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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Published 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 from since that of IEEE, NECA, NEMA, and UL. In matters of testing electrical equipment and systems NETA continues to reference other standards developers ôhead-to-comparable. NETA updating of presently published standards takes into account both national and international standards. NETAôs standards may be used internationally as global standardization. IEC standards as well as American consensus standards are taken into consideration by NETAôs 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

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 ïVisual 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 ïVisual 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

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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

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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 ïElectrical 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

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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 ($IR_{1\ min}$) 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)
   2. $IR_{1\ min}$ = 100 megohms for most dc armature and ac windings built after 1970 (form-wound coils).
   3. $IR_{1\ min}$ = 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

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Optional Tests

The purpose of these specifications is to assure that all tested electrical equipment and systems supplied by either contractor or owner are operating within established and 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?

Manufacturerôs Instruction Manual

It is important to follow the recommendations of 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 manufacturerôs published 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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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 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 ï ANSI

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

3. Association of Edison Illuminating Companies ï AEIC

4. Canadian Standards Association ï CSA

2. APPLICABLE REFERENCES

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

5. Electrical Apparatus Service Association ïEASA

ANSI/EASA AR100 *Recommended Practice for the Repair of Rotating Electrical Apparatus*

6. Institute of Electrical and Electronic Engineers ïIEEE

ANSI/IEEE C2	*National Electrical Safety Code*
ANSI/IEEE C37 Compilation	*Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses*
ANSI/IEEE C57 Compilation	*Distribution, Power, and Regulating Transformers*
ANSI/IEEE C62 Compilation	*Surge Protection*
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	*IEEE Standard for Separable Insulated Connectors System for Power Distribution Systems above 600 V*
ANSI/IEEE 399	*IEEE Recommended Practice for Power Systems Analysis (Brown Book)*
IEEE 400	*IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems*
ANSI/IEEE 421.3	*IEEE Standard for High-Potential-Test Requirements for Excitation Systems for Synchronous Machines*
ANSI/IEEE 446	*IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)*
ANSI/IEEE 450	*IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*
ANSI/IEEE 493	*IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)*
ANSI/IEEE 519	*IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*
ANSI/IEEE 602	*IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book)*
ANSI/IEEE 637	*IEEE Guide for the Reclamation of Insulating Oil and Criteria for Its Use*
IEEE 644	*Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines*
ANSI/IEEE 739	*IEEE Recommended Practice for Energy Management in Commercial and Industrial Facilities (Bronze Book)*
ANSI/IEEE 902	*IEEE Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems (Yellow Book)*
IEEE 1015	*IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)*
IEEE 1100	*IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)*
ANSI/IEEE 1106	*IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Batteries for Stationary Applications*

2. APPLICABLE REFERENCES

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

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

7. Insulated Cable Engineers Association ïICEA

ANSI/ICEA S-93-639/NEMA WC 74	*5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*
ANSI/ICEA S-94-649	*Standard for Concentric Neutral Cables Rated 5,000 ï46,000 Volts*
ANSI/ICEA S-97-682	*Standard for Utility Shielded Power Cables Rated 5,000 ï46,000 Volts*

8. InterNational Electrical Testing Association ïNETA

ANSI/NETA ETT	*Standard for Certification of Electrical Testing Technicians*
ANSI/NETA ATS	*Acceptance Testing Specifications for Electrical Power Equipment and Systems*

2. APPLICABLE REFERENCES

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

9. National Electrical Manufacturers Association ïNEMA

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 ïNFPA

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 ïOSHA

12. State and local codes and ordinances

13. Underwriters Laboratories, Inc. ïUL

2. APPLICABLE REFERENCES

2.2 Other Publications

Manufacturerôs instruction manuals for the equi

A Stitch in Time é The Complete Guide to Electric, 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 PCï2000 for Wé 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 ï ANSI
25 West 43rd Street 4th Fl.
New York, NY 10036
(212) 642-4900
www.ansi.org

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

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

Canadian Standards Association ï 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 ï EASA
1331 Baur Boulevard
St. Louis, MO 63132
(314) 993-2220
www.easa.com

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

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

International Electrotechnical Commission ï IEC
Contact through American National Standards Institute

InterNational Electrical Testing Association ï 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 ï 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 ïNFPA
1 Battery March Park
PO Box 901
Quincy, MA 02269-9101
(617) 984-7247
www.nfpa.org

Occupational Safety and Health Administration ïOSHA
U.S. Department of Labor
Occupational Safety and Health Administration
Office of Public Affairs ïRoom 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. ïCRC Press
2000 NW Corporate Blvd.
Boca Raton, FL 33431
(561) 361-6000
www.crcpress.com

Underwriters Laboratories, Inc. ïUL
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. Manufacturersô Service Personnel: Fiel 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. Indicat-found-lãeafdt òñ arse s u l t s , a s a p p l i c a

    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.

