

ANSI/NETA MTS-2011

AMERICAN NATIONAL STANDARD

STANDARD FOR
MAINTENANCE TESTING SPECIFICATIONS for
Electrical Power Equipment
and Systems

Secretariat
NETA (InterNational Electrical Testing Association)



Approved by
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FOREWORD

(This Foreword is not part of American National Standard ANSI/NETA MTS-2011)

The InterNational Electrical Testing Association (NETA) was formed in 1972 to establish uniform testing procedures for electrical equipment and apparatus. NETA has been an Accredited Standards Developer for the American National Standards Institute since 1996. NETA's scope of standards activity is different from that of IEEE, NECA, NEMA, and UL. In matters of testing electrical equipment and systems NETA continues to reference other standards developers' documents where applicable. NETA's review and updating of presently published standards takes into account both national and international standards. NETA's standards may be used internationally as well as in the United States. NETA firmly endorses a global standardization. IEC standards as well as American consensus standards are taken into consideration by NETA's ballot pools and reviewing committees.

The first NETA *Maintenance Testing Specifications for Electrical Power Equipment and Systems* was published in 1975. Since 1989, revised editions of the *Maintenance Testing Specifications* have been published in 1993, 1997, and 2001.

In 2005, this document was approved for the first time as an American National Standard. The 2011 *Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems* is the most current revision of this document.

The ANSI/NETA *Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems* was developed for use by those responsible for the continued operation of existing electrical systems and equipment to guide them in specifying and performing the necessary tests to ensure that these systems and apparatus perform satisfactorily, minimizing downtime and maximizing life expectancy. This document aids in ensuring safe, reliable operation of existing electrical power systems and equipment. Maintenance testing can identify potential problem areas before they become major problems requiring expensive and time-consuming solutions.

Suggestions for improvement of this standard are welcome. They should be sent to the InterNational Electrical Testing Association, 3050 Old Centre Avenue, Suite 102, Portage, MI 49024.



PREFACE

It is recognized by the Association that the needs for maintenance testing of commercial, industrial, governmental, and other electrical power systems vary widely. Many criteria are used in determining what equipment is to be tested and to what extent.

To help the user better understand and navigate more efficiently through this document, we offer the following information:

The Document Structure

The document is divided into twelve separate and defined sections:

Section	Description
Section 1	General Scope
Section 2	Applicable References
Section 3	Qualifications of Testing Organization and Personnel
Section 4	Division of Responsibility
Section 5	General
Section 6	Power System Studies
Section 7	Inspection and Test Procedures
Section 8	System Function Test
Section 9	Thermographic Survey
Section 10	Electromagnetic Field Testing
Tables	Reference Tables
Appendices	Various Informational Documents

Section 7 Structure

Section 7 is the main body of the document with specific information on what to do relative to the inspection and maintenance testing of electrical power distribution equipment and systems. It is not intended that this document explain how to test specific pieces of equipment or systems.

Expected Test Results

Section 7 consists of sections specific to each particular type of equipment. Within those sections there are, typically, three main bodies of information:

1. Visual and Mechanical Inspection
2. Electrical Tests
3. Test Values



PREFACE (continued)

Results of Visual and Mechanical Inspections

Some, but not all, visual and mechanical inspections have an associated test value or result. Those items with an expected result are referenced under Section 3.1 Test Values – Visual and Mechanical. For example, Section 7.1 Switchgear and Switchboard Assemblies, item 7.1.1.7.2 calls for verifying tightness of connections using a calibrated torque wrench method. Under the Test Values – Visual and Mechanical Section 7.1.3. 1.2, the expected results for that particular task are listed within Section 3.1, with reference back to the original task description on item 7.1.1.7.2.

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies

1. Visual and Mechanical Inspection

1. Inspect physical, electrical, and mechanical condition including evidence of moisture or corona.
2. Inspect anchorage, alignment, grounding, and required area clearances.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Verify that fuse and/or circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker's address for microprocessor-communication packages.
6. Verify that current and voltage transformer ratios correspond to drawings.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
8. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
 1. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
 2. Make key exchange with all devices included in the interlock scheme as applicable.
9. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
10. Verify correct barrier and shutter installation and operation.
11. Exercise all active components.
12. Inspect mechanical indicating devices for correct operation.
13. Verify that filters are in place and/or vents are clear.
14. Perform visual and mechanical inspection of instrument transformers in accordance with Section 7.10.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (continued)

2. Verify correct function of control transfer relays located in switchgear with multiple power sources.
9. Verify operation of switchgear/switchboard heaters and their controller, if applicable.
10. Perform system function tests in accordance with Section 8.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.1.1.7.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.1.1.7.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.1.1.7.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of bus insulation should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.
3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the test, the test dielectric withstand voltage specimen is considered to have passed the test.
4. Minimum insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Results of electrical tests on instrument transformers should be in accordance with Section 7.10.
6. Results of ground resistance tests should be in accordance with Section 7.13.
7. Accuracy of meters should be in accordance with Section 7.11.

* Optional

PREFACE (continued)

Results of Electrical Tests

Each electrical test has a corresponding expected result, and the test and the result have identical numbers. If the electrical test is item four, the expected result under the Test Values section is also item four. For example, under Section 7.15.1 Rotating Machinery, AC Induction Motors and Generators, item 7.15.1.2.2 (item 2 within the Electrical Tests section) calls for performing an insulation-resistance test in accordance with IEEE Standard 43. Under the Test Values – Electrical section, the expected results for that particular task are listed in the Test Values section under item 2.

7. INSPECTION AND TEST PROCEDURES

7.15.1 Rotating Machinery, AC Induction Motors and Generators

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Inspect air baffles, filter media, cooling fans, slip rings, brushes, and brush rigging.
4. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.15.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
5. Perform special tests such as air-gap spacing and machine alignment, if applicable.
6. Verify the application of appropriate lubrication and lubrication systems.
7. Verify the absence of unusual mechanical or electrical noise or signs of overheating.
8. Verify that resistance temperature detector (RTD) circuits conform to drawings.

2. Electrical Tests – AC Induction

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.15.1.1.
2. Perform insulation-resistance tests in accordance with ANSI/IEEE Standard 43.
 1. Machines larger than 200 horsepower (150 kilowatts):
Test duration shall be for ten minutes. Calculate polarization index.
 2. Machines 200 horsepower (150 kilowatts) and less:
Test duration shall be for one minute. Calculate the dielectric-absorption ratio.
3. Perform dc dielectric withstand voltage tests on machines rated at 2300 volts and greater in accordance with ANSI/IEEE Standard 95.
4. Perform phase-to-phase stator resistance test on machines 2300 volts and greater.
- *5. Perform insulation power-factor or dissipation-factor tests.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.15.1 Rotating Machinery, AC Induction Motors and Generators (continued)

3.2 Test Values – Electrical Tests

1. Compare bolted connection resistance values to values of similar connections. Investigate any values that deviate from similar bolted connections by more than 50 percent of the lowest value.
2. The dielectric absorption ratio or polarization shall be compared to previously obtained results and should not be less than 1.0. The recommended minimum insulation resistance ($IR_{1 \text{ min}}$) test results in megohms should be corrected to 40° C and read as follows:
 1. $IR_{1 \text{ min}} = kV + 1$ for most windings made before 1970, all field windings, and others not described in 2.2 and 2.3.
(kV is the rated machine terminal-to-terminal voltage in rms kV)
 2. $IR_{1 \text{ min}} = 100$ megohms for most dc armature and ac windings built after 1970 (form-wound coils).
 3. $IR_{1 \text{ min}} = 5$ megohms for most machines and random-wound stator coils and form-wound coils rated below 1 kV.

NOTE: Dielectric withstand voltage and surge comparison tests shall not be performed on machines having values lower than those indicated above.
3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
4. Investigate phase-to-phase stator resistance values that deviate by more than five percent.
5. Power-factor or dissipation-factor values shall be compared with previous values of similar machines.
6. Tip-up values should indicate no significant increase in power factor.
7. If no evidence of distress, insulation failure, or lack of waveform nesting is observed by the end of the total time of voltage application during the surge comparison test, the test specimen is considered to have passed the test.
8. Bearing insulation-resistance measurements should be within manufacturer's published tolerances. In the absence of manufacturer's published tolerances, the comparison shall be made to similar machines.
9. Test results of surge protection devices shall be in accordance with Section 7.19 and Section 7.20.

* Optional

PREFACE (*continued*)

Optional Tests

The purpose of these specifications is to assure that all tested electrical equipment and systems supplied by either contractor or owner are operational and within applicable standards and manufacturer's published tolerances and that equipment and systems are installed in accordance with design specifications.

Certain tests are assigned an optional classification. The following considerations are used in determining the use of the optional classification:

1. Does another listed test provide similar information?
2. How does the cost of the test compare to the cost of other tests providing similar information?
3. How commonplace is the test procedure? Is it new technology?

Manufacturer's Instruction Manuals

It is important to follow the recommendations contained in the manufacturer's published data. Many of the details of a complete and effective testing procedure can be obtained from this source.

Summary

The guidance of an experienced testing professional should be sought when making decisions concerning the extent of testing. It is necessary to make an informed judgment for each particular system regarding how extensive a procedure is justified. The approach taken in these specifications is to present a comprehensive series of tests applicable to most industrial and larger commercial systems. In smaller systems, some of the tests can be deleted. In other cases, a number of the tests indicated as optional should be performed.

Likewise, guidance of an experienced testing professional should also be sought when making decisions concerning the results of test data and their significance to the overall analysis of the device or system under test. Careful consideration of all aspects of test data, including manufacturer's published data and recommendations, must be included in the overall assessment of the device or system under test.

The Association encourages comment from users of this document. Please contact the NETA office or your local NETA Accredited Company.

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CONTENTS

1.	GENERAL SCOPE	1
2.	APPLICABLE REFERENCES	2
3.	QUALIFICATIONS OF TESTING PERSONNEL	11
4.	DIVISION OF RESPONSIBILITY	12
5.	GENERAL.....	13
5.1	Safety and Precautions.....	13
5.2	Suitability of Test Equipment.....	13
5.3	Test Instrument Calibration	14
5.4	Test Report.....	15
6.	POWER SYSTEM STUDIES	16
6.1	Short-Circuit Studies.....	16
6.2	Coordination Studies.....	17
6.3	Arc-Flash Hazard Analysis.....	19
6.4	Load-Flow Studies	21
6.5	Stability Studies	22
6.6	Harmonic-Analysis Studies	23
7.	INSPECTION AND TEST PROCEDURES.....	24
7.1	Switchgear and Switchboard Assemblies	24
7.2.1.1	Transformers, Dry-Type, Air-Cooled, Low-Voltage, Small	28
7.2.1.2	Transformers, Dry-Type, Air-Cooled, Large.....	30
7.2.2	Transformers, Liquid-Filled.....	34
7.3.1	Cables, Low-Voltage, Low-Energy – Reserved	38
7.3.2	Cables, Low-Voltage, 600 Volt Maximum.....	39
7.3.3	Cables, Medium- and High-Voltage	41
7.4	Metal-Enclosed Busways.....	44
7.5.1.1	Switches, Air, Low-Voltage	46
7.5.1.2	Switches, Air, Medium-Voltage, Metal-Enclosed.....	49
7.5.1.3	Switches, Air, Medium- and High-Voltage, Open	52
7.5.2	Switches, Oil, Medium-Voltage	55
7.5.3	Switches, Vacuum, Medium-Voltage.....	58
7.5.4	Switches, SF ₆ , Medium-Voltage.....	61
7.5.5	Switches, Cutouts.....	64
7.6.1.1	Circuit Breakers, Air, Insulated-Case/Molded-Case	66
7.6.1.2	Circuit Breakers, Air, Low-Voltage Power	69
7.6.1.3	Circuit Breakers, Air, Medium-Voltage	73
7.6.2	Circuit Breakers, Oil, Medium- and High-Voltage	77
7.6.3	Circuit Breakers, Vacuum, Medium-Voltage	82
7.6.4	Circuit Breakers, SF ₆	86
7.7	Circuit Switchers.....	90



CONTENTS (continued)

7.8	Network Protectors, 600-Volt Class	93
7.9.1	Protective Relays, Electromechanical and Solid-State	97
7.9.2	Protective Relays, Microprocessor-Based	104
7.10	Instrument Transformers	106
7.11.1	Metering Devices, Electromechanical and Solid-State	112
7.11.2	Metering Devices, Microprocessor-Based	114
7.12.1.1	Regulating Apparatus, Voltage, Step-Voltage Regulators	116
7.12.1.2	Regulating Apparatus, Voltage, Induction Regulators	121
7.12.2	Regulating Apparatus, Current – Reserved	125
7.12.3	Regulating Apparatus, Load Tap-Changers	126
7.13	Grounding Systems	130
7.14	Ground-Fault Protection Systems, Low-Voltage	132
7.15.1	Rotating Machinery, AC Induction Motors and Generators	135
7.15.2	Rotating Machinery, Synchronous Motors and Generators	139
7.15.3	Rotating Machinery, DC Motors and Generators	145
7.16.1.1	Motor Control, Motor Starters, Low-Voltage	148
7.16.1.2	Motor Control, Motor Starters, Medium-Voltage	151
7.16.2.1	Motor Control, Motor Control Centers, Low-Voltage	155
7.16.2.2	Motor Control, Motor Control Centers, Medium-Voltage	155
7.17	Adjustable-Speed Drive Systems	156
7.18.1.1	Direct-Current Systems, Batteries, Flooded Lead-Acid	159
7.18.1.2	Direct-Current Systems, Batteries, Vented Nickel-Cadmium	162
7.18.1.3	Direct Current Systems, Batteries, Valve-Regulated Lead-Acid	165
7.18.2	Direct-Current Systems, Chargers	167
7.18.3	Direct-Current Systems, Rectifiers – Reserved	169
7.19.1	Surge Arresters, Low-Voltage Surge Protection Devices	170
7.19.2	Surge Arresters, Medium- and High-Voltage Surge Protection Devices	172
7.20.1	Capacitors and Reactors, Capacitors	174
7.20.2	Capacitors and Reactors, Capacitor Control Devices – Reserved	176
7.20.3.1	Capacitors and Reactors, Reactors (Shunt and Current-Limiting), Dry-Type	177
7.20.3.2	Capacitors and Reactors, Reactors (Shunt and Current-Limiting), Liquid-Filled ..	179
7.21	Outdoor Bus Structures	183
7.22.1	Emergency Systems, Engine Generator	185
7.22.2	Emergency Systems, Uninterruptible Power Systems	187
7.22.3	Emergency Systems, Automatic Transfer Switches	190
7.23	Communications – Reserved	193
7.24.1	Automatic Circuit Reclosers and Line Sectionalizers, Automatic Circuit Reclosers, Oil/Vacuum	194
7.24.2	Automatic Circuit Reclosers and Line Sectionalizers Automatic Line Sectionalizers, Oil	198
7.25	Fiber-Optic Cables	201
8.	SYSTEM FUNCTION TESTS	202
9.	THERMOGRAPHIC SURVEY	203
10.	ELECTROMAGNETIC FIELD TESTING	204
11.	CORONA STUDIES – RESERVED	205



CONTENTS (continued)

TABLES

100.1	Insulation Resistance Test Values, Electrical Apparatus and Systems.....	208
100.2	Switchgear Withstand Test Voltages	209
100.3	Dissipation Factor/Power Factor at 20° C; Liquid-Filled Transformers, Regulators and Reactors, Maintenance Test Values.....	210
100.4	Insulating Fluid Limits	
100.4.1	Suggested Limits for Class I Insulating Oil, Mineral Oil	211
100.4.2	Suggested Limits for Less-Flammable Hydrocarbon Insulating Liquid.....	212
100.4.3	Suggested Limits for Service-Aged Silicone Insulating Liquid	213
100.4.4	Suggested Limits for Service-Aged Tetrachloroethylene Insulating Fluid	213
100.5	Transformer Insulation Resistance, Maintenance Testing.....	214
100.6	Cables, Maintenance Test Values	
100.6.1	Medium-Voltage Cables, Maintenance Test Values, DC Test Voltages.....	215
100.6.2	Field Test Voltages for Laminated Dielectric, Shielded Power Cable Systems Rated 5,000 Volts and Above with High DC Voltage.....	216
100.6.3	Very Low Frequency Testing Levels for Medium-Voltage Cable 0.1 Hz Test Voltage (rms).....	217
100.7	Molded-Case Circuit Breakers, Inverse Time Trip Test.....	218
100.8	Instantaneous Trip Tolerances for Field Testing of Circuit Breakers.....	219
100.9	Instrument Transformer Dielectric Tests, Field Maintenance	220
100.10	Maximum Allowable Vibration Amplitude.....	221
100.11	Withdrawn	222
100.12	Bolt-Torque Values for Electrical Connections, US Standard Fasteners	
100.12.1	Heat-Treated Steel – Cadmium or Zinc Plated	223
100.12.2	Silicon Bronze Fasteners, Torque (Pound-Feet).....	223
100.12.3	Aluminum Alloy Fasteners, Torque (Pound-Feet)	224
100.12.4	Stainless Steel Fasteners, Torque (Pound-Feet).....	224
100.13	SF ₆ Gas Tests	225
100.14	Insulation Resistance Conversion Factors	
100.14.1	Insulation Resistance Conversion Factors (20° C)	226
100.14.2	Insulation Resistance Conversion Factors (40° C)	227
100.15	High-Potential Test Voltage for Automatic Circuit Reclosers	228
100.16	High-Potential Test Voltage for Periodic Test of Line Sectionalizers	229
100.17	Metal-Enclosed Bus Dielectric Withstand Test Voltages.....	230
100.18	Thermographic Survey, Suggested Actions Based on Temperature Rise	231
100.19	Dielectric Withstand Test Voltages for Electrical Apparatus Other than Inductive Equipment.....	232
100.20	Rated Control Voltages and Their Ranges for Circuit Breakers	
100.20.1	Rated Control Voltages and Their Ranges for Circuit Breakers.....	233
100.20.2	Rated Control Voltages and Their Ranges for Circuit Breakers, Solenoid-Operated Devices	235
100.21	Accuracy of IEC Class TP Current Transformers, Error Limit.....	236
100.22	Minimum Radii for Power Cable.....	237

APPENDICES

Appendix A	– Definitions.....	241
Appendix B	– Frequency of Maintenance Tests.....	243



CONTENTS (*continued*)

Appendix C – About the InterNational Electrical Testing Association.....	247
Appendix D – Form for Comments	249
Appendix E – Form for Proposals	250



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1. GENERAL SCOPE

1.1 Maintenance Testing Specifications

1. These specifications cover the suggested field tests and inspections that are available to assess the suitability for continued service and reliability of electrical power distribution equipment and systems.
2. The purpose of these specifications is to assure that tested electrical equipment and systems are operational, are within applicable standards and manufacturer's tolerances, and are suitable for continued service.
3. The work specified in these specifications may involve hazardous voltages, materials, operations, and equipment. These specifications do not purport to address all of the safety problems associated with their use. It is the responsibility of the user to review all applicable regulatory limitations prior to the use of these specifications.



2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications

All inspections and field tests shall be in accordance with the latest edition of the following codes, standards, and specifications except as provided otherwise herein.

1. American National Standards Institute – ANSI

2. ASTM International – ASTM

ASTM D 92 *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*

ASTM D 445 *Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)*

ASTM D 664 *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration*

ASTM D 877 *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids using Disk Electrodes*

ASTM D 923 *Standard Practices for Sampling Electrical Insulating Liquids*

ASTM D 924 *Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids*

ASTM D 971 *Standard Test Method for Interfacial Tension of Oil against Water by the Ring Method*

ASTM D 974 *Standard Test Method for Acid and Base Number by Color-Indicator Titration*

ASTM D 1298 *Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*

ASTM D 1500 *Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)*

ASTM D 1524 *Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field*



2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

- | | |
|-------------|---|
| ASTM D 1533 | <i>Standard Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration</i> |
| ASTM D 1816 | <i>Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes</i> |
| ASTM D 2029 | <i>Standard Test Methods for Water Vapor Content of Electrical Insulating Gases by Measurement of Dew Point</i> |
| ASTM D 2129 | <i>Standard Test Method for Color of Clear Electrical Insulating Liquids (Platinum-Cobalt Scale)</i> |
| ASTM D 2284 | <i>Standard Test Method of Acidity of Sulfur Hexafluoride</i> |
| ASTM D 2285 | <i>Standard Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin against Water by the Drop-Weight Method</i> |
| ASTM D 2477 | <i>Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies</i> |
| ASTM D 2685 | <i>Standard Test Method for Air and Carbon Tetrafluoride in Sulfur Hexafluoride by Gas Chromatography</i> |
| ASTM D 2759 | <i>Standard Practice for Sampling Gas from a Transformer under Positive Pressure</i> |
| ASTM D 3284 | <i>Standard Test Method for Combustible Gases in the Gas Space of Electrical Apparatus Using Portable Meters</i> |
| ASTM D 3612 | <i>Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography</i> |
| ASTM D 3613 | <i>Standard Practice for Sampling Electrical Insulating Oils for Gas Analysis and Determination of Water Content</i> |
3. Association of Edison Illuminating Companies – AEIC
 4. Canadian Standards Association – CSA



2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

5. Electrical Apparatus Service Association – EASA
ANSI/EASA AR100 *Recommended Practice for the Repair of Rotating Electrical Apparatus*
6. Institute of Electrical and Electronic Engineers – IEEE
ANSI/IEEE C2 *National Electrical Safety Code*
ANSI/IEEE C37 *Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses*
ANSI/IEEE C57 *Distribution, Power, and Regulating Transformers*
Compilation
ANSI/IEEE C62 *Surge Protection*
Compilation
ANSI/IEEE 43 *IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery*
ANSI/IEEE 48 *IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV through 765 kV*
IEEE 81 *IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part I: Normal Measurements*
ANSI/IEEE 81.2 *IEEE Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems*
ANSI/IEEE 95 *IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage*
IEEE 100 *The Authoritative Dictionary of IEEE Standards Terms*
IEEE 141 *IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants (Red Book)*
ANSI/IEEE 142 *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book)*
ANSI/IEEE 241 *IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book)*
ANSI/IEEE 242 *IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)*



2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

IEEE 386	<i>IEEE Standard for Separable Insulated Connectors System for Power Distribution Systems above 600 V</i>
ANSI/IEEE 399	<i>IEEE Recommended Practice for Power Systems Analysis (Brown Book)</i>
IEEE 400	<i>IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems</i>
ANSI/IEEE 421.3	<i>IEEE Standard for High-Potential-Test Requirements for Excitation Systems for Synchronous Machines</i>
ANSI/IEEE 446	<i>IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)</i>
ANSI/IEEE 450	<i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications</i>
ANSI/IEEE 493	<i>IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)</i>
ANSI/IEEE 519	<i>IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems</i>
ANSI/IEEE 602	<i>IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book)</i>
ANSI/IEEE 637	<i>IEEE Guide for the Reclamation of Insulating Oil and Criteria for Its Use</i>
IEEE 644	<i>Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines</i>
ANSI/IEEE 739	<i>IEEE Recommended Practice for Energy Management in Commercial and Industrial Facilities (Bronze Book)</i>
ANSI/IEEE 902	<i>IEEE Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems (Yellow Book)</i>
IEEE 1015	<i>IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)</i>
IEEE 1100	<i>IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)</i>
ANSI/IEEE 1106	<i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Batteries for Stationary Applications</i>



2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

ANSI/IEEE 1159	<i>IEEE Recommended Practice on Monitoring Electrical Power Quality</i>
ANSI/IEEE 1188	<i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications</i>
IEEE 1584	<i>IEEE Guide for Performing Arc-Flash Hazard Calculations</i>
IEEE 1584a	<i>IEEE Guide for Performing Arc-Flash Hazard Calculations – Amendment 1</i>

7. Insulated Cable Engineers Association – ICEA

ANSI/ICEA S-93-639/NEMA WC 74	<i>5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy</i>
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ANSI/ICEA S-94-649	<i>Standard for Concentric Neutral Cables Rated 5,000 – 46,000 Volts</i>
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ANSI/ICEA S-97-682	<i>Standard for Utility Shielded Power Cables Rated 5,000 – 46,000 Volts</i>
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8. InterNational Electrical Testing Association – NETA

ANSI/NETA ETT	<i>Standard for Certification of Electrical Testing Technicians</i>
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ANSI/NETA ATS	<i>Acceptance Testing Specifications for Electrical Power Equipment and Systems</i>
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2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

9. National Electrical Manufacturers Association – NEMA
 - NEMA AB4 *Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications*
 - ANSI/NEMA C84.1 *Electrical Power Systems and Equipment Voltage Ratings (60 Hz)*
 - NEMA MG1 *Motors and Generators*
10. National Fire Protection Association – NFPA
 - ANSI/NFPA 70 *National Electrical Code*
 - ANSI/NFPA 70B *Recommended Practice for Electrical Equipment Maintenance*
 - ANSI/NFPA 70E *Standard for Electrical Safety in the Workplace*
 - ANSI/NFPA 99 *Standard for Healthcare Facilities*
 - ANSI/NFPA 101 *Life Safety Code*
 - ANSI/NFPA 110 *Emergency and Standby Power Systems*
 - ANSI/NFPA 780 *Installation of Lightning Protection Systems*
11. Occupational Safety and Health Administration – OSHA
12. State and local codes and ordinances
13. Underwriters Laboratories, Inc. – UL



2. APPLICABLE REFERENCES

2.2 Other Publications

Manufacturer's instruction manuals for the equipment to be tested.

A Stitch in Time...The Complete Guide to Electrical Insulation Testing, Megger.

Electrical Power Equipment Maintenance and Testing, Paul Gill, New York: Taylor & Francis Books.

Electrical Safety Handbook, John C. Cadick, New York: McGraw Hill.

The Electrical Safety Program Book, Kenneth G. Mastrullo, Ray A. Jones, Jane G. Jones, National Fire Protection Association.

Instruction Book PC – 2000 for Wecosol™ Fluid-Filled Primary and Secondary Unit Substation Transformer, ABB Power T&D.

