock**.
See Also exclusive lock, lock, transaction.

shared tablespace
Another way of referring to the **system tablespace** or to a **general tablespace**. General tablespaces were introduced in MySQL 5.7
See Also general tablespace, system tablespace.

sharp checkpoint
The process of **flushing** to disk all **dirty** buffer pool pages whose redo entries are contained in certain portion of the **redo log**. Occurs before `InnoDB` reuses a portion of a log file; the log files are used in a circular fashion. Typically occurs with write-intensive **workloads**.

See Also dirty page, flush, redo log, workload.

shutdown
The process of stopping the MySQL server. By default, this process cleans up operations for **InnoDB** tables, so `InnoDB` can be **slow** to shut down, but fast to start up later. If you skip the cleanup operations, it is **fast** to shut down but the cleanup must be performed during the next restart.

The shutdown mode for `InnoDB` is controlled by the `innodb_fast_shutdown` option.
See Also fast shutdown, InnoDB, slow shutdown, startup.

slave server
Frequently shortened to “slave”. A database **server** machine in a **replication** scenario that receives changes from another server (the **master**) and applies those same changes. Thus it maintains the same contents as the master, although it might lag somewhat behind.

In MySQL, slave servers are commonly used in disaster recovery, to take the place of a master servers that fails. They are also commonly used for testing software upgrades and new settings, to ensure that database configuration changes do not cause problems with performance or reliability.

Slave servers typically have high workloads, because they process all the **DML** (write) operations relayed from the master, as well as user queries. To ensure that slave servers can apply changes from the master fast enough, they frequently have fast I/O devices and sufficient CPU and memory to run multiple database instances on the same slave server. For example, the master server might use hard drive storage while the slave servers use **SSD**s.
See Also DML, master server, replication, server, SSD.

slow query log
A type of **log** used for performance tuning of SQL statements processed by the MySQL server. The log information is stored in a file. You must enable this feature to use it. You control which categories of “slow” SQL statements are logged. For more information, see Section 5.4.5, “The Slow Query Log”.
See Also general query log, log.

slow shutdown
A type of **shutdown** that does additional `InnoDB` flushing operations before completing. Also known as a **clean shutdown**. Specified by the configuration parameter `innodb_fast_shutdown=0` or the command `SET GLOBAL innodb_fast_shutdown=0;`. Although the shutdown itself can take longer, that time will be saved on the subsequent startup.
See Also clean shutdown, fast shutdown, shutdown.

snapshot
A representation of data at a particular time, which remains the same even as changes are **committed** by other **transactions**. Used by certain **isolation levels** to allow **consistent reads**.
See Also commit, consistent read, isolation level, transaction.

sort buffer
The buffer used for sorting data during creation of an `InnoDB` index. Sort buffer size is configured using the `innodb_sort_buffer_size` configuration option.

space ID
An identifier used to uniquely identify an `InnoDB` **tablespace** within a MySQL instance. The space ID for the **system tablespace** is always zero; this same ID applies to all tables within the system tablespace or within a general tablespace. Each **file-per-table** tablespace and **general tablespace** has its own space ID.

Prior to MySQL 5.6, this hardcoded value presented difficulties in moving `InnoDB` tablespace files between MySQL instances. Starting in MySQL 5.6, you can copy tablespace files between instances by using the **transportable tablespace** feature involving the statements `FLUSH TABLES ... FOR EXPORT`, `ALTER TABLE ... DISCARD TABLESPACE`, and `ALTER TABLE ... IMPORT TABLESPACE`. The information needed to adjust the space ID is conveyed in the **.cfg file** which you copy along with the tablespace. See Copying File-Per-Table Tablespaces to Another Instance for details.

