

# M02

## Performance Standards for Antimicrobial Disk Susceptibility Tests

This standard covers the current recommended methods for disk susceptibility testing and criteria for quality control testing.

A standard for global application developed through the Clinical and Laboratory Standards Institute consensus process.

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### Abstract

Antimicrobial susceptibility testing is indicated for any organism that contributes to an infectious process warranting antimicrobial chemotherapy, if its susceptibility cannot be reliably predicted from knowledge of the organism's identity. Susceptibility tests are most often indicated when the causative organism is thought to belong to a species capable of exhibiting resistance to commonly used antimicrobial agents.

Various laboratory methods can be used to measure the *in vitro* susceptibility of bacteria to antimicrobial agents. In many medical microbiology laboratories, an agar disk diffusion method is used routinely for testing common, rapidly growing, and certain fastidious bacterial pathogens. Clinical and Laboratory Standards Institute standard M02—*Performance Standards for Antimicrobial Disk Susceptibility Tests* includes a series of procedures to standardize the way disk diffusion tests are performed. The performance, applications, and limitations of the current CLSI-recommended methods are also described.

The supplemental information (M100<sup>1</sup> tables) used with this standard represents the most current information for drug selection, interpretation, and quality control using the procedures standardized in M02.

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## Contents

Abstract .....	i
Committee Membership .....	iii
Foreword .....	xi
Summary of CLSI Processes for Establishing Breakpoints and Quality Control Ranges .....	xiii
CLSI Reference Methods vs Commercial Methods and CLSI vs US Food and Drug Administration Breakpoints .....	xiv
Subcommittee on Antimicrobial Susceptibility Testing Mission Statement .....	xv
Chapter 1: Introduction .....	1
1.1 Scope .....	1
1.2 Background .....	1
1.3 Standard Precautions .....	2
1.4 Terminology .....	2
Chapter 2: Indications for Performing Antimicrobial Susceptibility Tests .....	7
2.1 Selecting Antimicrobial Agents for Routine Testing and Reporting .....	7
2.2 Routine Reports .....	8
2.3 Antimicrobial Agent Classes .....	8
2.4 Selection Guidelines .....	12
2.5 Suggested Guidelines for Routine and Selective Testing and Reporting .....	12
Chapter 3: Disk Diffusion Antimicrobial Susceptibility Testing Process .....	15
3.1 Disk Diffusion Test Reagents .....	17
3.2 Testing Strains That Fail to Grow Satisfactorily .....	18
3.3 Antimicrobial Disks .....	18
3.4 Preparing Inoculum for Disk Diffusion Tests .....	19
3.5 Inoculating the Test Plates .....	21
3.6 Applying Disks to Inoculated Agar Plates .....	22
3.7 Reading Plates and Interpreting Results .....	22
3.8 Special Considerations for Fastidious Organisms .....	24
3.9 Special Considerations for Detecting Resistance .....	28
3.10 Supplemental (Not Routine) Tests .....	37
3.11 Disk Diffusion Method Limitations .....	39
Chapter 4: Quality Control and Quality Assurance .....	41
4.1 Quality Control Purpose .....	41
4.2 Quality Control Responsibilities .....	42
4.3 Selecting Strains for Quality Control .....	42
4.4 Maintaining and Testing Quality Control Strains .....	43
4.5 Batch or Lot Quality Control .....	43
4.6 Zone Diameter Quality Control Ranges .....	44
4.7 Quality Control Testing Frequency .....	44
4.8 Out-of-Range Results With Quality Control Strains and Corrective Action .....	46
4.9 Reporting Patient Results When Out-of-Range Quality Control Results Are Observed .....	49
4.10 Confirming Results When Testing Patient Isolates .....	49
4.11 End-Point Interpretation Control .....	50