2.3 Contact Information

ABB Power T&D
Small Transformer Division
PO Box 920
South Boston, VA 24592
(434) 572-5695
www.abb.com

American National Standards Institute – ANSI
25 West 43rd Street 4th Fl.
New York, NY 10036
(212) 642-4900
www.ansi.org

ASTM International – ASTM
100 Barr Harbor Drive
W. Conshohocken, PA 19428
(610) 832-9585
www.astm.org

Association of Edison Illuminating Companies – AEIC
600 N. 18th Street; PO Box 2641
Birmingham, AL 35291
(205) 257-2530
www.aeic.org

Canadian Standards Association – CSA
178 Rexdale Boulevard
Toronto, ON M9W 1R3
(416) 747-4000
www.csa.ca



2. APPLICABLE REFERENCES

2.3 Contact Information (*continued*)

Electrical Apparatus Service Association – EASA
1331 Baur Boulevard
St. Louis, MO 63132
(314) 993-2220
www.easa.com

Institute of Electrical and Electronic Engineers – IEEE
PO Box 1331
Piscataway, NJ 08855
(732) 981-0060
www.ieee.org

Insulated Cable Engineers Association – ICEA
c/o Global Document Engineers
15 Inverness Way East
Englewood, CO 80112
(303) 397-7956
www.icea.net

International Electrotechnical Commission – IEC
Contact through American National Standards Institute

InterNational Electrical Testing Association – NETA
3050 Old Centre Ave. Suite 102
Portage, MI 49024
(269)488-6382 or (888) 300-NETA (6382)
www.netaworld.org

The McGraw-Hill Companies
P.O. Box 182604
Columbus, OH 43272
(877) 833-5524
www.mcgraw-hill.com

Megger
4271 Bronze Way
Dallas, TX 75237
(214) 723-2861
www.megger.com

National Electrical Manufacturers Association– NEMA
1300 N. 17th St. Suite 1847
Rosslyn, VA 22209
(703) 841-3200
www.nema.org



2. APPLICABLE REFERENCES

2.3 Contact Information (*continued*)

National Institute of Standards and Technology
100 Bureau Drive
Gaithersburg, SD 20899
(301) 975-6478
www.nist.gov

National Fire Prevention Association – NFPA
1 Battery March Park
PO Box 901
Quincy, MA 02269-9101
(617) 984-7247
www.nfpa.org

Occupational Safety and Health Administration – OSHA
U.S. Department of Labor
Occupational Safety and Health Administration
Office of Public Affairs – Room N3647
200 Constitution Avenue
Washington, D.C. 20210
(202) 693-1999
www.osha.gov

Square D Company, Anderson Product Division
P.O. Box 455
Leeds, AL 35094
205-699-2411
www.squared.com

Taylor and Francis Books, Inc. – CRC Press
2000 NW Corporate Blvd.
Boca Raton, FL 33431
(561) 361-6000
www.crcpress.com

Underwriters Laboratories, Inc. – UL
333 Pfingsten Road
Northbrook, IL 60062
(847) 272-8800
www.ul.com



3. QUALIFICATIONS OF TESTING PERSONNEL

1. The subjective assessment required by this NETA maintenance standard is unique compared to other American National Standards in that it deals with the evaluation of service-aged equipment. While technicians performing tests and inspections on new equipment deal with finite test values, those working with service-aged equipment must form recommendations based on judgment.
2. Technicians performing these electrical tests and inspections shall be trained and experienced concerning the apparatus and systems being evaluated. These individuals shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must be able to evaluate the test data and make a judgment on the continued serviceability or nonserviceability of the specific equipment.
3. Test technicians shall have knowledge of and experience with the specific device under test. Additional personnel qualifications are as follows:
 1. Testing organizations: Owners utilizing testing companies shall require that each on-site crew leader shall hold a current certification, Level III or higher, in electrical testing. This certification shall be in accordance with ANSI/NETA ETT-2010, *Standard for Certification of Electrical Testing Personnel*.
 2. Manufacturers' Service Personnel: Field service personnel of the manufacturer of the equipment being evaluated shall be certified by the manufacturer to perform these electrical tests and inspections. The manufacturer shall provide sufficient documentation to satisfy the owner that its service personnel are trained and qualified to perform these electrical tests and inspections.
 3. In-House Testing Personnel: Owners having in-house testing personnel shall utilize an independent, outside certification organization or have some system of qualification which provides an equivalent level of assurance that their personnel are qualified to perform electrical testing. Owners are encouraged to utilize ANSI/NETA ETT-2010 as a means of determining that their electrical testing personnel possess the training, experience, and proof (examination) requirements now being promulgated by various governmental agencies.



4. DIVISION OF RESPONSIBILITY

4.1 The User

The user shall be responsible for all power switching of equipment and for providing equipment in a ready-to-test condition. The user shall provide the testing organization with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, and a protective device setting sheet as described in Section 6, if applicable.
2. The most current set of electrical drawings and instruction manuals applicable to the scope of work relative to the equipment under test.
3. An itemized description of equipment to be inspected and tested.
4. A determination of who shall provide a suitable and stable source of electrical power to each test site.
5. Notification of when equipment becomes available for maintenance tests. Work shall be coordinated to expedite project scheduling.
6. Site-specific hazard notification and safety training.

4.2 The Testing Organization

The testing organization shall provide the following:

1. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform such tests and inspections.
2. Specific power requirements for test equipment.
3. Notification to the owner's representative prior to commencement of any testing.
4. A timely notification of any system, material, or workmanship which is found deficient on the basis of maintenance tests.
5. A record of all tests and a final report.



5. GENERAL

5.1 Safety and Precautions

All parties involved must be cognizant of industry-standard safety procedures. This document does not include any procedures, including specific safety procedures. It is recognized that an overwhelming majority of the tests and inspections recommended in these specifications are potentially hazardous. Individuals performing these tests shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved.

1. Safety practices shall include, but are not limited to, the following requirements:
 1. All applicable provisions of the Occupational Safety and Health Act, particularly OSHA 29CFR 1910.
 2. ANSI/NFPA 70E, *Standard for Electrical Safety in the Workplace*
 3. *The Electrical Safety Program Book*, Kenneth G. Mastrullo, Ray A. Jones, Jane G. Jones, NFPA.
 4. Applicable state and local safety operating procedures.
 5. Owner's safety practices.
2. A safety lead person shall be identified prior to commencement of work.
3. A safety briefing shall be conducted prior to the commencement of work.
4. All tests shall be performed with the apparatus de-energized and grounded except where otherwise specifically required to be ungrounded or energized for certain tests.
5. The testing organization shall have a designated safety representative on the project to supervise operations with respect to safety. This individual may be the same person described in 5.1.2.

5.2 Suitability of Test Equipment

1. All test equipment shall meet the requirements in Section 5.3 and be in good mechanical and electrical condition.
2. Field test metering used to check power system meter calibration must be more accurate than the instrument being tested.
3. Accuracy of metering in test equipment shall be appropriate for the test being performed.
4. Waveshape and frequency of test equipment output waveforms shall be appropriate for the test and the tested equipment.



5. GENERAL

5.3 Test Instrument Calibration

1. The testing organization shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy for each test instrument calibrated.
2. The firm providing calibration service shall maintain up-to-date instrument calibration instructions and procedures for each test instrument calibrated.
3. The accuracy shall be directly traceable to the National Institute of Standards and Technology (NIST).
4. Instruments shall be calibrated in accordance with the following frequency schedule:
 1. Field instruments: Analog and digital, 12 months maximum.
 2. Laboratory instruments: 12 months maximum.
 3. Leased specialty equipment: 12 months maximum.
5. Dated calibration labels shall be visible on all test equipment.
6. Records, which show date and results of instruments calibrated or tested, must be kept up-to-date.
7. Calibrating standard shall be of higher accuracy than that of the instrument tested.



5. GENERAL

5.4 Test Report

1. The test report shall include the following:
 1. Summary of project.
 2. Description of equipment tested.
 3. Description of tests.
 4. Test data.
 5. Analysis and recommendations.
2. Test data records shall include the following minimum requirements:
 1. Identification of the testing organization.
 2. Equipment identification.
 3. Humidity, temperature, and other conditions that may affect the results of the tests/calibrations.
 4. Date of inspections, tests, maintenance, and/or calibrations.
 5. Identification of the testing technician.
 6. Indication of inspections, tests, maintenance, and/or calibrations to be performed and recorded.
 7. Indication of expected results when calibrations are to be performed.
 8. Indication of “as-found” and “as-left” results, as applicable.
 9. Sufficient spaces to allow all results and comments to be indicated.
3. The testing organization shall furnish a copy or copies of the complete report as specified in the maintenance testing contract.

6. POWER SYSTEM STUDIES

6.1 Short-Circuit Studies

1. Scope of Study

Determine the short-circuit current available at each component of the electrical system and the ability of the component to withstand and/or interrupt the current. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

2. Procedure

The short-circuit study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE standard 399 and the step-by-step procedures outlined in the short-circuit calculation chapters of IEEE standard 141 and ANSI/IEEE standard 242.

3. Study Report

Results of the short-circuit study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study.
2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and identification of the scenario used to evaluate equipment short-circuit ratings.
4. Tabulations of equipment short-circuit ratings versus available fault duties. The tabulation shall identify percentage of rated short circuit and clearly note equipment with insufficient ratings.
5. Conclusions and recommendations.



6. POWER SYSTEM STUDIES

6.2 Coordination Studies

1. Scope of Study

1. Determine the extent of overcurrent protective device coordination for the scope:
 1. Selective coordination: determine the protective device types, characteristics, settings, or ampere ratings which provide selective coordination, equipment protection, and correct interrupting ratings for the full range of available short-circuit currents at points of application for each overcurrent protective device.
 2. Compromised coordination: determine protective device types, characteristics, settings, or ampere ratings which permit ranges of non-coordination of overcurrent protective devices. In this case, overcurrent protective device coordination may be compromised due to the overcurrent protective devices selected or already installed or in order to achieve protection of equipment that is selected or already installed. Objective is to maximize coordination of overcurrent protective devices to extent possible based on the type of devices. Determine protective device characteristics, settings, or sizes which provide a balance between equipment protection and selective device operation that is optimum for the electrical system.
2. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

2. Procedure

The coordination study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE standard 399 and ANSI/IEEE standard 242. Protective device selection and settings shall comply with requirements of the *National Electrical Code*.

3. Study Report

Results of the coordination study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study and a corresponding one-line diagram.
2. Time-current curves, selective coordination ratios of fuses, or selective coordination tables of circuit breakers demonstrating the coordination of overcurrent protective devices to the scope.
3. Tabulations of protective devices identifying circuit location, manufacturer, type, range of adjustment, IEEE device number, current transformer ratios, recommended settings or device size, and referenced time-current curve.



6. POWER SYSTEM STUDIES

6.2 Coordination Studies (*continued*)

4. Conclusions and recommendations.

4. Implementation

The owner shall engage an independent testing firm for the purpose of inspecting, setting, testing, and calibrating the protective relays, circuit breakers, fuses, and other applicable devices as outlined in this specification.



6. POWER SYSTEM STUDIES

6.3 Arc-Flash Hazard Analysis

1. Scope of Study

Determine arc-flash incident energy levels and flash protection boundary distances based on the results of the short-circuit and coordination studies. Perform the analysis under worst-case arc-flash conditions for all modes of operation. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions to the subject system.

2. Procedure

Identify all locations and equipment to be included in the arc-flash hazard analysis.

1. Prepare a one-line diagram of the power system.
2. Perform a short-circuit study in accordance with Section 6.1.
3. Perform a coordination study in accordance with Section 6.2.
4. Identify the possible system operating modes, including tie-breaker positions, parallel generation, etc.
5. Calculate the arcing fault current flowing through each branch for each fault location using empirical formula in accordance with NFPA, IEEE, or other standards.
6. Determine the time required to clear the arcing fault current using the protective device settings and associated trip curves.
7. Select the working distances based on system voltage and equipment class.
8. Calculate the incident energy at each fault location at the prescribed working distance.
9. Determine the hazard/risk category (HRC) for the estimated incident energy level.
10. Calculate the flash protection boundary at each fault location.
11. Document the assessment in reports and one-line diagrams.
12. Place appropriate labels on the equipment.

3. Study Report

Results of the arc-flash study shall be summarized in a final report containing the following items:

1. Basis, method of hazard assessment, description, purpose, scope, and date of the study.



6. POWER SYSTEM STUDIES

6.3 Arc-Flash Hazard Analysis (*continued*)

2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and identification of the scenario used to evaluate equipment ratings.
4. Tabulations of equipment incident energies, hazard risk categories, and flash protection boundaries. The tabulation shall identify and clearly note equipment that exceeds allowable incident energy ratings.
5. Required arc-flash labeling and placement of labels.
6. Conclusions and recommendations.



6. POWER SYSTEM STUDIES

6.4 Load-Flow Studies

1. Scope of Study

Determine active and reactive power, voltage, current, and power factor throughout the electrical system. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

2. Procedure

The load-flow study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE standard 399.

3. Study Report

Results of the load-flow study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study.
2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and the basis for each.
4. Tabulations of power and current flow versus equipment ratings. The tabulation shall identify percentage of rated load and the scenario for which the percentage is based. Overloaded equipment shall be clearly noted.
5. Tabulations of system voltages versus equipment ratings. The tabulation shall identify percentage of rated voltage and the scenario for which the percentage is based. Voltage levels outside the ranges recommended by equipment manufacturers, ANSI C84.1, or other appropriate standards shall be clearly noted.
6. Tabulations of system real and reactive power losses with areas of concern clearly noted.
7. Conclusions and recommendations.



6. POWER SYSTEM STUDIES

6.5 Stability Studies

1. Scope of Study

Determine the ability of the electrical system's synchronous machines to remain in step with one another following a disturbance. Provide an analysis of disturbances for all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

2. Procedure

The stability study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE standard 399.

3. Study Report

Results of the stability study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study.
2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and tabulations or graphs showing the calculation results.
4. Conclusions and recommendations.



6. POWER SYSTEM STUDIES

6.6 Harmonic-Analysis Studies

1. Scope of Study

Determine the impact of nonlinear loads and their associated harmonic contributions on the voltage and currents throughout the electrical system. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

2. Procedure

The harmonic-analysis study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE standard 399.

3. Study Report

Results of the harmonic-analysis study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study.
2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and the basis for each.
4. Tabulations of rms voltages, peak voltages, rms currents, and total capacitor bank loading versus associated equipment ratings. Equipment with insufficient ratings shall be clearly identified for each of the scenarios evaluated.
5. Tabulations of calculated voltage distortion factors, current distortion factors, and individual harmonics versus the limits specified by IEEE standard 519. Calculated values exceeding the limits specified in the standard shall be clearly noted.
6. Plots of impedance versus frequency showing resonant frequencies to be avoided.
7. Tabulations of the system transformer capabilities based on the calculated nonsinusoidal load current and the procedures set forth in ANSI/IEEE C57.110. Overloaded transformers shall be clearly noted.
8. Conclusions and recommendations.



7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies

1. Visual and Mechanical Inspection

1. Inspect physical, electrical, and mechanical condition including evidence of moisture or corona.
2. Inspect anchorage, alignment, grounding, and required area clearances.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Verify that fuse and/or circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker's address for microprocessor-communication packages.
6. Verify that current and voltage transformer ratios correspond to drawings.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
8. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
 1. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
 2. Make key exchange with all devices included in the interlock scheme as applicable.
9. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
10. Verify correct barrier and shutter installation and operation.
11. Exercise all active components.
12. Inspect mechanical indicating devices for correct operation.
13. Verify that filters are in place and/or vents are clear.
14. Perform visual and mechanical inspection of instrument transformers in accordance with Section 7.10.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (*continued*)

15. Inspect control power transformers.
 1. Inspect for physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
 2. Verify that primary and secondary fuse ratings or circuit breakers match drawings.
 3. Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.
16. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter in accordance with Section 7.1.1, if applicable.
2. Perform insulation-resistance tests for one minute on each bus section, phase-to-phase and phase-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
- *3. Perform a dielectric withstand voltage test on each bus section, each phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 100.2. The test voltage shall be applied for one minute. Refer to Section 7.1.3 before performing test.
- *4. Perform insulation-resistance tests on control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
5. Perform electrical tests on instrument transformers in accordance with Section 7.10.
6. Perform ground-resistance tests in accordance with Section 7.13.
7. Determine accuracy of all meters and calibrate watt-hour meters in accordance with Section 7.11.
8. Control Power Transformers
 1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (*continued*)

2. Verify correct function of control transfer relays located in switchgear with multiple power sources.
9. Verify operation of switchgear/switchboard heaters and their controller, if applicable.
10. Perform system function tests in accordance with Section 8.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.1.1.7.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.1.1.7.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.1.1.7.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of bus insulation should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.
3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the test, the test dielectric withstand voltage specimen is considered to have passed the test.
4. Minimum insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Results of electrical tests on instrument transformers should be in accordance with Section 7.10.
6. Results of ground resistance tests should be in accordance with Section 7.13.
7. Accuracy of meters should be in accordance with Section 7.11.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (*continued*)

8. Control Power Transformers

1. Insulation-resistance values of control power transformers should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
 2. Control transfer relays should perform as designed.
9. Heaters should be operational.
10. Results of system function tests shall be in accordance with Section 8.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.1.1 Transformers, Dry Type, Air-Cooled, Low-Voltage, Small

NOTE: This category consists of power transformers with windings rated 600 volts or less and sizes equal to or less than 167 kVA single-phase or 500 kVA three-phase.

1. Visual and Mechanical Inspection.

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use a of low-resistance ohmmeter in accordance with Section 7.2.1.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
6. Perform as-left tests.
7. Verify that as-left tap connections are as specified.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.1.1.1.
2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate the dielectric absorption ratio or polarization index.
- *3. Perform turns-ratio tests at the designated tap position.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.1.1 Transformers, Dry Type, Air-Cooled, Low-Voltage, Small (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.2.1.1.1.5.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.1.1.1.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.2.1.1.1.5.3)
4. Tap connections are left as found unless otherwise specified. (7.2.1.1.7)

3.2 Test Values – Electrical

1. Compare bolted electrical connection resistances to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Minimum insulation-resistance values of transformer insulation should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The dielectric absorption ratio or polarization index shall be compared to previously obtained results and should not be less than 1.0.
3. Turns-ratio test results should not deviate more than one-half percent from either the adjacent coils or the calculated ratio.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.1.2 Transformers, Dry Type, Air-Cooled, Large

NOTE: This category consists of power transformers with windings rated higher than 600 volts and low-voltage transformers larger than 167 kVA single-phase or 500 kVA three-phase.

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition including evidence of moisture and corona.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
- *5. Verify that control and alarm settings on temperature indicators are as specified.
6. Verify that cooling fans operate correctly.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.2.1.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
8. Perform specific inspections and mechanical tests as recommended by the manufacturer.
9. Perform as-left tests.
10. Verify that as-left tap connections are as specified.
11. Verify the presence of surge arresters.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.1.2 Transformers, Dry Type, Air-Cooled, Large (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.1.2.1.
2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.
3. Perform insulation power-factor or dissipation-factor tests on all windings in accordance with the test equipment manufacturer's published data.
- *4. Perform a power-factor or dissipation-factor tip-up test on windings rated greater than 2.5 kV.
5. Perform turns-ratio tests at the designated tap position.
6. Perform an excitation-current test on each phase.
- *7. Measure the resistance of each winding at the designated tap position.
8. Measure core insulation resistance at 500 volts dc if the core is insulated and if the core ground strap is removable.
- *9. Perform an applied voltage test on all high- and low-voltage windings-to-ground. See ANSI/IEEE C57.12.91, Sections 10.2 and 10.9.
10. Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.
11. Test surge arresters in accordance with Section 7.19.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.1.2 Transformers, Dry Type, Air-Cooled, Large (*continued*)

3.1 Test Values – Visual and Mechanical

1. Control and alarm settings on temperature indicators should operate within manufacturer's recommendations for specified settings. (7.2.1.2.1.5)
2. Cooling fans should operate. (7.2.1.2.1.6)
3. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.2.1.2.1.7.1)
4. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.1.2.1.7.2)
5. Results of the thermographic survey shall be in accordance with Section 9. (7.2.1.2.1.7.3)
6. Tap connections shall be left as found unless otherwise specified. (7.2.1.2.1.10)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Minimum insulation-resistance values of transformer insulation should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall be compared to previously obtained results and should not be less than 1.0.
3. C_H and C_L power-factor or dissipation-factor values will vary due to support insulators and bus work utilized on dry transformers. The following should be expected on C_{HL} power factors:
Power transformers: 2.0 percent or less
Distribution transformers: 5.0 percent or less
Consult transformer manufacturer's or test equipment manufacturer's data for additional information.
4. Power-factor or dissipation-factor tip-up exceeding 1.0 percent should be investigated.
5. Turns-ratio test results should not deviate more than one-half percent from either the adjacent coils or the calculated ratio.
6. The typical excitation current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.1.2 Transformers, Dry Type, Air-Cooled, Large (*continued*)

7. Temperature-corrected winding-resistance values should compare within one percent of previously-obtained results.
8. Core insulation-resistance values should be comparable to previously-obtained results but not less than one megohm at 500 volts dc.
9. AC dielectric withstand test voltage shall not exceed 65 percent of factory test voltage for one minute duration. DC dielectric withstand test voltage shall not exceed 100 percent of the ac rms test voltage specified in ANSI C57.12.91, Section 10.2 for one minute duration. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
10. Phase-to-phase and phase-to-neutral secondary voltages should be in agreement with nameplate data.
11. Test results for surge arresters shall be in accordance with Section 7.19.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Verify the presence of PCB labeling, if applicable.
4. Prior to cleaning the unit, perform as-found tests, if required.
5. Clean bushings and control cabinets.
- *6. Verify operation of alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relay, if applicable.
7. Verify that cooling fans and/or pumps operate correctly.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.2.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
9. Verify correct liquid level in tanks and bushings.
10. Verify that positive pressure is maintained on gas-blanketed transformers.
11. Perform inspections and mechanical tests as recommended by the manufacturer.
12. Test load tap-changer in accordance with Section 7.12, if applicable.
13. Verify the presence of transformer surge arresters.
14. Perform as-left tests.
15. Verify de-energized tap-changer position is left as specified.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.2.1.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (*continued*)

2. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.
3. Perform turns-ratio tests at the designated tap position.
4. Perform insulation power-factor or dissipation-factor tests on all windings in accordance with test equipment manufacturer's published data.
5. Perform power-factor or dissipation-factor tests on each bushing.
6. Perform excitation-current tests in accordance with the test equipment manufacturer's published data.
7. Measure the resistance of each winding at the designated tap position.
- *8. If the core ground strap is accessible, remove and measure the core insulation resistance at 500 volts dc.
- *9. Measure the percentage of oxygen in the gas blanket, if applicable.
10. Remove a sample of insulating liquid in accordance with ASTM D 923. The sample shall be tested for the following.
 1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
 2. Acid neutralization number: ANSI/ASTM D 974
 - *3. Specific gravity: ANSI/ASTM D 1298
 4. Interfacial tension: ANSI/ASTM D 971 or ANSI/ASTM D 2285
 5. Color: ANSI/ASTM D 1500
 6. Visual Condition: ASTM D 1524
 - *7. Water in insulating liquids: ASTM D 1533. (Required on 25 kV or higher voltages and on all silicone-filled units.)
 - *8. Measure power factor or dissipation factor in accordance with ASTM D 924.
11. Remove a sample of insulating liquid in accordance with ASTM D 3613 and perform dissolved-gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D3612.
12. Test the instrument transformers in accordance with Section 7.10.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (*continued*)

13. Test the surge arresters in accordance with Section 7.19.
14. Test the transformer neutral grounding impedance devices, if applicable.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Alarm, control, and trip circuits from temperature and level indicators as well as pressure relief device and fault pressure relay should operate within manufacturer's recommendations for their specified settings. (7.2.2.1.6)
2. Cooling fans and/or pumps should operate. (7.2.2.1.7)
3. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.2.2.1.8.1)
4. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.2.1.8.2)
5. Results of the thermographic survey shall be in accordance with Section 9. (7.2.2.1.8.3)
6. Liquid levels in the transformer tanks and bushings should be within indicated tolerances. (7.2.2.1.9)
7. Positive pressure should be indicated on pressure gauge for gas-blanketed transformers. (7.2.2.1.10)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Minimum insulation-resistance values of transformer insulation should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall be compared to previously obtained results and should not be less than 1.0.
3. Turns-ratio test results should not deviate by more than one-half percent from either the adjacent coils or the calculated ratio.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (*continued*)

4. Maximum power-factor/dissipation-factor values of liquid-filled transformers corrected to 20° C should be in accordance with the transformer manufacturer's published data. Representative values are indicated in Table 100.3.
5. Investigate bushing power-factor and capacitance values that vary from nameplate values by more than ten percent. Hot-collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.
6. Typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.
7. Temperature corrected winding-resistance values should compare within one percent of previously obtained results.
8. Core insulation values should be comparable to previously obtained results but not less than one megohm at 500 volts dc.
9. Investigate the presence of oxygen in the nitrogen gas blanket.
10. Insulating liquid values should be in accordance with Table 100.4.
11. Evaluate results of dissolved-gas analysis in accordance with ANSI/IEEE Standard C57.104.
12. Results of electrical tests on instrument transformers shall be in accordance with Section 7.10.
13. Results of surge arrester tests shall be in accordance with Section 7.19.
14. Compare grounding impedance device values to previously obtained results. In the absence of previously obtained values, compare obtained values to manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.3.1 Cables, Low-Voltage, Low-Energy

– RESERVED –

* Optional



7. INSPECTION AND TEST PROCEDURES

7.3.2 Cables, Low-Voltage, 600-Volt Maximum

1. Visual and Mechanical Inspection

1. Inspect exposed sections of cables for physical damage and evidence of overheating.
2. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.3.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
3. Inspect compression-applied connectors for correct cable match and indentation.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.3.2.1.
2. Perform an insulation-resistance test on each conductor with respect to ground and adjacent conductors. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. The test duration shall be one minute.
3. Verify uniform resistance of parallel conductors.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.3.2.1.2.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.3.2.1.2.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.3.2.1.2.3)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.3.2 Cables, Low-Voltage, 600-Volt Maximum (*continued*)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be comparable to previously obtained results and similar circuits but not less than two megohms.
3. Deviations in resistance between parallel conductors shall be investigated.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.3.3 Cables, Medium- and High-Voltage

1. Visual and Mechanical Inspection

1. Inspect exposed sections of cables for physical damage and evidence of overheating and corona.
2. Inspect terminations and splices for physical damage, evidence of overheating, and corona.
3. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.3.3.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
4. Inspect compression-applied connectors for correct cable match and indentation.
5. Inspect shield grounding and cable support.
6. Verify that visible cable bends meet or exceed ICEA and/or manufacturer's minimum allowable bending radius.
- *7. Inspect fireproofing in common cable areas.
8. If cables are terminated through window-type current transformers, inspect to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.3.3.1.
2. Perform an insulation-resistance test individually on each conductor with all other conductors and shields grounded. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a shield-continuity test on each power cable by ohmmeter method.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.3.3 Cables, Medium- and High-Voltage (*continued*)

Due to the various cable testing methods commercially available, the following section does not denote “optional” or “required” tests. It is only after careful analysis of all circuit parameters between the testing entity and the cable owner that a preferred testing method should be selected.

4. In accordance with ICEA, IEC, IEEE and other power cable consensus standards, testing can be performed by means of direct current, power frequency alternating current, or very low frequency alternating current. These sources may be used to perform insulation withstand tests, and diagnostic tests such as partial discharge analysis, and power factor or dissipation factor. The selection can only be made after an evaluation of the available test methods and a review of the installed cable system.

4.1 Dielectric Withstand

1. Direct current (DC) dielectric withstand voltage
2. Very low frequency (VLF) dielectric withstand voltage
3. Power frequency (50/60 Hz) dielectric withstand voltage

4.2 Diagnostic Tests

1. Power factor/dissipation factor (tan delta)
 1. Power frequency (50/60 Hz)
 2. Very low frequency (VLF)
2. DC insulation resistance
3. Partial discharge
 1. On line (50/60 Hz)
 2. Off line
 1. Power frequency (50/60 Hz)
 2. Very low frequency (VLF)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.3.3 Cables, Medium- and High-Voltage (*continued*)

3 Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.3.3.1.3.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.3.3.1.3.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.3.3.1.3.3)
4. The minimum bend radius to which insulated cables may be bent for permanent training shall be in accordance with Table 100.22. (7.3.3.1.6)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Shielding shall exhibit continuity. Investigate resistance values in excess of ten ohms per 1000 feet of cable.
- 4.1 If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the test, the test specimen is considered to have passed the test.
- 4.2 Based on the test methodology chosen, refer to applicable standards or manufacturer's literature for acceptable values.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.4 Metal-Enclosed Busways

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.4.2.
 2. Verify tightness of accessible bolted electrical connections and bus joints by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
4. Confirm physical orientation in accordance with manufacturer's labels to insure adequate cooling.
5. Examine outdoor busway for removal of "weep-hole" plugs, if applicable, and for the correct installation of joint shield.
6. Inspect and clean ventilating openings.