6.3 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 systemôs synchronous 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 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 manufacturerôs

    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 wi absence of manufacturerôs published data,

*3. Perform a dielectric withstand voltage test on each bus section, each phase-to-ground with phases not under test grounded, in accorda 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 v

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 watthour 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 published data. In the absence of manuf

* 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 ï 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 wit of manufacturerôs published data, use Table

3. Results of the thermographic survey shall be in accordance with Section 9. (7.1.1.7.3)

3.2 Test Values ï 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 sho published data. In the absence of manufactu insulation resistance less than ten megohms should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values. tions is table

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 manufacturerôs published data. In the a Table 100.5. Values of insulation resistance less than this tab 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 manufacturerôs
    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 manufacturerôs published dat 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 ïVisual 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 manufacturerôs 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 ïElectrical

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 manufacturerôs published data. In the absence of manufacturerôs published data, use Table 100.5. Values of insulation resistance 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 manufacturerôs
    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

7.2.1.2 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 manufacturerôs 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 manufacturerôs publishe

*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 ïVisual and Mechanical

1. Control and alarm settings on temperature i 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 wit of manufacturerôs published data, use Table

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 ïElectrical

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 manufacturerôs published data. In Table absen 100.5. Values of insulation resistance less 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 manufacturerôs or test eq 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

7.2.1.2 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 manufacturerôs

    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

7.2.2 Transformers, Liquid-Filled (*continued*)

2. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturerôs 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 manufacturerôs published da

5. Perform power-factor or dissipation-factor tests on each bushing.

6. Perform excitation-current tests in accordance with the test e 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 ïVisual and Mechanical

1. Alarm, control, and trip circuits from temperature and level indicators as well as pressure relief device and fault pressure relay should oper 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 manufacturerôs published data, or in the absence of manufacturerôs published data, use Table

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 ïElectrical

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 manufacturerôs published data, or in the absen published data, use Table 100.5. Values of insulation resistance less 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

7.2.2 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 manufacture 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

* Optional

7. INSPECTION AND TEST PROCEDURES

7.3.1 Cables, Low-Voltage, Low-Energy

ïRESERVED ï

* 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 ô

    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 ï 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 ô 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 ïElectrical

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 manufacturerô

    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 ex 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 absence of manufacturerôs published data,

3. Perform a shield-continuity test on each power cable by ohmmeter method.

* Optional

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

Due to the various cable testing methods commercially available, the following section does not denote ñoptionalò or ñrequiredò. 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 ï 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 manufacturerô s 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 ï 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 Table 100.16. Values of insulation resistance less than this table or manufacturerô s recommendations in the absence of manufacturerô s data.

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 manufacturerô s 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 manu 100.12.

    3. Perform a thermographic survey in accordance with Section 9.

4. Confirm physical orientation in accordance with manufacturerôs labels to cooling.

5. Examine outdoor bus-whaoyl efòo rp lruegmso, vailf oafp pñlwieceapb 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 manufacture manufacturerôs published data, use Table 10

3. Perform a dielectric withstand voltage test on each busway, phase-to-ground with phases not under test grounded, in accordance with manufacturerôs published c 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 ï 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 w of manufacturerôs published data, use Tab

3. Results of the thermographic survey shall be in accordance with Section 9. (7.4.1.3.3)

3.2 Test Values ï 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 manufacturerôs specifications or Table 10(1000-foot busway run. Use the following formula to convert the measured resistance value to the 1000-foot nominal value:

$$R_{1000\,ft} = \text{Measured Resistance} \quad x \quad \frac{\text{Length of Run}}{1000}$$

Converted values of insulation resistance 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 manufacturerôs published 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 manufacturerôs published data. In the abse 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 ï 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 w of manufacturerôs published data, use Tabl

3. Results of the thermographic survey shall be in accordance with Section 9. (7.1.1.1.8.3)

3.2 Test Values ï 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 manufacturerôs published investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

* Optional

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

3. Insulation-resistance values should be in accordance with manufacturerôs published data, unless absence of manufacturerôs published data, use this table or 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 ô
    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 manufacturerôs published data. In the absen 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 sh published data or Table 100.2.