**Contents (Continued)**

Chapter 5: Conclusion.....52

Chapter 6: Supplemental Information.....52

    References.....53

    Appendix A. Preparation of Media and Reagents.....56

    Appendix B. Conditions for Disk Diffusion Antimicrobial Susceptibility Tests .....60

    Appendix C. Quality Control Strain Maintenance.....64

    Appendix D. Quality Control Protocol Flow Charts.....66

    The Quality Management System Approach.....70

    Related CLSI Reference Materials .....71

## Foreword

The most current edition of CLSI document M100,<sup>1</sup> an annually published volume of tables, is made available with this standard to ensure users are aware of the latest recommendations related to the methods described in M02 and CLSI document M07.<sup>3</sup>

Many other editorial and procedural changes in this edition of M02 resulted from Subcommittee on Antimicrobial Susceptibility Testing meetings held since 2015. Specific changes to the tables are summarized at the beginning of M100.<sup>1</sup> The most important changes in M02 are summarized below.

## Overview of Changes

This standard replaces the previous edition of the approved standard, M02-A12, published in 2015. Several changes were made in this edition, including:

- **General:**
  - Harmonized language and information on drug selection and QC with CLSI document M07<sup>3</sup>
  - To harmonize with the International Organization for Standardization, the terms for the methods for inoculum preparation have been changed. “Growth method” has been changed to “broth culture method,” and “direct colony suspension method” has been changed to “colony suspension method” throughout the document
- **Subchapter 1.4.1, Definitions:**
  - Clarified definitions for breakpoint, interpretive category, susceptible, susceptible-dose dependent, intermediate, resistant, nonsusceptible, and quality control
  - Added definitions for minimal inhibitory concentration, routine test, supplemental test, surrogate agent test, CarbaNP test, and modified carbapenem inactivation method
- **Subchapter 1.4.2, Abbreviations and Acronyms:**
  - Deleted abbreviations for  $\beta$ -lactamase types
- **Subchapter 2.3.2.2, Folate Pathway Antagonists:**
  - Revised nomenclature from “folate pathway inhibitor” to “folate pathway antagonist”
- **Subchapter 2.3, Antimicrobial Agent Classes:**
  - Clarified and updated the antimicrobial agent classes
- **Subchapter 3.1.2, Handling and Storing Mueller-Hinton Agar Plates:**
  - Added information on proper storage of Mueller-Hinton agar plates
- **Subchapter 3.7, Reading Plates and Interpreting Results:**
  - Added reference to the *M02 Disk Diffusion Reading Guide*<sup>2</sup>
  - Added instruction to read vancomycin results for *Enterococcus* with transmitted light
- **Subchapter 3.8, Table 1. Testing Considerations for Fastidious Organisms:**
  - Clarified source plate incubation times and inoculum broth for some fastidious organisms
- **Subchapter 3.9, Special Considerations for Detecting Resistance:**
  - Reorganized and streamlined