2. Electrical Tests

1. Perform resistance measurements through bolted connections and bus joints with a low-resistance ohmmeter, if applicable, in accordance with Section 7.4.1.
2. Perform insulation resistance tests on each busway for one minute, phase-to-phase and phase-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a dielectric withstand voltage test on each busway, phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 100.17. Where no dc test value is shown in Table 100.17, ac value shall be used. The test voltage shall be applied for one minute.
- *4. Perform a contact-resistance test on each connection point of uninsulated busway. On insulated busway, measure resistance of assembled busway sections and compare values with the adjacent phases.
5. Verify operation of busway space heaters.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.4 Metal-Enclosed Busways (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.4.1.3.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.4.1.3.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.4.1.3.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance test voltages and resistance values shall be in accordance with manufacturer's specifications or Table 100.1. Minimum resistance values are for a nominal 1000-foot busway run. Use the following formula to convert the measured resistance value to the 1000-foot nominal value:

$$R_{1000\text{ft}} = \text{Measured Resistance} \times \frac{\text{Length of Run}}{1000}$$

Converted values of insulation resistance less than those in Table 100.1 or manufacturer's minimum should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.

3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
4. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values which deviate from those of similar bus connections and sections by more than 50 percent of the lowest value.
5. Heaters should be operational.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.1.1 Switches, Air, Low-Voltage

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, grounding, and required clearances.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
6. Verify that fuse sizes and types are in accordance with drawings, short-circuit study, and coordination study.
7. Verify that each fuse has adequate mechanical support and contact integrity.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.5.1.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
9. Verify operation and sequencing of interlocking systems.
10. Verify phase-barrier mounting is intact.
11. Verify correct operation of indicating and control devices.
12. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Perform as-left tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.1.1 Switches, Air, Low-Voltage (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.1.1.1.
2. Measure contact resistance across each switchblade and fuseholder.
3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
4. Measure fuse resistance.
5. Verify cubicle space heater operation.
6. Perform a ground-fault test in accordance with Section 7.14, if applicable.
7. Perform tests on other protective devices in accordance with Section 7.9, if applicable.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.1.1.1.8.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.1.1.1.8.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.1.1.1.8.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.1.1 Switches, Air, Low-Voltage (*continued*)

3. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
4. Investigate fuse-resistance values that deviate from each other by more than 15 percent.
5. Heaters should be operational.
6. Ground fault tests should be in accordance with Section 7.14.
7. Results of protective device tests should be in accordance with Section 7.9.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.1.2 Switches, Air, Medium-Voltage, Metal-Enclosed

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, grounding, and required clearances.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation.
6. Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.
7. Verify that expulsion-limiting devices are in place on all fuses having expulsion-type elements.
8. Verify that each fuseholder has adequate mechanical support and contact integrity.
9. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.5.1.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
10. Verify operation and sequencing of interlocking systems.
11. Verify that phase-barrier mounting is intact.
12. Verify correct operation of all indicating and control devices.
13. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
14. Perform as-left tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.1.2 Switches, Air, Medium-Voltage, Metal-Enclosed (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.1.2.1.
2. Measure contact resistance across each switchblade assembly and fuseholder.
3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
4. Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 100.2.
5. Measure fuse resistance.
6. Verify cubicle space heater operation.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.1.2.1.9.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.1.2.1.9.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.1.2.1.9.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.1.2 Switches, Air, Medium-Voltage, Metal-Enclosed (*continued*)

3. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.
4. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
5. Investigate fuse resistance values that deviate from each other by more than 15 percent.
6. Heaters should be operational.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.1.3 Switches, Air, Medium- and High-Voltage, Open

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, grounding, and required clearances.
3. Prior to cleaning insulators, perform as-found tests, if required.
4. Clean the insulators.
5. Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation.
6. Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.
7. Verify that each fuseholder has adequate mechanical support and contact integrity.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.5.1.3.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
9. Verify operation and sequencing of interlocking systems.
10. Perform mechanical operator tests in accordance with manufacturer's published data, if applicable.
11. Verify correct operation and adjustment of motor operator limit switches and mechanical interlocks, if applicable.
12. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Perform as-left tests.
14. Record as-found and as-left operation counter readings.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.1.3 Switches, Air, Medium- and High-Voltage, Open (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.1.3.1.
2. Perform a contact-resistance test across each switchblade and fuseholder.
3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
- *4. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
5. Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 100.19.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.1.3.1.8.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.1.3.1.8.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.1.3.1.8.3)
4. Operation counter should advance one digit per close-open cycle. (7.5.1.3.1.14)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available,

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.1.3 Switches, Air, Medium- and High-Voltage, Open (*continued*)

investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

3. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.
4. Minimum insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.2 Switches, Oil, Medium-Voltage

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, grounding, and required clearances.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Perform mechanical operator tests in accordance with manufacturer's published data, if applicable.
6. Verify correct operation and adjustment of motor operator limit switches and mechanical interlocks, if applicable.
- *7. Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation.
8. Verify that each fuseholder has adequate mechanical support and contact integrity, if applicable.
9. Verify that fuse sizes and types are in accordance with drawings, short circuit studies, and coordination study.
10. Test all electrical and mechanical interlock systems for correct operation and sequencing.
11. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.5.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
12. Verify that insulating oil level is correct.
13. Inspect and/or replace gaskets as recommended by the manufacturer.
14. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.2 Switches, Oil, Medium-Voltage (*continued*)

15. Perform as-left tests.
16. Record as-found and as-left operation counter readings, if applicable.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.2.1.
2. Perform a contact/pole-resistance test.
3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with the switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
- *4. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
- *5. Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 100.19.
- *6. Remove a sample of insulating liquid in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.
 1. Dielectric breakdown voltage: ASTM D 877
 2. Color: ANSI/ASTM D 1500
 3. Visual condition: ASTM D 1524

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.2.1.11.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.2.1.11.2)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.2 Switches, Oil, Medium-Voltage (*continued*)

3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.2.1.11.3)
4. Operations counter should advance one digit per close-open cycle. (7.5.2.1.16)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.
3. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.
4. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
6. Insulating liquid test results should be in accordance with Table 100.4.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.3 Switches, Vacuum, Medium-Voltage

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, grounding, and required clearances.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Perform mechanical operator tests in accordance with manufacturer's published data, if applicable.
6. Verify correct operation and adjustment of motor operator limit switches and mechanical interlocks, if applicable.
7. Measure critical distances on operating mechanism as recommended by the manufacturer.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter. See Section 7.5.3.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
9. Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
10. Verify that each fuseholder has adequate support and contact integrity.
11. Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.
12. Test all electrical and mechanical interlock systems for correct operation and sequencing.
13. Verify that insulating oil level is correct, if applicable.
14. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
15. Perform as-left tests.
16. Record as-found and as-left operation counter readings, if applicable.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.3 Switches, Vacuum, Medium-Voltage (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. See Section 7.5.3.1.
2. Perform a contact/pole-resistance test.
3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
4. Perform a vacuum bottle integrity (dielectric withstand voltage) test across each vacuum bottle with the switch in the open position in strict accordance with manufacturer's published data.
5. Remove a sample of insulating liquid, if applicable, in accordance with ASTM D 923. The sample shall be tested in accordance with the referenced standard.
 1. Dielectric breakdown voltage: ASTM D 877
 2. Color: ASTM D 1500
 3. Visual condition: ASTM D 1524
- *6. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow the manufacturer's recommendation.
- *7. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
8. Verify open and close operation from control devices, if applicable.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Critical distances of operating mechanism should be in accordance with manufacturer's published data. (7.5.3.1.7)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.3.1.8.1)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.3 Switches, Vacuum, Medium-Voltage (*continued*)

3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.3.1.8.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.5.3.1.8.3)
5. Operation counter should advance one digit per close-open cycle. (7.5.3.1.16)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.
3. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.
4. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the vacuum bottle integrity test, the test specimen is considered to have passed the test.
5. Insulating liquid test results should be in accordance with Table 100.4.
6. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
7. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
8. Results of open and close operation from control devices should be in accordance with system design.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.4 Switches, SF₆, Medium-Voltage

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, grounding, and required clearances.
3. Prior to cleaning the unit, perform as-found tests, if applicable.
4. Clean the unit.
5. Inspect and service mechanical operator and SF₆ gas insulated system in accordance with the manufacturer's published data.
6. Verify correct operation of SF₆ gas pressure alarms and limit switches, if applicable, as recommended by the manufacturer.
7. Measure critical distances as recommended by the manufacturer.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.5.4.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
9. Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.
10. Verify that each fuseholder has adequate mechanical support and contact integrity.
11. Verify operation and sequencing of interlocking systems.
12. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Test for SF₆ gas leaks in accordance with manufacturer's published data.
14. Perform as-left tests.
15. Record as-found and as-left operation counter readings, if applicable.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.4 Switches, SF₆, Medium-Voltage (*continued*)

2. Electrical Tests

1. Perform resistance measurements through accessible bolted electrical connections with a low-resistance ohmmeter, if applicable. See Section 7.5.4.1.
2. Perform a contact-resistance test.
3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
- *4. Remove a sample of SF₆ gas and test in accordance with Table 100.13.
5. Perform a dielectric withstand voltage test across each gas bottle with the switch in the open position in accordance with manufacturer's published data.
- *6. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
- *7. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
8. Verify open and close operation from control devices, if applicable.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Critical distances of operating mechanism should be in accordance with manufacturer's published data. (7.5.4.1.7)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.4.1.8.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.4.1.8.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.5.4.1.8.3)
5. Operations counter should advance one digit per close-open cycle. (7.5.4.1.15)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.4 Switches, SF₆, Medium-Voltage (*continued*)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.
3. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.
4. Results of SF₆ gas tests should be in accordance with Table 100.13.
5. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
6. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
7. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
8. Results of open and close operation from control devices should be in accordance with system design.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.5 Switches, Cutouts

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding, if applicable.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.5.5.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
6. Verify correct blade alignment, blade penetration, travel stops, latching mechanism, and mechanical operation.
7. Verify that fuse size and types are in accordance with drawings, short-circuit study, and coordination study.
8. Verify that each fuseholder has adequate mechanical support and contact integrity.
9. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.5.5.1.
2. Measure contact resistance across each cutout.
3. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
4. Perform a dielectric withstand voltage test on each pole, phase to ground with cutout closed. Ground adjacent cutouts, if applicable. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.5.5 Switches, Cutouts (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.5.5.1.5.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.5.5.1.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.5.1.5.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values which deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.
3. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.
4. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.1 Circuit Breakers, Air, Insulated-Case/Molded-Case

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage and alignment.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Operate the circuit breaker to insure smooth operation.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.6.1.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
7. Inspect operating mechanism, contacts, and arc chutes in unsealed units.
8. Perform adjustments for final protective device settings in accordance with coordination study provided by end user.
9. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.1.1.1.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a contact/pole-resistance test.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.1 Circuit Breakers, Air, Insulated-Case/Molded-Case (*continued*)

- *4. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
5. Determine long-time pickup and delay by primary current injection.
6. Determine short-time pickup and delay by primary current injection.
7. Determine ground-fault pickup delay by primary current injection.
8. Determine instantaneous pickup current by primary injection.
- *9. Test functions of the trip unit by means of secondary injection.
10. Perform minimum pickup voltage test on shunt trip and close coils in accordance with Table 100.20.
11. Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, antipump function, and trip unit battery condition.
12. Reset all trip logs and indicators.
13. Verify operation of charging mechanism.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.6.1.1.1.6.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.1.1.1.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.6.1.1.1.6.3)
4. Settings shall comply with coordination study recommendations. (7.6.1.1.1.8)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.1 Circuit Breakers, Air, Insulated-Case/Molded-Case (*continued*)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
4. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Long-time pickup values should be as specified, and the trip characteristic should not exceed manufacturer's published time-current characteristic tolerance band, including adjustment factors. If manufacturer's curves are not available, trip times should not exceed the value shown in Table 100.7.
6. Short-time pickup values should be as specified, and the trip characteristic should not exceed manufacturer's published time-current tolerance band.
7. Ground fault pickup values should be as specified, and the trip characteristic should not exceed manufacturer's published time-current tolerance band.
8. Instantaneous pickup values of molded-case circuit breakers should fall within manufacturer's published tolerances and/or Table 100.8.
9. Pickup values and trip characteristics should be within manufacturer's published tolerances.
10. Minimum pickup voltage on shunt trip and close coils should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.20.
11. Breaker open, close, trip, trip-free, antipump, and auxiliary features should function as designed.
12. Trip logs and indicators are reset.
13. The charging mechanism should operate in accordance with manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.2 Circuit Breakers, Air, Low-Voltage Power

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Verify that all maintenance devices are available for servicing and operating the breaker.
4. Prior to cleaning the unit, perform as-found tests, if required.
5. Clean the unit.
6. Inspect arc chutes.
7. Inspect moving and stationary contacts for condition, wear, and alignment.
8. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
9. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism in accordance with manufacturer's published data.
10. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.6.1.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
11. Verify cell fit and element alignment.
12. Verify racking mechanism operation.
13. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
14. Perform adjustments for final protective device settings in accordance with coordination study provided by end user.
15. Perform as-left tests.
16. Record as-found and as-left operation counter readings, if applicable.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.2 Circuit Breakers, Air, Low-Voltage Power (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.1.2.1.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a contact/pole-resistance test.
- *4. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
5. Determine long-time pickup and delay by primary current injection.
6. Determine short-time pickup and delay by primary current injection.
7. Determine ground-fault pickup and delay by primary current injection.
8. Determine instantaneous pickup current by primary current injection.
- *9. Test functions of the trip unit by means of secondary injection.
10. Perform minimum pickup voltage test on shunt trip and close coils in accordance with Table 100.20.
11. Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, antipump function, and trip unit battery condition.
12. Reset all trip logs and indicators.
13. Verify operation of charging mechanism.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.2 Circuit Breakers, Air, Low-Voltage Power (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.6.1.2.1.10.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.1.2.1.10.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.6.1.2.1.10.3)
4. Settings shall comply with coordination study recommendations. (7.6.1.2.1.15)
5. Operations counter should advance one digit per close-open cycle. (7.6.1.2.1.16)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of breakers should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
4. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Long-time pickup values should be as specified, and the trip characteristic shall not exceed manufacturer's published time-current characteristic tolerance band.
6. Short-time pickup values should be as specified, and the trip characteristic should not exceed manufacturer's published time-current tolerance band.
7. Ground fault pickup values should be as specified, and the trip characteristic should not exceed manufacturer's published time-current tolerance band.
8. Instantaneous pickup values should be within the tolerances of manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.2 Circuit Breakers, Air, Low-Voltage Power (*continued*)

9. Pickup values and trip characteristic should be as specified and within manufacturer's published tolerances.
10. Minimum pickup voltage on shunt trip and close coils should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.20.
11. Auxiliary features should operate in accordance with manufacturer's published data.
12. Trip logs and indicators are reset.
13. The charging mechanism should operate in accordance with manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.3 Circuit Breakers, Air, Medium-Voltage

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Verify that all maintenance devices are available for servicing and operating the breaker.
- *4. Perform operator analysis (first-trip) test.
5. Prior to cleaning the unit, perform as-found tests, if required.
6. Clean the unit.
7. Inspect arc chutes.
8. Inspect moving and stationary contacts for condition, wear, and alignment.
9. If recommended by manufacturer, slow close/open breaker and check for binding, friction, contact alignment, contact sequence, and penetration. Verify that contact sequence is in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to ANSI/IEEE C37.04.
10. Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.
11. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.6.1.3.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
12. Verify cell fit and element alignment.
13. Verify racking mechanism operation.
14. Inspect puffer operation.
15. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.3 Circuit Breakers, Air, Medium-Voltage (*continued*)

- *16. Perform time-travel analysis.
- 17. Perform as-left tests.
- 18. Record as-found and as-left operation-counter readings.

2. Electrical Tests

- 1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. See Section 7.6.1.3.1.
- 2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
- *3. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
- 4. Perform a contact/pole-resistance test.
- 5. With the breaker in a test position, perform the following tests:
 - 1. Trip and close breaker with the control switch.
 - 2. Trip breaker by operating each of its protective relays.
 - 3. Verify mechanism charge, trip-free, and antipump functions.
- *6. Perform minimum pickup voltage tests on trip and close coils in accordance with Table 100.20.
- *7. Perform power-factor or dissipation-factor tests with breaker in both the open and closed positions.
- *8. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/capacitance tap. In the absence of a power-factor/capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
- *9. Perform a dielectric withstand voltage test on each phase with the circuit breaker closed and the poles not under test grounded. Test voltage should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.3 Circuit Breakers, Air, Medium-Voltage (*continued*)

10. Verify blowout coil circuit continuity.
11. Verify operation of cubicle space heaters, if applicable.
- *12. Test instrument transformers in accordance with Section 7.10.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare first-trip operation time and trip-coil current waveform to manufacturer's published data. In the absence of manufacturer's published data, compare first-trip operation time and trip-coil current waveform to previously obtained results. (7.6.1.3.1.4)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.6.1.3.1.11.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.1.3.1.11.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.6.1.3.1.11.3)
5. Compare travel and velocity values to manufacturer's published data and previous test data. (7.6.1.3.1.16)
6. Operations counter should advance one digit per close-open cycle. (7.6.1.2.1.18)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of circuit breakers should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
4. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available,

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.1.3 Circuit Breakers, Air, Medium-Voltage (*continued*)

investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.

5. Breaker mechanism charge, close, open, trip, trip-free, and antipump features shall function as designed.
6. Minimum pickup for trip and close coils shall be in accordance with manufacturer's published data. In the absence of manufacturer's data, refer to Table 100.20.
7. Power-factor or dissipation-factor values shall be compared with previous test results of similar breakers or manufacturer's published data.
8. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliamperere/milliwatt loss basis, and the results should be compared to values of similar bushings.
9. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the circuit breaker is considered to have passed the test.
10. The blowout coil circuit should exhibit continuity.
11. Cubicle space heaters should be operational.
12. The results of instrument transformer tests shall be in accordance with Section 7.10.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.2 Circuit Breakers, Oil, Medium- and High-Voltage

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Verify that maintenance devices are available for servicing and operating the breaker.
- *4. Perform operator analysis (first-trip) test.
5. Verify correct oil level in tanks and bushings.
6. Verify that breather vents are clear.
7. Prior to cleaning the unit, perform as-found tests.
8. Clean the unit.
9. Inspect and service hydraulic or pneumatic system and/or air compressor in accordance with manufacturer's published data.
10. Test alarms, pressure switches, and limit switches for pneumatic and/or hydraulic operators as recommended by the manufacturer.
11. Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.
- *12. If performing internal inspection:
 1. Remove oil. Lower tanks or remove manhole covers as necessary. Inspect bottom of tank for broken parts and debris and clean carbon residue from tank.
 2. Inspect lift rod and toggle assemblies, contacts, interrupters, bumpers, dashpots, bushing current transformers, tank liners, and gaskets.
 3. If recommended by manufacturer, slow close/open breaker and check for binding, friction, contact alignment, and penetration. Verify that contact sequence is in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to ANSI C37.04.
 4. Refill tank(s) with filtered oil to correct levels.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.2 Circuit Breakers, Oil, Medium- and High-Voltage (*continued*)

13. Inspect all bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.6.2.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
14. Verify cell fit and element alignment, if applicable.
15. Verify racking mechanism operation, if applicable.
16. Perform time-travel analysis.
17. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
18. Perform as-left tests.
19. Record as-found and as-left operation counter readings.

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.2.1.12.1.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with circuit breaker closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a contact/pole-resistance test.
- *4. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or for control devices that cannot tolerate the voltage, follow manufacturer's recommendation.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.2 Circuit Breakers, Oil, Medium- and High-Voltage (*continued*)

5. Remove a sample of insulating liquid in accordance with ASTM D 923. The sample shall be tested in accordance with the referenced standard.
 1. Dielectric breakdown voltage: ASTM D 877
 2. Color: ANSI/ASTM D 1500
 - *3. Power factor: ASTM D 924
 - *4. Interfacial tension: ANSI/ASTM D 971 or ANSI/ASTM D 2285
 - *5. Visual condition: ASTM D 1524
6. With breaker in a test position, make the following tests:
 1. Trip and close breaker with the control switch.
 2. Trip breaker by operating each of its protective relays.
 3. Verify trip-free and antipump functions.
 - *4. Perform minimum pickup voltage tests on trip and close coils in accordance with Table 100.20.
7. Perform power-factor or dissipation-factor tests on each pole with the breaker open and each phase with the breaker closed. Determine tank loss index.
8. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/capacitance tap. In the absence of a power-factor/capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
- *9. Perform a dielectric withstand voltage test on each phase with the circuit breaker closed and the poles not under test grounded. Test voltage should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19.
10. Verify operation of heaters.
- *11. Test instrument transformers in accordance Section 7.10.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare first-trip operation time and trip-coil current waveform to manufacturer's published data. In the absence of manufacturer's published data, compare first-trip operation time and trip-coil current waveform to previously obtained results. (7.6.2.1.4)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.2 Circuit Breakers, Oil, Medium- and High-Voltage (*continued*)

2. Settings for alarm, pressure, and limit switches should be in accordance with manufacturer's published data. (7.6.2.1.10)
3. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.6.2.1.13.1)
4. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.2.1.13.2)
5. Results of the thermographic survey shall be in accordance with Section 9. (7.6.2.1.13.3)
6. Compare travel and velocity values to manufacturer's published data and previous test data. (7.6.2.1.16)
7. Operations counter should advance one digit per close-open cycle. (7.6.2.1.19)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of circuit breakers should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
4. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Insulating liquid test results should be in accordance with Table 100.4.
6. Open, close, trip-free, and antipump features should function in accordance with manufacturer's design. Minimum pickup for trip and close coils should conform to manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.20.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.2 Circuit Breakers, Oil, Medium- and High-Voltage (*continued*)

7. Power-factor or dissipation-factor values and tank loss index shall be compared to manufacturer's published data. In the absence of manufacturer's published data, the comparison shall be made to test data from similar breakers or data from test equipment manufacturers.
8. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliamperes/milliwatt loss basis, and the results should be compared to values of similar bushings.
9. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
10. Heaters should be operational.
11. Results of electrical tests on instrument transformers should be in accordance with Section 7.10.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.3 Circuit Breakers, Vacuum, Medium-Voltage

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Verify that all maintenance devices are available for servicing and operating the breaker.
- *4. Perform operator analysis (first-trip) test.
5. Prior to cleaning the unit, perform as-found tests, if required.
6. Clean the unit.
7. Inspect vacuum bottle assemblies.
8. Measure critical distances such as contact gap as recommended by the manufacturer.
9. If recommended by the manufacturer, slow close/open the breaker and check for binding, friction, contact alignment, contact sequence, and penetration.
10. Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.
11. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.6.3.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
12. Verify cell fit and element alignment.
13. Verify racking mechanism operation.
14. Inspect vacuum bellows operation.
15. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.3 Circuit Breakers, Vacuum, Medium-Voltage (*continued*)

- *16. Perform time-travel analysis.
- 17. Perform as-left tests.
- 18. Record as-found and as-left operation counter readings.

2. Electrical Tests

- 1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.3.1.10.
- 2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with circuit breaker closed and across each pole with the breaker open. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
- *3. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
- 4. Perform a contact/pole-resistance test.
- 5. With breaker in a test position, perform the following tests:
 - 1. Trip and close breaker with the control switch.
 - 2. Trip breaker by operating each of its protective relays.
 - 3. Verify mechanism charge, trip-free, and antipump functions.
- *6. Perform minimum pickup voltage tests on trip and close coils in accordance with Table 100.20.
- *7. Perform power-factor or dissipation-factor tests on each pole with the breaker open and each phase with the breaker closed.
- *8. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/capacitance tap. In the absence of a power-factor/capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
- 9. Perform a vacuum bottle integrity (dielectric withstand voltage) test across each vacuum bottle with the breaker in the open position in strict accordance with manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.3 Circuit Breakers, Vacuum, Medium-Voltage (*continued*)

- *10. Perform a dielectric withstand voltage test on each phase with the circuit breaker closed and the poles not under test grounded. Test voltage should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19.
- 11. Verify operation of heaters, if applicable.
- 12. Test instrument transformers in accordance with Section 7.10.

3. Test Values

3.1 Test Values – Visual and Mechanical

- 1. Compare first-trip operation time and trip-coil current waveform to manufacturer's published data. In the absence of manufacturer's published data, compare first-trip operation time and trip-coil current waveform to previously obtained results. (7.6.3.1.4)
- 2. Mechanical operation and contact alignment should be in accordance with manufacturer's published data. (7.6.3.1.9)
- 3. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.6.3.1.11.1)
- 4. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.3.1.11.2)
- 5. Results of the thermographic survey shall be in accordance with Section 9. (7.6.3.1.11.3)
- 6. Compare travel and velocity values to manufacturer's published data and previous test data. (7.6.3.1.16)
- 7. Operation counter should advance one digit per close-open cycle. (7.6.3.1.18)

3.2 Test Values – Electrical

- 1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
- 2. Insulation-resistance values of circuit breakers should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.3 Circuit Breakers, Vacuum, Medium-Voltage (*continued*)

3. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
4. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
5. Breaker mechanism charge, close, open, trip, trip-free, and antipump features shall function as designed.
6. Minimum pickup for trip and close coils shall be in accordance with manufacturer's published data. In the absence of manufacturer's data, refer to Table 100.20.
7. Power-factor or dissipation-factor values shall be compared to manufacturer's published data. In the absence of manufacturer's published data the comparison shall be made to similar breakers.
8. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.
9. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the vacuum bottle integrity test, the test specimen is considered to have passed the test.
10. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
11. Heaters should be operational.
12. Results of instrument transformer tests shall be in accordance with Section 7.10.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.4 Circuit Breakers, SF₆

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Verify that all maintenance devices are available for servicing and operating the breaker.
- *4. Perform operator analysis (first-trip) test.
5. Prior to cleaning the unit, perform as-found tests, if required.
6. Clean the unit.
- *7. When provisions are made for sampling, remove a sample of SF₆ gas and test in accordance with Table 100.13. Do not break seal or distort sealed-for-life interrupters.
8. Inspect and service operating mechanism and/or hydraulic or pneumatic system and SF₆ gas-insulated system in accordance with manufacturer's published data.
9. Test for SF₆ gas leaks in accordance with manufacturer's published data.
10. Test alarms, pressure switches, and limit switches for pneumatic and/or hydraulic operators and SF₆ gas pressure in accordance with manufacturer's published data.
11. If recommended by manufacturer, slow close/open breaker and check for binding, friction, contact alignment, and penetration. Verify that contact sequence is in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to ANSI/IEEE C37.04.
12. Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.
13. Inspect all bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.6.4.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
14. Verify cell fit and element alignment.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.4 Circuit Breakers, SF₆ (continued)

15. Verify racking mechanism operation.
16. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
17. Perform time-travel analysis.
18. Perform as-left tests.
19. Record as-found and as-left operation counter readings.