See Also .cfg file, file-per-table, general tablespace, .ibd file, system tablespace, tablespace, transportable tablespace.

sparse file
A type of file that uses file system space more efficiently by writing metadata representing empty blocks to disk instead of writing the actual empty space. The `InnoDB` **transparent page compression** feature relies on sparse file support. For more information, see InnoDB Page Compression.
See Also hole punching, transparent page compression.

spin
A type of **wait** operation that continuously tests whether a resource becomes available. This technique is used for resources that are typically held only for brief periods, where it is more efficient to wait in a "busy loop" than to put the thread to sleep and perform a context switch. If the resource does not become available within a short time, the spin loop ceases and another wait technique is used.
See Also latch, lock, mutex, wait.

SQL
The Structured Query Language that is standard for performing database operations. Often divided into the categories **DDL**, **DML**, and **queries**. MySQL includes some additional statement categories such as **replication**. See Chapter 9, *Language Structure* for the building blocks of SQL syntax, Chapter 11, *Data Types* for the data types to use for MySQL table columns, Chapter 13, *SQL Statement Syntax* for details about SQL statements and their associated categories, and Chapter 12, *Functions and Operators* for standard and MySQL-specific functions to use in queries.
See Also DDL, DML, query, replication.

SSD
Acronym for "solid-state drive". A type of storage device with different performance characteristics than a traditional hard disk drive (**HDD**): smaller storage capacity, faster for random reads, no moving parts, and with a number of considerations affecting write performance. Its performance characteristics can influence the throughput of a **disk-bound** workload.
See Also disk-bound, HDD.

startup
The process of starting the MySQL server. Typically done by one of the programs listed in Section 4.3, "MySQL Server and Server-Startup Programs". The opposite of **shutdown**.
See Also shutdown.

statement-based replication
A form of **replication** where SQL statements are sent from the **master server** and replayed on the **slave server**. It requires some care with the setting for the `innodb_autoinc_lock_mode` option, to avoid potential timing problems with **auto-increment locking**.
See Also auto-increment locking, innodb_autoinc_lock_mode, master server, replication, row-based replication, slave server.

statistics
Estimated values relating to each `InnoDB` **table** and **index**, used to construct an efficient **query execution plan**. The main values are the **cardinality** (number of distinct values) and the total number of table rows or index entries. The statistics for the table represent the data in its **primary key** index. The statistics for a **secondary index** represent the rows covered by that index.

The values are estimated rather than counted precisely because at any moment, different **transactions** can be inserting and deleting rows from the same table. To keep the values from being recalculated frequently, you can enable **persistent statistics**, where the values are stored in `InnoDB` system tables, and refreshed only when you issue an `ANALYZE TABLE` statement.

You can control how **NULL** values are treated when calculating statistics through the `innodb_stats_method` configuration option.

Other types of statistics are available for database objects and database activity through the **INFORMATION_SCHEMA** and **PERFORMANCE_SCHEMA** tables.

See Also cardinality, index, INFORMATION_SCHEMA, NULL, Performance Schema, persistent statistics, primary key, query execution plan, secondary index, table, transaction.

stemming
The ability to search for different variations of a word based on a common root word, such as singular and plural, or past, present, and future verb tense. This feature is currently supported in `MyISAM` **full-text search** feature but not in **FULLTEXT indexes** for `InnoDB` tables.
See Also full-text search, FULLTEXT index.

stopword
In a **FULLTEXT index**, a word that is considered common or trivial enough that it is omitted from the **search index** and ignored in search queries. Different configuration settings control stopword processing for `InnoDB` and `MyISAM` tables. See Section 12.9.4, “Full-Text Stopwords” for details.
See Also FULLTEXT index, search index.

storage engine
A component of the MySQL database that performs the low-level work of storing, updating, and querying data. In MySQL 5.5 and higher, **InnoDB** is the default storage engine for new tables, superceding `MyISAM`. Different storage engines are designed with different tradeoffs between factors such as memory usage versus disk usage, read speed versus write speed, and speed versus robustness. Each storage engine manages specific tables, so we refer to `InnoDB` tables, `MyISAM` tables, and so on.