5. Measure fuse resistance.

6. Verify cubicle space heater operation.

3. Test Values

3.1 Test Values ï 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 manufacturerôs published d of manufacturerôs published data, use Table

3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.1.2.1.9.3)

3.2 Test Values ï 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 manufacturerôs published d investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

* Optional

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

3. Insulation-resistance values should be in accord absence of manufacturerôs published data, than this table mmendations 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 Table 100.12. manufacturer's

    3. Perform a thermographic survey in accordance with Section 9.

9. Verify operation and sequencing of interlocking systems.

10. Perform mechanical operator tests in accord 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

7.5.1.3 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 manufacturerôs published data. In the abse 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 manufacturerô

5. Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test published data or Table 100.19.

3. Test Values

3.1 Test Values ïVisual 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 manufacturerôs published of manufacturerôs published data, use Tabl

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 ïElectrical

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 manufacturerôs published

* Optional

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 manufacturerôs published data, unless in the absence of manufacturerôs published data, use the values in this table. 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 accor 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 ô

    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 manufacturerôs puebnlcies hoefd mdaantuaf.a cItnu rtehreô sa bpsu b l 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 vo

*5. Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test 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 ï 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 wit of manufacturerôs published data, use Table 1

* Optional

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 ï 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 manufacturerôs published 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 accord absence of manufacturerôs published data, than this table or manufacturerôs published data, 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 accord 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 manufacturerôs

    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

7.5.3 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 manufacturerôs published data. In the abse 100.1.

4. Perform a vacuum bottle integrity (dielectric withstand voltage) test across each vacuum bottle with the switch in the open position in str

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 manufacturerôs recommendation.

*7. Perform a dielectric withstand voltage test in accordance with ma

8. Verify open and close operation from control devices, if applicable.

3. Test Values

3.1 Test Values ï Visual and Mechanical

1. Critical distances of operating mechanism 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

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

3. Bolt-torque levels should be in accordance wi t h m a n u f a c t u r e r ô s p u b l i s h
o f m a n u f a c t u r e r ô s p u b l i s h e d d a t a , u s e T a b l e

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 ïElectrical

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
i n d i c a t e d i n t h e m a n u f a c t u r e r ô s p u b l i s h e d d
investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

3. Insulation- r e s i s t a n c e v a l u e s s h o u l d b e i n a c c o r d a n
a b s e n c e o f m a n u f a c t u r e r ô s p u b l i s h e d d a t a , u
t h a n t h i s t a b l e o r m a n u f a c t u r e r ô s r e c o m m e n d
tigated. 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, SF_6, 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 SF_6 gas insulated system in accordance with the manufacturerôs published data.

6. Verify correct operation of SF_6 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 manufacturerô manufacturerôs 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 SF_6 gas leaks in accordance with manufact

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, SF_6, 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 manufacturerôs published data. In the absence of man 100.1.

*4. Remove a sample of SF_6 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 manufacturerôs

*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 manufacturerôs recommendation.

*7. Perform a dielectric withstand voltage test in accordance with manufacturerôs published

8. Verify open and close operation from control devices, if applicable.

3. Test Values

3.1 Test Values ï Visual and Mechanical

1. Critical distances of operating mechanisms 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 manufacture of manufacturerôs published data, use Table

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

7.5.4 Switches, SF_6, Medium-Voltage (*continued*)

3.2 Test Values ïElectrical

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 manufacturerôs published 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 accord absence of manufacturerôs published resistance ta, than this table or manufacturerôs test. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.

4. Results of SF_6 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 manufacturerôs manufacturer ra, use Table 100.12 published dat

    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 manufacturerôs published data. In the absen 100.1.

4. Perform a dielectric withstand voltage test on each pole, phase to ground with cutout closed. Ground adjacent cutouts, if applicable. Tes published data. In the absence of manufactu

* Optional

7. INSPECTION AND TEST PROCEDURES

7.5.5 Switches, Cutouts (*continued*)

3. Test Values

3.1 Test Values ïVisual 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 accordan c e w i t h m a n u f a c t u r e r ô s p u o f m a n u f a c t u r e r ô s p u b l i s h e d d a t a , u s e T a b

3. Results of the thermographic survey shall be in accordance with Section 9. (7.5.5.1.5.3)

3.2 Test Values ïElectrical

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 i n d i c a t e d i n t h e m a n u f a c t u r e r ô s p u b l i s h e d investigate values which deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

3. Insulation-r e s i s t a n c e v a l u e s s h o u l d b e i n a c c o r d a a b s e n c e o f m a n u f a c t u r e r ô s p u b l i s h e d d a t a , t h a n t h i s t a b l e o r m a n u f a c t u r e r ô s Dielectric withstand m e r 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 manufacturerôs 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 manufacturerôs published data or Table 100.1.