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.6.4.1.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with breaker closed, and across each open pole. For single-tank breakers, perform insulation resistance tests from pole-to-pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a contact/pole-resistance test.
- *4. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or for control devices that cannot tolerate the voltage, follow manufacturer's recommendation.
5. With breaker in a test position, perform the following tests:
 1. Trip and close breaker with the control switch.
 2. Trip breaker by operating each of its protective relays.
 3. Verify trip-free and antipump functions.
- *4. Perform minimum pickup voltage tests on trip and close coils in accordance with Table 100.20.
6. Perform power-factor or dissipation-factor tests on each pole with the breaker open and on each phase with breaker closed.
7. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/capacitance tap. In the absence of a power-factor/capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.4 Circuit Breakers, SF₆ (*continued*)

- *8. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
- 9. Verify operation of heaters.
- *10. Test instrument transformers in accordance with Section 7.10.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare first-trip operation time and trip-coil current waveform to manufacturer's published data. In the absence of manufacturer's published data, compare first-trip operation time and trip-coil current waveform to previously obtained results. (7.6.4.1.4) .
2. SF₆ gas should have values in accordance with Table 100.13. (7.6.4.1.7)
3. Results of the SF₆ gas leak test should confirm that no SF₆ gas leak exists. (7.6.4.1.9)
4. Settings for alarm, pressure, and limit switches should be in accordance with manufacturer's published data. (7.6.4.1.10)
5. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.6.4.1.13.1)
6. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.6.4.1.13.2)
7. Results of the thermographic survey shall be in accordance with Section 9. (7.6.4.1.13.3)
8. Compare circuit breaker travel and velocity values with manufacturer's published data and previous test data. (7.6.4.1.17)
9. Operations counter should advance one digit per close-open cycle. (7.6.4.1.19)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of circuit breakers should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.6.4 Circuit Breakers, SF₆ (*continued*)

3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
4. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Open, close, trip-free, and antipump features should function in accordance with the manufacturer's design. Minimum pickup for trip and close coils should conform to manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.20.
6. Power-factor or dissipation-factor values shall be compared to manufacturer's published data. In the absence of manufacturer's published data, the comparison shall be made to test data from similar breakers or data from test equipment manufacturers.
7. Power-factor or dissipation-factor and capacitance test values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliamper/milliwatt loss basis, and the results should be compared to values of similar bushings.
8. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
9. Heaters should be operational.
10. Results of electrical tests on instrument transformers should be in accordance with Section 7.10.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.7 Circuit Switchers

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Perform all mechanical operational tests on both the circuit switcher and its operating mechanism.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.7.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
7. Verify operation of SF₆ interrupters is in accordance with manufacturer's published data.
8. Verify SF₆ pressure is in accordance with manufacturer's published data.
9. Verify operation of isolating switch is in accordance with manufacturer's published data.
10. Test all interlocking systems for correct operation and sequencing.
11. Verify all indicating and control devices for correct separation.
12. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Perform as-left tests.
14. Record as-found and as-left operation counter readings.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.7 Circuit Switchers (*continued*)

2. Electrical Tests

1. Perform resistance measurements through all connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.7.1.
2. Perform contact-resistance tests of interrupters and isolating switches.
3. Perform insulation-resistance tests on each pole, phase-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
- *4. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
5. Perform minimum pickup voltage tests on trip and close coils in accordance with Table 100.20.
6. Verify correct operation of auxiliary features such as electrical close and trip operation, trip-free, and antipump function. Reset all trip logs and indicators.
7. Trip circuit switcher by operation of each protective device.
8. Verify correct operation of electrical trip of interrupters.
9. Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
10. Verify operation of heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.7.1.6.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.7.1.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.7.1.6.3)
4. SF₆ interrupters should operate in accordance with manufacturer's published data. (7.7.1.7)
5. SF₆ pressure should be in accordance with manufacturer's published data. (7.7.1.8)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.7 Circuit Switchers (*continued*)

6. Isolating switch should operate in accordance with manufacturer's design. (7.7.1.9)
7. Interlocking systems should operate per system lockout design. (7.7.1.10)
8. Results of open and close operation from control devices should be in accordance with system design. (7.7.1.11)
9. Operation counter should advance one digit per close-open cycle. (7.7.1.14)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
3. Insulation-resistance values of circuit switchers should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
4. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Minimum pickup for trip and close coils should conform to manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.20.
6. Switcher mechanism charge, close, open, trip, trip-free, and antipump features shall function as designed.
7. Electrical trip interrupters shall function as designed.
8. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the circuit switcher is considered to have passed the test.
9. Heaters should be operational.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.8. Network Protectors, 600-Volt Class

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Inspect arc chutes.
6. Inspect moving and stationary contacts for condition, wear, and alignment.
7. Verify that maintenance devices are available for servicing and operating the protector.
8. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
9. Perform mechanical operator and contact alignment tests on both the protector and its operating mechanism.
10. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.8.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
11. Verify cell fit and element alignment.
12. Verify racking mechanism operation.
13. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
14. Perform as-left tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.8. Network Protectors, 600-Volt Class (*continued*)

15. Record the as-found and as-left operations counter readings.
16. Perform a leak test, if applicable, on submersible enclosure in accordance with manufacturer's published data.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.8.1.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with protector closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a contact/pole-resistance test.
- *4. Perform insulation-resistance test on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or for control devices that cannot tolerate the voltage, follow manufacturer's recommendation.
- *5. Verify current transformer ratios in accordance with Section 7.10.
6. Measure the resistance of each protector power fuse.
7. Measure minimum pickup voltage of the motor control relay.
- *8. Verify that the motor can charge the closing mechanism at the minimum voltage specified by the manufacturer.
9. Measure minimum pickup voltage of the trip actuator. Verify that the actuator resets correctly.
10. Calibrate the network protector relays in accordance with Section 7.9.
11. Perform operational tests.
 1. Verify correct operation of all mechanical and electrical interlocks.
 2. Verify trip-free operation.
 3. Verify correct operation of the auto-open-close control handle.
 4. Verify the protector will close with voltage on the transformer side only.
 5. Verify the protector will open when the source feeder breaker is opened.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.8. Network Protectors, 600-Volt Class (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.8.1.10.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.8.1.10.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.8.1.10.3)
4. Operations counter should advance one digit per close-open cycle. (7.8.1.15)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation resistance of the network protector should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.
3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar protectors by more than 50 percent of the lowest value.
4. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Results of current transformer ratios shall be in accordance with Section 7.10.
6. Investigate fuse resistance values that deviate from each other by more than 15 percent.
7. Minimum pickup voltage of the motor control relay should be in accordance with manufacturer's published data, but not more than 75 percent of rated control circuit voltage.
8. Minimum acceptable motor closing voltage should not exceed 75 percent of rated control circuit voltage.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.8. Network Protectors, 600-Volt Class (*continued*)

9. Calibration should not exceed 7.5 percent of rated control circuit voltage.
10. Results of network protector relays should be in accordance with Section 7.9.
11. Network protector operation should be in accordance with design requirements.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.9.1 Protective Relays, Electromechanical and Solid-State

1. Visual and Mechanical Inspection

1. Inspect relays and cases for physical damage.
2. Prior to cleaning the unit, perform as-found tests, if required.
3. Clean the unit.
4. Relay Case
 1. Tighten case connections.
 2. Inspect cover for correct gasket seal.
 3. Clean cover glass. Inspect shorting hardware, connection paddles, and/or knife switches.
 4. Remove any foreign material from the case.
 5. Verify target reset
5. Relay
 1. Inspect relay for foreign material, particularly in disk slots of the damping and electromagnets.
 2. Verify disk clearance. Verify contact clearance and spring bias.
 3. Inspect spiral spring convolutions. Inspect disk and contacts for freedom of movement and correct travel. Verify tightness of mounting hardware and connections. Burnish contacts. Inspect bearings and/or pivots.
6. Verify that all settings are in accordance with coordination study or setting sheet supplied by owner.
7. Perform as-left tests.

2. Electrical Tests

1. Perform insulation-resistance test on each circuit-to-frame. Procedures for performing insulation-resistance tests on solid-state relays should be determined from the relay manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.9.1 Protective Relays, Electromechanical and Solid-State (*continued*)

2. Inspect targets and indicators.
 1. Determine pickup and dropout of electromechanical targets.
 2. Verify operation of all light-emitting diode indicators.
 3. Set contrast for liquid-crystal display readouts.

3. Functional Operation

1. 2/62 Timing Relay
 1. Determine time delay.
 2. Verify operation of instantaneous contacts.
2. 21 Distance Relay
 1. Determine maximum reach.
 2. Determine maximum torque angle.
 3. Determine offset.
 - *4. Plot impedance circle.
3. 24 Volts/Hertz Relay
 1. Determine pickup frequency at rated voltage.
 2. Determine pickup frequency at a second voltage level.
 3. Determine time delay.
4. 25 Sync Check Relay
 1. Determine closing zone at rated voltage.
 2. Determine maximum voltage differential that permits closing at zero degrees.
 3. Determine live line, live bus, dead line, and dead bus set points.
 4. Determine time delay.
 5. Verify dead bus/live line, dead line/live bus and dead bus/dead line control functions.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.9.1 Protective Relays, Electromechanical and Solid-State (*continued*)

5. 27 Undervoltage Relay
 1. Determine dropout voltage.
 2. Determine time delay.
 3. Determine the time delay at a second point on the timing curve for inverse time relays.
6. 32 Directional Power Relay
 1. Determine minimum pickup at maximum torque angle.
 2. Determine closing zone.
 3. Determine maximum torque angle.
 4. Determine time delay.
 5. Verify the time delay at a second point on the timing curve for inverse time relays.
 - *6. Plot the operating characteristic.
7. 40 Loss of Field (Impedance) Relay
 1. Determine maximum reach.
 2. Determine maximum torque angle.
 3. Determine offset.
 - *4. Plot impedance circle.
8. 46 Current Balance Relay
 1. Determine pickup of each unit.
 2. Determine percent slope.
 3. Determine time delay.
9. 46N Negative Sequence Current Relay
 1. Determine negative sequence alarm level.
 2. Determine negative sequence minimum trip level.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.9.1 Protective Relays, Electromechanical and Solid-State (*continued*)

3. Determine maximum time delay.
 4. Verify two points on the $(I_2)^2t$ curve.
10. 47 Phase Sequence or Phase Balance Voltage Relay
1. Determine positive sequence voltage to close the normally open contact.
 2. Determine positive sequence voltage to open the normally closed contact (undervoltage trip).
 3. Verify negative sequence trip.
 4. Determine time delay to close the normally open contact with sudden application of 120 percent of pickup.
 5. Determine time delay to close the normally closed contact upon removal of voltage when previously set to rated system voltage.
11. 49R Thermal Replica Relay
1. Determine time delay at 300 percent of setting.
 2. Determine a second point on the operating curve.
 - *3. Determine pickup.
12. 49T Temperature (RTD) Relay
1. Determine trip resistance.
 2. Determine reset resistance.
13. 50 Instantaneous Overcurrent Relay
1. Determine pickup.
 2. Determine dropout.
 - *3. Determine time delay.
14. 51 Time Overcurrent
1. Determine minimum pickup.
 2. Determine time delay at two points on the time current curve.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.9.1 Protective Relays, Electromechanical and Solid-State (*continued*)

15. 55 Power Factor Relay
 1. Determine tripping angle.
 2. Determine time delay.
16. 59 Overvoltage Relay
 1. Determine overvoltage pickup.
 2. Determine time delay to close the contact with sudden application of 120 percent of pickup.
17. 60 Voltage Balance Relay
 1. Determine voltage difference to close the contacts with one source at rated voltage.
 - *2. Plot the operating curve for the relay.
18. 63 Transformer Sudden Pressure Relay
 1. Determine rate-of-rise or the pickup level of suddenly applied pressure in accordance with manufacturer's published data.
 2. Verify operation of the 63 FPX seal-in circuit.
 3. Verify trip circuit to remote operating device.
19. 64 Ground Detector Relay

Determine maximum impedance to ground causing relay pickup.
20. 67 Directional Overcurrent Relay
 1. Determine directional unit minimum pickup at maximum torque angle.
 2. Determine closing zone.
 - *3. Determine maximum torque angle.
 - *4. Plot operating characteristics.
 5. Determine overcurrent unit pickup.
 6. Determine overcurrent unit time delay at two points on the time current curve.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.9.1 Protective Relays, Electromechanical and Solid-State (*continued*)

21. 79 Reclosing Relay
 1. Determine time delay for each programmed reclosing interval.
 2. Verify lockout for unsuccessful reclosing.
 3. Determine reset time.
 - *4. Determine close pulse duration.
 5. Verify instantaneous overcurrent lockout.
22. 81 Frequency Relay
 1. Verify frequency set points.
 2. Determine time delay.
 3. Determine undervoltage cutoff.
23. 85 Pilot Wire Monitor
 1. Determine overcurrent pickup.
 2. Determine undercurrent pickup.
 3. Determine pilot wire ground pickup level.
24. 87 Differential
 1. Determine operating unit pickup.
 2. Determine the operation of each restraint unit.
 3. Determine slope.
 4. Determine harmonic restraint.
 5. Determine instantaneous pickup.
 - *6. Plot operating characteristics for each restraint.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.9.1 Protective Relays, Electromechanical and Solid-State (*continued*)

4. Control Verification

Verify that each of the relay contacts performs its intended function in the control scheme including breaker trip tests, close inhibit tests, 86 lockout tests, and alarm functions.

5. Test Values

1. When not otherwise specified, use manufacturer's recommended tolerances.
2. When critical test points are specified, the relay should be calibrated to those specified points even though other test points may be out of tolerance.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.9.2 Protective Relays, Microprocessor-Based

1. Visual and Mechanical Inspection

1. Record model number, style number, serial number, firmware revision, software revision, and rated control voltage.
2. Download all events from the event recorder in filtered and unfiltered mode before performing any tests on the relay. Download the sequence-of-events recorder prior to testing the relay.
3. Verify operation of light-emitting diodes, display, and targets.
4. Record passwords for all access levels.
5. Clean the front panel and remove foreign material from the case.
6. Check tightness of connections.
7. Verify that the frame is grounded in accordance with manufacturer's instructions.
8. Download settings from the relay. Print a copy of the settings for the report and compare the settings to those specified in the coordination study.

2. Electrical Tests

1. Perform insulation-resistance tests from each circuit to the grounded frame in accordance with manufacturer's published data.
2. Apply voltage or current to all analog inputs and verify correct registration of the relay meter functions.

*3. Functional Operation

Check functional operation of each element used in the protection scheme as described for electromechanical and solid-state relays in 7.9.1.3.

4. Control Verification

1. Check operation of all active digital inputs.
2. Check all output contacts or SCRs, preferably by operating the controlled device such as circuit breaker, auxiliary relay, or alarm.
- *3. Check all internal logic functions used in the protection scheme.
4. For pilot schemes, perform a loop-back test to check the receive and transmit communication circuits.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.9.2 Protective Relays, Microprocessor-Based (*continued*)

- *5. For pilot schemes, perform satellite synchronized (GPS) end-to-end tests.
6. For pilot schemes with direct transfer trip (DTT), perform transmit and received DTT at each terminal.
7. Upon completion of testing reset all min/max recorders, fault counters, sequence of events recorder, and all event records.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Prior to cleaning the unit, perform as-found tests, if required.
3. Clean the unit.
4. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.10.2 and 7.10.3.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
5. Verify that all required grounding and shorting connections provide contact.
6. Verify correct operation of transformer withdrawal mechanism and grounding operation, if applicable.
7. Verify correct primary and secondary fuse sizes for voltage transformers.
8. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
9. Perform as-left tests.

2. Electrical Tests

2.1 Electrical Tests – Current Transformers

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.
2. Perform insulation-resistance test of each current transformer and wiring-to-ground at 1000 volts dc for one minute. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

- *3. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
- *4. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1.
- *5. Perform an excitation test on transformers used for relaying applications in accordance with ANSI/IEEE C57.13.1.
- *6. Measure current circuit burdens at transformer terminals.
- 7. When applicable, perform insulation-resistance tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.5.
- 8. When applicable, perform dielectric withstand voltage tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.9 respectively.
- *9. Measure insulation power factor or dissipation factor in accordance with test equipment manufacturer's published data.
- 10. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. (*IEEE Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases*).

2.2 Electrical Tests – Voltage Transformers

- 1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.
- 2. Perform insulation-resistance tests for one minute winding-to-winding and each winding-to-ground. Test voltages shall be applied in accordance with Table 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.
- *3. Perform a polarity test on each transformer, as applicable, to verify the polarity marks or H1-X1 relationship.
- 4. Perform a turns-ratio test on all tap positions, if applicable.
- *5. Measure voltage circuit burdens at transformer terminals.
- *6. Perform a dielectric withstand voltage test on the primary windings with the secondary windings connected to ground. The dielectric voltage shall be in accordance with Table 100.9. The test voltage shall be applied for one minute.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

- *7. Measure insulation power factor or dissipation factor in accordance with test equipment manufacturer's published data.
- 8. Verify that potential circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.

2.3 Electrical Tests – Coupling-Capacitor Voltage Transformers

- 1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.10.1.
- 2. Perform insulation-resistance tests for one minute, winding-to-winding and each winding-to-ground. Test voltages shall be applied in accordance with Table 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.
- *3. Perform a polarity test on each transformer, as applicable, to verify the polarity marks or H1-X1 relationship. See ANSI/IEEE C93.1 for standard polarity marking.
- 4. Perform a turns ratio test on the as-found tap position, if applicable.
- *5. Measure voltage circuit burdens at transformer terminals.
- *6. Perform a dielectric withstand voltage test on the primary windings with the secondary windings connected to ground. The dielectric withstand voltage shall be in accordance with Table 100.9. The test voltage shall be applied for one minute.
- 7. Measure capacitance of capacitor sections.
- 8. Measure insulation power factor or dissipation factor in accordance with test equipment manufacturer's published data
- 9. Verify that potential circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.10.1.4.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.10.1.4.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.10.1.4.3)

3.2.1 Test Values – Current Transformers – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of instrument transformers should not be less than values shown in Table 100.5.
3. Polarity results should agree with transformer markings.
4. Ratio errors should not be greater than values shown in Table 100.21.
5. Excitation results should match the curve supplied by the manufacturer or be in accordance with ANSI C57.13.1.
6. Compare measured burdens to instrument transformer ratings.
7. Insulation-resistance values of instrument transformers should not be less than values shown in Table 100.5.
8. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the primary winding is considered to have passed the test.
9. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.
10. Test results should indicate that the circuits have only one grounding point.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

3.2.2 Test Values – Voltage Transformers – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of instrument transformers should not be less than values shown in Table 100.5.
3. Polarity results should agree with transformer markings.
4. In accordance with IEEE C57.13; 8.1.1 the ratio error should be as follows:
 1. Revenue metering applications: equal to or less than ± 0.1 percent for ratio and ± 0.9 mrad (three minutes) for phase angle.
 2. Other applications: equal to or less than $+1.2$ percent for ratio and ± 17.5 mrad (one degree) for phase angle.
5. Compare measured burdens to instrument transformer ratings.
6. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the primary windings are considered to have passed the test.
7. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.
8. Test results should indicate that the circuits have only one grounding point.

3.2.3 Test Values – Coupling Capacitor Voltage Transformers

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of instrument transformers should not be less than values shown in Table 100.5.
3. Polarity results should agree with transformer markings.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.10 Instrument Transformers (*continued*)

4. In accordance with IEEE C57.13; 8.1.1 the ratio error should be as follows:
 1. Revenue metering applications: equal to or less than ± 0.1 percent for ratio and ± 0.9 mrad (three minutes) for phase angle.
 2. Other applications: equal to or less than $+1.2$ percent for ratio and ± 17.5 mrad (one degree) for phase angle.
5. Compare measured burdens to instrument transformer ratings.
6. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
7. Capacitance of capacitor sections of coupling-capacitance voltage transformers should be in accordance with manufacturer's published data.
8. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.
9. Test results should indicate that the circuits have only one grounding point.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.11.1 Metering Devices, Electromechanical and Solid-State

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.11.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
3. Inspect cover gasket, cover glass, condition of spiral spring, disk clearance, contacts, and case-shorting contacts, as applicable.
4. Prior to cleaning the unit, perform as-found tests, if required.
5. Clean the unit.
6. Verify freedom of movement, end play, and alignment of rotating disk(s).
7. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.11.1.
2. Verify accuracy of meters at all cardinal points.
3. Calibrate meters in accordance with manufacturer's published data.
- *4. Verify all instrument multipliers.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.11.1 Metering Devices, Electromechanical and Solid-State (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.11.1.2.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.11.1.2.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.11.1.2.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Meter accuracy should be in accordance with manufacturer's published data.
3. Calibration results should be within manufacturer's specified tolerances.
4. Instrument multipliers should be in accordance with specified system design.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.11.2 Metering Devices, Microprocessor-Based

1. Visual and Mechanical Inspection

1. Inspect meters and cases for physical damage.
2. Clean front panel .
3. Check tightness of electrical connections.
4. Record model number, serial number, firmware revision, software revision, and rated control voltage.
5. Verify operation of display and indicating devices.
6. Record passwords.
7. Verify unit is grounded in accordance with manufacturer's instructions.
8. Verify unit is connected in accordance with manufacturer's instructions and project drawings.
9. Download settings from the meter, print a copy of the settings for the report, and compare the settings to those specified.

2. Electrical Tests

1. Apply voltage or current as appropriate to each analog input and verify correct measurement and indication.
2. Confirm correct operation and setting of each auxiliary input/output feature in use, including mechanical relay, digital, and analog.
3. Confirm measurements and indications are consistent with loads present.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Tightness of electrical connections shall assure a low resistance connection. (7.11.2.1.3)
2. Display and indicating devices shall operate per manufacturer's published data. (7.11.2.1.5)

3.2 Test Values – Electrical

1. Measurement and indication of applied values of voltage and current should be within manufacturer's published tolerances for accuracy.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.11.2 Metering Devices, Microprocessor-Based (*continued*)

2. All auxiliary input/output features should operate per settings and manufacturer's published data
3. Measurements and indications should be consistent with energized system loads.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.1.1 Regulating Apparatus, Voltage, Step-Voltage Regulators

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Record position indicator as-found, maximum, and minimum values.
4. Prior to cleaning the unit, perform as-found tests, if required.
5. Clean the unit.
6. Verify auxiliary device operation.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.12.1.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
8. Verify correct operation of motor and drive train and automatic motor cutoff at maximum lower and maximum raise positions.
9. Verify correct liquid level in all tanks and bushings.
10. Perform specific inspections and mechanical tests as recommended by the manufacturer.
- *11. Perform an internal inspection:
 1. Remove oil.
 2. Clean carbon residue and debris from compartment.
 3. Inspect contacts for wear and alignment.
 4. Inspect all electrical and mechanical connections for tightness using calibrated torque wrench method in accordance with manufacturer's published data or Table 100.12.
 5. Inspect tap-changer compartment terminal board, contact support boards, and insulating operating components for evidence of moisture, cracks, excessive wear, breakage, and/or signs of electrical tracking.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.1.1 Regulating Apparatus, Voltage, Step Voltage Regulators (*continued*)

6. Electrically operate tap-changer through full range of taps.
7. Replace gaskets and seal compartment.
8. Fill with filtered oil.
12. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Perform as-left tests.
14. Record as-found and as-left operation counter readings.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.12.1.1.1.
2. Perform insulation-resistance tests on each winding-to-ground in any off-neutral position. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.
3. Perform insulation power-factor or dissipation-factor tests on windings in accordance with test equipment manufacturer's published data.
4. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
5. Measure winding resistance of source windings in the neutral position. Measure the resistance of all taps on load windings.
6. Perform special tests and adjustments as recommended by manufacturer.
- *7. If the regulator has a separate tap-changer compartment, measure the percentage of oxygen of the nitrogen gas blanket in the main tank.
8. Perform turns-ratio test on each voltage step position. Verify that the tap position indicator correctly identifies all tap positions.
9. Verify accurate operation of voltage range limiter.
10. Verify operation and accuracy of bandwidth, time delay, voltage, and line-drop compensation adjustments of tap-changer control device

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.1.1 Regulating Apparatus, Voltage, Step Voltage Regulators (*continued*)

- *11. If regulator has a separate tap-changer compartment, sample insulating liquid in the main tank in accordance with ASTM D 3613 and perform dissolved-gas analysis in accordance with ANSI/IEEE C57.104 or ASTM D 3612.
- 12. Remove a sample of insulating liquid from the main tank or common tank in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.
 - 1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
 - 2. Acid neutralization number: ANSI/ASTM D 974
 - 3. Specific gravity: ANSI/ASTM D 1298
 - 4. Interfacial tension: ANSI/ASTM D 971 or ASTM D 2285
 - 5. Color: ANSI/ASTM D 1500
 - 6. Visual condition: ASTM D 1524
- *7. Power factor: ASTM D 924
Required when the regulator voltage is 46 kV or higher.
- *8. PPM water: ASTM D 1533
Required when the regulator voltage is 25 kV or higher and on all silicone-filled units.
- 13. Remove a sample of insulating liquid from the tap-changer tank in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.
 - 1. Dielectric breakdown voltage: ASTM D 877
 - 2. Color: ANSI/ASTM D 1500
 - 3. Visual condition: ASTM D 1524
- *14. Remove a sample of insulating liquid from the tap-changer compartment or common tank in accordance with ASTM D 3613 and perform dissolved-gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D 3612.
- 15. Verify operation of heaters.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.1.1 Regulating Apparatus, Voltage, Step Voltage Regulators (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Auxiliary devices should operate in accordance with system design. (7.12.1.1.1.6)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.12.1.1.1.7.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.12.1.1.1.7.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.12.1.1.1.7.3)
5. Motor, drive train, and automatic cutoff should operate in accordance with manufacturer's design. (7.12.1.1.1.8)
6. Liquid level in tanks and bushings should be within indicated tolerances. (7.12.1.1.1.9)
7. On internal inspection, contact alignment and wear should be within manufacturer's recommendations for continued service. (7.12.1.1.1.11.3)
8. Bolt torque levels should be in accordance with Table 100.12 unless otherwise specified by the manufacturer. (7.12.1.1.1.11.4)
9. Terminal board, contact support boards, and insulating operating components should not show signs of moisture, cracking, excessive wear, breakage, or electrical cracking. (7.12.1.1.1.11.5)
10. The tap-changer should operate electrically through the full range of taps. (7.12.1.1.1.11.6)
11. The operation counter should move incrementally for each operation performed. (7.12.1.1.1.14)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Resistance values shall be temperature corrected in accordance with Table 100.14. The polarization index shall be compared to previously obtained results.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.1.1 Regulating Apparatus, Voltage, Step Voltage Regulators (*continued*)

3. Maximum power-factor or dissipation-factor values of liquid-filled regulators should be in accordance with manufacturer's published data. In the absence of manufacturer's data, compare to test equipment manufacturer's published data. Representative values are indicated in Table 100.3.
4. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliamperere/milliwatt loss basis, and the results should be compared to values of similar bushings.
5. Consult manufacturer if winding-resistance values vary by more than one percent from test results of adjacent windings.
6. Special tests and adjustments should meet manufacturer's published requirements.
7. Investigate presence of oxygen in nitrogen gas blanket.
8. Turns-ratio test results should maintain a normal deviation between each voltage step and should not deviate more than one-half percent from the calculated voltage ratio.
9. Voltage range limiter should operate within manufacturer's recommendations.
10. Accuracy of bandwidth, time-delay, voltage, and live drop compensation adjustments should be as specified.
11. Results of dissolved-gas analysis of insulating liquid on the main tank of regulators having a separate tap-changer compartment shall be evaluated in accordance with ANSI/IEEE C57.104 or ASTM D 3612.
12. Results of insulating liquid tests on the main tank or common tank of single tank voltage regulators should be in accordance with Table 100.4.
13. Results of insulating liquid tests on the tap-changer tank of regulators having a separate tap-changer compartment should be in accordance with Table 100.4.
14. Compare results of dissolved gas analysis to previous test results.
15. Heaters should be operational.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Record position indicator as-found, maximum, and minimum values.
4. Prior to cleaning the unit, perform as-found tests, if required.
5. Clean the unit.
6. Verify correct auxiliary device operation.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.12.1.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
8. Check motor and drive train for correct operation and automatic motor cutoff at maximum lower and maximum raise.
9. Verify appropriate liquid level in all tanks and bushings, if applicable.
10. Perform specific inspections and mechanical tests as recommended by the manufacturer.
11. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
12. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.12.1.2.1.
2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators (*continued*)