The **MySQL Enterprise Backup** product is optimized for backing up `InnoDB` tables. It can also back up tables handled by `MyISAM` and other storage engines.
See Also InnoDB, MySQL Enterprise Backup, table type.

strict mode
The general name for the setting controlled by the `innodb_strict_mode` option. Turning on this setting causes certain conditions that are normally treated as warnings, to be considered errors. For example, certain invalid combinations of options related to **file format** and **row format**, that normally produce a warning and continue with default values, now cause the `CREATE TABLE` operation to fail. `innodb_strict_mode` is enabled by default in MySQL 5.7.

MySQL also has something called strict mode. See Section 5.1.8, “Server SQL Modes”.
See Also file format, innodb_strict_mode, row format.

sublist
Within the list structure that represents the **buffer pool**, pages that are relatively old and relatively new are represented by different portions of the **list**. A set of parameters control the size of these portions and the dividing point between the new and old pages.
See Also buffer pool, eviction, list, LRU.

supremum record
A **pseudo-record** in an index, representing the **gap** above the largest value in that index. If a transaction has a statement such as `SELECT ... FROM ... WHERE col > 10 FOR UPDATE;`, and the largest value in the column is 20, it is a lock on the supremum record that prevents other transactions from inserting even larger values such as 50, 100, and so on.
See Also gap, infimum record, pseudo-record.

surrogate key
Synonym name for **synthetic key**.
See Also synthetic key.

synthetic key
An indexed column, typically a **primary key**, where the values are assigned arbitrarily. Often done using an **auto-increment** column. By treating the value as completely arbitrary, you can avoid overly restrictive rules and faulty application assumptions. For example, a numeric sequence representing employee numbers might have a gap if an employee was approved for hiring but never actually joined. Or employee number 100 might have a later hiring date than employee number 500, if they left the company and later rejoined. Numeric values also produce shorter values of predictable length. For example, storing numeric codes meaning

"Road", "Boulevard", "Expressway", and so on is more space-efficient than repeating those strings over and over.

Also known as a **surrogate key**. Contrast with **natural key**.
See Also auto-increment, natural key, primary key, surrogate key.

system tablespace
One or more data files (**ibdata files**) containing metadata for `InnoDB`-related objects (the `InnoDB` **data dictionary**), and the storage areas for one or more **undo logs**, the **change buffer**, and the **doublewrite buffer**. Depending on the `innodb_file_per_table` setting, it might also contain table and index data for `InnoDB` tables. The data and metadata in the system tablespace apply to all **databases** in a MySQL **instance**.
See Also Barracuda, change buffer, compression, data dictionary, database, doublewrite buffer, dynamic row format, file-per-table, general tablespace, .ibd file, ibdata file, innodb_file_per_table, instance, MySQL Enterprise Backup, off-page column, tablespace, undo log.

T

.TRG file
A file containing trigger parameters. Files with this extension are always included in backups produced by the `mysqlbackup` command of the **MySQL Enterprise Backup** product.
See Also MySQL Enterprise Backup, mysqlbackup command, .TRN file.

.TRN file
A file containing trigger namespace information. Files with this extension are always included in backups produced by the `mysqlbackup` command of the **MySQL Enterprise Backup** product.
See Also MySQL Enterprise Backup, mysqlbackup command, .TRG file.

table
Each MySQL table is associated with a particular **storage engine**. **InnoDB** tables have particular **physical** and **logical** characteristics that affect performance, **scalability**, **backup**, administration, and application development.

In terms of file storage, an `InnoDB` table belongs to one of the following tablespace types:

- The shared `InnoDB` **system tablespace**, which is comprised of one or more **ibdata files**.
- A **file-per-table** tablespace, comprised of an individual **.ibd file**.
- A shared **general tablespace**, comprised of an individual `.ibd` file. General tablespaces were introduced in MySQL 5.7.6.

`.ibd` data files contain both table and **index** data.