3. Perform a contact/pole-resistance test.

* Optional

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 manufacturerôs 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 ïVisual 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 w of manufacturerôs published data, use Tabl (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 ïElectrical

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 manufacturerôs published data. In the absence of manufacturerôs published data, use values not less than this table or manufacturerôs recommend

3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturerôs published d 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 manufacturerôs published current-time characteristic tolerance band, including adjustment factors. If manufacturerôs curves are not a in Table 100.7.

6. Short-time pickup values should be as specified, and the trip characteristic should not exceed manufacturerôs published current-time tolerance band.

7. Ground fault pickup values should be as specified, and the trip characteristic should not exceed manufacturerôs published current-time tolerance band.

8. Instantaneous pickup values of molded-case circuit breakers shoul published tolerances and/or Table 100.8.

9. Pickup values and trip characteristics shou

10. Minimum pickup voltage on shunt trip and close coils should be in accordance with manufacturerôs published data. In the absen 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 man

* 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 mar

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 ô

    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

7.6.1.2 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 manufacturerôs published data. In the 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 manufacturerôs

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 ï 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 w of manufacturerôs published data, use Table

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 ï 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 data. In the absence of manufacturerôs pu resistance less than this table or manufacture

3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturerôs published data, if available. Compare values to previously obtained 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 manufacturerôs current characteristic tolerance band time

6. Short-time pickup values should be as specified, and the trip characteristic should not exceed manufacturerôs current tolerance band time

7. Ground fault pickup values should be as specified, and the trip characteristic should not exceed manufacturerôs current tolerance band time

8. Instantaneous pickup values should be within the toler

* Optional

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

9. Pickup values and trip characteristic shoul published tolerances.

10. Minimum pickup voltage on shunt trip and close coils should be in accordance with manufacturerôs published data. In the absen Table 100.20.

11. Auxiliary features should operate in accord

12. Trip logs and indicators are reset.

13. The charging mechanism should operate in ac

* 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 manufacturerôs published d data, refer to ANSI/IEEE C37.04.

10. Perform all mechanical operation tests on the operating mechanism in accordance with manufacturerôs 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 manufacturerô

    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

7.6.1.3 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 manufacturerôs published data. In the 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 manufacturerôs recomme

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 manu.facture

*9. Perform a dielectric withstand voltage test on each phase with the circuit breaker closed and the poles not under test grounded. Test voltage published data. In the absence of manufacturerôs publis

* Optional

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 ïVisual and Mechanical

1. Compare first-trip operation time and trip-coil current waveform to manufacturer's 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 manufacturerôs published data, use Table 11.12. (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 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 ïElectrical

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 published data, values of insulation resistance less than this table 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 manufacturerôs published

* Optional

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 sha data. In the absence of manufacturerôs data, refer

7. Power-factor or dissipation-factor values shall be compared with previous test results of similar breakers or manufacturerôs 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 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 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 manufacturerôs 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 manufacturerôs 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 manufacturerôs published data. If no publishe published data, refer to ANSI C37.04.

    4. Refill tank(s) with filtered oil to correct levels.

* Optional

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 w i t h m a n u f a c t u r e r ô s p u b l i s h e d d m a n u f a c t u r e r ô s p u b l i s h e d d a t a , u s e T a b l e

    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 w i t h m a n u f a c t u r e r ô s p u b l i s h e d d a t a . I n t h e 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 d e v i c e s t h a t c a n n o t t o l e r a t e t h e v o l t a g e , f

* Optional

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 th

*9. Perform a dielectric withstand voltage test on each phase with the circuit breaker closed and the poles not under test grounded. Test voltag published data. In the absence of manufact

10. Verify operation of heaters.

*11. Test instrument transformers in accordance Section 7.10.

3. Test Values

3.1 Test Values ïVisual and Mechanical

1. Compare first-trip operation time and trip-coil current waveform to manufacturer 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

2. Settings for alarm, pressure, and limit swi
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 manufacturerôs published da
of manufacturerôs published data, use Table
(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 vel published data and previous test data to manuf
(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 ïElectrical

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 s
published data. In the absence of manufacturerôs published data, us
insulation resistance less than this table
investigated.

3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturerôs published data.
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 manufacturerôs design. Minimum pickup for trip and close coils should conform to manufacturerôs published data. In the absen
100.20.

* Optional

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 manufacturerôs published data. In the abse 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 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 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 manufacturerôs 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 manufacturerôs publishe manufacturerôs published data, use Table

    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

7.6.3 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 the manufacturer's data. In the absence of 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 v

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 pu

9. Perform a vacuum bottle integrity (dielectric withstand voltage) test across each vacuum bottle with the breaker in the open position. In s

* Optional

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 published data. In the absence of manufactu

11. Verify operation of heaters, if applicable.

12. Test instrument transformers in accordance with Section 7.10.

3. Test Values

3.1 Test Values ï Visual and Mechanical

1. Compare first-trip operation time and trip-coil current waveform to manufacturerôs 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 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 manufacturerôs published data of manufacturerôs published data, use Table 100.2. (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 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 ï 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 s published data. In the absence of manufactu insulation resistance less than this table investigated.