3. Perform power-factor or dissipation-factor tests on winding insulation in accordance with test equipment manufacturer's published data.
4. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
5. Verify voltage regulation.
6. Verify that the indicator correctly identifies neutral position.
7. Perform winding resistance tests on each winding.
8. Sample insulating liquid, if applicable, in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.
 1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
 2. Acid neutralization number: ANSI/ASTM D 974
 - *3. Specific gravity: ANSI/ASTM D 1298
 4. Interfacial tension: ANSI/ASTM D 971 or ASTM D 2285
 5. Color: ANSI/ASTM D 1500
 6. Visual condition: ASTM D 1524
 - *7. Power factor: ASTM D 924
Required when the regulator voltage is 46 kV or higher.
 - *8. Water content: ASTM D 1533
Required when the regulator voltage is 25 kV or higher.
- *9. Remove a sample of insulating liquid, if applicable, in accordance with ASTM D 3613 and perform dissolved-gas analysis (DGA) in accordance with ASTM D 3612 or ANSI.IEEE C57.104.
- *10. Test for the presence of oxygen in the gas blanket of liquid-filled regulators.
11. Verify operation of control cabinet space heater.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Auxiliary devices should operate in accordance with system design. (7.12.1.2.1.6)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.12.1.2.1.7.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.12.1.2.1.7.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.12.1.2.1.7.3)
5. Motor, drive train, and automatic cutoff should operate in accordance with manufacturer's design intent and automatic motor cutoff should operate at maximum lower and maximum raise positions. (7.12.1.2.1.8)
6. Liquid level in tanks and bushings should be within indicated tolerances. (7.12.1.2.1.9)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall be compared to previously obtained results.
3. Maximum power-factor or dissipation-factor values of liquid-filled regulators should be in accordance with manufacturer's published data. In the absence of manufacturer's data, compare to test equipment manufacturer's published data. Representative values are indicated in Table 100.3.
4. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.
5. The regulation should be a linear ratio throughout the range between the maximum raise and the maximum lower positions.
6. Indicator should indicate neutral position correctly.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators (*continued*)

7. Consult the manufacturer if winding-resistance values vary by more than one percent from measurements of adjacent windings.
8. Results of insulating liquid tests should be in accordance with Table 100.4.
9. Evaluate results of dissolved-gas analysis in accordance with ANSI/IEEE C57.104.
10. Investigate presence of oxygen in nitrogen gas blanket.
11. Heaters should be operational.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.2 Regulating Apparatus, Current

– RESERVED –

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Record position indicator as-found, maximum, and minimum values.
4. Prior to cleaning the unit, perform as-found tests.
5. Clean the unit.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.12.3.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
7. Verify correct auxiliary device operation.
8. Verify motor and drive train for correct operation and automatic motor cutoff at maximum lower and maximum raise.
9. Verify correct liquid level in all tanks.
10. Perform specific inspections and mechanical tests as recommended by the manufacturer.
11. Visually inspect wear/erosion indicators on vacuum bottles, if applicable.
- *12. Perform an internal inspection:
 1. Remove oil.
 2. Clean carbon residue and debris from compartment.
 3. Inspect contacts for wear and alignment.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers (*continued*)

4. Inspect all electrical and mechanical connections for tightness using calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
5. Inspect tap-changer compartment terminal board, contact support boards, and insulated operating components for evidence of moisture, cracks, excessive wear, breakage, and/or signs of electrical tracking.
6. Electrically operate tap-changer through full range of taps.
7. Replace gaskets and seal compartment.
8. Fill with filtered oil.
13. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
14. Perform as-left tests.
15. Record as-found and as-left operation counter readings.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.12.3.1.
2. Perform insulation-resistance tests in any off-neutral position in accordance with Section 7.2.2.
3. Perform insulation power-factor or dissipation-factor tests in off-neutral position in accordance with Section 7.2.2.
- *4. Perform winding-resistance test.
5. Perform special tests and adjustments as recommended by the manufacturer.
6. Perform turns-ratio test at all tap positions.
7. Remove a sample of insulating liquid in accordance with ASTM D 923. The sample shall be tested for the following in accordance with the referenced standard.
 1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
 2. Color: ANSI/ASTM D 1500
 3. Visual condition: ASTM D 1524

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers (*continued*)

8. Remove a sample of insulating liquid in accordance with ASTM D 3613 and perform dissolved gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D 3612.
9. Perform vacuum bottle integrity tests (dielectric withstand voltage) across each vacuum bottle with the contacts in the open position in strict accordance with manufacturer's published data.
10. Verify operation of heaters.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.12.3.1.6.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.12.3.1.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.12.3.1.6.3)
4. Auxiliary device operation should be in accordance with design intent. (7.12.3.1.7)
5. Motor, drive train, and automatic cutoff should operate in accordance with manufacturer's design intent and automatic motor cutoff should operate at maximum lower and maximum raise positions.
6. Liquid level in tanks should be within indicated tolerances. (7.12.3.1.9)
7. Vacuum bottle wear/erosion indicators should be within manufacturer's recommended tolerances. (7.12.3.1.11)
8. Contact wear and alignment should be within manufacturer's recommended tolerances. (7.12.3.1.12.3)
9. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.12.3.1.12.4)
10. No evidence of moisture, cracks, excessive wear, breakage, or electrical tracking should be found. (7.12.3.1.12.5)
11. The tap-changer should operate through the full range of taps. (7.12.3.1.12.6)
12. Operations counter should have had an incremental change in accordance with tap-changer operation. (7.12.3.1.15)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers (*continued*)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Maximum winding insulation power-factor or dissipation-factor values of liquid-filled transformers should be in accordance with manufacturer's specifications. Representative values are indicated in Table 100.3. Also, compare with test equipment manufacturer's published data.
4. Consult the manufacturer if winding-resistance values vary by more than one percent from measurements of adjacent windings.
5. Special tests and adjustments should conform to manufacturer's specifications.
6. Turns-ratio test results should maintain a normal deviation between each voltage step and should not deviate more than one-half percent from the calculated voltage ratio.
7. Results of insulating liquid tests should be in accordance with Table 100.4.
8. Evaluate results of dissolved-gas analysis in accordance with ANSI/IEEE C57.104.
9. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
10. Heaters should be operational.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.13 Grounding Systems

1. Visual and Mechanical Inspection

1. Verify ground system is in compliance with ANSI/NFPA 70, *National Electrical Code*, Article 250.
2. Inspect physical and mechanical condition.
3. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.13.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
4. Inspect anchorage.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with section 7.13.1.
2. Perform fall-of-potential or alternative test in accordance with IEEE Standard 81 on the main grounding electrode or system.
3. Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and/or derived neutral points.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Grounding system electrical and mechanical connections should be free of corrosion. (7.13.1.2)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.13.1.3.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.13.1.3.2)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.13 Grounding Systems (*continued*)

2. The resistance between the main grounding electrode and ground should be no greater than five ohms for large commercial or industrial systems and 1.0 ohm or less for generating or transmission station grounds unless otherwise specified by the owner. (Reference ANSI/IEEE Standard 142)
3. Investigate point-to-point resistance values which exceed 0.5 ohm.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.14 Ground-Fault Protection Systems, Low-Voltage

1. Visual and Mechanical Inspection

1. Inspect the components for damage and errors in polarity or conductor routing.
 1. Verify that the ground connection is made on the source side of the neutral disconnect link and also on the source side of any ground fault sensor.
 2. Verify that the neutral sensors are connected with correct polarity on both primary and secondary.
 3. Verify that all phase conductors and the neutral pass through the sensor in the same direction for zero sequence systems.
 4. Verify that grounding conductors do not pass through zero sequence sensors.
 5. Verify that the grounded conductor is solidly grounded.
2. Prior to cleaning the unit, perform as-found tests.
3. Clean the unit.
4. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.14.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
5. Verify correct operation of all functions of the self-test panel, if applicable.
6. Verify pickup and time-delay settings in accordance with the settings provided in the owner's specifications. Record appropriate operation and test sequences as required by ANSI/NFPA 70 *National Electrical Code*, Article 230.95.
7. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.14.1.
2. Measure the system neutral-to-ground insulation resistance with the neutral disconnect link temporarily removed. Replace neutral disconnect link after testing.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.14 Ground-Fault Protection Systems, Low-Voltage (*continued*)

- *3. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
4. Perform ground fault protective device pickup tests using primary current injection.
5. For summation type systems utilizing phase and neutral current transformers, verify correct polarities by applying current to each phase-neutral current transformer pair. This test also applies to molded-case breakers utilizing an external neutral current transformer.
6. Measure time delay of the ground fault protective device at a value equal to or greater than 150 percent of the pickup value.
7. Verify that reduced control voltage tripping capability is 55 percent for ac systems and 80 percent for dc systems.
8. Verify blocking capability of zone interlock systems.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.14.1.4.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.14.1.4.2)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. System neutral-to-ground insulation resistance should be a minimum of one megohm.
3. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
4. Results of pickup test should be greater than 90 percent of the ground fault protection device pickup setting and less than 1200 amperes or 125 percent of the pickup setting, whichever is smaller.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.14 Ground-Fault Protection Systems, Low-Voltage (*continued*)

5. The ground fault protective device should operate when current direction is the same relative to polarity marks in the two current transformers. The ground fault protective device should not operate when current direction is opposite relative to polarity marks in the two current transformers.
6. Relay timing should be in accordance with manufacturer's specifications but must be no longer than one second at 3000 amperes in accordance with ANSI/NFPA 70, *National Electrical Code*, Article 230.95.
7. The circuit interrupting device should operate when control voltage is 55 percent of nominal voltage for ac circuits and 80 percent of nominal voltage for dc circuits.
8. Results of zone-blocking tests should be in accordance with manufacturer's published data and/or design specifications.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.1 Rotating Machinery, AC Induction Motors and Generators

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Inspect air baffles, filter media, cooling fans, slip rings, brushes, and brush rigging.
4. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.15.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
5. Perform special tests such as air-gap spacing and machine alignment, if applicable.
6. Verify the application of appropriate lubrication and lubrication systems.
7. Verify the absence of unusual mechanical or electrical noise or signs of overheating.
8. Verify that resistance temperature detector (RTD) circuits conform to drawings.

2. Electrical Tests – AC Induction

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.15.1.1.
2. Perform insulation-resistance tests in accordance with ANSI/IEEE Standard 43.
 1. Machines larger than 200 horsepower (150 kilowatts):
Test duration shall be for ten minutes. Calculate polarization index.
 2. Machines 200 horsepower (150 kilowatts) and less:
Test duration shall be for one minute. Calculate the dielectric-absorption ratio.
3. Perform dc dielectric withstand voltage tests on machines rated at 2300 volts and greater in accordance with ANSI/IEEE Standard 95.
4. Perform phase-to-phase stator resistance test on machines 2300 volts and greater.
- *5. Perform insulation power-factor or dissipation-factor tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.1 Rotating Machinery, AC Induction Motors and Generators (*continued*)

- *6. Perform power-factor tip-up tests.
- *7. Perform surge comparison tests.
- 8. Perform insulation-resistance test on insulated bearings in accordance with manufacturer's published data, if applicable.
- 9. Test surge protection devices in accordance with Section 7.19 and Section 7.20.
- 10. Test motor starter in accordance with Section 7.16.
- 11. Perform resistance tests on resistance temperature detector (RTD) circuits.
- 12. Verify operation of machine space heater, if applicable.
- *13. Perform vibration test.

3. Test Values

3.1 Test Values – Visual and Mechanical

- 1. Inspection (7.15.1.1.3)
 - 1. Air baffles should be clean.
 - 2. Filter media should be clean.
 - 3. Cooling fans should operate.
 - 4. Slip ring wear should be within manufacturer's tolerances for continued use.
 - 5. Brushes should be within manufacturer's tolerances for continued use.
 - 6. Brush rigging should be intact.
- 2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.15.1.1.4.1)
- 3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.15.1.1.4.2)
- 4. Results of the thermographic survey shall be in accordance with Section 9. (7.15.1.1.4.3)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.1 Rotating Machinery, AC Induction Motors and Generators (*continued*)

3.2 Test Values – Electrical Tests

1. Compare bolted connection resistance values to values of similar connections. Investigate any values that deviate from similar bolted connections by more than 50 percent of the lowest value.
2. The dielectric absorption ratio or polarization shall be compared to previously obtained results and should not be less than 1.0. The recommended minimum insulation resistance ($IR_{1 \text{ min}}$) test results in megohms should be corrected to 40° C and read as follows:
 1. $IR_{1 \text{ min}} = kV + 1$ for most windings made before 1970, all field windings, and others not described in 2.2 and 2.3.

(kV is the rated machine terminal-to-terminal voltage in rms kV)
 2. $IR_{1 \text{ min}} = 100$ megohms for most dc armature and ac windings built after 1970 (form-wound coils).
 3. $IR_{1 \text{ min}} = 5$ megohms for most machines and random-wound stator coils and form-wound coils rated below 1 kV.

NOTE: Dielectric withstand voltage and surge comparison tests shall not be performed on machines having values lower than those indicated above.

3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
4. Investigate phase-to-phase stator resistance values that deviate by more than five percent.
5. Power-factor or dissipation-factor values shall be compared with previous values of similar machines.
6. Tip-up values should indicate no significant increase in power factor.
7. If no evidence of distress, insulation failure, or lack of waveform nesting is observed by the end of the total time of voltage application during the surge comparison test, the test specimen is considered to have passed the test.
8. Bearing insulation-resistance measurements should be within manufacturer's published tolerances. In the absence of manufacturer's published tolerances, the comparison shall be made to similar machines.
9. Test results of surge protection devices shall be in accordance with Section 7.19 and Section 7.20.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.1 Rotating Machinery, AC Induction Motors and Generators (*continued*)

10. Test results of motor starter equipment shall be in accordance with Section 7.16.
11. RTD circuits should conform to design intent and/or machine protection device manufacturer's specifications.
12. Heaters should be operational.
13. Vibration amplitudes of the uncoupled and unloaded machine should not exceed values shown in Table 100.10. If values exceed those in Table 100.10, perform complete vibration analysis.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.2 Rotating Machinery, Synchronous Motors and Generators

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Inspect air baffles, filter media, cooling fans, slip rings, brushes, and brush rigging.
4. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.15.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
5. Perform special tests such as air-gap spacing and machine alignment, if applicable.
6. Verify the application of appropriate lubrication and lubrication systems.
7. Verify the absence of unusual mechanical or electrical noise or signs of overheating.
8. Verify that resistance temperature detector (RTD) circuits conform to drawings.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.15.2.1.
2. Perform insulation-resistance tests in accordance with ANSI/IEEE Standard 43.
 1. Machines larger than 200 horsepower (150 kilowatts):
Test duration shall be for ten minutes. Calculate polarization index.
 2. Machines 200 horsepower (150 kilowatts) and less:
Test duration shall be for one minute. Calculate the dielectric-absorption ratio.
3. Perform dc dielectric withstand voltage tests on machines rated at 2300 volts and greater in accordance with ANSI/IEEE Standard 95.
4. Perform phase-to-phase stator resistance test on machines 2300 volts and greater.
- *5. Perform insulation power-factor or dissipation-factor tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.2 Rotating Machinery, Synchronous Motors and Generators (*continued*)

- *6. Perform power-factor tip-up tests.
- *7. Perform surge comparison tests.
8. Perform insulation-resistance test on insulated bearings in accordance with manufacturer's published data, if applicable.
9. Test surge protection devices in accordance with Section 7.19 and Section 7.20.
10. Test motor starter in accordance with Section 7.16.
11. Perform resistance tests on resistance temperature detector (RTD) circuits.
12. Verify operation of machine space heater, if applicable.
- *13. Perform vibration test.
14. Perform insulation-resistance tests on the main rotating field winding, the exciter-field winding, and the exciter-armature winding in accordance with ANSI/IEEE Standard 43.
- *15. Perform an ac voltage-drop test on all rotating field poles.
- *16. Perform a high-potential test on the excitation system in accordance with ANSI/IEEE Standard 421.3.
17. Measure resistance of machine-field winding, exciter-stator winding, exciter-rotor windings, and field discharge resistors.
- *18. Perform front-to-back resistance tests on diodes and gating tests of silicon-controlled rectifiers for field application semiconductors.
19. Prior to re-energizing, apply voltage to the exciter supply and adjust exciter-field current to nameplate value.
20. Verify that the field application timer and the enable timer for the power-factor relay have been tested and set to the motor drive manufacturer's recommended values.
- *21. Record stator current, stator voltage, and field current for the complete acceleration period including stabilization time for a normally loaded starting condition. From the recording determine the following information:
 1. Bus voltage prior to start.
 2. Voltage drop at start.
 3. Bus voltage at machine full-load.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.2 Rotating Machinery, Synchronous Motors and Generators (*continued*)

4. Locked-rotor current.
 5. Current after synchronization but before loading.
 6. Current at maximum loading.
 7. Acceleration time to near synchronous speed.
 8. RPM just prior to synchronization.
 9. Field application time.
 10. Time to reach stable synchronous operation.
- *22. Plot a V-curve of stator current versus excitation current at approximately 50 percent load to check correct exciter operation.
- *23. If the range of exciter adjustment and machine loading permit, reduce excitation to cause power factor to fall below the trip value of the power-factor relay. Verify relay operation.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Inspection (7.15.2.1.3)
 1. Air baffles should be clean.
 2. Filter media should be clean.
 3. Cooling fans should operate.
 4. Slip ring wear should be within manufacturer's tolerances for continued use.
 5. Brushes should be within manufacturer's tolerances for continued use.
 6. Brush rigging should be intact.
2. Compare bolted connection resistance values to values of similar connections. Investigate any values that deviate from similar bolted connections by more than 50 percent of the lowest value. (7.15.2.1.4.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.15.2.1.4.2)
4. Results of thermographic survey shall be in accordance with Section 9. (7.15.2.1.4.3)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.2 Rotating Machinery, Synchronous Motors and Generators (*continued*)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate any values that deviate from similar bolted connections by more than 50 percent of the lowest value.
2. The dielectric absorption ratio or polarization index shall be compared to previously obtained results and should not be less than 1.0. The recommended minimum insulation resistance ($IR_{1 \text{ min}}$) test results in megohms should be corrected to 40° C and read as follows:
 1. $IR_{1 \text{ min}} = kV + 1$ for most windings made before 1970, all field windings and others not described in 2.2 and 2.3.

(kV is the rated machine terminal-to-terminal voltage in rms kV)
 2. $IR_{1 \text{ min}} = 100$ megohms for most dc armature and ac windings built after 1970 (form-wound coils).
 3. $IR_{1 \text{ min}} = 5$ megohms for most machines and random-wound stator coils and form-wound coils rated below 1 kV.

NOTE: Dielectric withstand voltage, high-potential, and surge comparison tests shall not be performed on machines having values lower than those indicated above.

3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
4. Investigate phase-to-phase stator resistance values that deviate by more than five percent.
5. Power-factor or dissipation-factor values shall be compared with previous values of similar machines.
6. Tip-up values should indicate no significant increase in power factor.
7. If no evidence of distress, insulation failure, or lack of waveform nesting is observed by the end of the total time of voltage application during the surge comparison test, the test specimen is considered to have passed the test.
8. Insulation resistance of bearings should be within manufacturer's published tolerances. In the absence of manufacturer's published tolerances, the comparison shall be made to similar machines.
9. Test results of surge protection devices shall be in accordance with Section 7.19 and Section 7.20.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.2 Rotating Machinery, Synchronous Motors and Generators (*continued*)

10. Test results of motor starter equipment shall be in accordance with Section 7.16.
11. RTD circuits should conform to design intent and/or machine protection device manufacturer's specifications.
12. Heaters should be operational.
13. Vibration amplitudes of the uncoupled and unloaded machine should not exceed values shown in Table 100.10. If values exceed those in Table 100.10, perform complete vibration analysis.
14. The recommended minimum insulation resistance ($IR_{1 \text{ min}}$) test results in megohms should be corrected to 40° C and read as follows:
 1. $IR_{1 \text{ min}} = kV + 1$ for most windings made before 1970, all field windings, and others not described in 2.2 and 2.3.

(kV is the rated machine terminal-to-terminal voltage in rms kV)
 2. $IR_{1 \text{ min}} = 100$ megohms for most dc armature and ac windings built after 1970 (form-wound coils).
 3. $IR_{1 \text{ min}} = 5$ megohms for most machines and random-wound stator coils and form-wound coils rated below 1 kV.

NOTE: Dielectric withstand voltage, high-potential, and surge comparison tests shall not be performed on machines having values lower than those indicated above.
15. The pole-to-pole ac voltage drop shall not exceed 10 percent variance between poles.
16. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage, test, the winding is considered to have passed the test.
17. The measured resistance values of motor-field windings, exciter-stator windings, exciter-rotor windings, and field-discharge resistors shall be compared to manufacturer's recommended values.
18. Resistance test results of diodes and gating tests of silicon-controlled rectifiers should be in accordance with industry standards and system design requirements.
19. Exciter power supply should allow exciter-field current to be adjusted to nameplate value.
20. Application timer and enable timer for power factor relay test results should comply with manufacturer's recommended values.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.2 Rotating Machinery, Synchronous Motors and Generators (*continued*)

21. Recorded values should be in accordance with system design requirements.
22. Plotted V-curve should indicate correct exciter operation.
23. When reduced excitation falls below trip value for the power-factor relay, the relay should operate.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.3 Rotating Machinery, DC Motors and Generators

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Inspect air baffles, field media, cooling fans, brushes, and brush rigging.
4. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of low-resistance ohmmeter in accordance with Section 7.15.3.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
5. Inspect commutator and tachometer generator.
6. Perform special tests such as air-gap spacing and machine alignment, if applicable.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.15.3.1.
2. Perform insulation-resistance tests on all windings in accordance with ANSI/IEEE Standard 43.
 1. Machines larger than 200 horsepower (150 kilowatts):
Test duration shall be for ten minutes. Calculate polarization index.
 2. Machines 200 horsepower (150 kilowatts) and less:
Test duration shall be for one minute. Calculate the dielectric absorption ratio.
3. Perform high-potential test in accordance with NEMA MG 1, paragraph 3.01.
- *4. Perform an ac voltage-drop test on all field poles.
5. Measure armature running current and field current or voltage. Compare to nameplate.
- *6. Perform vibration tests.
7. Verify that all protective devices are in accordance with Section 7.16.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.3 Rotating Machinery, DC Motors and Generators (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Inspection (7.15.3.1.3)
 1. Air baffles should be clean
 2. Filter media should be clean.
 3. Cooling fans should operate.
 4. Brushes should be within manufacturer's tolerances for continued use.
 5. Brush rigging should be intact.
2. Compare bolted connection resistance values to values of similar connections. Investigate any values that deviate from similar bolted connections by more than 50 percent of the lowest value. (7.15.3.1.4.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.15.3.1.4.2)
4. Results of thermographic survey shall be in accordance with Section 9. (7.15.3.1.4.3)
5. Commutator and tachometer generator should be in accordance with manufacturer's published data and/or system design. (7.15.3.1.5)
6. Air-gap spacing and machine alignment should be within manufacturer's recommendations. (7.15.3.1.6)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate any values that deviate from similar bolted connections by more than 50 percent of the lowest value.
2. The dielectric absorption ratio or polarization index shall be compared to previously obtained results and should not be less than 1.0. The recommended minimum insulation resistance ($IR_{1 \min}$) test results in megohms should be corrected to 40° C and read as follows:
 1. $IR_{1 \min} = kV + 1$ for most windings made before 1970, all field windings, and others not described in 2.2 and 2.3.

(kV is the rated machine terminal-to-terminal voltage, in rms kV)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.15.3 Rotating Machinery, DC Motors and Generators (*continued*)

2. $IR_{1\text{ min}} = 100$ megohms for most dc armature and ac windings built after 1970 (form-wound coils).
3. $IR_{1\text{ min}} = 5$ megohms for most machines and random-wound stator coils and form-wound coils rated below 1 kV.

NOTE: Dielectric withstand voltage, high-potential, and surge comparison tests shall not be performed on machines having values lower than those indicated above.

3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the winding is considered to have passed the test.
4. The pole-to-pole voltage drop shall not exceed five percent variance between poles.
5. Measured running current and field current or voltage should be comparable to nameplate data.
6. Vibration amplitudes of the uncoupled and unloaded machine should not exceed values shown in Table 100.10. If values exceed those in Table 100.10, perform complete vibration analysis.
7. Test results of motor starter equipment shall be in accordance with Section 7.16.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.16.1.1 Motor Control, Motor Starters, Low-Voltage

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Inspect contactors.
 1. Verify mechanical operation.
 2. Inspect and adjust contact gap, wipe, alignment, and pressure in accordance with manufacturer's published data.

*6. Motor-Running Protection

1. Compare overload element rating with motor full-load current rating to verify correct sizing.
 2. If motor-running protection is provided by fuses, verify correct fuse rating considering motor characteristics and power-factor correction capacitors.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
1. Use of a low-resistance ohmmeter in accordance with Section 7.16.1.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
8. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
 9. Perform as-left tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.16.1.1 Motor Control, Motor Starters, Low-Voltage (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.16.1.1.1.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with starter closed, and across each open pole. Test voltage shall be in accordance with manufacturer's published data or Table 100.1.
- *3. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
4. Test motor protection devices in accordance with manufacturer's published data. In the absence of manufacturer's data, use Section 7.19.
5. Test circuit breakers in accordance with Section 7.6.1.1.
6. Perform operational tests by initiating control devices.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.16.1.1.1.7.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.16.1.1.1.7.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.16.1.1.1.7.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.16.1.1 Motor Control, Motor Starters, Low-Voltage (*continued*)

3. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
4. Motor protection parameters shall be in accordance with manufacturer's published data or Section 7.9.
5. Circuit breaker test results shall be in accordance with Section 7.6.1.1.
6. Control devices should perform in accordance with system design and/or requirements.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.16.1.2 Motor Control, Motor Starters, Medium-Voltage

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition including evidence of moisture and corona.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests, if required.
4. Clean the unit.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.16.1.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
6. Test electrical and mechanical interlock systems for correct operation and sequencing.
7. Verify correct barrier and shutter installation and operation.
8. Exercise active components and confirm correct operation of indicating devices.
9. Inspect contactors.
 1. Verify mechanical operation.
 2. Inspect and adjust contact gap, wipe, alignment, and pressure in accordance with manufacturer's published data.
10. Compare overload protection rating with motor nameplate to verify correct size. Set adjustable or programmable devices according to the protective device coordination study.
11. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
12. Perform as-left tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.16.1.2 Motor Control, Motor Starters, Medium-Voltage (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.16.1.2.1.
2. Perform insulation-resistance tests on contactor(s) for one minute, phase-to-ground and phase-to-phase with the contactor closed, and across each open contact. Test voltage shall be in accordance with manufacturer's published data or Table 100.1.
- *3. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
- *4. Perform a dielectric withstand voltage test in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19.
5. Perform vacuum bottle integrity test (dielectric withstand voltage), if applicable, across each vacuum bottle with the contacts in the open position in strict accordance with manufacturer's published data. Do not exceed maximum voltage stipulated for this test.
6. Perform contact resistance tests.
7. Measure blowout coil circuit resistance, if applicable.
8. Measure resistance of power fuses.
9. Energize contactor using an auxiliary source. Adjust armature to minimize operating vibration where applicable.
10. Test control power transformers in accordance with Section 7.1.2.8.
11. Test starting transformers, if applicable, in accordance with Section 7.2.1.
12. Test starting reactors, if applicable, in accordance with Section 7.20.3.
13. Test motor protection devices in accordance with manufacturer's published data. In the absence of manufacturer's data, test in accordance with Section 7.9.
- *14. Perform system function test in accordance with Section 8.
15. Verify operation of cubicle space heater.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.16.1.2 Motor Control, Motor Starters, Medium-Voltage (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.16.1.2.1.5.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.16.1.2.1.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.16.1.2.1.5.3)
4. Electrical and mechanical interlocks should operate in accordance with system design. (7.16.1.2.1.6)
5. Barrier and shutter installation and operation should be in accordance with manufacturer's design. (7.16.1.2.1.7)
6. Indicating devices should operate in accordance with system design. (7.16.1.2.1.8)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
4. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
5. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the vacuum bottle integrity test, the vacuum bottle is considered to have passed the test.
6. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available,

* Optional



7. INSPECTION AND TEST PROCEDURES

7.16.1.2 Motor Control, Motor Starters, Medium-Voltage (*continued*)

investigate values which deviate from those of similar connections by more than 50 percent of the lowest value.