`InnoDB` tables created in file-per-table tablespaces can use the **Barracuda** file format, and Barracuda tables can use **DYNAMIC** or **COMPRESSED** row format. These row formats enable `InnoDB` features such as **compression**, efficient storage of **off-page columns**, and large index key prefixes (see `innodb_large_prefix`). General tablespaces support all row formats regardless of the `innodb_file_format` setting.

Up to MySQL 5.7.5, `InnoDB` tables inside the system tablespace had to use the **Antelope** file format for backward compatibility with MySQL 5.1 and earlier. The **Antelope** file format supports **COMPACT** and **REDUNDANT** row format. The system tablespace supports tables that use **DYNAMIC** row format as of MySQL 5.7.6.

The **rows** of an `InnoDB` table are organized into an index structure known as the **clustered index**, with entries sorted based on the **primary key** columns of the table. Data access is optimized for queries that filter and sort on the primary key columns, and each index contains a copy of the associated primary key columns for each entry. Modifying values for any of the primary key columns is an expensive operation. Thus

an important aspect of InnoDB table design is choosing a primary key with columns that are used in the most important queries, and keeping the primary key short, with rarely changing values.
See Also Antelope, backup, Barracuda, clustered index, compact row format, compressed row format, compression, dynamic row format, Fast Index Creation, file-per-table, .ibd file, index, off-page column, primary key, redundant row format, row, system tablespace, tablespace.

table lock
A lock that prevents any other **transaction** from accessing a table. InnoDB makes considerable effort to make such locks unnecessary, by using techniques such as **online DDL**, **row locks** and **consistent reads** for processing **DML** statements and **queries**. You can create such a lock through SQL using the LOCK TABLE statement; one of the steps in migrating from other database systems or MySQL storage engines is to remove such statements wherever practical.
See Also consistent read, DML, lock, locking, online DDL, query, row lock, table, transaction.

table scan
See full table scan.

table statistics
See statistics.

table type
Obsolete synonym for **storage engine**. We refer to InnoDB tables, MyISAM tables, and so on.
See Also InnoDB, storage engine.

tablespace
A data file that can hold data for one or more InnoDB **tables** and associated **indexes**.

The **system tablespace** contains the InnoDB **data dictionary**, and prior to MySQL 5.6 holds all other InnoDB tables by default.

The innodb_file_per_table option, enabled by default in MySQL 5.6 and higher, allows tables to be created in their own tablespaces. File-per-table tablespaces support features such as efficient storage of **off-page columns**, table compression, and transportable tablespaces. See Section 14.10.4, “InnoDB File-Per-Table Tablespaces” for details.

InnoDB introduced general tablespaces in MySQL 5.7.6. General tablespaces are shared tablespaces created using CREATE TABLESPACE syntax. They can be created outside of the MySQL data directory, are capable of holding multiple tables, and support tables of all row formats.

MySQL NDB Cluster also groups its tables into tablespaces. See Section 18.5.12.1, “NDB Cluster Disk Data Objects” for details.
See Also compressed row format, data dictionary, data files, file-per-table, general tablespace, index, innodb_file_per_table, system tablespace, table.

temporary table
A **table** whose data does not need to be truly permanent. For example, temporary tables might be used as storage areas for intermediate results in complicated calculations or transformations; this intermediate data would not need to be recovered after a crash. Database products can take various shortcuts to improve the performance of operations on temporary tables, by being less scrupulous about writing data to disk and other measures to protect the data across restarts.

Sometimes, the data itself is removed automatically at a set time, such as when the transaction ends or when the session ends. With some database products, the table itself is removed automatically too.
See Also table.

temporary tablespace
The tablespace for non-compressed InnoDB **temporary tables** and related objects, introduced in MySQL 5.7. The innodb_temp_data_file_path configuration file option defines a relative path for the temporary tablespace data file. If innodb_temp_data_file_path is not specified, the default behavior is to create a single auto-extending 12MB data file named ibtmp1 in the data directory. The temporary tablespace is

recreated on each server start and receives a dynamically generated **space ID**, which helps avoid conflicts with existing space IDs. The temporary tablespace cannot reside on a raw device. Startup is refused if the temporary tablespace cannot be created.