* Optional

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 manufacturerôs published 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 manufacturerôs publ data. In the absence of manufacturerôs dat

7. Power-factor or dissipation-factor values shall be compare In the absence of manufacturerôs published data 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, SF_6

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 SF_6 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 SF_6 gas-insulated system in accordance with manufac

9. Test for SF_6 gas leaks in accordance with manufactu

10. Test alarms, pressure switches, and limit switches for pneumatic and/or hydraulic operators and SF_6 gas pressure in accordance with manufactu

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 manufacturerôs published data. In the absen ANSI/IEEE C37.04.

12. Perform all mechanical operation tests on the operating mechanism in accordance with manufacturerôs 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 manufacturerôs manufacturerôs published data, use Table

    3. Perform a thermographic survey in accordance with Section 9.

14. Verify cell fit and element alignment.

* Optional

7.6.4 Circuit Breakers, SF_6 (*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 acc published data. In the absence of manufact

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 manufacturerôs

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

* Optional

7.6.4 Circuit Breakers, SF_6 (*continued)*

*8. Perform a dielectric withstand voltage test in accordance with manu

9. Verify operation of heaters.

*10. Test instrument transformers in accordance with Section 7.10.

3. Test Values

3.1 Test Values ï Visual and Mechanical

1. Compare first-trip operation time and trip-coil current waveform to manufacturerôs 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. SF_6 gas should have values in accordance with Table 100.13. (7.6.4.1.7)

3. Results of the SF_6 gas leak test should confirm that no SF_6 gas leak exists. (7.6.4.1.9)

4. Settings for alarm, pressure, and limit switches should be in acc 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 wit of manufacturerôs published data, use Table 13.2) (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 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 ï 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 shoul published data. In the absence of manufactu insulation resistance less than this table investigated.

* Optional

7.6.4 Circuit Breakers, SF_6 (*continued)*

3. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturerôs published 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 manufacturerôs design. Minimum pickup for manufacturerôs published data. In the abse 100.20.

6. Power-factor or dissipation-factor values shall be compared to manuf In the absence of manufacturerôs publishe 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 milliampere/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 manufacturerôs publis manufacturerôs published data, use Table

    3. Perform a thermographic survey in accordance with Section 9.

7. Verify operation of SF_6 interrupters is in accordance with published data.

8. Verify SF_6 pressure is in accordance with manufac

9. Verify operation of isolating switch is in accordance with manufacturerôs publi

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 manufacturerôs published data, use the 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 manufacturerôs 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 ma

10. Verify operation of heaters.

3. Test Values

3.1 Test Values ïVisual 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 w of manufacturerôs publ 7.1.6.2) ed data, use Tabl

3. Results of the thermographic survey shall be in accordance with Section 9. (7.7.1.6.3)

4. SF_6 interrupters should operate in accordanc

5. SF_6 pressure should be in published data. (7.7.1.8) e with ma

* Optional

7. INSPECTION AND TEST PROCEDURES

7.7 Circuit Switchers (*continued*)

6. Isolating switch should operate in accordan

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 ïElectrical

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 manufacturerôs published d 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 published data. In the absence of manufactu insulation resistance less than hould be is table 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 sho the absence of manufacturerôs published data,

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 acc o r d a n c e w i t h m a n u f a c t u r e r ô s p u b l i m a n u f a c t u r e r ô s p u b l i s h e d d a t a , u s e T a b l

    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 subm 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 manufacturerôs published data. In the absen 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, f

*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 ïVisual 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 w of manufacturerôs published data, use Tabl

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 ïElectrical

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 prote published data. In the absence of manufacturerôs p insulation resistance less than this table 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 manufacturerôs published 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 manufacturerôs 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

7.8. 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 manufacturerôs published data.

* Optional

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

7.9.1 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

7.9.1 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

7.9.1 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 manufacturerôs published da

    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

7.9.1 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

7.9.1 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 manufact

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 accord

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 manufacturerôs 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

7.9.2 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 manufacturerôs

    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 ï 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 manufacturerôs recommendati

* 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 Table100.9 respectively.