- Moved Subchapters 3.9.4 (Inducible Clindamycin Resistance) and 3.9.6 ( $\beta$ -Lactamase Tests) to create a new subchapter, 3.10 (Supplemental [Not Routine] Tests)
- **Subchapter 3.9.1, Staphylococci:**
  - Added information for *Staphylococcus pseudintermedius* and *Staphylococcus schleiferi*
  - Reorganized and clarified information for staphylococci
- **Subchapter 3.9.4, Gram-Negative Bacilli:**
  - Expanded and clarified information on  $\beta$ -lactamases
  - Added footnote to Table 4, Enzyme Classifications for  $\beta$ -Lactamases, to clarify the difference between cephalosporin subclasses and generations
  - Updated nomenclature for *Enterobacter aerogenes* to *Klebsiella* (formerly *Enterobacter aerogenes*<sup>4</sup>)
- **Appendixes:**
  - Reorganized to reflect the order in which they are referenced in the main text, as follows:
    - **Appendix A. Preparation of Media and Reagents** (formerly Appendix B)
    - **Appendix B. Conditions for Disk Diffusion Antimicrobial Susceptibility Tests** (formerly Appendix C)
    - **Appendix C. Quality Control Strain Maintenance** (formerly Appendix E)
    - **Appendix D. Quality Control Protocol Flow Charts** (formerly Appendix A)
  - Deleted **Quality Control Strains for Antimicrobial Susceptibility Tests** (formerly Appendix D) (see M100<sup>1</sup> Appendix C)
- **Appendix A. Preparation of Media and Reagents:**
  - Reorganized procedures into step-action tables
- **Appendix B. Conditions for Disk Diffusion Antimicrobial Susceptibility Tests:**
  - Table B1. Conditions for Disk Diffusion Antimicrobial Susceptibility Tests for Nonfastidious Organisms:
    - Added information regarding linezolid and daptomycin for *Staphylococcus* and *Enterococcus*
  - Table B2. Conditions for Disk Diffusion Antimicrobial Susceptibility Tests for Fastidious Organisms:
    - Clarified source plate incubation times for some fastidious organisms
    - Clarified QC for *Haemophilus influenzae* and *Haemophilus parainfluenzae*
    - Clarified oxacillin disk QC when testing *Streptococcus pneumoniae*
- **Appendix C. Quality Control Strain Maintenance:**
  - Clarified maintenance and subculture of QC strains
- **Appendix D. Quality Control Protocol Flow Charts:**
  - Recreated QC flow charts in black-and-white format for easier viewing
  - Revised Appendixes D1 and D2 flow charts



## Summary of CLSI Processes for Establishing Breakpoints and Quality Control Ranges

The Clinical and Laboratory Standards Institute (CLSI) is an international, voluntary, not-for-profit, interdisciplinary, standards-developing, and educational organization accredited by the American National Standards Institute that develops and promotes the use of consensus-developed standards and guidelines within the health care community. These consensus standards and guidelines are developed in an open and consensus-seeking forum to cover critical areas of diagnostic testing and patient health care. CLSI is open to anyone or any organization that has an interest in diagnostic testing and patient care. Information about CLSI is found at [www.clsi.org](http://www.clsi.org).

The CLSI Subcommittee on Antimicrobial Susceptibility Testing reviews data from a variety of sources and studies (eg, *in vitro*, pharmacokinetics-pharmacodynamics, and clinical studies) to establish antimicrobial susceptibility test methods, breakpoints, and QC parameters. The details of the data necessary to establish breakpoints, QC parameters, and how the data are presented for evaluation are described in CLSI document M23.<sup>5</sup>

Over time, a microorganism's susceptibility to an antimicrobial agent may decrease, resulting in a lack of clinical efficacy and/or safety. In addition, microbiological methods and QC parameters may be refined to ensure more accurate and better performance of susceptibility test methods. Because of these types of changes, CLSI continually monitors and updates information in its documents. Although CLSI standards and guidelines are developed using the most current information available at the time, the field of science and medicine is always changing; therefore, standards and guidelines should be used in conjunction with clinical judgment, current knowledge, and clinically relevant laboratory test results to guide patient treatment.

Additional information, updates, and changes in this standard are found in the meeting summary minutes of the Subcommittee on Antimicrobial Susceptibility Testing at [www.clsi.org](http://www.clsi.org).

## **CLSI Reference Methods vs Commercial Methods and CLSI vs US Food and Drug Administration Breakpoints**

It is important for users of M02, M07,<sup>3</sup> and the M100<sup>1</sup> supplement to recognize that the standard methods described in CLSI documents are reference methods. These methods may be used for routine antimicrobial susceptibility testing of patient isolates, for evaluating commercial devices that will be used in medical laboratories, or by drug or device manufacturers for testing of new agents or systems. Results generated by reference methods, such as those contained in CLSI documents, may be used by regulatory authorities to evaluate the performance of commercial susceptibility testing devices as part of the approval process. Clearance by a regulatory authority indicates the commercial susceptibility testing device provides susceptibility results that are substantially equivalent to results generated using reference methods for the organisms and antimicrobial agents described in the device manufacturer's approved package insert.