The temporary tablespace is removed on normal shutdown or on an aborted initialization. The temporary tablespace is not removed when a crash occurs. In this case, the database administrator may remove the temporary tablespace manually or restart the server with the same configuration, which removes and recreates the temporary tablespace.
See Also ibtmp file, space ID, system tablespace, temporary table.

text collection
The set of columns included in a **FULLTEXT index**.
See Also FULLTEXT index.

thread
A unit of processing that is typically more lightweight than a **process**, allowing for greater **concurrency**.
See Also concurrency, master thread, process, Pthreads.

torn page
An error condition that can occur due to a combination of I/O device configuration and hardware failure. If data is written out in chunks smaller than the `InnoDB` **page size** (by default, 16KB), a hardware failure while writing could result in only part of a page being stored to disk. The `InnoDB` **doublewrite buffer** guards against this possibility.
See Also doublewrite buffer.

TPS
Acronym for "**transactions** per second", a unit of measurement sometimes used in benchmarks. Its value depends on the **workload** represented by a particular benchmark test, combined with factors that you control such as the hardware capacity and database configuration.
See Also transaction, workload.

transaction
Transactions are atomic units of work that can be **committed** or **rolled back**. When a transaction makes multiple changes to the database, either all the changes succeed when the transaction is committed, or all the changes are undone when the transaction is rolled back.

Database transactions, as implemented by `InnoDB`, have properties that are collectively known by the acronym **ACID**, for atomicity, consistency, isolation, and durability.
See Also ACID, commit, isolation level, lock, rollback.

transaction ID
An internal field associated with each **row**. This field is physically changed by `INSERT`, `UPDATE`, and `DELETE` operations to record which **transaction** has locked the row.
See Also implicit row lock, row, transaction.

transparent page compression
A feature added in MySQL 5.7.8 that permits page-level compression for `InnoDB` tables that reside in **file-per-table** tablespaces. Page compression is enabled by specifying the `COMPRESSION` attribute with `CREATE TABLE` or `ALTER TABLE`. For more information, see InnoDB Page Compression.
See Also file-per-table, hole punching, sparse file.

transportable tablespace
A feature that allows a **tablespace** to be moved from one instance to another. Traditionally, this has not been possible for `InnoDB` tablespaces because all table data was part of the **system tablespace**. In MySQL 5.6 and higher, the `FLUSH TABLES ... FOR EXPORT` syntax prepares an `InnoDB` table for copying to another server; running `ALTER TABLE ... DISCARD TABLESPACE` and `ALTER TABLE ... IMPORT TABLESPACE` on the other server brings the copied data file into the other instance. A separate **.cfg file**, copied along with the **.ibd file**, is used to update the table metadata (for example the **space ID**) as the tablespace is imported. See Copying File-Per-Table Tablespaces to Another Instance for usage information.
See Also .cfg file, .ibd file, space ID, system tablespace, tablespace.

troubleshooting
The process of determining the source of a problem. Some of the resources for troubleshooting MySQL problems include:

- Section 2.10.2.1, “Troubleshooting Problems Starting the MySQL Server”
- Section 6.2.7, “Troubleshooting Problems Connecting to MySQL”
- Section B.5.3.2, “How to Reset the Root Password”
- Section B.5.2, “Common Errors When Using MySQL Programs”
- Section 14.23, “InnoDB Troubleshooting”.

truncate
A **DDL** operation that removes the entire contents of a table, while leaving the table and related indexes intact. Contrast with **drop**. Although conceptually it has the same result as a `DELETE` statement with no `WHERE` clause, it operates differently behind the scenes: `InnoDB` creates a new empty table, drops the old table, then renames the new table to take the place of the old one. Because this is a DDL operation, it cannot be **rolled back**.