*9. Measure insulation power factor or dissipation factor in accordance with test equipment manufacturerôs 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 ï 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 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

7.10 Instrument Transformers (*continued*)

*7. Measure insulation power factor or dissipation factor in accordance with test equipment manufacturerôs 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 ïCoupling-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 a 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 manufacturerôs 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 ïVisual 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 w of manufacturerôs published data, use Tabl

3. Results of the thermographic survey shall be in accordance with Section 9. (7.10.1.4.3)

3.2.1 Test Values ïCurrent Transformers ïElectrical

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 acco data. In the absence of manufacturerôs pub 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 ïVoltage Transformers ïElectrical

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- f a c t o r v a l u e s s h a l l b e i n a c c o r d d a t a . I n t h e a b s e n c e o f m aqnuui fpamcetnutr emraônsu fpaucbt lu published data.

8. Test results should indicate that the circuits have only one grounding point.

3.2.3 Test Values ïCoupling 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

7.10 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 manufacturerôs published data.

8. Power-factor or dissipation-factor values shall be in acco data. In the absence of manufacturerôs pub 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 manufacturerôs manufacturerôs published data, use Table

    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 manufacturerô

*4. Verify all instrument multipliers.

* Optional

3. Test Values

3.1 Test Values ïVisual 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 shoul d b e i n a c c o r d a n c e w i t h m a n u f a c t o f m a n u f a c t u r e r ô s p u b l i s h e d d a t a , u s e T a b l

3. Results of the thermographic survey shall be in accordance with Section 9. (7.11.1.2.3)

3.2 Test Values ïElectrical

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 m a n u f a c t u r e r ô s p u b l i s h e

3. C a l i b r a t i o n r e s u l t s s h o u l d b e w i t h i n m a n u f

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
8. Verify unit is connected in accordance with manufacturerôs
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 ï Visual and Mechanical

1. Tightness of electrical connections shall assure a low resistance connection. (7.11.2.1.3)
2. Display and indicating devices operat (7.11.2.1.5)

3.2 Test Values ï Electrical

1. Measurement and indication of applied values of voltage and current should be within manufacturerôs published tolerances for acc

* Optional

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

2. All auxiliary input/output features should operate per settings and 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 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 manufac

    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

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 manufactu manufacturerôs published data, use Table 1

3. Perform insulation power-factor or dissipation-factor tests on windings in accordance with test equipment manufacturerôs 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 th

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

7.12.1.1 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 ïVisual 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 w of manufacturerôs published data, use Tabl

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 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 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 ïElectrical

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 accord absence of manufacturerôs recommend data, use Table 100.5. Values of insulation resistance less than this table or manufacturerôs recommen 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 manufacturerôs published data to test equipment 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. 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 manufacturerôs published require

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

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 manufacturerô manufacturerôs published data, use Tabl

    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 manufacturerôs published data, use Table 100.5. Calculate polarization index.

* Optional

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 manufacturerôs 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

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 ïVisual 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 w of manufacturerôs published data, use Tabl (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 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 ïElectrical

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 accord absence of published data, use Table 100.5 Values of insulation resistance less than this table or manufacturerôs recommen 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 manufacturerôs published d to test equipment manufacturerôs published 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

7.12.1.2 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

7.12.2 Regulating Apparatus, Current

ïRESERVED ï

* 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 manufacturerôs published data. manufacturerôs published data, use Table

    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

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

4. Inspect all electrical and mechanical connections for tightness using calibrated torque-wrench method in accordance with manufa

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

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 s

10. Verify operation of heaters.

3. Test Values

3.1 Test Values ï 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 wit of manufacturerôs published data, use Table

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 sh 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 shoul tolerances. (7.12.3.1.11)

8. Contact wear and alignment should be within manufacturerôs recomm (7.12.3.1.12.3)

9. Bolt-torque levels should be in accordance wit of manufacturerôs published data, use Table

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 ïElectrical

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 accord absence of manufacturerôs published data, than this table or manufacturerôs recommen should be investigated.

3. Maximum winding insulation power-factor or dissipation-factor values of liquid-filled transformers should be in accordance with are indicated in Table 100.3. Also, compare with test equipment manuf

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 confo

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 manufacturerôs

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 ï 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 wit of manufacturerôs published data, use Table 3.2)

3.2 Test Values ï 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

7.13 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 manufacturerôs published data. In the absence of manufacturerôs published data, use Table

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 ôs 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

7.14 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 v

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 ïVisual 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 wi of manufacturer's data, u Table 100.12 (7.14.1.4.2)

3.2 Test Values ïElectrical

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

7.14 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 manufacturerôs specificati 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 accordanc 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 manufacturerô manufacturerôs published data, use Tabl

    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 ï 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 bearin 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 ïVisual 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 manufact

    5. Brushes should be within manufacturerôs

    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 wit of manufacturerôs published data, use Table

4. Results of the thermographic survey shall be in accordance with Section 9. (7.15.1.1.4.3)

* Optional

3.2 Test Values ïElectrical 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 ($IR_{1\ min}$) 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)

   2. $IR_{1\ min}$ = 100 megohms for most dc armature and ac windings built after 1970 (form-wound coils).