CLSI breakpoints may differ from those approved by various regulatory authorities for many reasons, including use of different databases, differences in data interpretation, differences in doses used in different parts of the world, and public health policies. Differences also exist because CLSI proactively evaluates the need for changing breakpoints. The reasons why breakpoints may change and the manner in which CLSI evaluates data and determines breakpoints are outlined in CLSI document M23.<sup>5</sup>

Following a decision by CLSI to change an existing breakpoint, regulatory authorities may also review data to determine how changing breakpoints may affect the safety and effectiveness of the antimicrobial agent for the approved indications. If the regulatory authority changes breakpoints, commercial device manufacturers may have to conduct a clinical trial, submit the data to the regulatory authority, and await review and approval. For these reasons, a delay of one or more years may be needed if a breakpoint and interpretive category change is to be implemented by a device manufacturer. In the United States, it is acceptable for laboratories that use US Food and Drug Administration (FDA)–cleared susceptibility testing devices to use existing FDA breakpoints. Either FDA or CLSI susceptibility breakpoints are acceptable to laboratory accrediting organizations in the United States. Policies in other countries may vary. Each laboratory should check with the manufacturer of its antimicrobial susceptibility test system for additional information on the breakpoints and interpretive categories used in its system's software.

Following discussions with appropriate stakeholders (eg, infectious diseases and pharmacy practitioners, the pharmacy and therapeutics and infection control committees of the medical staff, and antimicrobial stewardship teams), newly approved or revised breakpoints may be implemented by laboratories. Following verification, CLSI disk diffusion test breakpoints may be implemented as soon as they are published in M100.<sup>1</sup> If a device includes antimicrobial test concentrations sufficient to allow interpretation of susceptibility and resistance to an agent using the CLSI breakpoints, a laboratory could choose to, after appropriate verification, interpret and report results using CLSI breakpoints.

## Subcommittee on Antimicrobial Susceptibility Testing Mission Statement

The Subcommittee on Antimicrobial Susceptibility Testing is composed of representatives from the professions, government, and industry, including microbiology laboratories, government agencies, health care providers and educators, and pharmaceutical and diagnostic microbiology industries. Using the CLSI voluntary consensus process, the subcommittee develops standards that promote accurate antimicrobial susceptibility testing and appropriate reporting. The mission of the Subcommittee on Antimicrobial Susceptibility Testing is to:

- Develop standard reference methods for antimicrobial susceptibility tests.
- Provide quality control parameters for standard test methods.
- Establish breakpoints for the results of standard antimicrobial susceptibility tests and provide epidemiological cutoff values when breakpoints are not available.
- Provide suggestions for testing and reporting strategies that are clinically relevant and cost-effective.
- Continually refine standards and optimize detection of emerging resistance mechanisms through development of new or revised methods, breakpoints, and quality control parameters.
- Educate users through multimedia communication of standards and guidelines.
- Foster a dialogue with users of these methods and those who apply them.

The ultimate purpose of the subcommittee's mission is to provide useful information to enable laboratories to assist the clinician in the selection of appropriate antimicrobial therapy for patient care. The standards and guidelines are meant to be comprehensive and to include all antimicrobial agents for which the data meet established CLSI guidelines. The values that guide this mission are quality, accuracy, fairness, timeliness, teamwork, consensus, and trust.

**NOTE:** The content of this standard is supported by the CLSI consensus process and does not necessarily reflect the views of any single individual or organization.