If the table being truncated contains **foreign keys** that reference another table, the truncation operation uses a slower method of operation, deleting one row at a time so that corresponding rows in the referenced table can be deleted as needed by any `ON DELETE CASCADE` clause. (MySQL 5.5 and higher do not allow this slower form of truncate, and return an error instead if foreign keys are involved. In this case, use a `DELETE` statement instead.
See Also DDL, drop, foreign key, rollback.

tuple
A technical term designating an ordered set of elements. It is an abstract notion, used in formal discussions of database theory. In the database field, tuples are usually represented by the columns of a table row. They could also be represented by the result sets of queries, for example, queries that retrieved only some columns of a table, or columns from joined tables.
See Also cursor.

two-phase commit
An operation that is part of a distributed **transaction**, under the **XA** specification. (Sometimes abbreviated as 2PC.) When multiple databases participate in the transaction, either all databases **commit** the changes, or all databases **roll back** the changes.
See Also commit, rollback, transaction, XA.

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undo
Data that is maintained throughout the life of a **transaction**, recording all changes so that they can be undone in case of a **rollback** operation. It is stored in the **undo log** either within the **system tablespace** or in separate **undo tablespaces**. As of MySQL 8.0, undo logs reside in undo tablespaces by default.
See Also rollback, rollback segment, system tablespace, transaction, undo log, undo tablespace.

undo buffer
See undo log.

undo log
A storage area that holds copies of data modified by active **transactions**. If another transaction needs to see the original data (as part of a **consistent read** operation), the unmodified data is retrieved from this storage area.

In MySQL 5.6 and higher, you can use the `innodb_undo_tablespaces` to create undo logs in **undo tablespaces**, optionally stored on another storage device such as an **SSD**. In MySQL 8.0, undo logs reside in undo tablespaces by default.

The undo log is split into separate portions, the **insert undo buffer** and the **update undo buffer**.
See Also consistent read, rollback segment, SSD, system tablespace, transaction, undo tablespace.

undo log segment
A collection of **undo logs**. Undo log segments exists within **rollback segments**. An undo log segment might contain undo logs from multiple transactions. An undo log segment can only be used by one transaction at a time but can be reused after it is released at transaction **commit** or **rollback**. May also be referred to as an "undo segment".
See Also commit, rollback, rollback segment, undo log.

undo tablespace
An undo tablespace contains **undo logs**. Undo logs exist within **undo log segments**, which are contained within **rollback segments**. Rollback segments have traditionally resided in the system tablespace. As of MySQL 5.6, rollback segments can reside in undo tablespaces. The number of undo tablespaces is controlled by the `innodb_undo_tablespaces` configuration option.

For more information, see Configuring Undo Tablespaces.
See Also rollback segment, system tablespace, undo log, undo log segment.

unique constraint
A kind of **constraint** that asserts that a column cannot contain any duplicate values. In terms of **relational** algebra, it is used to specify 1-to-1 relationships. For efficiency in checking whether a value can be inserted (that is, the value does not already exist in the column), a unique constraint is supported by an underlying **unique index**.
See Also constraint, relational, unique index.

unique index
An index on a column or set of columns that have a **unique constraint**. Because the index is known not to contain any duplicate values, certain kinds of lookups and count operations are more efficient than in the normal kind of index. Most of the lookups against this type of index are simply to determine if a certain value exists or not. The number of values in the index is the same as the number of rows in the table, or at least the number of rows with non-null values for the associated columns.

Change buffering optimization does not apply to unique indexes. As a workaround, you can temporarily set `unique_checks=0` while doing a bulk data load into an `InnoDB` table.
See Also cardinality, change buffering, unique constraint, unique key.

unique key
The set of columns (one or more) comprising a **unique index**. When you can define a `WHERE` condition that matches exactly one row, and the query can use an associated unique index, the lookup and error handling can be performed very efficiently.
See Also cardinality, unique constraint, unique index.

V

variable-length type
A data type of variable length. `VARCHAR`, `VARBINARY`, and `BLOB` and `TEXT` types are variable-length types.