7. Resistance values of blowout coils should be in accordance with manufacturer's published data.
8. Resistance values should not deviate by more than 15 percent between identical fuses.
9. Contactor coil should operate with minimal vibration and noise.
10. Control power transformer test results shall be in accordance with Section 7.1.2.8.
11. Starting transformer test results shall be in accordance with Section 7.2.1.
12. Starting reactor test results shall be in accordance with Section 7.20.3.
13. Motor protection parameters shall be in accordance with manufacturer's published data.
14. System function test results should be in accordance with manufacturer's published data and/or system design.
15. Heaters should be operational.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.16.2.1 Motor Control, Motor Control Centers, Low-Voltage

1. Refer to Section 7.1 for appropriate inspections and tests of the motor control center bus.
2. Refer to Section 7.5.1.1 for appropriate inspections and tests of the motor control center switches.
3. Refer to Section 7.6 for appropriate inspections and tests of the motor control center circuit breakers.
4. Refer to Section 7.16.1.1 for appropriate inspections and tests of the motor control center starters.

7.16.2.2 Motor Control, Motor Control Centers, Medium-Voltage

1. Refer to Section 7.1 for appropriate inspections and tests of the motor control center bus.
2. Refer to Section 7.5.1.2 for appropriate inspections and tests of the motor control center switches.
3. Refer to Section 7.6 for appropriate inspections and tests of the motor control center circuit breakers.
4. Refer to Section 7.16.1.2 for appropriate inspections and tests of the motor control center starters.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.17 Adjustable-Speed Drive Systems

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Ensure vent path openings are free from debris and that heat transfer surfaces are not contaminated by oil, dust, or dirt.
6. Verify correct connections of circuit boards, wiring, disconnects, and ribbon cables.
7. Motor running protection
 1. Compare drive overcurrent set points with motor full-load current rating to verify correct settings.
 2. If drive is used to operate multiple motors, compare individual overload element ratings with motor full-load current ratings.
 3. Apply minimum and maximum speed set points. Confirm set points are within limitations of the load coupled to the motor.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.17.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
9. Verify correct fuse sizing in accordance with manufacturer's published data.
10. Perform as-left tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.17 Adjustable-Speed Drive Systems (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.17.1.
2. Test the motor overload relay elements by injecting primary current through the overload circuit and monitoring trip time of the overload element.
3. Test input circuit breaker by primary injection in accordance with Section 7.6.
- *4. Perform insulation resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
5. Test for the following parameters in accordance with relay calibration procedures outlined in Section 7.9 or as recommended by the manufacturer:
 1. Input phase loss protection
 2. Input overvoltage protection
 3. Output phase rotation
 4. Overtemperature protection
 5. DC overvoltage protection
 6. Overfrequency protection
 7. Drive overload protection
 8. Fault alarm outputs
6. Perform continuity tests on bonding conductors in accordance with Section 7.13.
7. Perform operational tests by initiating control devices.
 1. Slowly vary drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration.
 2. Verify operation of drive from remote start/stop and speed control signals.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.17 Adjustable-Speed Drive Systems (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.17.1.8.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.17.1.8.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.17.1.8.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Overload test trip times at 300 percent of overload element rating should be in accordance with manufacturer's published time-current curve.
3. Input circuit breaker test results shall be in accordance with Section 7.6.
4. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Relay calibration test results shall be in accordance with Section 7.9.
6. Continuity of bonding conductors shall be in accordance with Section 7.13.
7. Control devices should perform in accordance with system requirements.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.1.1 Direct-Current Systems, Batteries, Flooded Lead-Acid

1. Visual and Mechanical Inspection

1. Verify the battery area ventilation system is operable.
2. Verify existence of suitable eyewash equipment.
3. Inspect physical and mechanical condition.
4. Inspect battery support racks, mounting, battery spill containment system, anchorage, clearances, alignment, and grounding.
5. Prior to cleaning or adding electrolyte, perform as-found tests, if applicable.
6. Verify electrolyte level. Measure electrolyte specific gravity and temperature levels.
7. Verify presence of flame arresters.
8. Neutralize acid on exterior surfaces and rinse with water.
9. Clean corroded/oxidized terminals and apply an oxide inhibitor.
10. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.18.1.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey under load in accordance with Section 9.
11. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.18.1.1.1.
2. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended settings.
3. Verify all charger functions and alarms.
4. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.1.1 Direct-Current Systems, Batteries, Flooded Lead-Acid (*continued*)

5. Measure intercell connection resistances.
6. Perform internal ohmic measurement tests.
- *7. Perform a load test in accordance with manufacturer's specifications or ANSI/IEEE 450, *Recommended Practice for Maintenance, Testing and Replacement of Large Lead Storage Batteries for Generating Stations and Substations*.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Electrolyte level and specific gravity should be within normal limits. (7.18.1.1.1.6)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.18.1.1.1.10.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.18.1.1.1.10.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.1.1.10.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Charger float and equalize voltage levels should be in accordance with battery manufacturer's published data.
3. The results of charger functions and alarms should be in accordance with manufacturer's published data.
4. Cell voltages should be within 0.05 volt of each other or in accordance with manufacturer's published data.
5. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
6. Cell internal ohmic values (resistance, impedance or conductance) values should not vary by more than 25 percent between identical cells that are in a fully charged state.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.1.1 Direct-Current Systems, Batteries, Flooded Lead-Acid (*continued*)

7. Results of load tests should be in accordance with manufacturer's published data or ANSI/IEEE 450.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.1.2 Direct-Current Systems, Batteries, Vented Nickel-Cadmium

1. Visual and Mechanical Inspection

1. Verify that battery area ventilation system is operable.
2. Verify existence of suitable eyewash equipment.
3. Inspect physical and mechanical condition.
4. Verify adequacy of battery support racks or cabinets, mounting, battery spill containment system, anchorage, alignment, grounding, and clearances.
5. Prior to cleaning or adding electrolyte, perform as-found tests.
6. Verify electrolyte level and measure pilot-cell electrolyte temperature.
7. Verify the units are clean.
8. Verify application of an oxide inhibitor on battery terminal connections.
9. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.18.1.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
10. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.18.1.2.1.
2. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended settings.
3. Verify all charger functions and alarms.
4. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.
5. Measure intercell connection resistances.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.1.2 Direct-Current Systems, Batteries, Vented Nickel-Cadmium (*continued*)

6. Perform internal ohmic measurement tests.
- *7. Perform a load test in accordance with manufacturer's published data or ANSI/IEEE 1106.
8. Measure the battery system voltage from positive-to-ground and negative-to-ground.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Electrolyte level shall be within normal limits. (7.18.1.2.1.7)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.18.1.2.1.10.1)
3. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.18.1.2.1.10.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.2.1.10.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Charger float and equalize voltage levels should be in accordance with battery manufacturer's published data.
3. The results of charger functions and alarms should be in accordance with manufacturer's published data.
4. Cell voltages should be within 0.05 volt of each other or in accordance with manufacturer's published data.
5. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
6. Cell internal ohmic values (resistance, impedance, or conductance) should not vary by more than 25 percent between identical cells that are in a fully charged state, or should be in accordance with manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.1.2 Direct-Current Systems, Batteries, Vented Nickel-Cadmium (*continued*)

7. Results of load tests should be in accordance with manufacturer's published data or ANSI/IEEE 1106.
8. Voltage measured from positive-to-ground should be equal in magnitude to the voltage measured from negative-to-ground.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.1.3 Direct-Current Systems, Batteries, Valve-Regulated Lead-Acid

1. Visual and Mechanical Inspection

1. Verify the battery ventilation system is operable.
2. Verify the existence of suitable eyewash equipment.
3. Inspect physical and mechanical condition.
4. Inspect battery support racks or cabinets, mounting, anchorage, clearances, alignment, and grounding.
5. Prior to cleaning, perform as-found tests.
6. Neutralize acid on exterior surfaces and rinse with water.
7. Clean corroded/oxidized terminals and apply an oxide inhibitor.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.18.1.3.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey under load in accordance with Section 9.
9. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.18.1.3.1.
2. Measure negative post temperature.
3. Measure charger float and equalizing voltage levels.
4. Verify all charger functions and alarms.
5. Measure each monoblock/cell voltage and total battery voltage with charger energized and in float mode of operation.
6. Measure intercell connection resistances.
7. Perform internal ohmic measurement tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.1.3 Direct-Current Systems, Batteries, Valve-Regulated Lead-Acid (*continued*)

8. Perform an annual load test in accordance with manufacturer's specifications or IEEE 1188, *Recommended Practice for Maintenance, Testing and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.18.1.3.9.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.18.1.3.9.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.3.9.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Negative post temperature should be within manufacturer's published data or IEEE 1188.
3. Charger float and equalize voltage levels should be in accordance with the battery manufacturer's published data.
4. Results of charger functions and alarms should be in accordance with manufacturer's published data.
5. Monoblock/cell voltages should be in accordance with manufacturer's published data.
6. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
7. Monoblock/cell internal ohmic values (resistance, impedance, or conductance) should not vary by more than 25 percent between identical monoblocks/cells that are in a fully charged state.
8. Results of load tests should be in accordance with manufacturer's published data or IEEE 1188.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.2 Direct-Current Systems, Chargers

1. Visual and Mechanical Inspection

1. Inspect for physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Inspect all bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.18.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey under load in accordance with Section 9.
6. Inspect filter and tank capacitors.
7. Verify operation of cooling fans. Clean filters if provided.
8. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.18.2.1.
2. Verify float voltage, equalize voltage, and high-voltage shutdown settings.
3. Verify current limit.
4. Verify correct load sharing (parallel chargers).
5. Verify calibration of meters in accordance with Section 7.11.
6. Verify operation of alarms.
7. Measure and record input and output voltage and current.
8. Measure and record ac ripple current and/or voltage imposed on battery.
- *9. Perform full load testing of charger.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.2 Direct-Current Systems, Chargers (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.18.2.1.5.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.18.2.1.5.1)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.18.2.1.5.1)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Float and equalize voltage settings should be in accordance with the battery manufacturer's published data.
3. Current limit should be within manufacturer's recommended maximum.
4. Results of load sharing between parallel chargers should be in accordance with system design specifications.
5. Results of meter calibration should be in accordance with Section 7.11.
6. Results of alarm operation should be in accordance with manufacturer's published data and system design.
7. Input and output voltage should be in accordance with manufacturer's published data.
8. AC ripple current and/or voltage imposed on the battery should be in accordance with manufacturer's published data.
9. Charger should be capable of manufacturer's specified full load.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.18.3 Direct-Current Systems, Rectifiers

– RESERVED –

* Optional



7. INSPECTION AND TEST PROCEDURES

7.19.1 Surge Arresters, Low-Voltage Surge Protection Devices

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.19.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
7. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.19.1.1.
2. Perform insulation-resistance test on each arrester, from the phase terminal to ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Test grounding connection in accordance with Section 7.13.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.19.1 Surge Arresters, Low-Voltage Surge Protection Devices (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.19.1.1.5.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.19.1.1.5.2)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Resistance between the arrester ground terminal and the ground system should be less than 0.5 ohm and in accordance with Section 7.13.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.19.2 Surge Arresters, Medium- and High-Voltage Surge Protection Devices

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.19.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
7. Verify that stroke counter, if present, is correctly mounted and electrically connected.
8. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.19.2.1.
2. Perform insulation-resistance tests from phase terminal(s) to case for one minute. Test voltage and minimum resistance shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.1.
3. Test the grounding connection in accordance with Section 7.13.
- *4. Perform a watts-loss test in accordance with test equipment manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.19.2 Surge Arresters, Medium- and High-Voltage Surge Protection Devices (continued)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.19.2.1.5.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.19.2.1.5.2)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated
3. Resistance between the arrester ground terminal and the ground system should be less than 0.5 ohm and in accordance with Section 7.13.
4. Watts loss values are evaluated on a comparison basis with similar units and test equipment manufacturer's published data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.20.1 Capacitors and Reactors, Capacitors

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, grounding, and required clearances.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Verify that capacitors are electrically connected in their specified configuration.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.20.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
7. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. See Section 7.20.1.1.
2. Perform insulation-resistance tests from phase terminal(s) to case for one minute. Test voltage and minimum resistance shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.1.
3. Measure the capacitance of all terminal combinations.
4. Measure resistance of internal discharge resistors.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.20.1 Capacitors and Reactors, Capacitors (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.20.1.1.6.1)
2. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12. (7.20.1.1.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.20.1.1.6.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated
3. Investigate capacitance values differing from manufacturer’s published data.
4. Investigate discharge resistor values differing from manufacturer’s published data. In accordance with ANSI/NFPA 70 *National Electrical Code*, Article 460, residual voltage of a capacitor shall be reduced to 50 volts in the following time intervals after being disconnected from the source of supply:

<u>Rated Voltage</u>	<u>Discharge Time</u>
≤ 600 volts	1 minute
> 600 volts	5 minutes

* Optional



7. INSPECTION AND TEST PROCEDURES

7.20.2 Capacitors and Reactors, Capacitor Control Devices

– RESERVED –

* Optional



7. INSPECTION AND TEST PROCEDURES

7.20.3.1 Capacitors and Reactors, Reactors (Shunt and Current-Limiting), Dry Type

1. Visual and Mechanical Inspections

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.20.3.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
6. Verify that tap connections are as specified, if applicable.
7. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with low-resistance ohmmeter, if applicable, in accordance with Section 7.20.3.1.1.
2. Perform winding-to-ground insulation-resistance tests. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Measure winding resistance.
- *4. Perform dielectric withstand voltage tests on each winding-to-ground.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.20.3.1 Capacitors and Reactors, Reactors (Shunt and Current-Limiting), Dry Type (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.20.3.1.1.5.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.20.3.1.1.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.20.3.1.1.5.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. If winding-resistance test results vary by more than one percent from factory tests, consult the manufacturer.
4. AC dielectric withstand test voltage shall not exceed 75 percent of factory test voltage for one minute duration. DC dielectric withstand test voltage shall not exceed 100 percent of the factory rms test voltage for one minute duration. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.20.3.2 Capacitors and Reactors, Reactors (Shunt and Current-Limiting), Liquid-Filled

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Verify settings and operation of all temperature devices, if applicable.
6. Verify that cooling fans and pumps operate correctly and that fan and pump motors have correct overcurrent protection, if applicable.
7. Verify operation of all alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relay, if applicable.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.20.3.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
9. Perform as-left tests.
10. Verify correct liquid level in all tanks and bushings.
11. Verify that positive pressure is maintained on nitrogen-blanketed reactors.
12. Perform specific inspections and mechanical tests as recommended by the manufacturer.
13. Verify that tap connections are as specified, if applicable.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.20.3.2 Capacitors and Reactors, Reactors (Shunt and Current-Limiting), Liquid-Filled (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.20.3.2.1.
2. Perform winding-to-ground insulation-resistance tests. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Calculate polarization index.
3. Perform insulation power-factor or dissipation-factor tests on windings in accordance with the test equipment manufacturer's published data.
4. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
5. Measure winding resistance.
6. Measure the percentage of oxygen in the nitrogen gas blanket, if applicable.
7. Remove a sample of insulating liquid in accordance with ASTM D-923. Sample shall be tested for the following:
 1. Dielectric breakdown voltage: ASTM D-877
 2. Acid neutralization number: ASTM D-974
 3. Specific gravity: ASTM D-1298
 4. Interfacial tension: ASTM D-971 or ASTM D-2285
 5. Color: ASTM D-1500
 6. Visual Condition: ASTM D-1524
 7. Water in insulating liquids: ASTM D-1533 (Required on 25 kV or higher voltages and on all silicone-filled units)
 - *8. Measure power factor or dissipation factor in accordance with ASTM D-924
8. Remove a sample of insulating liquid in accordance with ASTM D-3613 and perform dissolved-gas-analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D-3612.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.20.3.2 Capacitors and Reactors, Reactors (Shunt and Current-Limiting), Liquid-Filled (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Operation of temperature devices should be in accordance with system requirements. (7.20.3.2.1.5)
2. Operation of pumps and fans should be in accordance with manufacturer's recommendations and system design. (7.20.3.2.1.6)
3. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.20.3.2.1.8.1)
4. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.20.3.2.1.8.2)
5. Results of the thermographic survey shall be in accordance with Section 9. (7.20.3.2.1.8.3)
6. Liquid levels should be in accordance with manufacturer's indicated tolerances. (7.20.3.2.1.10)
7. Positive pressure should be indicated on the pressure gauge for gas-blanketed reactors. (7.20.3.2.1.11)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index should be greater than 1.0 and should be compared to previous data.
3. Maximum power-factor or dissipation-factor values of liquid-filled reactors should be in accordance with manufacturer's published data. In the absence of manufacturer's data, compare to test equipment manufacturer's published data. Representative values are indicated in Table 100.3.
4. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.20.3.2 Capacitors and Reactors, Reactors (Shunt and Current-Limiting), Liquid-Filled (*continued*)

5. Consult the manufacturer if winding-resistance values vary more than one percent from factory tests.
6. Investigate presence of oxygen in the nitrogen gas blanket.
7. Insulating liquid values should be in accordance with Table 100.4.
8. Evaluate results of dissolved-gas analysis in accordance with IEEE Standard C57.104. Compare results to previous test data.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.21 Outdoor Bus Structures

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.21.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
6. Clean the insulators.
7. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.21.1.
- *2. Measure insulation resistance of each bus, phase-to-ground with other phases grounded. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform dielectric withstand voltage test on each bus phase, phase-to-ground with other phases grounded in accordance with manufacturer's published data. In the absence of manufacturer's data use Table 100.19. Test duration shall be for one minute.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.21 Outdoor Bus Structures (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.21.1.5.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.21.1.5.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.21.1.5.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data or Table 100.1.
3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.22.1 Emergency Systems, Engine Generator

NOTE: The prime mover is not addressed in these specifications.

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Perform as-left tests.

2. Electrical and Mechanical Tests

1. Perform an insulation-resistance test on the generator winding-to-ground in accordance with ANSI/IEEE Standard 43. Calculate the polarization index.
2. Test protective relay devices in accordance with Section 7.9.
3. Functionally test engine shutdown for low oil pressure, overtemperature, overspeed, and other protection features as applicable.
- *4. Perform vibration test for each main bearing cap.
5. Conduct performance test in accordance with ANSI/NFPA Standard 110.
6. Verify correct functioning of governor and regulator.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Anchorage, alignment, and grounding should be in accordance with manufacturer's published data and system design.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.22.1 Emergency Systems, Engine Generator (*continued*)

3.2 Test Values – Electrical

1. Insulation resistance values should be in accordance with ANSI/IEEE Standard 43.
2. The dielectric absorption ratio or polarization shall be compared to previously obtained results and should not be less than 1.0. The recommended minimum insulation resistance ($IR_{1 \text{ min}}$) test results in megohms should be corrected to 40° C and read as follows:
 1. $IR_{1 \text{ min}} = kV + 1$ for most windings made before 1970, all field windings, and others not described in 2.2 and 2.3.

(kV is the rated machine terminal-to-terminal voltage, in rms kV)
 2. $IR_{1 \text{ min}} = 100$ megohms for most dc armature and ac windings built after 1970 (form-wound coils).
 3. $IR_{1 \text{ min}} = 5$ megohms for most machines and random-wound stator coils and form-wound coils rated below 1 kV.

NOTE: Dielectric withstand voltage high-potential, and surge comparison tests shall not be performed on machines having values lower than those indicated above.

3. Protective relay device test results shall be in accordance with Section 7.9.
4. Low oil pressure, overtemperature, overspeed, and other protection features should operate in accordance with manufacturer's and system design requirements.
5. Vibration levels should be in accordance with manufacturer's published data and shall be compared to baseline data.
6. Performance tests should conform to manufacturer's published data and ANSI/NFPA Standard 110.
7. Governor and regulator should operate in accordance with manufacturer's and system design requirements.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.22.2 Emergency Systems, Uninterruptible Power Systems

NOTE: There are many configurations of uninterruptible power supply installations. Some are as simple as a static switch selecting between two highly reliable sources, while others are complex systems using a combination of rectifiers, batteries, inverters, motor/generators, static switches and bypass switches. It is the intent of these specifications to list possible tests and maintenance of the major components of the system and more specifically the system as a whole. It is important that the manufacturer's recommended maintenance be performed.

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Check for anchorage, alignment, grounding, and required clearances.
3. Verify that fuse sizes and types correspond to drawings.
4. Prior to cleaning the unit, perform as-found tests, if required.
5. Clean the unit.
6. Test all electrical and mechanical interlock systems for correct operation and sequencing.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.22.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
8. Perform as-left tests.
9. Check operation of forced ventilation.
10. Verify that filters are in place and/or vents are clear.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.22.2 Emergency Systems, Uninterruptible Power Systems (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.22.2.1.
2. Test static transfer from inverter to bypass and back. Use normal load, if possible.
3. Set free running frequency of oscillator.
4. Test dc undervoltage trip level on inverter input breaker. Set according to manufacturer's published data.
5. Test alarm circuits.
6. Verify sync indicators for static switch and bypass switches.
7. Perform electrical tests for UPS system breakers in accordance with Section 7.6.1.
8. Perform electrical tests for UPS system automatic transfer switches in accordance with Section 7.22.3.
9. Perform electrical tests for UPS system batteries in accordance with Section 7.18.
10. Perform electrical tests for UPS rotating machinery in accordance with Section 7.15.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Electrical and mechanical interlock systems should operate in accordance with system design requirements. (7.22.2.1.6)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.22.2.1.7.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.22.2.1.7.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.22.2.1.7.3)

* Optional



7. INSPECTION AND TEST PROCEDURES

7.22.2 Emergency Systems, Uninterruptible Power Systems (*continued*)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Static transfer should function in accordance with manufacturer's published data.
3. Oscillator free running frequency should be within manufacturer's recommended tolerances.
4. DC undervoltage should trip inverter input breaker.
5. Alarm circuits should operate in accordance with design requirements.
6. Sync indicators should operate in accordance with design requirements.
7. Breaker performance shall be in accordance with Section 7.6.1
8. Automatic transfer switch performance shall be in accordance with Section 7.22.3.
9. Battery test results shall be in accordance with Section 7.18.
10. Rotating machinery performance shall be in accordance with Section 7.15.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.22.3 Emergency Systems, Automatic Transfer Switches

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, grounding, and required clearances.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
6. Verify that manual transfer warnings are attached and visible.
7. Verify tightness of all control connections.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.22.3.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
9. Perform manual transfer operation.
10. Verify positive mechanical interlocking between normal and alternate sources.
11. Perform as-left tests.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.22.3 Emergency Systems, Automatic Transfer Switches (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.22.3.1.
- *2. Perform insulation resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or for control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
3. Perform a contact/pole-resistance test.
4. Verify settings and operation of control devices.
5. Calibrate and set all relays and timers in accordance with Section 7.9.
6. Perform automatic transfer tests:
 1. Simulate loss of normal power.
 2. Return to normal power.
 3. Simulate loss of emergency power.
 4. Simulate all forms of single-phase conditions.
7. Verify correct operation and timing of the following functions:
 1. Normal source voltage-sensing and frequency sensing relays.
 2. Engine start sequence.
 3. Time delay upon transfer.
 4. Alternate source voltage-sensing and frequency sensing relays.
 5. Automatic transfer operation.
 6. Interlocks and limit switch function.
 7. Time delay and retransfer upon normal power restoration.
 8. Engine cool down and shutdown feature.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.22.3 Emergency Systems, Automatic Transfer Switches (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.22.3.1.8.1)
2. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.22.3.1.8.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.22.3.1.8.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.
4. Control devices should operate in accordance with manufacturer's published data.
5. Relay test results shall be in accordance with Section 7.9.
6. Automatic transfers should operate in accordance with manufacturer's design.
7. Operation and timing should be in accordance with manufacturer's and/or system design requirements.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.23 Communications

– RESERVED –

* Optional



7. INSPECTION AND TEST PROCEDURES

7.24.1 Automatic Circuit Reclosers and Line Sectionalizers, Automatic Circuit Reclosers, Oil/Vacuum

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Perform all mechanical operation and contact alignment tests on both the recloser and its operating mechanism in accordance with manufacturer's published data.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.24.1.2.1.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
7. Inspect for correct insulating liquid level, if applicable.
8. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.24.1.1.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with recloser closed and across each pole with the recloser open. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a contact/pole-resistance test.
- *4. Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.24.1 Automatic Circuit Reclosers and Line Sectionalizers, Automatic Circuit Reclosers, Oil/Vacuum (*continued*)

5. Remove a sample of insulating liquid, if applicable, in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.
 1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
 2. Color: ANSI/ASTM D 1500
 3. Visual condition: ASTM D 1524
- *6. Perform minimum pickup voltage tests on trip and close coils in accordance with Table 100.20.
- *7. Perform power-factor or dissipation-factor tests on each pole with the recloser open and each phase with the recloser closed.
- *8. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests should be in accordance with the test equipment manufacturer's published data.
 9. Perform vacuum bottle integrity test (dielectric withstand voltage), if applicable, across each vacuum bottle with the recloser in the open position in strict accordance with manufacturer's published data.
10. Perform dielectric withstand voltage test on each phase with the recloser closed and the poles not under test grounded. Test voltage should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19.
11. Verify operation of heaters, if applicable.
12. Test all protective functions in accordance with Section 7.9.
13. Test all metering and instrumentation in accordance with Section 7.11.
14. Test instrument transformers in accordance with Section 7.10.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.24.1 Automatic Circuit Reclosers and Line Sectionalizers, Automatic Circuit Reclosers, Oil/Vacuum (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Mechanical operation and contact alignment should be in accordance with manufacturer's published data. (7.24.1.1.5)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.24.1.1.6.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.24.1.1.6.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.24.1.1.6.3)
5. Insulating liquid level should be in accordance with manufacturer's recommended tolerances.