### Key Words

Agar diffusion, antibiotic, antimicrobial agents, disk diffusion, Kirby-Bauer, susceptibility testing



# Performance Standards for Antimicrobial Disk Susceptibility Tests

## Chapter 1: Introduction

This chapter includes:

- Standard's scope and applicable exclusions
- Background information pertinent to the standard's content
- Standard precautions information
- Terms and definitions used in the standard
- Abbreviations and acronyms used in the standard

### 1.1 Scope

This standard describes the reference agar disk diffusion method used to determine the *in vitro* antimicrobial susceptibility of bacteria that grow aerobically and includes:

- Agar plate preparation
- Testing conditions, including inoculum preparation and standardization, incubation time, and incubation temperature
- Results interpretation
- QC procedures
- Disk diffusion method limitations

To assist the medical laboratory, suggestions are provided for selecting antimicrobial agents for routine testing and reporting.

Standards for testing the *in vitro* antimicrobial susceptibility of bacteria that grow aerobically using dilution methods are found in CLSI document M07.<sup>3</sup> Standards for testing the *in vitro* antimicrobial susceptibility of bacteria that grow anaerobically are found in CLSI document M11.<sup>6</sup> Guidelines for standardized antimicrobial susceptibility testing (AST) of infrequently isolated or fastidious bacteria that are not included in CLSI documents M02, M07,<sup>3</sup> or M11<sup>6</sup> are available in CLSI document M45.<sup>7</sup> The AST methods provided in this standard can be used in laboratories around the world including but not limited to:

- Medical laboratories
- Public health laboratories
- Research laboratories
- Food laboratories
- Environmental laboratories

### 1.2 Background

Various laboratory methods can be used to measure the *in vitro* susceptibility of bacteria to antimicrobial agents. In many medical microbiology laboratories, an agar disk diffusion method is used routinely for testing common, rapidly growing, and certain fastidious bacterial pathogens. This standard describes the performance, applications, and limitations of the standardized disk diffusion test method. Recommendations<sup>8</sup> and governmental regulations<sup>9,10</sup> proposed by the US Food and Drug Administration

# M100

## Performance Standards for Antimicrobial Susceptibility Testing

This document includes updated tables for the Clinical and Laboratory Standards Institute antimicrobial susceptibility testing standards M02, M07, and M11.

A CLSI supplement for global application.

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### Abstract

The data in the tables are valid only if the methodologies in CLSI documents M02,<sup>1</sup> M07,<sup>2</sup> and M11<sup>3</sup> are followed. These standards contain information about disk diffusion (M02<sup>1</sup>) and dilution (M07<sup>2</sup> and M11<sup>3</sup>) test procedures for aerobic and anaerobic bacteria. Clinicians depend heavily on information from the microbiology laboratory for treating their seriously ill patients. The clinical importance of antimicrobial susceptibility test results demands that these tests be performed under optimal conditions and that laboratories have the capability to provide results for the newest antimicrobial agents. The tables presented in M100 represent the most current information for drug selection, interpretation, and quality control using the procedures standardized in M02,<sup>1</sup> M07,<sup>2</sup> and M11.<sup>3</sup> Users should replace previously published tables with these new tables. Changes in the tables since the previous edition appear in boldface type.

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**Contents**

Abstract.....	i
Committee Membership.....	iii
Overview of Changes.....	xiv
Summary of CLSI Processes for Establishing Breakpoints and Quality Control Ranges .....	xxvii
CLSI Reference Methods vs Commercial Methods and CLSI vs US Food and Drug Administration Breakpoints .....	xxviii
CLSI Breakpoint Additions/Revisions Since 2010.....	xxix
CLSI Epidemiological Cutoff Value Additions/Revisions Since 2015 .....	xxxii
CLSI Archived Resources.....	xxxii
Subcommittee on Antimicrobial Susceptibility Testing Mission Statement .....	xxxiii
Instructions for Use of Tables.....	1
References.....	16
Table 1A. Suggested Groupings of Antimicrobial Agents Approved by the US Food and Drug Administration for Clinical Use That Should Be Considered for Testing and Reporting on Nonfastidious Organisms by Microbiology Laboratories in the United States.....	18
Table 1B. Suggested Groupings of Antimicrobial Agents Approved by the US Food and Drug Administration for Clinical Use That Should Be Considered for Testing and Reporting on Fastidious Organisms by Microbiology Laboratories in the United States.....	24
Table 1C. Suggested Groupings of Antimicrobial Agents Approved by the US Food and Drug Administration for Clinical Use That Should Be Considered for Testing and Reporting on Anaerobic Organisms by Microbiology Laboratories in the United States .....	30
Table 2A. Zone Diameter and MIC Breakpoints for <i>Enterobacteriaceae</i> .....	32
Table 2B-1. Zone Diameter and MIC Breakpoints for <i>Pseudomonas aeruginosa</i> .....	42