   3. $IR_{1\ min}$ = 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 tolerances. In the absence of manufacture made to similar machines.

9. Test results of surge protection devices shall be in accordance with Section 7.19 and Section 7.20.

* Optional

7.15.1 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 dev 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 ô manufacturer ta, ôuse Table 100.12 i shed da

    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

7.15.2 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 bearin 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 manufactu

*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

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 ïVisual 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 manufac

    5. Brushes should be within manufacturerôs

    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 ô s published data of manufacturerôs published data, use Tabl

4. Results of thermographic survey shall be in accordance with Section 9. (7.15.2.1.4.3)

* Optional

3.2 Test Values ïElectrical

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)

   2. $IR_{1\ min}$ = 100 megohms for most dc armature and ac windings built after 1970 (form-wound coils).

   3. $IR_{1\ min}$ = 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 with i n m a n u f a c t u r e r ô s p u b l i s a b s e n c e o f m a n u f a c t u r e r ô s p u b l i s h e d t o l e r a n machines.

9. Test results of surge protection devices shall be in accordance with Section 7.19 and Section 7.20.

* Optional

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 inte 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 ($IR_{1\ min}$) 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)

    2. $IR_{1\ min}$ = 100 megohms for most dc armature and ac windings built after 1970 (form-wound coils).

    3. $IR_{1\ min}$ = 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 compa 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 manufacturerôs recommended values.

* Optional

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 manufacturerô manufacturerôs published data, use Tabl

    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 ï 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 manufacturerô s

    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 wit of manufacturerô s published data, use Table

4. Results of thermographic survey shall be in accordance with Section 9. (7.15.3.1.4.3)

5. Commutator and tachometer generator should data and/or system design. (7.15.3.1.5)

6. Air-gap spacing and machine alignment should be within manufacturerô s (7.15.3.1.6)

3.2 Test Values ï 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

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

2. $IR_{1\ min}$ = 100 megohms for most dc armature and ac windings built after 1970 (form-wound coils).

3. $IR_{1\ min}$ = 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 manufacturerôs 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 manufacturerôs manufacturerôs published data, use Table

    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

7.16.1.1 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 manufacturerôs published data or Table 10

*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 manufacturerôs recommendation.

4. Test motor protection devi published data. In the absence of manufacturerôs data, use Section 7. 69 and

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 ï 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 manufacturerôs p of manufacturerôs published data, use Tabl

3. Results of the thermographic survey shall be in accordance with Section 9. (7.16.1.1.1.7.3)

3.2 Test Values ï 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 manufacturerôs pub absence of manufacturerôs published data, than this table or manufacturerôs recommen

* Optional

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 acc 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 manufacturerô manufacturerôs published data, use Tabl

    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 manufacturerôs 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 manufacturerôs published da

*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 manufacturerôs recommendation.

*4. Perform a dielectric withstand voltage test in accordance with manu the absence of manufacturerôs published dat

5. Perform vacuum bottle integrity test (dielectric withstand voltage), if applicable, across each vacuum bottle with the contacts in the open position in 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 devi published data. In the absence of manufacturerôs data, test in accordance

*14. Perform system function test in accordance with Section 8.

15. Verify operation of cubicle space heater.

* Optional

3. Test Values

3.1 Test Values ïVisual 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 manufacture of manufacturerôs published data, use Tabl

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 opera 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 ïElectrical

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 accord absence of manufacturerôs published data, than this table or manufacturerôs recommen 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 manufacturerôs published

* Optional

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 b

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 acc

14. System function test results should be in a system design.

15. Heaters should be operational.

* Optional

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 manufacturerôs

    3. Perform a thermographic survey in accordance with Section 9.

9. Verify correct fuse sizing in accordance wi

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 manufacturerôs 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 ï 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 manufacturerôs published of manufacturerôs published data, use Table

3. Results of the thermographic survey shall be in accordance with Section 9. (7.17.1.8.3)

3.2 Test Values ï 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 manufacturerôs 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 manufacturerô
    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 volta 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

7.18.1.1 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 manu *Recommended Practice for Maintenance, Testing and Replacement of Large Lead Storage Batteries for Generating Stations and Substations.*

3. Test Values

3.1 Test Values ï 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 accIn the absence wit of manufacturerôs published data, use Table

4. Results of the thermographic survey shall be in accordance with Section 9. (7.18.1.1.1.10.3)

3.2 Test Values ï 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 s published data.

3. The results of charger functions and alarms published data.

4. Cell voltages should be within 0.05 volt of 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

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

7. Results of load tests should be in accorda
450.

* Optional

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 the manufacturerôs
    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 voltag 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

7.18.1.2 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, use Table 11.10.12.