`InnoDB` treats fixed-length fields greater than or equal to 768 bytes in length as variable-length fields, which can be stored **off-page**. For example, a `CHAR(255)` column can exceed 768 bytes if the maximum byte length of the character set is greater than 3, as it is with `utf8mb4`.
See Also off-page column, overflow page.

victim
The **transaction** that is automatically chosen to be **rolled back** when a **deadlock** is detected. `InnoDB` rolls back the transaction that has updated the fewest rows.

Deadlock detection can be disabled using the `innodb_deadlock_detect` configuration option.
See Also deadlock, deadlock detection, innodb_lock_wait_timeout, transaction.

W

wait
: When an operation, such as acquiring a **lock**, **mutex**, or **latch**, cannot be completed immediately, `InnoDB` pauses and tries again. The mechanism for pausing is elaborate enough that this operation has its own name, the **wait**. Individual threads are paused using a combination of internal `InnoDB` scheduling, operating system `wait()` calls, and short-duration **spin** loops.

  On systems with heavy load and many transactions, you might use the output from the `SHOW INNODB STATUS` command or **Performance Schema** to determine whether threads are spending too much time waiting, and if so, how you can improve **concurrency**.
  See Also concurrency, latch, lock, mutex, Performance Schema, spin.

warm backup
: A **backup** taken while the database is running, but that restricts some database operations during the backup process. For example, tables might become read-only. For busy applications and web sites, you might prefer a **hot backup**.
  See Also backup, cold backup, hot backup.

warm up
: To run a system under a typical **workload** for some time after startup, so that the **buffer pool** and other memory regions are filled as they would be under normal conditions. This process happens naturally over time when a MySQL server is restarted or subjected to a new workload.

  Typically, you run a workload for some time to warm up the buffer pool before running performance tests, to ensure consistent results across multiple runs; otherwise, performance might be artificially low during the first run.

  In MySQL 5.6, you can speed up the warmup process by enabling the `innodb_buffer_pool_dump_at_shutdown` and `innodb_buffer_pool_load_at_startup` configuration options, to bring the contents of the buffer pool back into memory after a restart. These options are enabled by default in MySQL 5.7. See Saving and Restoring the Buffer Pool State.
  See Also buffer pool, workload.

workload
: The combination and volume of **SQL** and other database operations, performed by a database application during typical or peak usage. You can subject the database to a particular workload during performance testing to identify **bottlenecks**, or during capacity planning.
  See Also bottleneck, CPU-bound, disk-bound, SQL.

write combining
: An optimization technique that reduces write operations when **dirty pages** are **flushed** from the `InnoDB` **buffer pool**. If a row in a page is updated multiple times, or multiple rows on the same page are updated, all of those changes are stored to the data files in a single write operation rather than one write for each change.
  See Also buffer pool, dirty page, flush.

X

XA
: A standard interface for coordinating distributed **transactions**, allowing multiple databases to participate in a transaction while maintaining **ACID** compliance. For full details, see Section 13.3.7, “XA Transactions”.

  XA Distributed Transaction support is enabled by default. If you are not using this feature, you can disable the `innodb_support_xa` configuration option, avoiding the performance overhead of an extra fsync for each transaction.

  As of MySQL 5.7.10, disabling `innodb_support_xa` is not permitted as it makes replication unsafe and prevents performance gains associated with **binary log** group commit. The `innodb_support_xa` configuration option is removed in MySQL 8.0.

See Also ACID, binary log, commit, transaction, two-phase commit.

Y

young
: A characteristic of a **page** in the `InnoDB` **buffer pool** meaning it has been accessed recently, and so is moved within the buffer pool data structure, so that it will not be **flushed** soon by the **LRU** algorithm. This term is used in some **INFORMATION_SCHEMA** column names of tables related to the buffer pool.
See Also buffer pool, flush, INFORMATION_SCHEMA, LRU, page.