**Contents (Continued)**

Table 2B-2. Zone Diameter and MIC Breakpoints for *Acinetobacter* spp. .... 46

Table 2B-3. Zone Diameter and MIC Breakpoints for *Burkholderia cepacia* complex..... 50

Table 2B-4. Zone Diameter and MIC Breakpoints for *Stenotrophomonas maltophilia* ..... 52

Table 2B-5. MIC Breakpoints for Other Non-*Enterobacteriaceae* (Refer to General Comment 1) ..... 54

Table 2C. Zone Diameter and MIC Breakpoints for *Staphylococcus* spp. .... 58

Table 2D. Zone Diameter and MIC Breakpoints for *Enterococcus* spp. .... 68

Table 2E. Zone Diameter and MIC Breakpoints for *Haemophilus influenzae* and *Haemophilus parainfluenzae* ..... 74

Table 2F. Zone Diameter and MIC Breakpoints for *Neisseria gonorrhoeae* ..... 78

Table 2G. Zone Diameter and MIC Breakpoints for *Streptococcus pneumoniae* ..... 82

Table 2H-1. Zone Diameter and MIC Breakpoints for *Streptococcus* spp.  $\beta$ -Hemolytic Group..... 88

Table 2H-2. Zone Diameter and MIC Breakpoints for *Streptococcus* spp. Viridans Group ..... 92

Table 2I. Zone Diameter and MIC Breakpoints for *Neisseria meningitidis* ..... 96

Table 2J. MIC Breakpoints for Anaerobes ..... 100

Table 3A. Tests for Extended-Spectrum  $\beta$ -Lactamases in *Klebsiella pneumoniae*, *Klebsiella oxytoca*, *Escherichia coli*, and *Proteus mirabilis* ... 104

Introduction to Tables 3B and 3C. Tests for Carbapenemases in *Enterobacteriaceae* and *Pseudomonas aeruginosa*..... 108

Table 3B. CarbaNP Test for Suspected Carbapenemase Production in *Enterobacteriaceae* and *Pseudomonas aeruginosa* ..... 110

Table 3B-1. Modifications of Table 3B When Using MIC Breakpoints for Carbapenems Described in M100-S20 (January 2010)..... 114