8. Measure the battery system voltage from positive-to-ground and negative-to-ground.

3. Test Values

3.1 Test Values ï 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, use Table 11.10.12. (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 ï 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 published data.

3. The results of charger functions and alarms should be in accordance with published data.

4. Cell voltages should be within 0.05 volt of each other or in accordance with 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 d

* Optional

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

7. Results of load tests should be in accordance with manufactur
1106.

8. Voltage measured from positive-to-ground should be equal in magnitude to the voltage measured from negative-to-ground.

* Optional

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 ô
    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 w *Recommended Practice for Maintenance, Testing and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications.*

3. Test Values

3.1 Test Values ï 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 wit of manufacturerôs published data, or in 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 ï 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

3. Charger float and equalize voltage levels should be in accordance with the battery manufacturerôs published data.

4. Results of charger functions and alarms sho data.

5. Monoblock/cell voltages should be in accord 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 accordan 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 manufacturerô
    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 ï 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 wit of manufacturerôs published data, use Table

3. Results of the thermographic survey shall be in accordance with Section 9. (7.18.2.1.5.1)

3.2 Test Values ï 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 published data.

3. Current limit should be within manufacturer

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 sh published data and in acc system design.

7. Input and output voltage should be in accor

8. AC ripple current and/or voltage imposed on the battery should be in accordance with manufacturerôs published data.

9. Charger should be capable of manufacturerôs spec

* Optional

7.18.3 Direct-Current Systems, Rectifiers

ïRESERVED ï

* 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 manufacturerôs

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 accordsanpcueb lwiisthhe dnachautfaa.c tIunr etrhôe a 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 ïVisual 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 w of manufacturerôs published data, use Tabl

3.2 Test Values ïElectrical

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 shown in the order of data. In the absence of manufacturerôs published data, than this table or manufacturerôs recommen

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

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 terminals(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 man

* Optional

3. Test Values

3.1 Test Values ïVisual 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 manufacturerôs publish of manufacturerôs published data, use Tabl

3.2 Test Values ïElectrical

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 accord absence of manufacturerôs ues of insulation resistance less ta, than this table or manufacturerôs recommen

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 manufacturera.ôs published dat

* 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 manufacturerôs
    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 ïVisual 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 manufacturerôs published data, using 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 ïElectrical

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 Table 100.5, in the absence of manufacturerôs recommendations. Values of insulation resistance less than this table or manufacturerôs recommendations

3. Investigate capacitance values differing from

4. Investigate discharge resistor values differing from manufacturerôs published. 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:

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

* Optional

7.20.2 Capacitors and Reactors, Capacitor Control Devices

ïRESERVED ï

* 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 manufacturerô

    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 manufacturerôs published data. In the abse 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 ï 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 manufacturerôs published data, use Table (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 ï 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 manufacturerôs published data, in the absence of manufacturerôs published insulation-resistance data, use Table than this table or manufacturerôs recommend

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 manufacturerô

    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

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 manufacturerôs published data. In the absen 100.1. Calculate polarization index.

3. Perform insulation power-factor or dissipation-factor tests on windings in accordance with the test equipment manufacturerôs published dat

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

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 ï 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 a 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 the manufacturerôs published data. In the absence of manufacturerôs published data, use Tabl

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 the manufacturerôs 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 ï 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 manufacturerôs published data. In the absence of manufacturerôs data, use Table 100.1. Values of insulation resistance less than this table or manufacturerôs recommen 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 manufacturerôs published d to test equipment manufacturerôs published 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

7.20.3.2 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 manufacturerôs

    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 the manufacturerôs a 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 manufacturerôs 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 ï 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 wit of manufacturerôs published data, use Table

3. Results of the thermographic survey shall be in accordance with Section 9. (7.21.1.5.3)

3.2 Test Values ï 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 accordan 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 ïVisual and Mechanical

1. Anchorage, alignment, and groundi n g s h o u l d b e i n a c c o r d a n c e
data and system design.

* Optional

7.22.1 Emergency Systems, Engine Generator (*continued*)

3.2 Test Values ïElectrical

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 ($IR_{1\ min}$) 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)

   2. $IR_{1\ min}$ = 100 megohms for most dc armature and ac windings built after 1970 (form-wound coils).

   3. $IR_{1\ min}$ = 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 manufacturerôs and system d

5. Vibration levels should be in accordance wi compared to baseline data.

6. Performance tests should conform to manufac turerôs published data ar 110.

7. Governor and regulator should operate in ac requirements.

* Optional