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar reclosers by more than 50 percent of the lowest value.
4. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
5. Insulating liquid test results should be in accordance with Table 100.4.
6. Minimum pickup for trip and close coils should conform with manufacturer's published data. In the absence of manufacturer's published data refer to Table 100.20.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.24.1 Automatic Circuit Reclosers and Line Sectionalizers, Automatic Circuit Reclosers, Oil/Vacuum (*continued*)

7. Power-factor or dissipation-factor values and tank loss index shall be compared to manufacturer's published data. In the absence of manufacturer's published data, the comparison shall be made to test data from similar circuit reclosers or sectionalizers or data from test equipment manufacturers.
8. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliamper/milliwatt loss basis, and the results should be compared to values of similar bushings.
9. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the vacuum bottle integrity test, the test specimen is considered to have passed the test
10. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
11. Heaters should be operational.
12. Protective device function test results shall be in accordance with Section 7.9.
13. Metering and instrumentation test results shall be in accordance with Section 7.11.
14. Instrument transformer test results shall be in accordance with Section 7.10.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.24.2 Automatic Circuit Reclosers and Line Sectionalizers, Automatic Line Sectionalizers, Oil

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Prior to cleaning the unit, perform as-found tests.
4. Clean the unit.
5. Perform all mechanical operation and contact alignment tests on both the sectionalizer and its operating mechanism in accordance with manufacturer's published data.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.24.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
7. Inspect for correct insulating liquid level.
8. Perform as-left tests.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.24.2.1.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with sectionalizer closed and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
3. Perform a contact/pole-resistance test.
4. Remove a sample insulating liquid in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.
 1. Dielectric breakdown voltage: ASTM D 877
 2. Color: ANSI/ASTM D 1500

* Optional



7. INSPECTION AND TEST PROCEDURES

7.24.2 Automatic Circuit Reclosers and Line Sectionalizers, Automatic Line Sectionalizers, Oil (*continued*)

3. Visual condition: ASTM D 1524
5. Perform dielectric withstand voltage tests on each pole-to-ground and pole-to-pole.
6. Test sectionalizer counting function by application of simulated fault current (greater than 160 percent of continuous current rating).
7. Test sectionalizer lockout function for all counting positions.
8. Test for reset timing on trip actuator.
- *9. Perform power-factor or dissipation-factor tests on each pole with the recloser open and each phase with the recloser closed.
- * 10. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests should be in accordance with the test equipment manufacturer's published data.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Mechanical operation and contact alignment should be in accordance with manufacturer's published data. (7.24.2.1.5)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.24.2.1.6.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.24.2.1.6.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.24.2.1.6.3)
5. Insulating liquid level should be in accordance with manufacturer's recommended tolerances.

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.24.2 Automatic Circuit Reclosers and Line Sectionalizers, Automatic Line Sectionalizers, Oil (*continued*)

2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer's published data. If manufacturer's data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.
4. Insulating liquid test results should be in accordance with Table 100.4.
5. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
6. Operations counter should advance one digit per close-open cycle.
7. Lockout function should operate in accordance with manufacturer's published data.
8. Reset timing of trip actuator should operate in accordance with manufacturer's published data.
9. Power-factor or dissipation-factor values and tank loss index shall be compared to manufacturer's published data. In the absence of manufacturer's published data, the comparison shall be made to test data from similar circuit reclosers or sectionalizers or data from test equipment manufacturers.
10. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliamperere/milliwatt loss basis, and the results should be compared to values of similar bushings.

* Optional



7. INSPECTION AND TEST PROCEDURES

7.25 Fiber-Optic Cables

1. Visual and Mechanical Inspection

1. Inspect cable and connections for physical and mechanical damage.
2. Verify that all connectors and splices are correctly installed.

2. Optical Tests

1. Perform cable length measurement, fiber fracture inspection, and construction defect inspection using an optical time domain reflectometer.
2. Perform connector and splice integrity test using an optical time domain reflectometer.
3. Perform cable attenuation loss measurement with an optical power loss test set.
4. Perform connector and splice attenuation loss measurement from both ends of the optical cable with an optical power loss test set.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Cable and connections should not have been subjected to physical or mechanical damage. (7.25.1.1)
2. Connectors and splices should be installed in accordance with industry standards. (7.25.1.2)

3.2 Test Values – Optical

1. The optical time domain reflectometer signal should be analyzed for excessive connection, splice, or cable backscatter by viewing the reflected power/distance graph.
2. The optical time domain reflectometer signal should be analyzed for excessive connection, splice, or cable backscatter by viewing the reflected power/distance graph.
3. Attenuation loss measurement shall be expressed in dB/km. Losses should be within the manufacturer's recommendations when no local site specifications are available.
4. Attenuation loss measurement shall be expressed in dB/km. Losses should be within the manufacturer's recommendations when no local site specifications are available.

* Optional



8. SYSTEM FUNCTION TESTS

It is the purpose of system function tests to prove the correct interaction of all sensing, processing, and action devices.

Perform system function tests upon completion of the maintenance tests defined, as system conditions allow.

1. Develop test parameters and perform tests for the purpose of evaluating performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.
2. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.
3. Verify the correct operation of all sensing devices, alarms, and indicating devices.



9. THERMOGRAPHIC SURVEY

1. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Remove panel covers or view the equipment through viewing ports designed to transmit applicable signals being measured.

2. Thermographic Survey Report

Provide a report which includes the following:

1. Description of equipment to be tested.
2. Discrepancies.
3. Temperature difference between the area of concern and the reference area.
4. Probable cause of temperature difference.
5. Areas inspected. Identify inaccessible and/or unobservable areas and/or equipment.
6. Identify load conditions at time of inspection.
7. Provide photographs and/or thermograms of the deficient area.
8. Provide recommended action for repair.

3. Test Parameters

1. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
2. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
3. Thermographic surveys should be performed during periods of maximum possible loading. Refer to ANSI/NFPA 70B 2006 edition, Section 21.17

4. Test Results

Suggested actions based on temperature rise can be found in Table 100.18.



10. ELECTROMAGNETIC FIELD SURVEY

1. Procedure

1. Take detailed measurements of the magnetic flux density, vector direction, and temporal variations at the locations or over the area, as necessary.
 1. Perform spot measurements of the magnetic fields (40 to 800 hertz) at grid intervals one meter above the floor throughout the office. Record x, y, z, and resultant magnetic flux density values for each measurement point.
 2. Take additional detailed spot measurements directly at floor level, at two meters above the floor, at grid point locations, and directly on the wall surface separating the measured area from suspected magnetic field source.
 3. If measured magnetic flux densities at any perimeter wall appear to be above 3.0 mG, take additional spot measurements of the adjoining space utilizing the same measurement grid spacing at a height of one meter above floor.
 4. Take a baseline magnetic flux density reading at a specific point in the immediate area of the suspected magnetic field source.
 5. Determine magnetic field temporal variations as required by positioning the Gaussmeter at or near the location of highest magnetic flux density for 24 to 48 hours.
2. Obtain and record electrical system information including current measurements.
3. The magnetic field evaluation shall be performed in accordance with the recommended practices and procedures in accordance with IEEE 644.

1. Survey Report

Provide a report which includes the following:

1. Basis, description, purpose, and scope of the survey.
2. Tabulations and or attached graphical representations of the magnetic flux density measurements corresponding to the time and area or space where the measurements were taken.
3. Descriptions of each of the operating conditions evaluated and identification of the condition that resulted in the highest magnetic flux density.
4. Descriptions of equipment performance issues that could be related to measured magnetic flux density.
5. Description of magnetic field test equipment.
6. Conclusions and recommendations.



11.0 CORONA STUDIES

– RESERVED –



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Tables



**Standard for
Maintenance Testing Specifications
for
Electrical Power
Equipment and Systems**

TABLE 100.1

**Insulation Resistance Test Values
Electrical Apparatus and Systems**

Nominal Rating of Equipment (Volts)	Minimum Test Voltage (DC)	Recommended Minimum Insulation Resistance (Megohms)
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
34,500 and above	15,000	100,000

In the absence of consensus standards dealing with insulation-resistance tests, the NETA Standards Review Council suggests the above representative values.

See Table 100.14 for temperature correction factors.

Test results are dependent on the temperature of the insulating material and the humidity of the surrounding environment at the time of the test.

Insulation-resistance test data may be used to establish a trending pattern. Deviations from the baseline information permit evaluation of the insulation.



TABLE 100.2

Switchgear Withstand Test Voltages

Type of Switchgear	Rated Maximum Voltage (kV) (rms)	Maximum Test Voltage (kV)	
		AC	DC
Low-Voltage Power Circuit Breaker Switchgear	.254/.508/.635	1.6	2.3
Metal-Clad Switchgear	4.76	14	20
	8.25	27	37
	15.0	27	37
	27.0	45	a
	38.0	60	a
Station-Type Cubicle Switchgear	15.5	37	a
	38.0	60	a
	72.5	120	a
Metal-Enclosed Interrupter Switchgear	4.76	14	20
	8.25	19	27
	15.0	27	37
	27	45	a
	38.0	60	a

Derived from ANSI/IEEE C37.20.1-1993 *Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear*, Paragraph 5; ANSI/IEEE C37.20.2-1999, *Standard for Metal-Clad Switchgear*, Paragraph 6.5; and ANSI/IEEE C37.20.3-2001 *Standard for Metal-Enclosed Interrupter Switchgear*, Paragraph 6.5. This table includes 0.75 multiplier with fraction rounded down.

The column headed “DC” is given as a reference only for those using dc tests to verify the integrity of connected cable installations without disconnecting the cables from the switchgear. It represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for voltage rating of switchgear. The presence of this column in no way implies any requirement for a dc withstand test on ac equipment or that a dc withstand test represents an acceptable alternative to the low-frequency withstand tests specified in these specifications, either for design tests, production tests, conformance tests, or field tests. When making dc tests, the voltage should be raised to the test value in discrete steps and held for a period of one minute.

- a. Because of the variable voltage distribution encountered when making dc withstand tests, the manufacturer should be contacted for recommendations before applying dc withstand tests to the switchgear. Voltage transformers above 34.5 kV should be disconnected when testing with dc. Refer to ANSI/IEEE C57.13-1993 (*IEEE Standard Requirements for Instrument Transformers*) paragraph 8.8.2.



TABLE 100.3

Maintenance Test Values
Recommended Dissipation Factor/Power Factor at 20° C
Liquid-Filled Transformers, Regulators, and Reactors

	Oil Maximum	Silicone Maximum	Tetrachloroethylene Maximum	High Fire Point Hydrocarbon Maximum
Power Transformers	1.0%	0.5%	3.0%	2.0%
Distribution Transformers	2.0%	0.5%	3.0%	3.0%

In the absence of consensus standards dealing with transformer dissipation/power factor values, the NETA Standards Review Council suggests the above representative values. Maximum values for oil are based on data from Doble Engineering Company.



TABLE 100.4.1**Suggested Limits for Class I Insulating Oil**

Mineral Oil ^a				
Test	ASTM Method	Acceptable Values		
		69 kV and Below	Above 69 kV - Below 230 kV	230 kV and Above
Dielectric breakdown, kV minimum ^b	D 877	26	26	26
Dielectric breakdown, kV minimum @ 1 mm (0.04 inch) gap	D 1816	23	28	30
Dielectric breakdown, kV minimum @ 2 mm (0.08 inch) gap	D 1816	40	47	50
Interfacial tension mN/m minimum	D 971 or D 2285	25	30	32
Neutralization number, mg KOH/g maximum	D 974	0.20	0.15	0.10
Water content, ppm maximum @ 60° C ^c	D 1533	35	25	20
Power factor at 25° C, %	D 924	0.5	0.5	0.5
Power factor at 100° C, %	D 924	5.0	5.0	5.0
Color ^d	D 1500	3.5	3.5	3.5
Visual Condition	D 1524	Bright, clear and free of particles	Bright, clear and free of particles	Bright, clear and free of particles
Specific Gravity (Relative Density) @ 15° C Maximum ^e	D 1298	0.91	0.91	0.91

- ANSI/IEEE C57.106-2002 *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 7.
- IEEE STD 637-1985 *Guide for Reclamation of Insulating Oil and Criteria for Its Use*, Table 1.
- ANSI/IEEE C57.106-2002 *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 5.
- In the absence of consensus standards, NETA's Standard Review Council suggests these values.
- ANSI/IEEE C57.106 *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Table 1.



TABLE 100.4.2**Suggested Limits
for Less-Flammable Hydrocarbon Insulating Liquid**

Test	ASTM Method	Acceptable Values
Dielectric breakdown voltage, kV minimum	D 877	24
Dielectric breakdown voltage for 1 mm (0.04 inch) gap, kV minimum	D 1816	34
Dielectric breakdown voltage for 2 mm (0.08 inch) gap, kV minimum	D 1816	24
Water content, ppm maximum	D 1533 B	35
Dissipation/power factor, 60 hertz, % max. @ 25° C	D 924	1.0
Fire point, ° C, minimum	D 92	300
Interfacial tension, mN/m, 25° C	D 971	24
Neutralization number, mg KOH/g	D 664	0.20

ANSI/IEEE C57.121-1998 *Guide for Acceptance and Maintenance of Less-Flammable Hydrocarbon Fluid in Transformers*, Table 4.

The values in this table are considered typical for acceptable service-aged LFH fluids as a general class. If actual test analysis approaches the values shown, consult the fluid manufacturer for specific recommendations.

If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.



TABLE 100.4.3

**Suggested Limits
for Service-Aged Silicone Insulating Liquid**

Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D 877	25
Visual	D 2129	Colorless, clear, free of particles
Water content, ppm maximum	D 1533	100
Dissipation/power factor, 60 hertz, maximum @ 25° C	D 924	0.2
Viscosity, cSt @ 25° C	D 445	47.5 – 52.5
Fire point, ° C, minimum	D 92	340
Neutralization number, mg KOH/g max.	D 974	0.2

ANSI/IEEE C57.111-1989 (R1995) *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 3.

TABLE 100.4.4

**Suggested Limits for Service-Aged Tetrachloroethylene Insulating
Fluid**

Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D 877	26
Visual	D 2129	Clear with purple iridescence
Water content, ppm maximum	D 1533	35
Dissipation/power factor, % maximum @ 25° C	D 924	12.0
Viscosity, cSt @ 25° C	D 445	0
Fire point, ° C, minimum	D 92	-
Neutralization number, mg KOH/g maximum	D 974	0.25
Neutralization number, mg KOH/g maximum	D 664	-
Interfacial tension, mN/m minimum @ 25° C	D 971	-

Instruction Book PC-2000 for Wecosol™ Fluid-Filled Primary and Secondary Unit Substation Transformers, ABB Power T&D.



TABLE 100.5

**Transformer Insulation Resistance
Maintenance Testing**

Transformer Coil Rating Type (Volts)	Minimum DC Test Voltage	Recommended Minimum Insulation Resistance (Megohms)	
		Liquid Filled	Dry
0 – 600	1000	100	500
601 – 5000	2500	1000	5000
Greater than 5000	5000	5000	25000

In the absence of consensus standards, the NETA Standards Review Council suggests the above representative values.

See Table 100.14 for temperature correction factors.

NOTE: Since insulation resistance depends on insulation rating (kV) and winding capacity (kVA), values obtained should be compared to manufacturer's published data.



TABLE 100.6.1

**Medium-Voltage Cables
Maintenance Test Values
DC Test Voltages**

Rated Voltage Phase-to- Phase (kV)	Conductor Size AWG or kcmil (mm)	Nominal Insulation Thickness mils (mm)		Maximum DC Field Test Voltages (kV) First 5 Years After Installation	
		100% Insulation Level	133% Insulation Level	100% Insulation Level	133% Insulation Level
5	8-1000 (8.4-507)	90 (2.29)	115 (2.92)	9	11
	Above 1000 (507)	140 (3.56)	140 (3.56)	9	11
8	6-1000 (13.3-507)	115 (2.92)	140 (3.56)	11	14
	Above 1000 (507)	175 (4.45)	175 (4.45)	11	14
15	2-1000 (33.6-507)	175 (4.45)	220 (5.59)	18	20
	Above 1000 (507)	220 (5.59)	220 (5.59)	18	20
25	1-2000 (42.4-1013)	260 (6.60)	320 (8.13)	25	30
28	1-2000 (42.4-1013)	280 (7.11)	345 (8.76)	26	31
35	1/0-2000 (53.5-1013)	345 (8.76)	420 (10.7)	31	39
46	4/0-2000 (107.2-1013)	445 (11.3)	580 (14.7)	41	54

Reproduction of tables from ICEA S-94-649-2004 *Standard for Concentric Neutral Cables Rated 5,000 – 46,000 Volts* and ICEA S-97-682-2007 *Utility Shielded Power Cables Rated 5,000 – 46,000 Volts*.



TABLE 100.6.2

**Field Test Voltages for Laminated Dielectric, Shielded Power
Cable Systems Rated 5,000 Volts and Above with High DC
Voltage**

System voltage, kV rms, phase-to-phase	System BIL, kV crest	Maintenance test, kV dc, phase-to-ground
5	75	23
8	95	29
15	110	46
25	150	61
28	170	68
35	200	75
46	250	95
69	350	130
115	450	170
115	550	205
138	650	245
161	750	280
230	1050	395
345	1175	440
345	1300	488
500	1425	535
500	1550	580
500	1675	629

NOTE 1 – Voltages higher than those listed, up to 80% of system BIL, may be considered, but the age and operating environment of the system should be taken into account. The user is urged to consult the suppliers of the cable and any/all accessories before applying the high voltage.

NOTE 2 – When older cables or other types/classes of cables or other equipment, such as transformers, switchgear, motors, etc. are connected to the cable to be tested, voltages lower than those shown in this table may be necessary to comply with the limitations imposed by such interconnected cables and equipment. See IEEE Std 95TM [B5]⁷ and Table 1 of IEEE Std C37.20.2TM-1999 [B7].

NOTE 3 – If the test voltage exceeds 50% of system BIL, surge protection against excessive overvoltages induced by flashovers at the termination should be provided.

NOTE 4 – It is strongly recommended that the user consult with the manufacturer(s) of all components that will be subjected to such testing before performing any tests on cables and cable accessories rated 115 kV and higher.

NOTE 5 – It should be noted that this table and the test procedures suggested in this guide do not necessarily agree with the recommendations of other organizations, such as those of the Association of Edison Illuminating Companies [B1], [B2], [B3], [B4]. Where there is concern, a user should consult the supplier of the cable and accessories to ascertain that the components will withstand the test.

Reproduction of table from IEEE Std 400.1-2007 *IEEE Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above with High Direct Current Voltage*.



TABLE 100.6.3

**Very Low Frequency Testing Levels for Medium-Voltage Cable
0.1 Hz Test Voltage (rms)**

Very Low Frequency Testing Levels 0.1 Hz Test Voltage (rms)	
System Voltage Phase-to-Phase (kV) (rms)	Maintenance Phase-to-Ground (kV) (rms)
5	7
8	10
15	16
25	23
35	33

Adaptation of table from IEEE Std 400.2-2004 *Guide for field testing of shielded power cable systems using very low frequency (VLF)*.



TABLE 100.7

**Molded-Case Circuit Breakers
Inverse Time Trip Test
(At 300% of Rated Continuous Current of Circuit Breaker)**

Range of Rated Continuous Current (Amperes)	Maximum Trip Time in Seconds for Each Maximum Frame Rating ^a	
	≤ 250 V	251 – 600 V
0-30	50	70
31-50	80	100
51-100	140	160
101-150	200	250
151-225	230	275
226-400	300	350
401-600	-----	450
601-800	-----	500
801-1000	-----	600
1001 – 1200	-----	700
1201-1600	-----	775
1601-2000	-----	800
2001-2500	-----	850
2501-5000	-----	900
6000	-----	1000

Derived from Table 5-3, NEMA Standard AB 4-2000, *Guidelines for Inspection and Preventative Maintenance of Molded-Case Circuit Breaker Used in Commercial and Industrial Applications.*

- a. Trip times may be substantially longer for integrally-fused circuit breakers if tested with the fuses replaced by solid links (shorting bars).



TABLE 100.8

**Instantaneous Trip Tolerances
for Field Testing of Circuit Breakers**

Breaker Type	Tolerance of Settings	Tolerances of Manufacturer's Published Trip Range	
		High Side	Low Side
Electronic Trip Units ⁽¹⁾	+30%	-----	-----
Adjustable ⁽¹⁾	+40% -30%	-----	-----
Nonadjustable ⁽²⁾	-----	+25%	-25%

NEMA AB4-2009 *Guidelines for Inspection and Preventative Maintenance of Molded-Case Circuit Breaker Used in Commercial and Industrial Applications, Table 4.*

1. Tolerances are based on variations from the nominal settings.
2. Tolerances are based on variations from the manufacturer's published trip band (i.e., -25% below the low side of the band; +25% above the high side of the band.)



TABLE 100.9

**Instrument Transformer Dielectric Tests
Field Maintenance**

Nominal System (kV)	BIL (kV)	Periodic Dielectric Withstand Test Field Test Voltage (kV)	
		AC	DC ^b
0.6	10	2.6	4
1.1	30	6.5	10
2.4	45	9.7	15
4.8	60	12.3	19
8.32	75	16.9	26
13.8	95	22.1	34
13.8	110	22.1	34
25	125	26.0	40
25	150	32.5	50
34.5	150	32.5	50
34.5	200	45.5	70
46	250	61.7	a
69	350	91.0	a
115	450	120.0	a
115	550	149.0	a
138	550	149.0	a
138	650	178.0	a
161	650	178.0	a
161	750	211.0	a
230	900	256.0	a
230	1050	299.0	a

Table is derived from Paragraph 8.8.2 and Tables 2 and 7 of ANSI/IEEE C57.13-1993, *Standard Requirements for Instrument Transformers*.

- a. Periodic dc potential tests are not recommended for transformers rated higher than 34.5 kV.
- b. Under some conditions transformers may be subjected to periodic insulation test using direct voltage. In such cases the test direct voltage should not exceed the original factory test rms alternating voltage. Periodic direct-voltage tests should not be applied to (instrument) transformers of higher than 34.5 kV voltage rating.



TABLE 100.10

Maximum Allowable Vibration Amplitude

RPM (at 60 Hz)	Velocity (in/s peak)	Velocity (mm/s)	RPM (at 50 Hz)	Velocity (in/s peak)	Velocity (mm/s)
3600	0.15	3.8	3000	0.15	3.8
1800	0.15	3.8	1500	0.15	3.8
1200	0.15	3.8	1000	0.13	3.3
900	0.12	3.0	750	0.10	2.5
720	0.09	2.3	600	0.08	2.0
600	0.08	2.0	500	0.07	1.7

Derived from NEMA MG 1-7.08, Table 7-1.

Table is unfiltered vibration limits for resiliently mounted machines. For machines with rigid mounting multiply the limiting values by 0.8.







TABLE 100.11

– WITHDRAWN –



TABLE 100.12.1**Bolt-Torque Values for Electrical Connections****US Standard Fasteners^a
Heat-Treated Steel – Cadmium or Zinc Plated^b**

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in ²)	64K	105K	133K	150K
Bolt Diameter (Inches)	Torque (Pound-Feet)			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

- a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.

Table 100.12.2**US Standard Fasteners^a
Silicon Bronze Fasteners^{b c}
Torque (Pound-Feet)**

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

- a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.



TABLE 100.12.3

**US Standard Fasteners^a
Aluminum Alloy Fasteners^{b c}
Torque (Pound-Feet)**

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

- a. Consult manufacturer for equipment supplied with metric fasteners.
- b. Table is based on national coarse thread pitch.
- c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 100.12.4

**US Standard Fasteners^a
Stainless Steel Fasteners^{b c}
Torque (Pound-Feet)**

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

- a. Consult manufacturer for equipment supplied with metric fasteners.
- b. Table is based on national coarse thread pitch.
- c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

Tables in 100.12 are compiled from Penn-Union Catalogue and Square D Company, Anderson Products Division, *General Catalog: Class 3910 Distribution Technical Data, Class 3930 Reference Data Substation Connector Products.*



TABLE 100.13**SF₆ Gas Tests**

Test	Method	Serviceability Limits ^a
Moisture	Hygrometer	Per manufacturer or ≥ 200 ppm ^b
SF ₆ decomposition byproducts	ASTM D 2685	≥ 500 ppm
Air	ASTM D 2685	≥ 5000 ppm ^c
Dielectric breakdown hemispherical contacts	2.54 mm (0.10 inch) gap at atmospheric pressure	11.5 – 13.5 kV ^d

- a. In the absence of consensus standards dealing with SF₆ circuit breaker gas tests, the NETA Standards Review Council suggests the above representative values.
- b. According to some manufacturers.
- c. Dominelli, N. and Wylie, L., *Analysis of SF₆ Gas as a Diagnostic Technique for GIS*, Electric Power Research Institute, Substation Equipment Diagnostics Conference IV, February 1996.
- d. Per Even, F.E., and Mani, G. Sulfur Fluorides, Kirk, *Othmer Encyclopedia of Chemical Technology*, 4th ed., 11,428, 1994.

Reference: IEC 61634 High-Voltage Switchgear and Controlgear – *Use and Handling of Sulfur Hexafluoride (SF₆) in High-Voltage Switchgear and Controlgear*.



TABLE 100.14.1

Insulation Resistance Conversion Factors (20° C)

Temperature		Multiplier	
° C	° F	Apparatus Containing Oil Immersed Insulation	Apparatus Containing Solid Insulation
-10	14	0.125	0.25
-5	23	0.180	0.32
0	32	0.25	0.40
5	41	0.36	0.50
10	50	0.50	0.63
15	59	0.75	0.81
20	68	1.00	1.00
25	77	1.40	1.25
30	86	1.98	1.58
35	95	2.80	2.00
40	104	3.95	2.50
45	113	5.60	3.15
50	122	7.85	3.98
55	131	11.20	5.00
60	140	15.85	6.30
65	149	22.40	7.90
70	158	31.75	10.00
75	167	44.70	12.60
80	176	63.50	15.80
85	185	89.789	20.00
90	194	127.00	25.20
95	203	180.00	31.60
100	212	254.00	40.00
105	221	359.15	50.40
110	230	509.00	63.20

Derived from Megger, *Stitch in Time...The Complete Guide to Electrical Insulation Testing*.

Formula:

$$R_c = R_a \times K$$

Where: R_c is resistance corrected to 20° C
 R_a is measured resistance at test temperature
 K is applicable multiplier

Example: Resistance test on oil-immersion insulation at 104° F

$$R_a = 2 \text{ megohms @ } 104^\circ \text{ F}$$

$$K = 3.95$$

$$R_c = R_a \times K$$

$$R_c = 2.0 \times 3.95$$

$$R_c = 7.90 \text{ megohms @ } 20^\circ \text{ C}$$



TABLE 100.14.2

Insulation Resistance Conversion Factors (40° C)

Temperature		Multiplier	
° C	° F	Apparatus Containing Oil Immersed Insulation	Apparatus Containing Solid Insulation
-10	14	0.03	0.10
-5	23	0.04	0.13
0	32	0.06	0.16
5	41	0.09	0.20
10	50	0.13	0.25
15	59	0.18	0.31
20	68	0.25	0.40
25	77	0.35	0.50
30	86	0.50	0.63
35	95	0.71	0.79
40	104	1.00	1.00
45	113	1.41	1.26
50	122	2.00	1.59
55	131	2.83	2.00
60	140	4.00	2.52
65	149	5.66	3.17
70	158	8.00	4.00
75	167	11.31	5.04
80	176	16.00	6.35
85	185	22.63	8.00
90	194	32.00	10.08
95	203	45.25	12.70
100	212	64.00	16.00
105	221	90.51	20.16
110	230	128.00	25.40

Derived from Megger, *Stitch in Time...The Complete Guide to Electrical Insulation Testing* and ANSI/IEEE 43-2000 *IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery*.

Notes: The insulation resistance coefficient is based on the halving of the insulation resistance to the change in temperature.
Apparatus Containing Immersed Oil Insulation Table uses 10° C change with temperature halving.
Apparatus Containing Solid Insulation Table uses 15° C change with temperature halving.