**Contents (Continued)**

Table 3C. Modified Carbapenem Inactivation Methods for Suspected Carbapenemase Production in <i>Enterobacteriaceae</i> and <i>Pseudomonas aeruginosa</i> .....	118
Table 3C-1. Modifications of Table 3C When Using MIC Breakpoints for Carbapenems Described in M100-S20 (January 2010).....	130
Table 3D. Test for Detection of $\beta$ -Lactamase Production in <i>Staphylococcus</i> spp.....	132
Table 3E. Test for Detecting Methicillin (Oxacillin) Resistance in <i>Staphylococcus</i> spp. ....	136
Table 3F. Vancomycin Agar Screen for <i>Staphylococcus aureus</i> and <i>Enterococcus</i> spp.....	140
Table 3G. Test for Detecting Inducible Clindamycin Resistance in <i>Staphylococcus</i> spp., <i>Streptococcus pneumoniae</i> , and <i>Streptococcus</i> spp. $\beta$ -Hemolytic Group .....	142
Table 3H. Test for Detecting High-Level Mupirocin Resistance in <i>Staphylococcus aureus</i> .....	146
Table 3I. Test for Detecting High-Level Aminoglycoside Resistance in <i>Enterococcus</i> spp. (Includes Disk Diffusion).....	148
Table 4A-1. Disk Diffusion QC Ranges for Nonfastidious Organisms and Antimicrobial Agents Excluding $\beta$ -Lactam Combination Agents.....	150
Table 4A-2. Disk Diffusion QC Ranges for Nonfastidious Organisms and $\beta$ -Lactam Combination Agents.....	154
Table 4B. Disk Diffusion QC Ranges for Fastidious Organisms .....	158
Table 4C. Disk Diffusion Reference Guide to QC Frequency.....	162
Table 4D. Disk Diffusion Troubleshooting Guide.....	164
Table 5A-1. MIC QC Ranges for Nonfastidious Organisms and Antimicrobial Agents Excluding $\beta$ -Lactam Combination Agents.....	168
Table 5A-2. MIC QC Ranges for Nonfastidious Organisms and $\beta$ -Lactam Combination Agents.....	174
Table 5B. MIC QC Ranges for Fastidious Organisms (Broth Dilution Methods).....	178
Table 5C. MIC QC Ranges for <i>Neisseria gonorrhoeae</i> (Agar Dilution Method) .....	182

**Contents (Continued)**

Table 5D. MIC QC Ranges for Anaerobes (Agar Dilution Method)..... 184

Table 5E. MIC QC Ranges for Anaerobes (Broth Microdilution Method)..... 186

Table 5F. MIC Reference Guide to QC Frequency ..... 188

Table 5G. MIC Troubleshooting Guide..... 190

Table 6A. Solvents and Diluents for Preparing Stock Solutions of Antimicrobial Agents ..... 194

Table 6B. Preparing Stock Solutions for Antimicrobial Agents Provided With Activity Expressed as Units ..... 200

Table 6C. Preparing Solutions and Media Containing Combinations of Antimicrobial Agents ..... 202

Table 7. Preparing Dilutions of Antimicrobial Agents to Be Used in Agar Dilution Susceptibility Tests..... 206

Table 8A. Preparing Dilutions of Antimicrobial Agents to Be Used in Broth Dilution Susceptibility Tests..... 208

Table 8B. Preparing Dilutions of Water-Insoluble Antimicrobial Agents to Be Used in Broth Dilution Susceptibility Tests ..... 210

Appendix A. Suggestions for Confirming Resistant, Intermediate, or Nonsusceptible Antimicrobial Susceptibility Test Results and Organism Identification ..... 212

Appendix B. Intrinsic Resistance..... 218

Appendix C. QC Strains for Antimicrobial Susceptibility Tests ..... 226

Appendix D. Cumulative Antimicrobial Susceptibility Report for Anaerobic Organisms..... 232

Appendix E. Dosage Regimens Used to Establish Susceptible or Susceptible-Dose Dependent Breakpoints ..... 238

Appendix F. Susceptible-Dose Dependent Interpretive Category ..... 242

Appendix G. Epidemiological Cutoff Values ..... 246

**Contents (Continued)**

Appendix H. Using Molecular Assays for Resistance Detection .....	252
Glossary I (Part 1). $\beta$ -Lactams: Class and Subclass Designations and Generic Name.....	266
Glossary I (Part 2). Non- $\beta$ -Lactams: Class and Subclass Designations and Generic Name.....	268
Glossary II. Antimicrobial Agent Abbreviation(s), Route(s) of Administration, and Drug Class.....	272
Glossary III. List of Identical Abbreviations Used for More Than One Antimicrobial Agent in US Diagnostic Products.....	278
The Quality Management System Approach .....	280
Related CLSI Reference Materials .....	281