Formula:

$$R_c = R_a \times K$$

Where: R_c is resistance corrected to 40° C

R_a is measured resistance at test temperature

K is applicable multiplier

Example: Resistance test on oil-immersion insulation at 68° F/20° C

$$R_a = 2 \text{ megohms @ } 68^\circ \text{ F}/20^\circ \text{ C}$$

$$K = 0.40$$

$$R_c = R_a \times K$$

$$R_c = 2.0 \times 0.40 = 0.8 \text{ megohms @ } 40^\circ \text{ C}$$



TABLE 100.15**High-Potential Test Voltage
for Automatic Circuit Reclosers****Maintenance Testing**

Nominal Voltage Class (kV)	Maximum Voltage (kV)	Rated Impulse Withstand Voltage (kV)	Maximum AC ^a Field Test Voltage (kV)
14.4 (1 ϕ and 3 ϕ)	15.0	95	26.2
14.4 (1 ϕ and 3 ϕ)	15.5	110	37.5
24.9 (1 ϕ and 3 ϕ)	27.0	150	45.0
34.5 (1 ϕ and 3 ϕ)	38.0	150	52.5
46.0 (3 ϕ)	48.3	250	78.7
69.0 (3 ϕ)	72.5	350	120.0

Derived from ANSI/IEEE C37.61-1973(R1992) *Standard Guide for the Application, Operation, and Maintenance of Automatic Circuit Reclosers* and from ANSI/IEEE C37.60-1981(R1992) *Standard Requirements for Overhead, Pad-Mounted, Dry-Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for AC Systems*, Table 2, Column 5.

- a. Derived from ANSI/IEEE C37.60-1981(R1992), Table 2, Column 5. In accordance with ANSI/IEEE C37.61, Section 6.2.2 (Servicing), a .75 multiplier has been applied to the values.



TABLE 100.16

**High-Potential Test Voltage
for Periodic Test of Line Sectionalizers**

Nominal Voltage Class (kV)	Maximum Voltage (kV)	Rated Impulse Withstand Voltage (kV)	Maximum AC Field Test Voltage (kV)	15 Minute DC Withstand (kV)
14.4 (1 ϕ)	15.0	95	26.2	39
14.4 (1 ϕ)	15.0	125	31.5	39
14.4 (3 ϕ)	15.5	110	37.5	39
24.9 (1 ϕ)	27.0	125	45.0	58
34.5 (3 ϕ)	38.0	150	52.5	77

Derived from ANSI/IEEE C37.63-1984(R1990) *Standard Requirements for Overhead, Pad-Mounted, Dry-Vault, and Submersible Automatic Line Sectionalizers of AC Systems*, Table 2.

The table includes a 0.75 multiplier with fractions rounded down.

In the absence of consensus standards, the NETA Standards Review Council suggests the above representative values.

NOTE: Values of ac voltage given are dry test, one-minute, factory test values.



TABLE 100.17**Metal-Enclosed Bus Dielectric Withstand Test Voltages**

Type of Bus	Rated kV	Maximum Test Voltage (kV)	
		AC	DC
Isolated Phase for Generator Leads	24.5	37.0	52.0
	29.5	45.0	--
	34.5	60.0	--
Isolated Phase for Other than Generator Leads	15.5	37.0	52.0
	25.8	45.0	--
	38.0	60.0	--
Nonsegregated Phase	0.635	1.6	2.3
	4.76	14.2	20.0
	15.0	27.0	37.0
	25.8	45.0	63.0
	38.0	60.0	--
Segregated Phase	15.5	37.0	52.0
	25.8	45.0	63.0
	38.0	60.0	--
DC Bus Duct ^a	0.3	1.6	2.3
	0.8	2.7	3.9
	1.2	3.4	4.8
	1.6	4.0	5.7
	3.2	6.6	9.3

Derived from ANSI-IEEE C37.23-1987 *Standard for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus*, Tables 3A, 3B, 3C, 3D and paragraph 6.4.2. The table includes a 0.75 multiplier with fractions rounded down.

Note:

- a. The presence of the column headed "DC" does not imply any requirement for a dc withstand test on ac equipment. This column is given as a reference only for those using dc tests and represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for each class of bus.

Direct current withstand tests are recommended for flexible bus to avoid the loss of insulation life that may result from the dielectric heating that occurs with rated frequency withstand testing.

Because of the variable voltage distribution encountered when making dc withstand tests and variances in leakage currents associated with various insulation systems, the manufacturer should be consulted for recommendations before applying dc withstand tests to this equipment.



TABLE 100.18

**Thermographic Survey
Suggested Actions Based on Temperature Rise**

Temperature difference (ΔT) based on comparisons between similar components under similar loading	Temperature difference (ΔT) based upon comparisons between component and ambient air temperatures	Recommended Action
1° C – 3° C	1° C – 10° C	Possible deficiency; warrants investigation
4° C – 15° C	11° C – 20° C	Indicates probable deficiency; repair as time permits
-----	21° C – 40° C	Monitor until corrective measures can be accomplished
>15° C	>40° C	Major discrepancy; repair immediately

Temperature specifications vary depending on the exact type of equipment. Even in the same class of equipment (i.e., cables) there are various temperature ratings. Heating is generally related to the square of the current; therefore, the load current will have a major impact on ΔT . In the absence of consensus standards for ΔT , the values in this table will provide reasonable guidelines.

An alternative method of evaluation is the standards-based temperature rating system as discussed in Section 8.9.2, Conducting an IR Thermographic Inspection, *Electrical Power Systems Maintenance and Testing* by Paul Gill, PE, 1998.

It is a necessary and valid requirement that the person performing the electrical inspection be thoroughly trained and experienced concerning the apparatus and systems being evaluated as well as knowledgeable of thermographic methodology.



TABLE 100.19**Dielectric Withstand Test Voltages for Electrical Apparatus
Other than Inductive Equipment**

Nominal System (Line) Voltage^a (kV)	Insulation Class (kV)	AC Factory Test (kV)	Maximum Field Applied AC Test (kV)	Maximum Field Applied DC Test (kV)
1.2	1.2	10	6.0	8.5
2.4	2.5	15	9.0	12.7
4.8	5.0	19	11.4	16.1
8.3	8.7	26	15.6	22.1
14.4	15.0	34	20.4	28.8
18.0	18.0	40	24.0	33.9
25.0	25.0	50	30.0	42.4
34.5	35.0	70	42.0	59.4
46.0	46.0	95	57.0	80.6
69.0	69.0	140	84.0	118.8

In the absence of consensus standards, the NETA Standards Review Council suggests the above representative values.

- a. Intermediate voltage ratings are placed in the next higher insulation class.



TABLE 100.20.1**Rated Control Voltages and Their Ranges for Circuit Breakers**

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

(11) Rated Control Voltage	Direct Current Voltage Ranges (1)(2)(3)(5) (8)(9)		Opening Functions All Types	Rated Control Voltage (60 Hz)	Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions				Closing, Tripping, and Auxiliary Functions
	Indoor Circuit Breakers	Outdoor Circuit Breakers		Single Phase	Single Phase
24 (6)	--	--	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
--	--	--	--	208Y/120	180Y/104–220Y/127
--	--	--	--	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities.*



TABLE 100.20.1

Rated Control Voltages and Their Ranges for Circuit Breakers

Notes

- (1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.
- (2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.
- (3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.
- (4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.
- (5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.
- (6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.
- (7) Includes heater circuits
- (8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.
- (8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.
- (9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges.
- (10) This table also applies to circuit breakers in gas-insulated substation installations.
- (11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.
- (12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.
- (13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.



TABLE 100.20.2

**Rated Control Voltages and Their Ranges for Circuit Breakers
Solenoid-Operated Devices**

Rated Voltage	Closing Voltage Ranges for Power Supply
125 dc	90 – 115 or 105 – 130
250 dc	180 – 230 or 210 – 260
230 ac	190 – 230 or 210 – 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.



TABLE 100.21

**Accuracy of IEC Class TP Current Transformers
Error Limit**

Class	At Rated Current		At Accuracy Limit Condition
	Ratio Error (%)	Phase Displacement Minimum	Peak Instantaneous Error (%)
TPX	± 0.5	± 30	10
TPY	± 1.0	± 60	10
TPZ	± 1.0	180 ± 18	10 (see note)
NOTE – Alternating current component error.			

There are four different TP classifications to meet different functional requirements as follows:

1. Class TPS low leakage flux design ct.
2. Class TPX closed core ct for specified transient duty cycle.
3. Class TPY gapped (low remanence) ct for specified transient duty cycle
4. Class TPZ linear ct (no remanence).

The error limit for TPS ct in terms of turn ratio error is ± .25% and the excitation voltage under limiting conditions should not be less than the specified value; furthermore, this value is such that an increase of 10 percent in magnitude does not result in an increase in the corresponding peak instantaneous exciting current exceeding 100 percent. In other words, the ct should not be in saturated state at the specified maximum operating voltage.

The accuracy limit conditions are specified on the rating plate. The required rating plate information is shown in the table below. (The obvious information such as rated primary and secondary currents is not shown.)

CT Class	TPS	TPX	TPY	TPZ
Symmetrical short-circuit current factor	x	x	x	x
Rated resistive burden (R_b)	x	x	x	x
Secondary winding resistance ($^{\circ}C$)	x	x	x	x
Rated Transient dimensioning factor	-	x	x	x
Steady-state error limit factor	x	-	-	-
Excitation limiting secondary voltage	x	-	-	-
Accuracy limiting secondary exciting current	x	-	-	-
Factor of construction*	-	x	x	x
Rated secondary loop time constant	-	-	x	-
Specified primary time constant (T_p)	-	x	x	x
Duty cycle	-	x	x	-

x = applicable, - = not applicable

*The factor construction is determined from the following ratio:

$$\frac{\text{Equivalent secondary accuracy limiting voltage } (V_{cal})}{\text{Equivalent secondary accuracy limiting e.m.f } (E_{cal})}$$

where

V_{cal} is the rms value of sinusoidal voltage of rated frequency, with, if applied to the secondary winding of a ct, would result in an exciting current corresponding to the maximum permissible error current appropriate to ct class

E_{cal} is the equivalent rms emf of rated frequency determined during test observed error current corresponds to the appropriate limit for the class
Derived from C37.110



TABLE 100.22

**Minimum Radii for Power Cable
Single and Multiple Conductor Cables with Interlocked Armor,
Smooth or Corrugated Aluminum Sheath or Lead Sheath**

Cable Type	Overall Diameter of Cable					
	inches 0.75 and less	mm 190 and less	inches 0.76 to 1.50	mm 191 to 381	inches 1.51 and larger	mm 382 and larger
	Minimum Bending Radius as a Multiple of Cable Diameter					
Smooth Aluminum Sheath Single Conductor Nonshielded, Multiple Conductor or Multiplexed, with Individually Shielded Conductors	10		12		15	
Single Conductor Shielded	12		12		15	
Multiple Conductor or Multiplexed, with Overall Shield	12		12		15	
Interlocked Armor or Corrugated Aluminum Sheath Nonshielded	7		7		7	
Multiple Conductor with Individually Shielded Conductor	12/7 ^a		12/7 ^a		12/7 ^a	
Multiple Conductor with Overall Shield	12		12		12	
Lead Sheath	12		12		12	

ANSI/ICEA S-93-639 2006, 5-46 kV *Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy, Appendix I – Recommended Bending Radii for Cables and Table II – Minimum Radii for Power Cable.*

1. 12 x individual shielded conductor diameter, or 7 x overall cable diameter, whichever is greater.



TABLE 100.22

Minimum Radii for Power Cable Single and Multiple Conductor Cables with Interlocked Armor, Smooth or Corrugated Aluminum Sheath or Lead Sheath

Notes

Specific references from Appendix I:

1. Interlocked-Armor and Metallic-Sheathed Cables

1.1 The minimum bending radius for interlocked-armored cables, smooth or corrugated aluminum sheath or lead sheath, shall be in accordance with Table 100.22.

2. Flat-Tape Armored or Wire-Armored Cables

2.1 The minimum bending radius for all flat-tape armored and all wire-armored cables is twelve times the overall diameter of cable.

3. Tape-Shielded Cables

3.1 The minimum bending radius for tape-shielded cables given above applies to helically applied flat or corrugated tape or longitudinally applied corrugated tape-shielded cables.

3.2 The minimum bending radius for a single-conductor cable is twelve times the overall diameter.

3.3 For multiple-conductor or multiplexed single-conductor cables having individually taped shielded conductors, the minimum bending radius is twelve times the diameter of the individual conductors or seven times the overall diameter, whichever is greater.

3.4 For multiple-conductor cables having an overall tape shield over the assembly, the minimum bending radius is twelve times the overall diameter of the cable.

4. Wire-Shielded Cables

4.1 The minimum bending radius for a single-conductor cable is eight times the overall diameter.

4.2 For multiple-conductor or multiplexed single-conductor cables having wire-shielded individual conductors, the minimum bending radius is eight times the diameter of the individual conductors or five times the overall diameter, whichever is greater.

4.3 For multiple-conductor cables having a wire shield over the assembly, the minimum bending radius is eight times the overall diameter of the cable.



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APPENDIX A

Definitions

NETA recognizes the IEEE 100, *IEEE Dictionary*, as its official source for electrical definitions. The definitions in the list provided by NETA either are not included in the IEEE reference or are more specific to electrical testing and to this document.

NETA defines equipment voltage ratings in accordance with ANSI/NEMA C37.84.1 *American National Standard for Electrical Power Systems and Equipment – Voltage Ratings (60 Hertz)*.

As-found

Condition of the equipment when taken out of service, prior to maintenance.

As-left

Condition of equipment at the completion of maintenance. As-left values refer to test values obtained after all maintenance has been performed on the device under test.

Comment

Suggested revision, addition, or deletion in an existing section of the NETA specifications.

Electrical tests

Electrical tests involve application of electrical signals and observation of the response. It may be, for instance, applying a potential across an insulation system and measuring the resultant leakage current magnitude or power factor/dissipation factor. It may also involve application of voltage and/or current to metering and relaying equipment to check for correct response.

Equipment condition

Suitability of the equipment for continued operation in the intended environment as determined by evaluation of the results of inspections and tests.

Exercise

To operate equipment in such a manner that it performs all its intended functions to allow observation, testing, measurement, and diagnosis of its operational condition.

Extra-high voltage

A class of nominal system voltages greater than 230,000 volts.

High voltage

A class of nominal system voltages equal to or greater than 100,000 volts and equal to or less than 230,000 volts.

Inspection

Examination or measurement to verify whether an item or activity conforms to specified requirements.

Interim amendment

An interim amendment is made by NETA's Standards Review Council when a potential hazard is identified with respect to the use of this document. The interim amendment is in force from the time of its issue until the next revision of the document.



APPENDIX A

Definitions

Low voltage

A class of nominal system voltages 1000 volts or less.

Manufacturer's published data

Data provided by the manufacturer concerning a specific piece of equipment.

Mechanical inspection

Observation of the mechanical operation of equipment not requiring electrical stimulation, such as manual operation of circuit breaker trip and close functions. It may also include tightening of hardware, cleaning, and lubricating.

Medium voltage

A class of nominal system voltages greater than 1000 volts and less than 100,000 volts.

Proposal

Draft of a section that is currently "reserved" in one of the NETA specifications.

Ready-to-test condition

Having the equipment which is to be tested isolated, source and load disconnected, the breaker grounded, and control and operating sources identified.

Shall

Indicates a mandatory requirement and is used when the testing firm has control over the result.

Should

Indicates that a provision is not mandatory but is recommended as good practice. This term is also used when a value is recommended and there is no practical capability of achieving that value.

System voltage

The root-mean-square (rms) phase-to-phase voltage of a portion of an alternating-current electric system. Each system voltage pertains to a portion of the system that is bounded by transformers or utilization equipment.

Verify

To investigate by observation or by test to determine that a particular condition exists.

Visual inspection

Qualitative observation of physical characteristics, including cleanliness, physical integrity, evidence of overheating, lubrication, etc.



APPENDIX B

Frequency of Maintenance Tests

NETA recognizes that the ideal maintenance program is reliability-based, unique to each plant and to each piece of equipment. In the absence of this information and in response to requests for a maintenance timetable, NETA's Standards Review Council presents the following time-based maintenance schedule and matrix.

One should contact a NETA Accredited Testing Company for a reliability-based evaluation.

The following matrix is to be used in conjunction with Appendix B, Inspections and Tests. Application of the matrix is recognized as a guide only.

Specific condition, criticality, and reliability must be determined to correctly apply the matrix. Application of the matrix, along with the culmination of historical testing data and trending, should provide a quality electrical preventive maintenance program.

MAINTENANCE FREQUENCY MATRIX				
		EQUIPMENT CONDITION		
		POOR	AVERAGE	GOOD
EQUIPMENT RELIABILITY REQUIREMENT	LOW	1.0	2.0	2.5
	MEDIUM	0.50	1.0	1.5
	HIGH	0.25	0.50	0.75



APPENDIX B

Frequency of Maintenance Tests (*continued*)

Inspections and Tests				
Frequency in Months				
(Multiply These Values by the Factor in the Maintenance Frequency Matrix)				
Section	Description	Visual	Visual & Mechanical	Visual & Mechanical & Electrical
7.1	Switchgear & Switchboard Assemblies	12	12	24
7.2	Transformers			
7.2.1.1	Small Dry-Type Transformers	2	12	36
7.2.1.2	Large Dry-Type Transformers	1	12	24
7.2.2	Liquid-Filled Transformers	1	12	24
	Sampling	–	–	12
7.3	Cables			
7.3.1	Low-Voltage, Low-Energy	–	–	–
7.3.2	Low-Voltage, 600 Volt Maximum	2	12	36
7.3.3	Medium- and High-Voltage	2	12	36
7.4	Metal-Enclosed Busways	2	12	24
	Infrared Only	–	–	12
7.5	Switches			
7.5.1.1	Air, Low-Voltage	2	12	36
7.5.1.2	Air, Medium-Voltage, Metal-Enclosed	–	12	24
7.5.1.3	Air, Medium- and High-Voltage Open	1	12	24
7.5.2	Oil, Medium-Voltage	1	12	24
7.5.3	Vacuum, Medium-Voltage	1	12	24
7.5.4	Medium-Voltage, SF ₆	1	12	24
7.5.5	Cutouts	12	24	24
7.6	Circuit Breakers			
7.6.1.1	Air, Insulated-Case/Molded-Case	1	12	36
7.6.1.2	Air, Low-Voltage Power	1	12	36
7.6.1.3	Air, Medium-Voltage	1	12	36
7.6.2	Oil, Medium-Voltage	1	12	36
	Sampling	–	–	12
7.6.2	Oil, High-Voltage	1	12	12
	Sampling	–	–	12
7.6.3	Vacuum, Medium-Voltage	1	12	24
7.6.4	SF ₆	1	12	12
7.7	Circuit Switchers	1	12	12
7.8	Network Protectors	12	12	24



APPENDIX B

Frequency of Maintenance Tests (*continued*)

Inspections and Tests				
Frequency in Months				
(Multiply These Values by the Factor in the Maintenance Frequency Matrix)				
Section	Description	Visual	Visual & Mechanical	Visual & Mechanical & Electrical
7.9	Protective Relays			
7.9.1	Electromechanical and Solid State	1	12	12
7.9.2	Microprocessor-Based	1	12	12
7.10	Instrument Transformers	12	12	36
7.11	Metering Devices			
7.11.1	Electromechanical and Solid-State	12	12	36
7.11.2	Microprocessor-Based	12	12	36
7.12	Regulating Apparatus			
7.12.1.1	Step-Voltage Regulators	1	12	24
	Sample Liquid	–	–	12
7.12.1.2	Induction Regulators	12	12	24
7.12.2	Current Regulators	1	12	24
7.12.3	Load Tap-changers	1	12	24
	Sample Liquid	–	–	12
7.13	Grounding Systems	2	12	24
7.14	Ground-Fault Protection Systems	2	12	12
7.15	Rotating Machinery			
7.15.1	AC Induction Motors and Generators	1	12	24
7.15.2	Synchronous Motors and Generators	1	12	24
7.15.3	DC Motors and Generators	1	12	24
7.16	Motor Control			
7.16.1.1	Motor Starters, Low-Voltage	2	12	24
7.16.1.2	Motor Starters, Medium-Voltage	2	12	24
7.16.2.1	Motor Control Centers, Low-Voltage	2	12	24
7.16.2.2	Motor Control Centers, Medium-Voltage	2	12	24
7.17	Adjustable-Speed Drive Systems	1	12	24
7.18	Direct-Current Systems			
7.18.1	Batteries	1	12	12
7.18.2	Battery Chargers	1	12	12
7.18.3	Rectifiers	1	12	24
7.19	Surge Arresters			
7.19.1	Low-Voltage Surge Protection Devices	2	12	24
7.19.2	Medium- and High-Voltage Surge Protection Devices	2	12	24



APPENDIX B

Frequency of Maintenance Tests (*continued*)

Inspections and Tests Frequency in Months (Multiply These Values by the Factor in the Maintenance Frequency Matrix)				
Section	Description	Visual	Visual & Mechanical	Visual & Mechanical & Electrical
7.20	Capacitors and Reactors			
7.20.1	Capacitors	1	12	12
7.20.2	Capacitor Control Devices	1	12	12
7.20.3.1	Reactors, (Shunt and Current-Limiting) Dry-Type	2	12	24
7.20.3.2	Reactors, (Shunt and Current-Limiting) Liquid-Filled	1	12	24
	Sampling	–	–	12
7.21	Outdoor Bus Structures	1	12	36
7.22	Emergency Systems			
7.22.1	Engine Generator	1	2	12
	Functional Testing	–	–	2
7.22.2	Uninterruptible Power Systems	1	12	12
	Functional Testing	–	–	2
7.22.3	Automatic Transfer Switches	1	12	12
	Functional Testing	–	–	2
7.23	Telemetry/Pilot Wire SCADA	1	12	12
7.24	Automatic Circuit Reclosers and Line Sectionalizers			
7.24.1	Automatic Circuit Reclosers, Oil/Vacuum	1	12	24
	Sample	–	–	12
7.24.2	Automatic Line Sectionalizers, Oil	1	12	24
	Sample	–	–	12
7.27	EMF Testing	12	12	12



APPENDIX C

About the InterNational Electrical Testing Association

(This appendix is not part of American National Standard ANSI/NETA MTS-2011)

The InterNational Electrical Testing Association (NETA) is an accredited standards developer for the American National Standards Institute (ANSI) and defines the standards by which electrical equipment is deemed safe and reliable. NETA Certified Technicians conduct the tests that ensure this equipment meets the Association's stringent specifications. NETA is the leading source of specifications, procedures, testing, and requirements, not only for commissioning new equipment but for testing the reliability and performance of existing equipment.

CERTIFICATION

Certification of competency is particularly important in the electrical testing industry. Inherent in the determination of the equipment's serviceability is the prerequisite that individuals performing the tests be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must also evaluate the test data and make an informed judgement on the continued serviceability, deterioration, or non-serviceability of the specific equipment. NETA, a nationally-recognized certification agency, provides recognition of four levels of competency within the electrical testing industry in accordance with *ANSI/NETA ETT-2010 Standard for Certification of Electrical Testing Technicians*.

QUALIFICATIONS OF THE TESTING ORGANIZATION

An independent overview is the only method of determining the long-term usage of electrical apparatus and its suitability for the intended purpose. NETA Accredited Companies best support the interest of the owner, as the objectivity and competency of the testing firm is as important as the competency of the individual technician. NETA Accredited Companies are part of an independent, third-party electrical testing association dedicated to setting world standards in electrical maintenance and acceptance testing. Hiring a NETA Accredited Company assures the customer that:

- The NETA Technician has broad-based knowledge -- this person is trained to inspect, test, maintain, and calibrate all types of electrical equipment in all types of industries.
- NETA Technicians meet stringent educational and experience requirements in accordance with *ANSI/NETA ETT-2010 Standard for Certification of Electrical Testing Technicians*.
- A Registered Professional Engineer will review all engineering reports.
- All tests will be performed objectively, according to NETA specifications, using calibrated instruments traceable to the National Institute of Science and Technology (NIST).
- The firm is a well-established, full-service electrical testing business.



APPENDIX C

About the InterNational Electrical Testing Association (*continued*)

(This appendix is not part of American National Standard ANSI/NETA MTS-2011)

SPECIFICATIONS AND PUBLICATIONS

As a part of its service to the industry, the InterNational Electrical Testing Association provides nationally-recognized publications:

ANSI/NETA ETT-2010	<i>Standard for Certification of Electrical Testing Technicians</i>
ANSI/NETA MTS-2011	<i>Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems</i>
ANSI/NETA ATS-2009	<i>Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems</i>

The Association also produces a quarterly technical journal, *NETA World*, which features articles of interest to electrical testing and maintenance companies, consultants, engineers, architects, and plant personnel directly involved in electrical testing and maintenance.

EDUCATIONAL PROGRAMS

PowerTest, NETA's annual technical conference, draws hundreds of qualified industry professionals from around the globe. This conference provides a forum for current industry advances, critical informational updates, networking, and more. Regular attendees include technicians from electrical testing and maintenance companies, consultants, engineers, architects, and plant personnel directly involved in electrical testing and maintenance. Paper presentations from field-experienced industry experts share practical knowledge and experience while in-depth seminars offer interactive training. At the Trade Show attendees enjoy the highest-quality gathering of industry-specific suppliers displaying state-of-the-art products and services directly related to the electrical testing industry. Attendance of PowerTest is the best opportunity for interaction and input in a professional technical environment.



APPENDIX D

Form for Comments

(This appendix is not part of American National Standard ANSI/NETA MTS-2011)

Anyone may comment on this document using this form:

Type of Comment (Check one) Technical Editorial

Paragraph Number _____

Recommend (Check One) *New Text *Revised Text *Deleted Text

This Comment is original material (Note: Original material is considered to be the submitter's own idea based on or as a result of his/her own experience, thought, or research and to the best of his/her knowledge is not copied from another source.)

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- *1. All comments must be relevant to the proposed standard.
- *2. Suggested changes must include (1) proposed text, including the wording to be added, revised (and how revised), or deleted, (2) a statement of the problem and substantiation for a technical change, and (3) signature of submitter. (Note: State the problem that will be resolved by your recommendation; give the specific reason for your comment, including copies of texts, research papers, testing experience, etc. If more than 200 words, it may be abstracted for publication.)
- *3. Editorial comments are welcome, but they cannot serve as the sole basis for a suggested change.

A comment that does not include all required information may be rejected by the Standards Review Council for that reason. Must use separate form for each comment. All comments must be typed or printed neatly. Illegible comments will be interpreted to the best of the staff's ability.

This form is available electronically on NETA's website at www.netaworld.org under Standards Activities.

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APPENDIX E

Form for Proposals

(This appendix is not part of American National Standard ANSI/NETA MTS-2011)

Anyone may propose a new section for this document using the following form:

When drafting a proposed section:

Use the most recent edition of the specifications as a guideline for format and wording.

Remember that NETA specifications are “what to do” documents and do not include “how to do” information.

Include references.

When applicable, use the standard base format:

1. Visual and Mechanical Inspection
2. Electrical Tests
3. Test Values

Date _____

Name _____ Tel No. _____

Company _____ Fax No. _____

Address _____ E-Mail _____

Please indicate organization represented (if any) _____

NETA document title _____ Year _____

Section/Number _____

Note 1: Type or print legibly in black ink.

Note 2: If supplementary material (photographs, diagrams, reports, etc.) is included, you may be required to submit sufficient copies for all Members and Alternates of the Section Panel.

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